Shocks and Exchange Rates in Small Open Economies*

Vito Cormun† Pierre De Leo‡

Preliminary Draft

November 1, 2019

Abstract

We propose a new approach to separately identify domestic and external shocks in small open economies, and find that they cause markedly different exchange rate dynamics. External shocks generate large deviations from uncovered interest parity, while domestic shocks do not. Besides, external shocks strongly comove with global risk aversion and are linked to U.S. economic fluctuations. We present a two-country small open economy model with international asset market imperfections that is consistent with these facts. In our model, global risk aversion shocks drive exchange rate dynamics, and a country's net foreign asset position governs their international transmission. We provide empirical evidence that a country's exposure to external shocks indeed depends on its net foreign asset position.

JEL classification: E52; F31; F33; F41
Keywords: Exchange rates; Identification; UIP deviations; Small open economy DSGE models; Global risk aversion.

*We are grateful to Susanto Basu, Ryan Chahrour, Jaromir Nosal, Pablo Guerrón Quintana, and Rosen Valchev for their generous guidance and support. We also thank Boragan Aruoba, Gianluca Benigno, Hafedh Bouakez, Marco Brianti, Danilo Cascaldi-Garcia, Benjamin Johannsen, Sebnem Kalemli-Ozcan, Robert King, Peter Ireland, Felipe Saffie, John Shea, Dongho Song and seminar and conference participants at Bank of Canada, Boston College, Central Bank of Brazil, College of William & Mary, Colgate University, European Central Bank, Federal Reserve Board, Federal Reserve of New York, HEC Montreal, Lancaster University, 2017 Spring Green Line Macro Meeting (BU), the 2017 Spring Midwest Macro Meeting (LSU), the 2017 SED Meeting (Edinburgh), Sverige Riksbank, University of Maryland, the 12th Annual Economics Graduate Student Conference (WUSTL) for helpful comments and advice. De Leo gratefully acknowledges financial support from the Clough Center at Boston College. This paper previously circulated under "International Spillovers and the Exchange Rate Channel of Monetary Policy".

†Boston College, cormun@bc.edu
‡University of Maryland, deleop@umd.edu

1 Introduction

This paper studies the properties of domestic and external shocks on exchange rates in small open economies (SOEs), thereby providing new guidance for open economy models. We begin by showing that it is possible to separately identify domestic and external shocks in SOEs using minimal assumptions that hold in any class of SOE models. By doing so, we uncover that external shocks are the main source of deviations from uncovered interest parity (UIP), while domestic shocks generate exchange rate dynamics largely consistent with UIP. Moreover, we find that the main external driver of exchange rates is associated with large movements in global risk aversion and significant U.S. economic fluctuations. We then present a model that explains these facts. Our model departs from the standard framework by assuming segmented international asset markets, risk averse international traders, and global risk aversion shocks, in the spirit of Gabaix and Maggiori (2015). In line with the predictions of the model, we document that a country's net foreign asset position governs the exposure of its exchange rate to external shocks.

To draw accurate conclusions about transmission mechanisms, SOE models should at a minimum be consistent with the properties of domestic and external disturbances. To disentangle different sources of variation, we observe that shocks originating from within a *small* economy should not influence world variables at any horizon, while external (or global) shocks should affect world variables at least at some horizon. In the context of vector autoregressions (VARs), we thus identify external shocks as those that explain all of contemporaneous and expected future movements in external variables. To do so, we apply a methodology developed by Uhlig (2003) to extract the exogenous shocks that explain as much as possible of the forecast error variance of an external variable in a VAR.[1] Our approach then requires domestic shocks to be orthogonal to all external disturbances. We implement this methodology on monthly data for a large number of SOEs, study the properties of these shocks, and interpret them by analyzing their impulse responses on the variables in the VAR.

Our first finding concerns the sources of time-varying deviations from UIP, often used as a metric to discriminate across different classes of open economy models. We document that external shocks are the prominent source of UIP deviations. Strikingly, these shocks

[1] Below, we draw a comparison with a the recursive identification approach.

account for about 80% of all fluctuations in currency excess returns, while the remaining part is explained by domestic disturbances.[2] Therefore, country-specific UIP shocks are not a satisfactory representation of the data, and understanding UIP deviations requires inspecting the transmission channels of external disturbances.

Then, our second finding speaks to the nature of external sources of exchange rate fluctuations. Our approach does not require that a single shock accounts for a large fraction of external variation or that any shocks have an appealing interpretation. Yet, when applying our decomposition, we find that one single external shock can account for about $3/4$ ($2/3$) of the external variation in exchange rates (currency excess returns). Moreover, we find that this shock is strongly correlated with innovations in the VIX – a common proxy of global risk aversion – as well as U.S. macroeconomic variables. The bulk of external variation identified by our procedure is characterized by the following comovement. When global risk aversion is low, U.S. output, inflation, and Federal Funds rate all significantly increase relative to steady state. In the SOE, interest rate declines in the short run, and their currencies appreciate against the dollar (with the exchange rate response being primarily shaped by the dynamic pattern of UIP deviations). This comovement implies that the bulk of time-varying UIP deviations is not disconnected from macroeconomic dynamics. Besides, the positive comovement among U.S. output, inflation and interest rates suggests that the bulk of foreign-sourced fluctuations is not driven by U.S. monetary policy shocks. In other words, SOE models with exogenous shocks to the external interest rate do not appear to be an adequate characterization of the data.

Taken together, these findings place a new set of restrictions for models of open-economy fluctuations and exchange rate dynamics. In this paper, we propose a departure from a canonical framework that can go a long way in explaining these facts. We build on a standard two-country SOE model with nominal rigidities, in which economic developments in the large economy (the U.S.) affect the small economy, but not *vice versa* (cf. Galí and Monacelli, 2005, and De Paoli, 2009).[3] We depart from the standard framework by assuming that international financial markets are segmented and financial traders are averse to holding currency risk, in the spirit of Gabaix and Maggiori (2015). In addition to the path of interest rate differentials, equilibrium exchange rates are determined by

[2] The conditional properties of UIP deviations lead to opposite comovement patterns between interest rate differentials and exchange rates across the two shocks.

[3] The two-country SOE environment is consistent with our key empirical identification restrictions.

the level of traders' risk aversion and the net foreign asset position of the SOE. In our framework, the net foreign asset position of the SOE is in fact the relevant measure of its external imbalances, and determines the amount of currency risk held by international traders.

Besides monetary innovations in both countries, we introduce a "global risk aversion shock," modeled as an exogenous change in the level of risk aversion of U.S. households and traders.[4] The comovement implied by this shock reproduces the anatomy of the main identified external shock, including the conditional patterns of UIP deviations. When global risk aversion declines, the increase in U.S. households' demand raises U.S. output and inflation, leading to an increase in the Federal Funds rate. Despite the increase in the Federal Funds rate, higher traders' risk-bearing capacity and improved domestic net foreign asset position lead to a large currency appreciation in the SOE, accounted for by a sharp decline in currency excess returns. Crucially, the resulting degree of currency appreciation and UIP deviations is larger for SOEs with higher average net foreign debt, which is a metric of traders' exposure to the SOE's currency risk.[5]

In this framework, domestic shocks have no effect on global risk aversion, a small impact on a country's financial imbalances, and therefore a mild effect on equilibrium currency excess returns. For example, a domestic monetary policy contraction leads to an impact appreciation of the domestic currency, with only small deviations from UIP. Overall, this parsimonious framework is therefore able to reproduce the conditional properties of UIP deviations that we documented empirically.

The model we propose assigns a prominent role to asset imbalances in the transmission of global risk aversion shocks to the exchange rate. In our model, to a first order, the direct effect of a global risk aversion shock on the exchange rate solely depends upon a country's average net foreign asset position. As a result, countries with large net foreign positions should be more exposed to exogenous changes in global risk aversion relative to countries with a negligible net foreign position. Using the cross-country dimension of our data, we provide empirical support to our key model's prediction. The extent of exchange rate appreciations following expansionary external shocks is indeed significantly larger for net-foreign debtors. Likewise, we find that the relative importance of external shocks is in

[4] International traders in our model are a subset of U.S. households.

[5] In response to this shock, domestic central banks cut their policy rate in the short run to avoid excessive fluctuations in consumer price inflation, in line with our empirical evidence.

fact larger for countries with a large net foreign position, in a way that is quantitatively in line with the ranking implied by our model. The degree of external exposure in our data is considerably heterogeneous across countries, ranging from around 80% to around 10%, and significantly correlated with a country's net foreign position.

Our finding that the domestic variation in exchange rates is largely in line with UIP contrasts with recent evidence on the exchange rate effects of domestic monetary policy shocks. In particular, Hnatkovska et al. (2016) find that the domestic currency tends to depreciate after domestic monetary tightening in several SOEs, which would imply a significant amount of domestic sources of UIP deviations. This evidence, labeled "the exchange rate response puzzle," is primarily based on recursive identification schemes within the framework of VARs, and presents critical challenges for standard open economy theories. The recursive identification strategy obtains a special case of our proposed identification strategy, which allows us to understand the nature of the differences in results. We show that VAR identification approaches based on recursive ordering are bound to commingle domestic and external shocks. In particular, we document that the structural shocks identified through recursive ordering and typically interpreted as "monetary policy shocks" of the SOE predict significant future movement in external variables, including U.S. interest rates and output – an observation that points to a precise misspecification problem. Identification schemes based on contemporaneous restrictions do not account for all contemporaneous and expected variation of the external variables included in the VAR. This outcome obtains because domestic interest rates and exchange rates display strong "anticipated effects," a feature that invalidates the standard assumption of block exogeneity.[6] We show that this type of misspecification problem is the source of "the exchange rate response puzzle," which disappears after controlling for the whole set of external disturbances.[7]

Relatedly, we use our model to test the empirical approach we take in decomposing the various sources of shocks. To do so, we simulate data from our calibrated model and perform a Monte Carlo estimation exercise. We find that our identification strategy succeeds in recovering the effects of both external and domestic shocks: domestic monetary policy shocks are correctly identified, while the identified external shock maps into the innova-

[6] By identifying external shocks as those that explain movements in external variables *at any horizon*, our identification approach is not subject to this misspecification problem.

[7] The puzzle arose primarily in developing and emerging economies because these are the countries with the largest net foreign debt, and therefore those in which external shocks have a larger quantitative importance on exchange rates.

tion to global risk aversion – the main external drivers of exchange rate fluctuations in the model – providing further support for our identification scheme. To the contrary, a recursive VAR analysis on model generated data reproduces the exchange rate puzzle, exactly because it conflates domestic and external shocks.

Related literature This paper builds on several strands of the literature concerned with understanding open economy fluctuations.

First, our paper is related to the vast literature that aims to explain the observed time-varying deviations from UIP (see Engel, 2014). We uncover a new conditional property of UIP deviations: they are large and persistent after external shocks, and small and short-lived after domestic shocks. In turn, we find that the bulk of external variation in exchange rates is largely related to changes in the risk appetite of global investors. These findings confirm and extend recent evidence on the patterns of UIP deviations. Lustig et al. (2011) identify a slope factor in exchange rate changes that is closely related to changes in volatility of equity markets around the world. Della Corte et al. (2016) show that investors' exposure to countries' external imbalances explains the cross-sectional variation in currency excess returns. Using firm-level data from Turkey, di Giovanni et al. (2017) document the presence of significant UIP deviations at both firm and country level, and show that these are strongly correlated with movements in the VIX.

Second, our paper is related to the literature on the empirical importance of global shocks, recently exemplified by Bruno and Shin (2015), Rey (2013), and Miranda-Agrippino and Rey (2015).[8] These authors document large financial spillovers to global asset prices associated with variations in global risk aversion, typically proxied by the VIX. One result of our decomposition is that the main external driver of SOEs' exchange rate is indeed associated with variations in global risk aversion. In addition, we show that this shock leads to demand-like comovement among U.S. output, inflation, and interest rates, and a country's net foreign asset position explains the strength of their spillover effects. We provide a dynamic model that explains both the comovement and the cross-sectional exposure to these shocks as the equilibrium response to exogenous changes in global risk aversion.

[8] Other papers that study the effect of various U.S. or global shocks on SOEs include Canova (2005), Uribe and Yue (2006), Mackowiak (2007), Akinci (2013), Levchenko and Pandalai-Nayar (2015), Ben Zeev et al. (2017), Vicondoa (2019), Scott Davis and Zlate (2019), Iacoviello and Navarro (2018), Cesa-Bianchi et al. (2018), Bhattarai et al. (2019), and Fernández et al. (2016)

Third, we contribute to the literature on SOE models. Our empirical findings point to an external shock that generates large UIP deviations as well as U.S. demand-driven economic fluctuations. Exogenous time-varying global risk aversion, in a model with a non-zero steady-state net foreign asset position, satisfies these properties. Recently, Itskhoki and Mukhin (2017, 2019) developed an open-economy model with UIP deviations generated by noise trader shocks in segmented international asset markets. Our proposed global risk aversion shock differs from noise-trader shocks in at least two dimensions. First, in our framework global risk aversion shocks affect both international traders and U.S. households, thereby generating the global comovement pattern that we document empirically. Second, global risk aversion shocks affect SOEs differently depending on their average net foreing asset position, a prediction for which we find empirical support. To the contrary, noise trader shocks have generally negligible effects on U.S. macroeconomic aggregates, and cannot explain the documented cross-country differences in exposure to external disturbances.[9]

Last, our analysis highlights some challenges faced by the VAR literature on identification of shocks in SOEs. In this context, we revisit some empirical evidence on the exchange rate response to domestic monetary policy (Hnatkovska et al., 2016).[10] We show that recent puzzling estimates of the exchange rate effects to monetary policy shocks arise because recursive identification approaches commingle domestic and external shocks, which feature opposite comovement patterns between interest rate differentials and exchange rates.

2 Decomposing exchange rate variation in SOEs

We are interested in decomposing the exchange rate variation of SOEs according to its sources. In this section, we briefly describe our dataset, outline our identifying assumptions, and explain how to implement our proposed approach in a VAR framework.

[9] Eichenbaum et al. (2017), Cavallino (2019), and Fanelli and Straub (2018) also present models with shocks to the UIP condition. These shocks share the same properties of noise-trader shocks.

[10] Jääskelä and Jennings (2011) and Carrillo and Elizondo (2015) use data simulated from specific models to examine the performance of different VAR schemes in recovering the effects of monetary policy in SOEs. A related literature is concerned with the ability of structural DSGE models to account for the substantial influence of external disturbances. See, for example, Justiniano and Preston (2010), Guerron-Quintana (2013), Alpanda and Aysun (2014), and Georgiadis and Jancoková (2017).

Data We focus on a benchmark group of advanced and emerging SOEs: United Kingdom, Canada, Japan, Italy, Germany and France, South Africa, Philippines, Indonesia, Brazil, South Korea and Mexico. We analyze time periods that are characterized by a flexible exchange rate regime, following Ilzetzki et al.'s (2017) classification.[11] Further details on data sources and selection criteria are reported in Appendix A.

Identifying assumptions At this stage, our objective is to decompose the sources of exchange rate variation in SOEs, while being agnostic about their structural interpretation. To do so, we impose a set of identifying restriction that is consistent with any class of SOE models – in fact with the very definition of a SOE – regardless of the underlying set of structural disturbances or transmission mechanisms. In an *open* economy, domestic variables respond to external shocks. In a *small* economy, domestic (i.e. idiosyncratic) shocks do not affect external variables. Thus, our identifying assumptions hold that any domestic shock of the SOE does not affect external variables *at any horizon*, while external shocks affect external variables at least at some horizon.

Baseline SOE VAR Throughout the paper, we present a number of VARs that feature domestic (SOE) variables and external (U.S.) variables. Our baseline is a three-variable VAR that features U.S. interest rates, domestic interest rates, and the exchange rate. A three-variable VAR allows us to compare our results to those obtained in standard UIP regressions (Section 3), and transparently compare the implications of different identification strategies (Section 7). In Section 4, we extend our VARs to feature additional macroeconomic and financial variables in order to trace out the effects of identified shocks on other macroeconomic variables.[12]

VAR implementation Consider a three-variable VAR with the Federal Funds rate ($r^{\star}$), the policy-controlled interest rate of SOE k (r_k), and the logarithm of the bilateral nominal exchange rate between country k's currency and the U.S. dollar (s). Exchange rates are in domestic currency units per US dollar, so that an increase is a depreciation of local currency

[11] The longest sample period covers 1974:1-2010:12. For Eurozone countries, we used their national exchange rates before the introduction of the Euro as separate episodes.

[12] In Appendix B, we show that our baseline VAR is informationally sufficient, in the sense that other macroeconomic and financial variables cannot predict the identified shocks.

relative to the US dollar. The model is specified in levels and the number of lags is chosen according to the Akaike information criterion. Unlike the case of a vector error correction model, the estimators of the impulse responses of a VAR in levels are consistent in the presence of nonstationary but cointegrated variables where the form of cointegration is unknown. Furthermore, estimators are consistent even in the absence of a cointegrating relations among the variables, provided that enough lags are included in the VAR (see Hamilton, 1994).

Thus, let $y_t \equiv [r_t^\star \;\; r_{k,t} \;\; s_t]'$ be the 3×1 vector of observable variables that have length T, including the Federal Funds rate, the policy-controlled interest rate of country k, and the log of the nominal exchange rate, respectively. Denote by $y_t = B(L)u_t$ the reduced-form moving average representation in the levels of the observable variables, formed by estimating an unrestricted VAR in levels. The relationship between reduced-form innovations and structural shocks is given by:

$$u_t = A_0 \varepsilon_t \tag{1}$$

which implies the following structural moving average representation:

$$y_t = B(L) A_0 \varepsilon_t. \tag{2}$$

We assume that the structural shocks are orthogonal with unitary variance, so that the impact matrix A_0 satisfies $A_0 A_0' = \Sigma$, where Σ is the variance-covariance matrix of innovations. In order to identify A_0, one needs to impose $n(n-1)/2$ additional restrictions, where n is the number of variables included in the VAR.

Within the above three-variable VAR, we propose an identification strategy designed to separately identify the effects of external shocks from those of idiosyncratic shocks stemming from country k. Specifically, we assume that the external variable in the VAR, the Federal Funds rate, is properly characterized as following a stochastic process driven by unanticipated and anticipated shocks (their respective statistical properties are described below). The domestic source of variation of the SOE is then identified as the linear combination of the VAR innovations that is orthogonal to (unanticipated and anticipated) external shocks.

To implement our identification scheme in the three-variable VAR presented above, we note that the impact matrix A_0, defined in Eq. (1), is unique up to any rotation D of the structural shocks. Specifically, for any 3×3 orthonormal matrix D, the entire space of permissible impact matrices can be written as $\widetilde{A}_0 D$, where $\widetilde{A}_0$ is an arbitrary orthogonalization (e.g. the one implied by a recursive identification scheme).

Here, the h-step ahead forecast error is

$$y_{t+h} - E_{t-1} y_{t+h} = \sum_{\tau=0}^{h} B_\tau \widetilde{A_0} D \varepsilon_{t+h-\tau}$$

where B_τ is the matrix of moving average coefficients at horizon τ. The share of the forecast error variance of variable i attributable to the structural shock j at horizon h is then:

$$\Omega_{i,j}(h) = \frac{\sum_{\tau=0}^{h} B_{i,\tau} \widetilde{A}_0 \gamma \gamma' \widetilde{A}_0' B_{i,\tau}'}{\sum_{\tau=0}^{h} B_{i,\tau} \Sigma B_{i,\tau}'}$$

where γ is the $j\text{-}th$ column of D, while $B_{i,\tau}$ corresponds to the $i\text{-}th$ row of B_τ.

To separately identify domestic and external sources of SOE fluctuations, we adopt a procedure that extends the identification scheme proposed by Barsky and Sims (2011).[13] This approach can be explained as composed of two steps. First, we recover the unanticipated and the anticipated movements in the Federal Funds rate. The former is identified as the orthogonal innovation in $r^\star$. The latter is identified as the shock that maximizes the contribution to the forecast error variance of the Federal Funds rate up to a truncation horizon H, subject to the restriction that this shock has no contemporaneous effect on the Federal Funds rate.[14] Formally, the identification of the anticipated external shock boils down to solving the following maximization problem:

$$\gamma * = \arg\max \sum_{h=0}^{H} \Omega_{1,2}(h) = \frac{\sum_{\tau=0}^{h} B_{i,\tau} \widetilde{A}_0 \gamma \gamma' \widetilde{A}_0' B_{i,\tau}'}{\sum_{\tau=0}^{h} B_{i,\tau} \Sigma B_{i,\tau}'}$$

s.t.

$$\begin{aligned} \widetilde{A}_0(1,j) &= 0 \quad \forall j > 1 \\ \gamma(1,1) &= 0 \\ \gamma'\gamma &= 1 \end{aligned}$$

[13] In using a maximum forecast error variance approach, Barsky and Sims (2011) build on earlier work by Faust (1998), Uhlig (2003). See also Francis et al. (2014).

[14] Our empirical results are robust to relaxing this contemporaneous restriction.

where the first two constraints ensure that the anticipated external shock has no contemporaneous effect on the Federal Funds rate, and the third restriction narrows the solution space to the one of possible orthogonalizations of the reduced form, by preserving the orthonormality of the rotation matrix D. By imposing that γ must be a unit vector, the second column γ of matrix D is identified. The second step consists in recovering the domestic shock of SOE k. This shock can be identified by making use of the condition that the matrix D must be orthonormal, i.e. $DD' = D'D = I$. More specifically, letting $\gamma * = [0\ \gamma_1\ \gamma_2]$ where $\gamma_2 = -\sqrt{1-\gamma_1^2}$, then one can express D as:[15]

$$D = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \gamma_1 & \gamma_2 \\ 0 & -\gamma_2 & \gamma_1 \end{bmatrix} \tag{3}$$

where the first column ensures that the unanticipated external shock ($\varepsilon_t^\star$) is the orthogonal innovation to the Federal Funds rate, the second column results from the maximization problem above and therefore captures the whole set of shocks that induce future movements in the Federal Funds rate ($\varepsilon_t^{\star\star}$), and the third column identifies the domestic shock of country k (ε_t^{SOE}) that may affect both the nominal exchange rate and the policy controlled interest rate, while it has no contemporaneous or future impact on the external variable ($r^\star$).[16] Last, *for any* orthogonalization $\widetilde{A}_0$ of residuals u_t which satisfies the first constraint of the above maximization problem, the structural shocks can be recovered from the relation

$$u_t = \widetilde{A}_0 D \varepsilon_t. \tag{4}$$

where D is the rotation matrix previously identified, and $\varepsilon_t \equiv [\varepsilon_t^\star\ \ \varepsilon_t^{\star\star}\ \ \varepsilon_t^{SOE}]'$.

3 Conditional properties of exchange rates in SOEs

How important are domestic and external sources of fluctuations in SOEs' exchange rates and currency excess returns? Do different shocks generate different dynamic patterns of currency excess returns? In this section, we illustrate the relative contribution of different

[15] The negative sign in front of γ_2 is just a normalization. Specifically, to preserve the orthonormality of D, one needs the 2×2 lower right submatrix of D to have either opposite diagonal elements or opposite off-diagonal elements.

[16] By construction, this condition is subjected to the maximization above, therefore results can still deliver that a domestic shock has some, but likely insignificant, future effects on the Federal Funds rate.

shocks for our variables of interest, and discuss their properties. The empirical evidence reported below is the result of estimating a set of individual-country VARs using the approach described in Section 2. We frame our main results in the form of impulse response functions (IRFs). Bias-corrected bootstrapped 90% confidence intervals are based on 1000 replications (see Kilian, 1998).

Definition of currency excess returns In line with the relevant literature, the ex ante excess return on the domestic bond held from period t to period $t+m$, inclusive of the expected currency return, is defined as:

$$\mathrm{E}_t\, \hat{x}_{t+m} \equiv \hat{r}_{t|m} - \hat{r}^{\star}_{t|m} - \mathrm{E}_t\, \Delta \hat{s}_{t+m} \tag{5}$$

where hatted variables denote series generated by our VAR, E_t is the expectation operator conditional on time-t information, and $\hat{r}_{t|m}$ ($\hat{r}^{\star}_{t|m}$) are m-month domestic (foreign) interest rates.[17] Non-zero ex ante excess returns point to violation of so-called UIP. In fact, under UIP the exchange rate is expected to depreciate at a rate that equals the interest rate differential.

In addition, let us define the counterfactual response of the exchange rate that one would observe under UIP. Following Engel (2016), we iterate Eq. (5) forward and obtain a relationship between the the level of the exchange rate and the expected path of interest rate differentials and excess returns:[18]

$$\hat{s}_t = \hat{s}_t^{UIP} + \mathrm{E}_t \sum_{j=0}^{\infty} \hat{x}_{t+j+1} \tag{6}$$

where $\hat{s}_t^{UIP} \equiv -\,\mathrm{E}_t \sum_{j=0}^{\infty} \left(\hat{r}_{t+j} - \hat{r}^{\star}_{t+j}\right)$ is the exchange rate level consistent with UIP. The difference between $\hat{s}_t$ and $\hat{s}_t^{UIP}$ is accounted for by the infinite sum of ex ante excess returns. Below we report $\mathrm{E}_t\, \hat{x}_{t+m}$ and $\hat{s}_t^{UIP}$ conditional on domestic (ε^{SOE}) and external shocks ($\varepsilon^{\star}$ and $\varepsilon^{\star\star}$), which are constructed using the expectations implied by the VAR.

[17] Below, we report the returns from an investment of one year maturity on the domestic bond. That is, $m = 12$ months, which is the typical maturity of the domestic interest rates in our sample.

[18] In deriving Eq. (6) we impose that $\lim_{j \to \infty} \hat{s}_{t+j} = 0$, consistent with the observation that our VAR generates stationary time series.

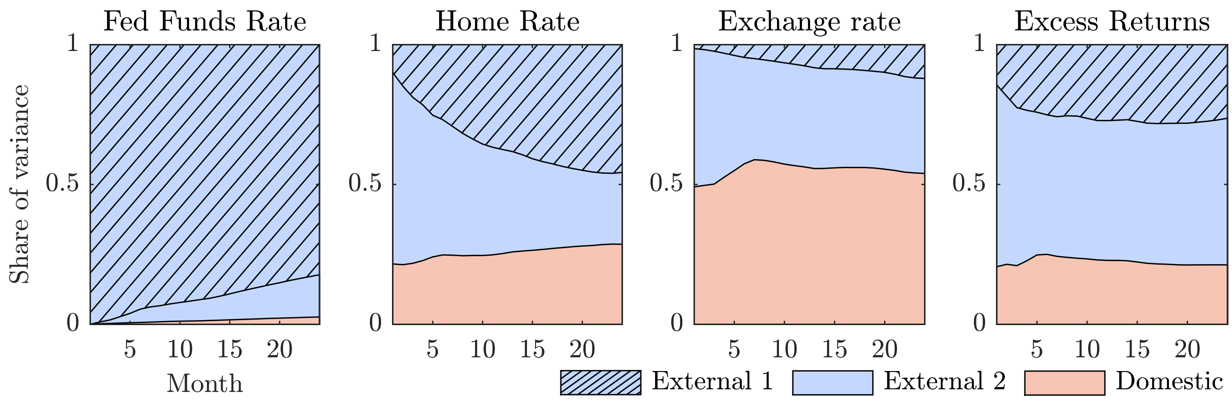


Figure 1: Relative contribution of domestic and external shocks

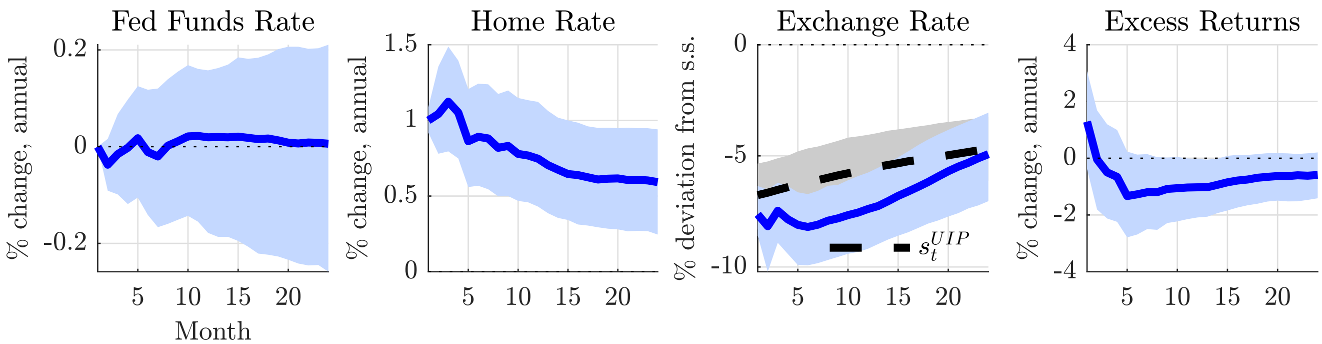
Note: The horizontal axes refer to forecast horizons, while the vertical axes denote the fraction of forecast error variance from each shock. External shocks consist of unanticipated (External 1) and anticipated (External 2) variation in the Federal Funds rate.

Relative importance of domestic and external shocks Figure 1 reports the variance decomposition for our baseline variables, along with currency excess returns. The Federal Funds rate appears to be exclusively explained by external disturbances. This outcome indicates that our two external shocks capture all the unpredictable fluctuations in the Federal Funds rate. The domestic interest rate is also predominantly driven by external shocks, in line with the observation that SOE monetary policy is largely devoted to respond to external sources of fluctuations. In the typical SOE, the exchange rate is explained by domestic and external shocks in almost equal parts.[19] However, currency excess returns in most part explained by external disturbances, suggesting that domestic and external shocks imply significantly different exchange rate dynamics.

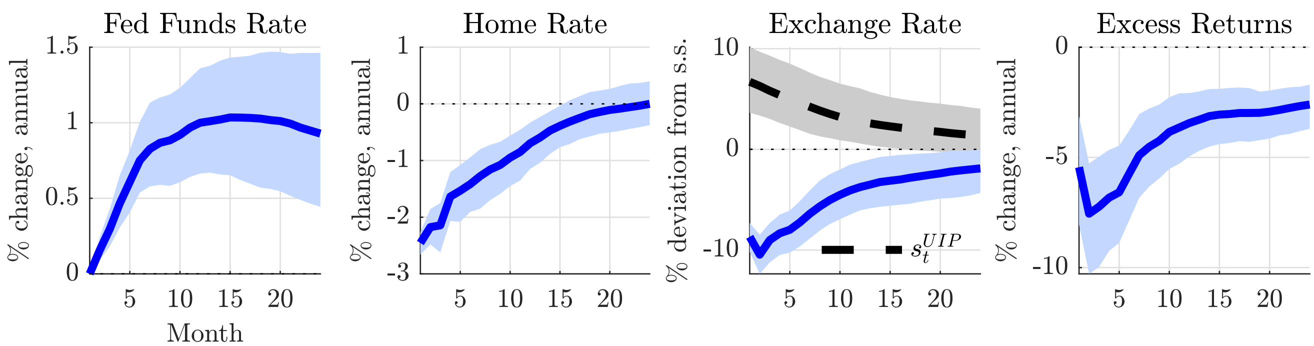
We note that between the two external shocks that we identify, the anticipated external shock ($\varepsilon^{\star\star}$) is by far the main external driver of exchange rates and excess returns. In fact, it explains more than $3/4$ of the external variation in exchange rates, and more than $2/3$ of the external variation in currency excess returns. For this reason, below we will solely focus on this source of external fluctuations, and we will refer to it as "the external shock."

Conditional exchange rate dynamics We are interested in understanding the comovement among interest rates, exchange rates, and one-year ahead ex ante excess returns implied by domestic and external shocks.

[19] Section 6 explores the cross-country differences in exchange rate exposure to external shocks.



(a) Empirical impulse responses to a domestic shock



(b) Empirical impulse responses to an external shock

Figure 2: Conditional properties of exchange rates

Note: The lines denote median IRFs by countries with corresponding 90% confidence intervals from 1000 bias-corrected bootstrap replications of the reduced-form VAR. Domestic shocks are normalized to deliver a 1% impact increase in the home interest rate, while external shocks are normalized to deliver a 1% increase in the Fed Funds rate at one-year horizon. Excess returns are one-year ahead expected excess returns.

Figure 2 collects our findings. A domestic shock that leads to a 1% increase in the domestic interest rate is associated with an impact exchange rate appreciation (Figure 2a) and a largely insignificant response of currency excess returns. In fact, exchange rate dynamics under domestic shocks are both qualitatively and quantitatively in line with the UIP-consistent exchange rate response, $\hat{s}_t^{UIP}$.

After an external shock that leads to an increase in the foreign interest rate, the domestic interest rate declines significantly. Because the interest rate differential is persistently negative, UIP predicts a significant currency depreciation. However, the observed exchange rate response implies a significant currency appreciation, accounted for by large and persistent decline in excess returns required on the domestic bond.

Therefore, our evidence points to large and persistent UIP deviations due to external shocks, but not in response to domestic shocks. The conditional differences in UIP deviations are so large that they generate an opposite comovement patterns in interest rate differentials and exchange rates across the two shocks. Figure B.1 in Appendix B documents that these conditional patterns also hold in country-specific VARs, with only few exceptions.

4 External shocks are global risk aversion shocks

Our evidence indicates that one external source of fluctuations is responsible for a large fraction of the observed variation in currency excess returns. A natural question is whether this external shock has an appealing interpretation. To do so, we trace out the effects of external shocks on key U.S. macroeconomic variables.

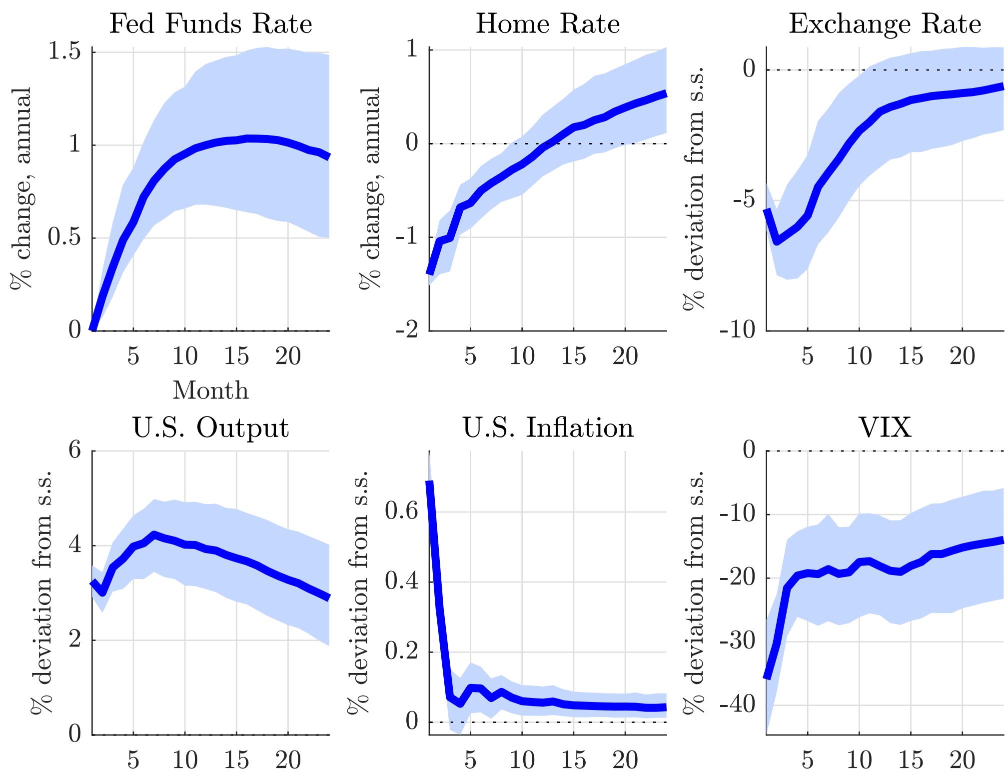


Figure 3: Empirical impulse responses to an external shock (Extended VAR)

Note: This figure features the estimated IRFs to an external shock on a set of external variables. We run a number of four-variable VARs that include the three baseline variables and either U.S. industrial production, U.S. CPI inflation, or the VIX ordered fourth. The lines denote median IRFs across countries. The shaded areas are the corresponding 90% confidence intervals from 1000 bias-corrected bootstrap replications of the reduced-form VAR.

In particular, we study the effects of the external shock in a set of extended VARs, that include U.S. industrial production, inflation in the U.S. Consumer Price Index (CPI), and

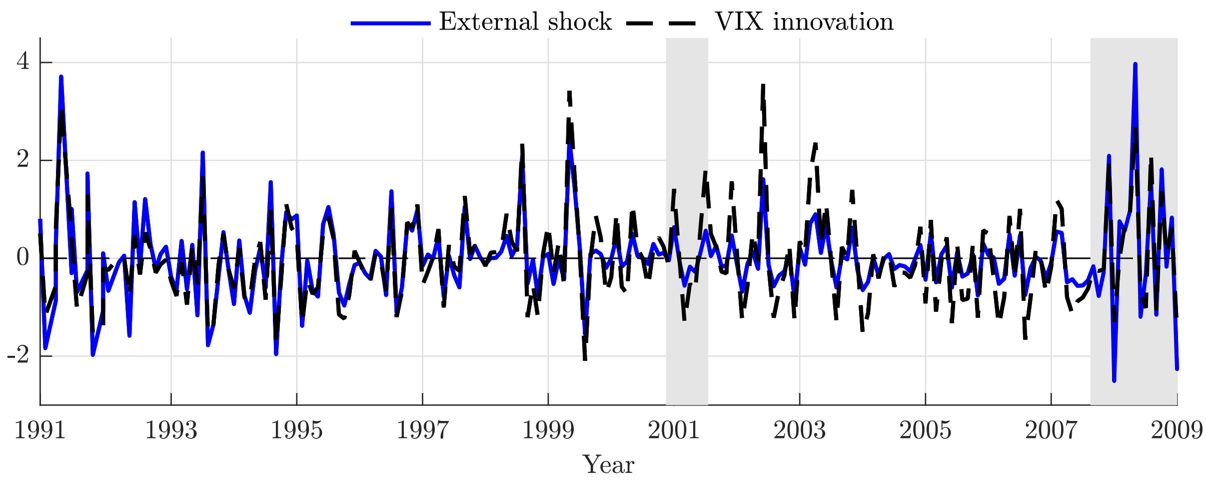


Figure 4: Identified external shocks and the VIX

Note: The figure plots the identified series of external shocks and the innovation in the VIX. The innovation in the VIX is computed as the residual of an AR(1) process.

the Chicago Board Options Exchange Volatility Index (VIX), a forward-looking measure of uncertainty and risk aversion. Figure 3 shows that the external shock leads to an increase in U.S. output, U.S. inflation and the Federal Funds rate – a comovement that is typical of demand-driven expansions. In addition, these U.S. economic expansions are accompanied by a temporary decline in the VIX, and generate significant appreciations of SOEs exchange rates against the U.S. dollar.

The international finance literature has documented that global asset prices display significant comovement with the VIX, a common proxy of gloabl risk aversion (see, e.g., Bruno and Shin, 2015, Rey, 2013, and Miranda-Agrippino and Rey, 2015). In Figure 4 we report the historical series of our external shock, along with the innovation in the VIX, computed as the residual of an AR(1) process. We find that our estimated external shocks are intimately associated with movements in global risk aversion. In fact, the correlation between our identified series of external shocks and the innovation in the VIX is around 0.8. This evidence suggests that the core of the external variation in the exchange rates may be the result of fluctuations in risk appetite in international asset markets that also give rise to U.S. economic fluctuations. In the next section, we formalize this interpretation in a dynamics two-country SOE model.

5 A SOE model with global risk aversion shocks

To rationalize our empirical findings, we build a two-country SOE dynamic general equilibrium model. After a brief introduction of the model environment, we present a summary of the equilibrium conditions and highlight the key economic mechanisms. Appendix C contains the full derivation of the model.

5.1 Environment

Our model economy consists of two countries, the SOE and a large economy. To characterize the SOE, we follow De Paoli (2009) in taking the limit of the home economy size to zero.[20] The foreign (large) economy is then interpreted as the U.S.. The core of our model belongs to the international macroeconomic tradition initiated by Obstfeld and Rogoff (1995), in that it consists of a dynamic general equilibrium open-economy model with monopolistically competitive producers, sticky prices, and complete exchange rate pass-through.[21] Asset markets are both incomplete and segmented. The only assets available in the economy are two nominal riskless bonds denominated in home and foreign currency. We assume that households in each economy can only trade the bond of their respective country, and all international transactions are intermediated by a set of financial traders who are averse to taking risky positions (Jeanne and Rose, 2002, Gabaix and Maggiori, 2015, Itskhoki and Mukhin, 2017). In our model, financial traders are a subset of U.S. households, and, crucially, we assume that their risk aversion is exogenous and time-varying.[22]

5.1.1 Households and the financial sector

The world economy is populated with a continuum of agents of unit mass, where the population in the segment $[0, n)$ belongs to the home (H) country and the population in the segment $(n, 1]$ belongs to the foreign (F) country.

Domestic economy. The domestic economy is populated by a representative household

[20] The limit is taken after having derived the equilibrium conditions for the two-country model.
[21] Complete exchange rate pass through obtains because prices are set in the producer's currency.
[22] Because financial traders are a subset of U.S. households, the U.S. is the center of the international financial system.

whose preferences are given by

$$\mathrm{E}_t \sum_{j=0}^{\infty} \beta^j \left[\frac{C_t^{1-\omega}}{1-\omega} - \frac{N_t^{1+\eta}}{1+\eta} \right] \tag{7}$$

where N_t denotes hours worked, and C_t is a composite consumption index defined by

$$C_t \equiv \left[(\nu)^{\frac{1}{\theta}} (C_{H,t})^{\frac{\theta-1}{\theta}} + (1-\nu)^{\frac{1}{\theta}} (C_{F,t})^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}$$

where $C_{H,t}$ is an index of consumption of domestic goods given by the CES function

$$C_{H,t} \equiv \left[\left(\frac{1}{n} \right)^{\frac{1}{\iota}} \int_0^n C_{H,t}(i)^{\frac{\iota-1}{\iota}} \mathrm{d}i \right]^{\frac{\iota}{\iota-1}}$$

where $i \in [0, 1]$ denotes the good variety. $C_{F,t}$ is an index of goods imported from the foreign country given by an analogous CES function:

$$C_{F,t} \equiv \left[\left(\frac{1}{1-n} \right)^{\frac{1}{\iota}} \int_n^1 C_{F,t}(i)^{\frac{\iota-1}{\iota}} \mathrm{d}i \right]^{\frac{\iota}{\iota-1}}$$

Parameter $\iota > 1$ denotes the elasticity of substitution between varieties (produced within any given country). Parameter $1 - \nu \in [0, 1]$ governs the home consumers' preferences for foreign goods, and is a function of the relative size of the foreign economy, $1 - n$, and of the degree of openness, λ, namely $1 - \nu = (1 - n)\lambda$. Parameter $\theta > 0$ measures the substitutability between domestic and foreign goods, from the viewpoint of the domestic consumer.

Domestic households can trade only a one-period nominal bond, which is denominated in domestic currency. The domestic household's flow budget constraint is given by

$$\frac{B_{t+1}}{R_t} + P_t C_t = W_t N_t + B_t$$

where B_{t+1} denotes the nominal balance of home bonds, R_t is the nominal interest rate on the home bond, P_t is the price index of the composite consumption good, C_t, and W_t is the nominal wage rate. The problem of the domestic household consists in maximizing its utility (Eq. 7) subject to the budget constraint (Eq. 8). The first-order conditions of this problem are standard and therefore relegated to Appendix C.

Foreign economy. The foreign economy is populated by a continuum of households. At the beginning of each period, all members of a household are identical and share the household's assets. During the period, the members are separated from each other, and each member receives a shock that determines her role in the period. A member will be a trader with probability m_t, and a worker with probability $1 - m_t$. These shocks are i.i.d. among the members. We assume that the share of members that operate as traders in the international financial market is proportional to the output of the home economy (that is, $m_t = \mu n P^{\star}_{H,t} Y_t$). This assumption entails that traders devote a larger part of their balance sheets to bonds issued by larger economies. The members' preferences are aggregated and represented by the following utility function of the household:

$$\mathrm{E}_t \sum_{j=0}^{\infty} \beta^{\star j} \left[m_t \mathcal{U}(\widetilde{C}^{\star}_t) + (1 - m_t) \mathcal{U}(C^{\star}_t, N^{\star}_t) \right]$$

where

$$\mathcal{U}(\widetilde{C}^{\star}_t) \equiv \frac{\left(\widetilde{C}^{\star}_t\right)^{1-\omega^{\star}_t}}{1 - \omega^{\star}_t} \tag{8}$$

and

$$\mathcal{U}(C^{\star}_t, N^{\star}_t) \equiv \frac{(C^{\star}_t)^{1-\omega^{\star}_t}}{1 - \omega^{\star}_t} - \frac{(N^{\star}_t)^{1+\eta}}{1 + \eta}$$

Here, $\widetilde{C}^{\star}_t$ is the consumption of traders, $C^{\star}_t$ is the consumption of workers, and $\omega^{\star}_t$ governs the degree of (relative) risk aversion of both household's members. We assume that foreign households' risk aversion is time varying. In particular, $\omega^{\star}_t = \omega^{\star} \exp(\xi_t)$ and its time-varying component evolves according to the following autoregressive process:

$$\xi_t = \rho_{\xi} \xi_{t-1} + \varepsilon_{\xi,t} \tag{9}$$

where $\varepsilon_{\xi,t}$ are i.i.d. disturbances drawn from a Normal distribution with mean zero and standard deviation σ_{ξ}. The problem of the worker-members of the foreign household is standard, and analogous to the one of the domestic household. Her intertemporal budget constraint reads

$$\frac{B^\star_{t+1}}{R^\star_t} + P^\star_t C^\star_t = B^\star_t + W^\star_t N^\star_t - \frac{m_t}{1-m_t} T^\star$$

where the last term is an intrahousehold transfer that accrues to the trader-members of the households, and ensures that their consumption is always positive. The other foreign variables are interpreted analogously to their domestic counterparts. The first-order conditions of this problem are standard and therefore relegated to Appendix C.

Traders on the foreign exchange market. The trader-members of the foreign household are the only agents who can trade bonds internationally.[23] Traders collectively take a zero-capital position $\widetilde{D}_{t+1}$ in home-currency bonds and short $\widetilde{D}^\star_{t+1} = -\widetilde{D}_{t+1}/S_t$ foreign-currency bonds, or *vice versa*. Here, S_t is the nominal exchange rate, defined to be the price of the foreign currency unit, as in the empirical section. The exchange rate is relevant for the balance sheet of international traders because each economy offers a bond in its own currency. A one U.S.-dollar position generates a U.S.-dollar return of $\widetilde{R}_{t+1} = R^\star_t - R_t \frac{S_t}{S_{t+1}}$. The problem of each individual trader consists in choosing a position $d^\star_{t+1}$ to maximize (8) subject to the budget constraint $P^\star_t \widetilde{C}^\star_t = T^\star + \widetilde{R}_{t+1} d^\star_{t+1}$.[24] In Appendix C.1, we show that the individual trader's problem is approximately equivalent to maximizing a mean-variance utility of returns. The resulting demand for home-currency bonds by the financial traders is then:

$$\widetilde{D}^\star_{t+1} = \frac{m_t}{\omega^\star_t} \frac{\mathrm{E}_t\, \widetilde{R}_{t+1}}{\mathrm{Var}_t(\widetilde{R}_{t+1})} \Rightarrow \frac{\widetilde{D}_{t+1}}{S_t} = -\frac{m_t}{\omega^\star_t} \frac{\mathrm{E}_t\, \widetilde{R}_{t+1}}{\mathrm{Var}_t(\widetilde{R}_{t+1})} \tag{10}$$

The financial market clears when the interest rates R_t and $R^\star_t$ are such that $B_{t+1} + D_{t+1} = 0$ and $B^\star_{t+1} + D^\star_{t+1} = 0$. This condition implies that in equilibrium the net foreign asset position of home equals net foreign liabilities of foreign, $nB_{t+1} = -(1-n)B^\star_{t+1} S_t$, in aggregate per-capita terms.[25] Thus, Eq. (10) becomes:

$$-\frac{B_{t+1}}{P_{H,t} Y_t} = \frac{\mu}{\omega^\star_t} \frac{\mathrm{E}_t \left(R_t \frac{S_t}{S_{t+1}} - R^\star_t \right)}{\mathrm{Var}_t(\widetilde{R}_{t+1})} \tag{11}$$

[23] Since traders are part of the foreign household, the foreign economy is interpreted as the center of the international financial system.

[24] Again, $T^\star$ denotes a constant intrahousehold transfer that ensures that each trader's consumption is always non-negative

[25] Here, $nD_t = \widetilde{D}_t$ and $(1-n)D^\star_t = \widetilde{D}^\star_t$.

Finally, we follow De Paoli (2009) in taking the limit for $n \to 0$ to portray our SOE. This implies that economic developments in the large economy affect the SOE, but the reverse is not true. Under this assumption, the mass of household-traders $m_t \to 0$, $\forall t$. As a result, traders influence the model's behavioral equations only through their pricing of the exchange rate. The resulting profits from their trading activity are infinitesimally small from the standpoint of the foreign economy, and don't affect the household's budget constraint.

We solve the model by log-linearization around a steady state with a non-zero net foreign asset position, and use $\mathtt{b} \equiv {}^{B}/_{P_H Y}$ to denote the steady-state net foreign asset position relative to GDP of the home economy. Using the international bond market clearing condition, the linearized version of the traders' bond demand (Eq. 11) reads:[26]

$$\chi\left(-b_{t+1} - \mathtt{b}\xi_t\right) \approx r_t - r_t^\star - \mathrm{E}_t\,\Delta s_{t+1} \tag{12}$$

where $\chi \equiv \frac{\sigma_s^2}{\mu/\omega^\star}$ governs traders' risk bearing capacity in steady state.

Before we close the model, we can outline the mechanism and a testable implication of our framework. Eq. (12) is the exchange rate determination equation of our model economy. As in Itskhoki and Mukhin (2017), the standard UIP condition obtains as a special case when the risk-bearing capacity of traders $\chi = 0$. In our model, $\chi = 0$ if traders are risk neutral ($\omega^\star = 0$), the size of the financial sector $\mu \to \infty$, or the exchange rate is non-stochastic ($\sigma_s^2 \equiv \mathrm{Var}_t(\Delta s_{t+1}) = 0$). The variance of the innovation to the nominal exchange rate, σ_s^2, is endogenously determined. If $\chi > 0$, the model economy features two sources of time-varying UIP deviations - endogenous movements in the net foreign asset position to GDP, b_{t+1} and exogenous changes in global risk aversion ξ_t.[27] First, as emphasized by Gabaix and Maggiori (2015), an equilibrium imbalance that requires traders to be long in a currency generates a positive expected excess return of this currency. In this model, a country's imbalance is directly related to its net foreign asset position to GDP. A negative net foreign asset position requires traders to be long in that country's currency and therefore requires a positive expected return on this currency. Second, for a given level

[26] For illustration purposes, Eq. (12) is an approximation in that it ignores the terms arising because of steady-state UIP deviations.

[27] Here, b_{t+1} denotes the equilibrium deviation of net foreign assets to GDP relative to its steady state value. That is $b_{t+1} \equiv {}^{B_{t+1}}/_{P_{H,t} Y_t} - {}^{B}/_{P_H Y}$

of the net foreign position, changes in global risk aversion affect the degree of expected returns demanded by traders in equilibrium. In our linearized model, changes in risk bearing capacity have a *direct* effect on exchange rate determination if a country's steady-state net foreign asset position is non-zero. If the steady-state net foreign asset position of a country is negative, higher global risk aversion requires higher expected returns on this currency to provide the incentive for risk-averse traders to keep absorbing the imbalance. The opposite reasoning holds for countries that are net creditors in steady state.

5.1.2 Firms

Each country features a continuum of firms that produce output under a constant-returns-to-scale production function. The economy-wide production functions are thus $Y_t = AN_t$ and $Y_t^\star = AN_t^\star$ for the domestic and foreign goods, respectively.

We assume that each producer sets its price in her own currency. In this case the law of one price holds. Under these conditions, $P_{H,t} = S_t P_{H,t}^\star$ and $P_{F,t} = S_t P_{F,t}^\star$ for each t. However, the home bias specification leads to deviations from purchasing power parity; that is, $P_t \neq S_t P_t^\star$. Prices follow a partial adjustment rule as in Calvo (1983). Producers of differentiated goods know the form of their individual demand functions, and maximize profits taking overall market prices as given. In each period a fraction, $\alpha \in [0,1)$, of randomly chosen producers is not allowed to change the nominal price of the goods they produce. The remaining fraction of firms, given by $1-\alpha$, chooses prices optimally by maximizing the expected discounted value of profits.

5.1.3 Monetary authorities

In each country, the monetary authority is assumed to follow a Taylor (1993)-type rule with interest-rate smoothing:

$$r_t^\star = \rho_r r_{t-1}^\star + (1-\rho_r)\phi\pi_t^\star + \varepsilon_{r^\star,t} \qquad r_t = \rho_r r_{t-1} + (1-\rho_r)\phi\pi_t + \varepsilon_{r,t}$$

where $\varepsilon_{r^\star,t}$ and $\varepsilon_{r,t}$ are i.i.d. disturbances drawn from a Normal distribution with mean zero and standard deviations $\sigma_{r^\star}$, and σ_r, respectively.[28] In line with central banks' practices, we assume that they target a measure of consumer price (CPI) inflation.

[28] Monetary authorities are assumed to target a zero inflation steady state.

5.2 Calibration and equilibrium conditions

In our model, the size of traders' balance sheet depends on risk perceptions. To account for risk in the computation of the model, we follow Coeurdacier et al. (2011) in deriving the "risky" steady state – a steady state in which agents expect future risk and the realization of shocks is zero at the current date. The risky steady state differs from the deterministic steady state only by second order terms related to variances and covariances of the endogenous variables. These second moments pin down the size of traders' long-run balance sheet. To analyze model dynamics, we then look at a first order log-linear approximation around the risky steady state. Crucially, we allow the steady-state net foreign assets, $\mathtt{b}$, to be non-zero.[29]

Calibration Our benchmark value for $\mathtt{b}$ is a net foreign asset position relative to (annual) GDP of around -15%, the median value in our sample of SOEs.[30] Our model is calibrated to a monthly frequency. We set $\beta^{\star} = 0.9967$ which implies a steady state annual interest rate of about 4%, and $\eta = 1$ which implies a unit Frisch elasticity. Our calibration of the Calvo parameter ($\alpha = 0.9167$) implies an average duration of price contracts of one year. We set the consumption share of imports $\lambda = 0.4$, and the trade elasticity $\theta = 1$. The Taylor-rule coefficient on consumer price inflation, ϕ, equals 1.5, while the parameter that governs the degree of interest rate smoothing, ρ_r, equals 0.947, in line with typically estimated values in the DSGE literature. We set $\rho_{\xi} = 0.90$.[31]

We choose the variances of the structural shocks so that the model reproduces three empirical moments: the unconditional variance of nominal exchange rate changes ($\mathrm{Var}(\Delta s_t)$), the observed unconditional deviation from UIP (α_1 in $\Delta s_{t+1} = \alpha_0 + \alpha_1(i_t - i_t^{\star})$) and the unconditional contemporaneous correlation between the exchange rate and the interest rate differential (β_1 in $\Delta s_t = \beta_0 + \beta_1 \Delta(i_t - i_t^{\star})$).

Equilibrium conditions We report below the model's log-linear equilibrium conditions, evaluated at the risky steady state.[32] The equilibrium conditions that govern economic

[29] In our model, we allow for different discount factors across countries, that is $\beta \neq \beta^{\star}$. This gives rise to different steady-state returns on the two countries' bonds, and a non-zero steady-state net foreign position.

[30] Data on annual net foreign asset position to GDP are from the updated and extended version of the dataset constructed by Lane and Milesi-Ferretti (2007).

[31] Without loss of generality we normalize the steady state so that $\ln(C^{\star}) = 1$.

[32] All variables are expressed as log deviations from their steady state, except for net foreign assets to GDP (b_t),

dynamics in the large (foreign) economy read:

$$\omega^\star \operatorname{E}_t \Delta c^\star_{t+1} + \omega^\star \operatorname{E}_t \Delta \xi_{t+1} = r^\star_t - \operatorname{E}_t \pi^\star_{t+1} \tag{13a}$$

$$\pi^\star_t = \beta^\star \operatorname{E}_t \pi^\star_{t+1} + \kappa^\star((\eta + \omega^\star)c^\star_t + \omega^\star \xi_t) \tag{13b}$$

$$r^\star_t = \rho r^\star_{t-1} + (1-\rho)\phi \pi^\star_t + \varepsilon_{r^\star,t} \tag{13c}$$

Given the exogenous processes, the economic dynamics in the large economy are fully described by the consumption Euler equation (Eq. 13a), the New Keynesian Phillips curve (Eq. 13b), and the monetary policy rule (Eq. 13c).[33] Both Eqs. (13a) and (13b) are influenced by shocks to foreign households' risk aversion ("global risk aversion shocks"), which act as taste shocks (cf. Stockman and Tesar, 1995).

Domestic variables are determined according to the following system of log-linear equations:

$$\omega \operatorname{E}_t \Delta c_{t+1} = r_t - \operatorname{E}_t \pi_{t+1} \tag{14a}$$

$$\pi_{H,t} = \beta \operatorname{E}_t \pi_{H,t+1} + \kappa(\omega c_t + \eta y_t + \lambda(1-\lambda)^{-1} q_t) \tag{14b}$$

$$r_t = \rho r_{t-1} + (1-\rho)\phi \pi_t + \varepsilon_{r,t} \tag{14c}$$

$$\pi_t = (1-\lambda)\pi_{H,t} + \lambda(\Delta s_t + \pi^\star_t) \tag{14d}$$

$$y_t = \theta\lambda(1-\lambda)^{-1} q_t + (1-\lambda)(1+\mathtt{b}-\widetilde{\beta}\mathtt{b})c_t + \left[1-(1-\lambda)(1+\mathtt{b}-\widetilde{\beta}\mathtt{b})\right](c^\star_t + \theta q_t) \tag{14e}$$

$$\widetilde{\beta}\,(b_{t+1} - \mathtt{b} r_t) - b_t + \mathtt{b}\,(\pi_{H,t} + \Delta y_t) = (1+\mathtt{b}-\widetilde{\beta}\mathtt{b})\left(y_t - c_t - \lambda(1-\lambda)^{-1} q_t\right) \tag{14f}$$

$$\Delta s_t = \Delta q_t - \pi^\star_t + \pi_t \tag{14g}$$

Since the SOE is effectively open to trade in goods and assets, it is affected by the dynamics of the exchange rate and foreign demand, as in the canonical model with complete exchange rate pass-through.[34] The key difference relative to the standard framework consists in the exchange rate determination, which is governed by Eq. (12), described above.

In this environment, there are three structural shocks: home and foreign monetary pol-

which is expressed as changes from its steady state. Also, $\widetilde{\beta} \equiv 1/\mathtt{R}$.

[33] The curvature parameter of the foreign economy's Phillips curve is given by $\kappa^\star \equiv \frac{(1-\beta^\star\alpha^\star)(1-\alpha^\star)}{\alpha^\star}$.

[34] Complete exchange rate pass-through implies that nominal exchange rate fluctuations directly translate into changes in home CPI (Eq. 14d), exactly because import prices are denominated in the (foreign) producer's currency, and these adjust sluggishly.

icy innovations ($\varepsilon_{r,t}$ and $\varepsilon_{r^\star,t}$), and shocks to global risk aversion ($\varepsilon_{\xi,t}$).

5.3 Equilibrium dynamics following a shock to global risk aversion

Figure 5 depicts the IRFs to a temporary reduction in global risk aversion. In the foreign economy, lower risk aversion induces households to increase current consumption, while firms' faced with higher demand raise their prices. The foreign central bank responds to the ensuing inflationary pressures by gradually raising the nominal interest rate, as per its desire for interest rate smoothing. In the foreign economy, a decline in global risk aversion is therefore associated with rising output, inflation, and nominal interest rate.

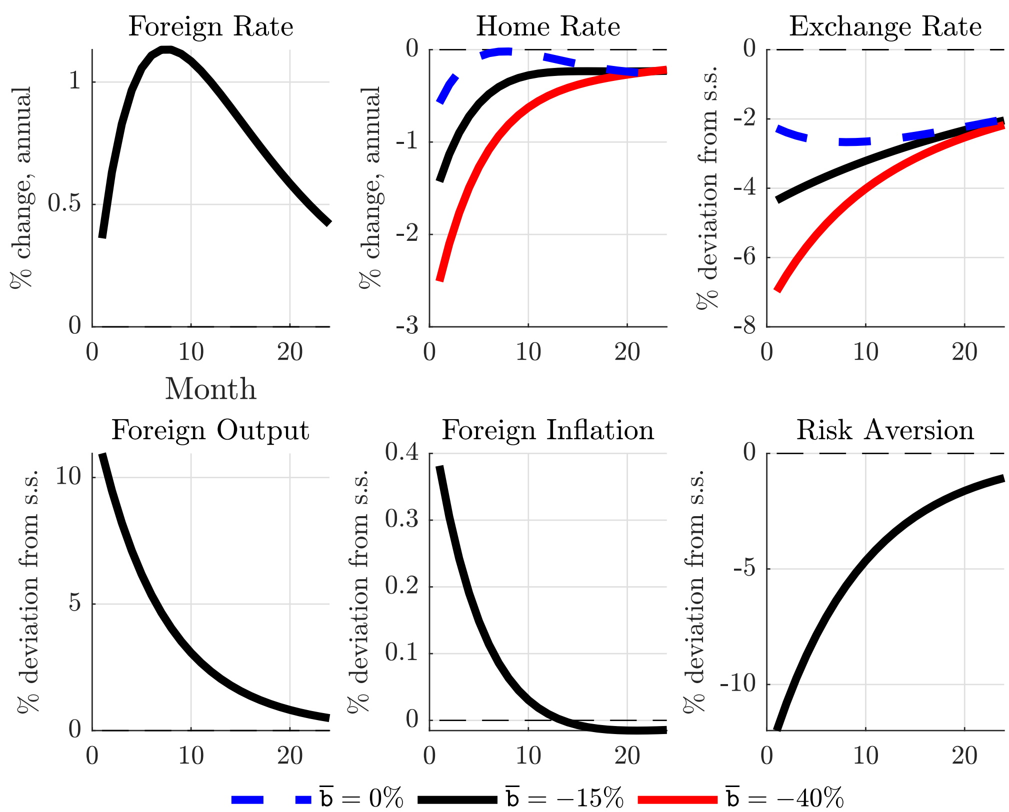


Figure 5: Theoretical IRFs to a temporary reduction in global risk aversion

Note: The impulse is an unanticipated 1% reduction in the foreign economy's degree of risk aversion.

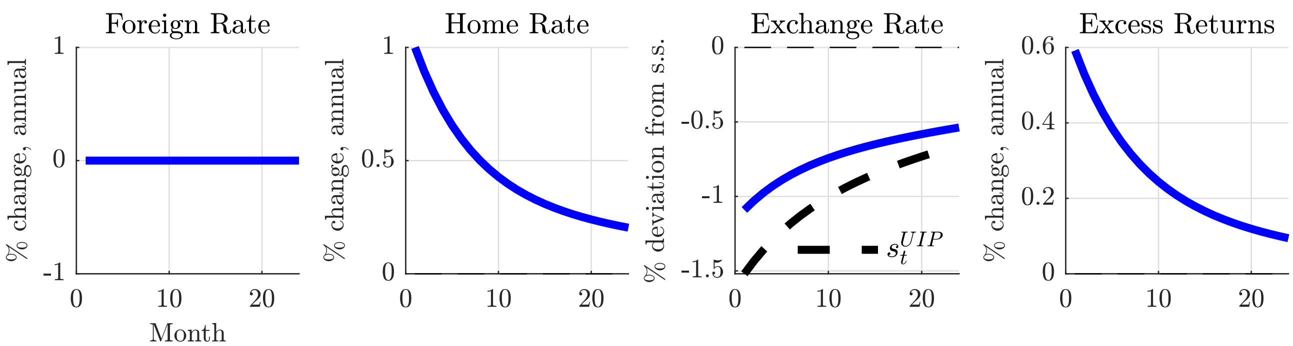
This shock affects the domestic economy through its effect on the exchange rate and foreign demand for home goods. *Ceteris paribus*, a decline in global risk aversion induces the financial sector to require lower excess returns on the domestic currency, thereby causing an instantaneous appreciation of the nominal exchange rate (Eq. 12). This effect is reinforced by higher external demand for domestic goods, which improves its net foreign asset to GDP position and reduces the degree to which international financial traders are exposed to home currency risk. These forces dominate over the nominal depreciation implied by the dynamics of the interest rate differential. In fact, the exchange rate response to this shock is largely shaped by the behavior of currency excess returns, as we will show below. In turn, the nominal appreciation of the small economy's exchange rate brings about a contemporaneous fall in import prices (in local currency) which puts downward pressure on domestic CPI inflation (see Eq. 14d). In our calibrated model, the deflationary forces implied by lower (domestic-currency) prices of imported goods govern the short-run dynamics of domestic CPI inflation.[35] As a result, the domestic central bank cuts the nominal interest rate. Thus, this shock acts as a favorable supply shock in the SOE, and leads to a procyclical response of an inflation-targeting monetary authority.

These impulse responses thus provide a natural interpretation of the comovement documented in Figure 3, as being driven by global risk aversion shocks.

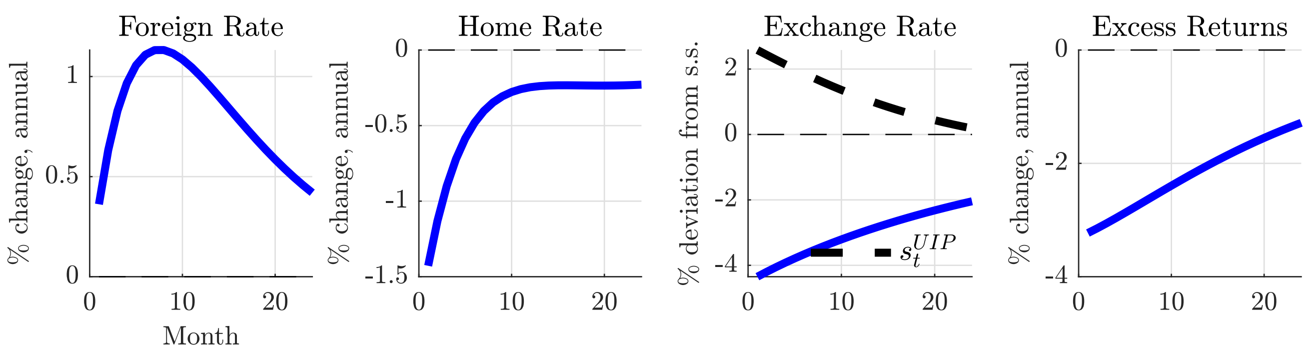
The role of net foreign assets Figure 5 also reports the impulse responses across different levels of the SOE's net foreign asset position to GDP. The blue line reports the impulse responses for an economy with $\texttt{b} = 0\%$, the value for the top quartile of our empirical sample, while the red line is for an economy with $\texttt{b} = -40\%$, the value for the top quartile of our empirical sample. In the economy with $\texttt{b} = 0\%$, changes in global risk aversion only influence exchange rates via the general equilibrium responses of the net foreign asset position and the interest rate differential (see Eq. 12). In this economy, a reduction in global risk aversion therefore brings about a lower degree of currency appreciation, relative to the benchmark economy. To the contrary, in the economy with high net foreign debt ($\texttt{b} = -40\%$ as in bottom quartile of our empirical sample), changes in global risk aversion exert a magnified effect relative to the benchmark case (see Eq. 12). Their exchange rate appreciates considerably more relative to the benchmark economy following a reduction in global risk aversion. The ranking in domestic interest rate responses across net foreign asset positions parallel to the one the the exchange rate responses. In fact, home CPI inflation – the variable that home central banks target – is largely determined by the imported inflation. In Section 6, we test these cross-country predictions of our model.

[35] The domestic component of CPI inflation reflects two opposing forces: higher product demand and adverse expenditure-switching effect due to worsening of the terms of trade.

Conditional UIP deviations Figure 6 depicts the theoretical IRFs of a country's exchange rate to transitory domestic and external shocks, which are taken to be the domestic monetary policy shock, and the global risk aversion shock, respectively.



(a) Theoretical impulse responses to a domestic shock



(b) Theoretical impulse responses to an external shock

Figure 6: Conditional properties of domestic and external shocks

Note: Domestic shocks are normalized to deliver a 1% impact increase in the home interest rate, while external shocks are normalized to deliver a 1% increase in the Fed Funds rate at one-year horizon. Excess returns are one-year ahead expected excess returns.

In our model, an unexpected domestic interest rate increase leads to a domestic currency appreciation (6a), an exchange rate response that is largely in line with the its UIP-consistent counterpart. Domestic monetary policy shocks (and, in fact, any shocks other than ξ_t) do not affect the level of global risk aversion. The variation in excess returns are due to the equilibrium worsening of the SOE net foreign asset position, which plays a minor quantitative role in determining exchange rate dynamics. To the contrary, the patterns of excess returns play a predominant role after shocks to global risk aversion (6b). The model is thus able to reproduce the patterns of conditional UIP deviations documented in

Figure 2.

6 Net foreign assets and exchange rate dynamics

In our model, the net foreign asset position of the SOE is *the* transmission mechanism of global risk aversion shocks (see Figure 5). In this section, we explore whether the data are consistent with this prediction.

In Figure 7, we report the empirical impulse responses to an external shock by group of countries, according to their NFA/GDP position. The ranking of responses of interest rates, exchange rates, and excess returns across NFA positions are very much in line with the prediction of our model. This evidence favors the idea that the net foreign asset position plays an important role in the international transmission mechanism, which is a natural feature of the exchange rate determination mechanism of our model with global risk aversion shocks.

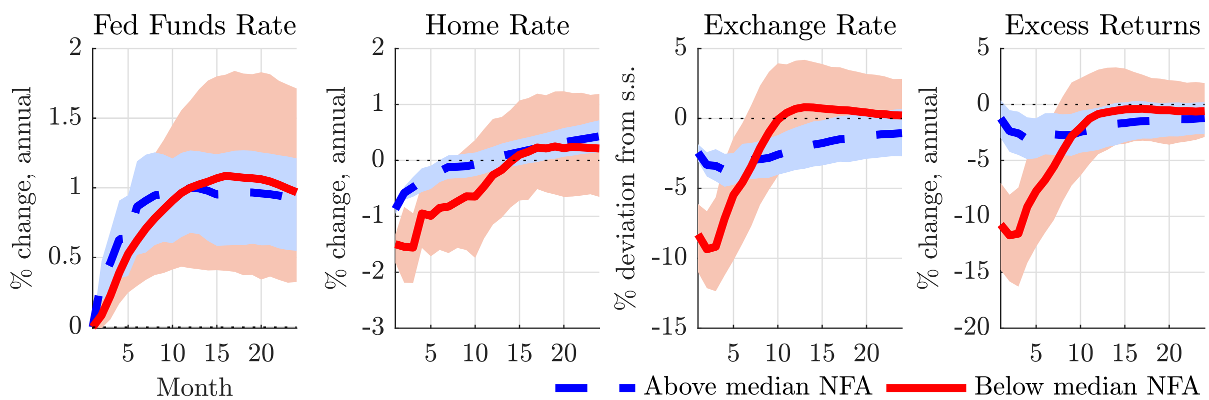


Figure 7: Empirical impulse responses to an external shock, by NFA position

Note: The lines denote median IRFs by group of countries with corresponding 90% confidence intervals from 1000 bias-corrected bootstrap replications of the reduced-form VAR. Groups denote above and below median NFAs. The shock is normalized to deliver a 1% increase in the Fed Funds rate at one-year horizon.

Besides, our model predicts that a country's net foreign asset position determines its exposure to external shocks. In particular, a country with a large NFA position should be more insulated from external shock relative to a country with a small one. A natural measure of exposure to external shocks is the fraction of the forecast error variance of a country's exchange rate explained by external disturbances. In Figure 8, we report a country's exposure to external shocks across net foreign asset position to GDP, along with the values predicted by our model. Countries with a higher ratio of net foreign liabilities to GDP indeed tend to be more exposed to external shocks, in a way that is quantitatively in line with our model's prediction. We take this as evidence that a country's net foreign asset position is a key determinant of exposure to external disturbances.[36]

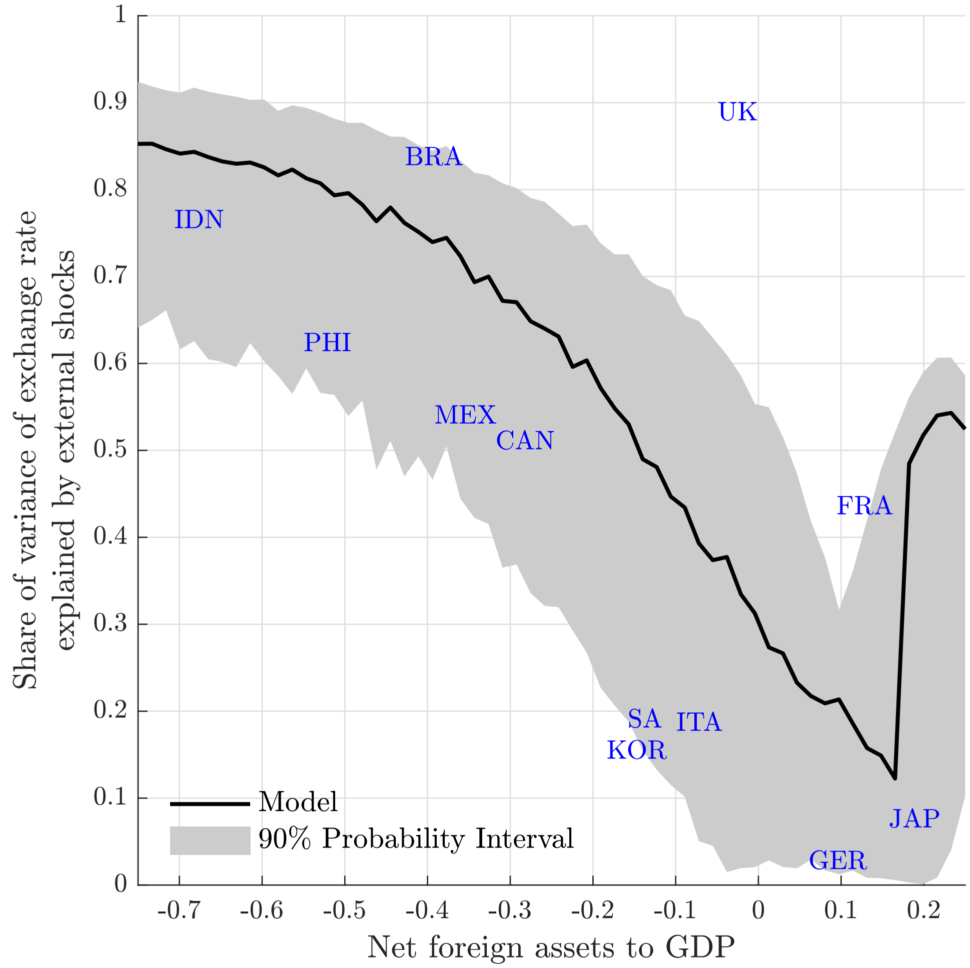


Figure 8: Net foreign assets and the exposure to external shocks

The black line denotes the fraction of forecast error variance of s_t that is explained by $\varepsilon_t^{\star\star}$ as we let b take values that we observe in our baseline sample.

[36] We also note that while a country's net foreign asset position is correlated with its development status, there are several exceptions that suggest that the level of development may not be the key factor that determines exposure to external shocks.

7 Domestic shocks and the ”exchange rate response puzzle”

One of our main empirical findings is that the domestic variation in exchange rates is largely consistent with UIP (Figure 2a). This feature is also present in our model, where only global risk aversion shocks generate large UIP deviations. In our model economy, a domestic monetary contraction brings about an increase in the home rate and an exchange rate appreciation, in line with standard open economy models (Figure **??**). This conclusion contrasts with the evidence in Hnatkovska et al. (2016) that the domestic currency tends to depreciate in response to a monetary tightening, especially in developing and emerging economies. This evidence, labeled “the exchange rate response puzzle,” is primarily based on recursive identification schemes within VARs. In this section, we show that recursive identification strategies are bound to confound the endogenous response of domestic variables to external shocks with the effect of domestic shocks. We then show that this misspecification problem is the source of the “exchange rate response puzzle.”

A recursive identification scheme The recursive identification scheme obtains as a special case of the identification approach we proposed in Section 2, when the D matrix is the identity matrix. In the context of a recursive identification, the exclusion restrictions consist in assuming that the impact matrix is lower triangular, that is

$$u_t = \begin{bmatrix} a_1 & 0 & 0 \\ a_2 & a_3 & 0 \\ a_4 & a_5 & a_6 \end{bmatrix} \widetilde{\varepsilon}_t \tag{15}$$

which is estimated with the Cholesky decomposition of Σ.

From Eq. (2), the restrictions on the impact matrix A_0 imply that the Federal Funds rate can respond contemporaneously only to its own innovations which are captured by the first element of the vector $\widetilde{\varepsilon}_t$. The policy controlled interest rate of the SOE is not allowed to react on impact to movements in the nominal exchange rate while it can respond to unanticipated movements in the Federal Funds rate. The second element element of the vector of structural shocks $\widetilde{\varepsilon}_t$ is thus typically interpreted as the monetary policy shock of the SOE. In this context, a domestic monetary policy shock influences the policy rate

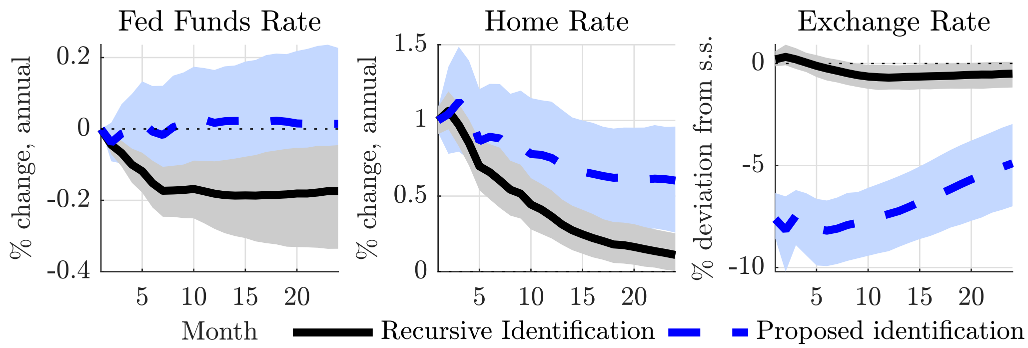


Figure 9: Empirical responses to a domestic shock across identification approaches

Note: The shaded areas are the 90% confidence intervals from 1000 bias-corrected bootstrap replications of the reduced-form VAR.

of the SOE (and possibly the exchange rate) contemporaneously, has no effect on the Federal Funds rate *contemporaneously*, and leaves the response of the Federal Funds rate unrestricted in the months following the shock.

Before discussing the estimated exchange rate response to monetary policy, we ask whether the identified monetary policy shocks are consistent with the assumptions of a SOE. To this end, Figure 9 depicts the impulse responses of the three variables in the baseline VAR to a domestic monetary policy shock obtained under recursive ordering, along with the impulse responses to a domestic shock obtained following our proposed identification approach. Under a recursive identification, a contractionary domestic monetary policy shock leads to a significant and persistent decline of the Federal Funds rate, the external variable of our VAR.[37]

There are two possible interpretations of the results in Figure 9. First, the U.S. economy, and, in turn, the Federal Reserve, may respond to disturbances that originate in SOEs, and in particular to their monetary policy innovations. Second, monetary policy in SOEs may respond to external shocks that affect the world interest rate with some delay. While both interpretations are valid in principle, we note that the first interpretation is both contrary to conventional wisdom and inconsistent with the very premise of a *small* open economy

[37] In Appendix B we perform a test of Granger causality that consists in regressing the Federal Funds rate or the cyclical component of U.S. industrial production on up to 36 lags of the identified monetary policy shock. The monetary policy shock identified through recursive ordering appears to systematically predict future movements in both external variables, especially when longer horizons are part of the regression. For the regression with the Federal Funds rate, we reject the null of no Granger causality in all countries at 5% level of significance with the exception of South Africa and Brazil. Somewhat similar figures appear when we perform the Granger causality test using the cyclical component of U.S. industrial production.

by which domestic shocks do not alter world interest rates and incomes.

We thus subscribe to the second interpretation, and argue that the domestic shocks identified through recursive schemes partly capture the endogenous response of domestic central banks to external shocks that influence the Federal Funds rate with some delay. These are the set of shocks that we identified as *anticipated* external shocks in Section 2. In addition, we note that these results question the applicability of the common block exogeneity restriction. In the context of the baseline VAR, block exogeneity is equivalent to setting the coefficients on domestic variables in the Federal Funds rate equation to zero. Under the null of no anticipated external shocks, these coefficients are in fact zero. However, if anticipated effects exist, as documented in Figure 9, these coefficients are not zero, and applying block exogeneity would be equivalent to imposing a counterfactual restriction.[38] While block exogeneity implies a restriction on the reduced-form parameters of the VAR, our proposed identification approach imposes a restriction on the propagation of shocks: domestic shocks have no effect on the world interest rate.

Comparison between identification schemes What is the relation between the shocks identified using a recursive identification and the ones identified with our proposed approach? By combining equations (1) and (4) one can show that

$$\widetilde{\varepsilon}_t^{mp} = \gamma_1 \varepsilon_t^{\star\star} + \gamma_2 \varepsilon_t^{SOE} \tag{16}$$

where $\widetilde{\varepsilon}_t^{mp}$ is the domestic monetary policy shock under a recursive identification, whereas $\varepsilon_t^{\star\star}$ and ε_t^{SOE} are the anticipated external shock and the domestic shock identified under the proposed alternative identification, respectively. Equation (16) implies the following. If the restrictions underlying a recursive identification were correct, both identification strategies would recover exactly the same set of shocks. In that case, the estimated value of γ_1 would be zero. However, if anticipated external shocks exist and spill over into the SOE (that is, if estimated $\gamma_1 \neq 0$), standard recursive identification schemes fail to correctly recover the true monetary policy shock. The empirical findings highlighted in Section 3 indicate that anticipated external shocks are important, and produce a comovement between domestic interest rates and exchange rates that is opposite from the one implied by domestic shocks.

[38] It is important to stress that the above statements are conditional on the information set spanned by the three variables included in the three-variable VAR outlined above.

These observations imply that conflating domestic and external sources of exchange rate fluctuations can lead to incorrect inference about the effects of domestic shocks.[39]

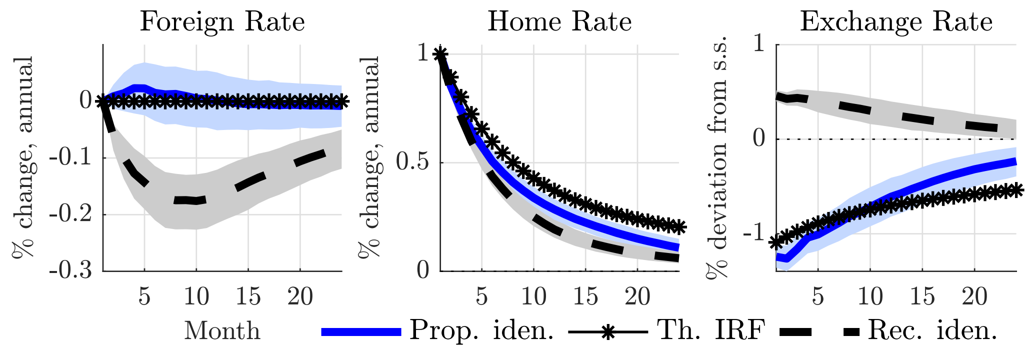
We argue that these observations point to the source of recent puzzling evidence on the exchange rate response to domestic monetary policy shocks. In particular, Hnatkovska et al. (2016) documented that the domestic currency tends to appreciate in advanced countries but depreciates in developing and emerging countries in response to a monetary tightening. This evidence, labeled "the exchange rate response puzzle," is primarily based on recursive identification schemes within VARs, and presents critical challenges for standard open economy theories. In Figure B.2, we show that the exchange rate response puzzle disappears after accounting for the effects of anticipated external shocks: in most countries, a monetary policy contraction is associated with a significant appreciation of the nominal exchange rate. Instead, a puzzle arises under a recursive identification scheme because it commingles domestic and external shocks, which give rise to opposite comovements between interest rates and exchange rates (see Figure 2).

7.1 Examining the performance of identification schemes

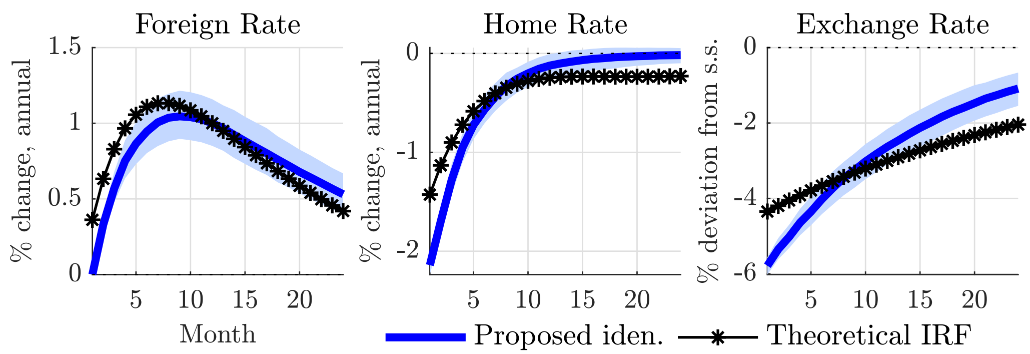
To examine the performance of our empirical approach, a three-variable system identical to the baseline empirical specification is estimated on model generated data. We show that our empirical approach correctly separates domestic and external sources of exchange rate variation, whereas a recursive VAR scheme reproduces the exchange rate puzzle.

Figure 10a indicates that the IRFs produced by our proposed identification approach correctly disentangle the different sources of variation. In fact, the identified domestic shock maps closely into the domestic monetary policy shock (the only domestic shock in our model), while the (anticipated) external shock maps into the global risk aversion shock. Figure 10b also presents the IRFs implied by a recursive identification presented above. The recursive VAR fails to correctly capture the exchange rate response to a domestic monetary policy innovation. In contrast to the theoretical response, the recursive VAR suggests that a policy-induced interest rate increase triggers a nominal depreciation. In addition,

[39] In Table B.2, we test the null of informational sufficiency of the VAR to recover the anticipated external shock. Following Forni and Gambetti (2014), we first compute the principal components of a large data set that captures all the relevant U.S. macroeconomic information, described in Appendix A. For each country, we then test whether the first h principal components, where $h = 1, \ldots, 5$, Granger cause the identified anticipated external shock, $\varepsilon_t^{\star\star}$. Table B.2 shows the p-value of the F-test statistics for the largest economies in our sample. We include 1, 3, and 5 principal components. We fail to reject the null of informational sufficiency at 5% level of significance in all countries.



(a) Domestic variation



(b) External variation

Figure 10: Model and Monte Carlo estimated IRFs: three-variable VAR

Note: The black starred line shows the theoretical IRF from the model presented in Section 5. Panel 10a reports the theroretical IRFs to a domestic monetary policy shock, while Panel 10b reports the theretical IRFs to a global risk aversion shock. The solid lines are the average estimated IRF from a Monte Carlo simulation with 45 repetitions (countries) and 150 observations per repetition. The shaded areas are the 90% confidence intervals from 1000 bias-corrected bootstrap replications of the reduced-form VAR. In Panel 10a both the recursive identification scheme ($\gamma_1 = 0$) and our proposed alternative are estimated on model-generated data.

the monetary policy shock series identified under the recursive scheme predicts significant changes in the Federal Funds rate, as documented empirically in Figure 9. This happens exactly because the recursive scheme conflates the independent variation in the domestic interest rates and its endogenous response to changes in global risk aversion.

8 Conclusions

The exchange rate is at the core of the international transmission mechanism, and a large literature has tried to understand the nature of its fluctuations. In this paper, we investigated what role domestic and external shocks played in shaping exchange rate dynamics in SOEs. Using an agnostic decomposition approach, we uncovered that one external shock drives a considerable part of the variation in exchange rate, and, especially, UIP deviations. Moreover, this external shock is significantly correlated with movements in global risk aversion, and connected to U.S. economic fluctuations. We illustrated that these empirical comovements can be interpreted as the equilibrium of a two-country SOE model with international financial market imperfections. In our model, global risk aversion shocks are an important driver of exchange rates and UIP deviations, and a country's net foreign asset position governs their international transmission. Our evidence accords well with our model predictions, suggesting that external imbalances are important in explaining exchange rate dynamics and their exposure to external shocks.

References

AKINCI, O. (2013): "Global financial conditions, country spreads and macroeconomic fluctuations in emerging countries," *Journal of International Economics*, 91, 358–371.

ALPANDA, S. AND U. AYSUN (2014): "International transmission of financial shocks in an estimated DSGE model," *Journal of International Money and Finance*, 47, 21–55.

BARSKY, R. B. AND E. R. SIMS (2011): "News shocks and business cycles," *Journal of Monetary Economics*, 58, 273–289.

BEN ZEEV, N., E. PAPPA, AND A. VICONDOA (2017): "Emerging economies business cycles: The role of commodity terms of trade news," *Journal of International Economics*, 108, 368–376.

BHATTARAI, S., A. CHATTERJEE, AND W. Y. PARK (2019): "Global Spillover Effects of US Uncertainty," *Journal of Monetary Economics*.

BRUNO, V. AND H. S. SHIN (2015): "Capital flows and the risk-taking channel of monetary policy," *Journal of Monetary Economics*, 71, 119–132.

CALVO, G. A. (1983): "Staggered prices in a utility-maximizing framework," *Journal of Monetary Economics*, 12, 383–398.

CANOVA, F. (2005): "The transmission of US shocks to Latin America," *Journal of Applied Econometrics*, 20, 229–251.

CARRILLO, J. A. AND R. ELIZONDO (2015): "How Robust Are SVARs at Measuring Monetary Policy in Small Open Economies?" Working Papers 2015-18, Banco de México.

CAVALLINO, P. (2019): "Capital Flows and Foreign Exchange Intervention," *American Economic Journal: Macroeconomics*, 11, 127–170.

CESA-BIANCHI, A., A. FERRERO, AND A. REBUCCI (2018): "International credit supply shocks," *Journal of International Economics*, 112, 219–237.

COEURDACIER, N., H. REY, AND P. WINANT (2011): "The Risky Steady State," *American Economic Review*, 101, 398–401.

DE PAOLI, B. (2009): "Monetary policy and welfare in a small open economy," *Journal of International Economics*, 77, 11–22.

DELLA CORTE, P., S. J. RIDDIOUGH, AND L. SARNO (2016): "Currency Premia and Global Imbalances," *Review of Financial Studies*, 29, 2161–2193.

di Giovanni, J., S. Kalemli-Ozcan, M. F. Ulu, and Y. S. Baskaya (2017): "International Spillovers and Local Credit Cycles," NBER Working Papers 23149, National Bureau of Economic Research, Inc.

Eichenbaum, M., B. K. Johannsen, and S. Rebelo (2017): "Monetary Policy and the Predictability of Nominal Exchange Rates," NBER Working Papers 23158, National Bureau of Economic Research, Inc.

Engel, C. (2014): "Exchange Rates and Interest Parity," Elsevier, vol. 4 of *Handbook of International Economics*, chap. 0, 453–522.

——— (2016): "Exchange Rates, Interest Rates, and the Risk Premium," *American Economic Review*, 106, 436–474.

Fanelli, S. and L. Straub (2018): "A Theory of Foreign Exchange Interventions," *Working paper*.

Faust, J. (1998): "The robustness of identified VAR conclusions about money," *Carnegie-Rochester Conference Series on Public Policy*, 49, 207–244.

Fernández, A., S. Schmitt-Grohé, and M. Uribe (2016): "World Shocks, World Prices, and Business Cycles: An Empirical Investigation," in *NBER International Seminar on Macroeconomics 2016*, National Bureau of Economic Research, Inc, NBER Chapters.

Forni, M. and L. Gambetti (2014): "Sufficient information in structural VARs," *Journal of Monetary Economics*, 66, 124–136.

Francis, N., M. T. Owyang, J. E. Roush, and R. DiCecio (2014): "A Flexible Finite-Horizon Alternative to Long-Run Restrictions with an Application to Technology Shocks," *The Review of Economics and Statistics*, 96, 638–647.

Gabaix, X. and M. Maggiori (2015): "International Liquidity and Exchange Rate Dynamics," *The Quarterly Journal of Economics*, 130, 1369–1420.

Galí, J. and T. Monacelli (2005): "Monetary Policy and Exchange Rate Volatility in a Small Open Economy," *Review of Economic Studies*, 72, 707–734.

Georgiadis, G. and M. Jancoková (2017): "Financial globalisation, monetary policy spillovers and macromodelling: tales from 1001 shocks," Working Paper Series 2082, European Central Bank.

Guerron-Quintana, P. A. (2013): "Common and idiosyncratic disturbances in developed small open economies," *Journal of International Economics*, 90, 33–49.

Hamilton, J. D. (1994): *Time Series Analysis*, Princeton University Press.

Hnatkovska, V., A. Lahiri, and C. A. Vegh (2016): "The Exchange Rate Response to Monetary Policy Innovations," *American Economic Journal: Macroeconomics*, 8, 137–81.

IACOVIELLO, M. AND G. NAVARRO (2018): "Foreign effects of higher U.S. interest rates," *Journal of International Money and Finance*.

ILZETZKI, E., C. M. REINHART, AND K. S. ROGOFF (2017): "The Country Chronologies to Exchange Rate Arrangements into the 21st Century: Will the Anchor Currency Hold?" NBER Working Papers 23135, National Bureau of Economic Research, Inc.

ITSKHOKI, O. AND D. MUKHIN (2017): "Exchange Rate Disconnect in General Equilibrium," NBER Working Papers 23401, National Bureau of Economic Research, Inc.

——— (2019): "Mussa Puzzle Redux," *Working paper*.

JÄÄSKELÄ, J. P. AND D. JENNINGS (2011): "Monetary policy and the exchange rate: Evaluation of VAR models," *Journal of International Money and Finance*, 30, 1358–1374.

JEANNE, O. AND A. K. ROSE (2002): "Noise Trading and Exchange Rate Regimes," *The Quarterly Journal of Economics*, 117, 537–569.

JUSTINIANO, A. AND B. PRESTON (2010): "Can structural small open-economy models account for the influence of foreign disturbances?" *Journal of International Economics*, 81, 61–74.

KILIAN, L. (1998): "Small-Sample Confidence Intervals for Impulse Response Functions," *The Review of Economics and Statistics*, 80, 218–230.

LANE, P. R. AND G. M. MILESI-FERRETTI (2007): "The external wealth of nations mark II: Revised and extended estimates of foreign assets and liabilities, 1970-2004," *Journal of International Economics*, 73, 223–250.

LEVCHENKO, A. A. AND N. PANDALAI-NAYAR (2015): "TFP, News, and 'Sentiments:' The International Transmission of Business Cycles," NBER Working Papers 21010, National Bureau of Economic Research, Inc.

LUSTIG, H., N. ROUSSANOV, AND A. VERDELHAN (2011): "Common Risk Factors in Currency Markets," *Review of Financial Studies*, 24, 3731–3777.

MACKOWIAK, B. (2007): "External shocks, U.S. monetary policy and macroeconomic fluctuations in emerging markets," *Journal of Monetary Economics*, 54, 2512–2520.

MIRANDA-AGRIPPINO, S. AND H. REY (2015): "US Monetary Policy and the Global Financial Cycle," NBER Working Papers 21722, National Bureau of Economic Research, Inc.

OBSTFELD, M. AND K. ROGOFF (1995): "Exchange Rate Dynamics Redux," *Journal of Political Economy*, 103, 624–60.

REINHART, C. M. AND K. S. ROGOFF (2004): "The Modern History of Exchange Rate Arrangements: A Reinterpretation," *The Quarterly Journal of Economics*, 119, 1–48.

Rey, H. (2013): "Dilemma not trilemma: the global cycle and monetary policy independence," *Proceedings - Economic Policy Symposium - Jackson Hole*, 1–2.

Scott Davis, J. and A. Zlate (2019): "Monetary policy divergence and net capital flows: Accounting for endogenous policy responses," *Journal of International Money and Finance*, 94, 15–31.

Stockman, A. C. and L. L. Tesar (1995): "Tastes and Technology in a Two-Country Model of the Business Cycle: Explaining International Comovements," *American Economic Review*, 85, 168–185.

Taylor, J. B. (1993): "Discretion versus policy rules in practice," *Carnegie-Rochester Conference Series on Public Policy*, 39, 195–214.

Uhlig, H. (2003): "What drives GNP?" *Working paper*.

Uribe, M. and V. Z. Yue (2006): "Country spreads and emerging countries: Who drives whom?" *Journal of International Economics*, 69, 6–36.

Vicondoa, A. (2019): "Monetary news in the United States and business cycles in emerging economies," *Journal of International Economics*, 117, 79–90.

A Dataset

- Nominal exchange rates (s_t, monthly): the preferred measure of exchange rates are official exchange rates. If these are not available, we use period average market rates, or period average principal exchange rates. The main data source is the International Financial Statistics (IFS) compiled by the International Monetary Fund (IMF).

- Policy-controlled interest rates (r_k, monthly): These rates are measured in the data as the period average T-bill rates, the closest to the overnight interbank lending rates. If these are not available, discount rates, or money market rates are used. The main data source is the International Financial Statistics (IFS) compiled by the International Monetary Fund (IMF).

- U.S. policy-controlled interest rates ($r^\star$, monthly): This rate is measured by the Federal Funds rate.

- Exchange rate regimes: these are determined according to the historical exchange rate classification in Reinhart and Rogoff (2004), recently updated by Ilzetzki et al. (2017). A country is deemed to have a flexible exchange rate regime if, in a given year, its exchange rate was either (i) within a moving band that is narrower than or equal to +/2 percent; or (ii) was classified as managed floating; or (iii) was classified as freely floating; or (iv) was classified as freely falling in Reinhart and Rogoff (2004). For countries that had multiple episodes of flexible exchange rates during this period, we consider each episode separately subject to the restriction that there were at least 24 months of data in each episode.

- U.S. industrial production (monthly):

- U.S. CPI inflation (monthly):

- Chicago Board Options Exchange Volatility Index (VIX, monthly):

- Net foreign asset positions to GDP (annual): Updated and extended version of dataset constructed by Lane and Milesi-Ferretti (2007).

- Data used for information sufficiency test (monthly):

- List of countries in the dataset: Brazil (1999:2-2007:12), Canada (1974:1-2010:11), France (1974:1-1998:12), Germany (1975:7-1998:12), Indonesia (1997:8-2007:12), Italy (1977:3-1998:12), Japan (1974:1-2010:11), Korea, Rep. of (1997:12-2007:12), Mexico (1995:1-2007:12), Philippines (1997:7-1999:11), South Africa (1995:3-2007:12), United Kingdom (1974:1-2010:10).

B Additional tables and figures

	Federal Funds rate			U.S. industrial prod.		
	1 lag	12 lags	36 lags	1 lag	12 lags	36 lags
Germany	0.00	0.00	0.31	0.00	0.00	0.00
Canada	0.00	0.00	0.00	0.00	0.00	0.01
Italy	0.03	0.60	0.93	0.06	0.05	0.00
France	0.00	0.00	0.00	0.00	0.00	0.00
Japan	0.02	0.01	0.04	0.20	0.54	1.00
United Kingdom	0.01	0.00	0.00	0.09	0.00	0.01
Indonesia	0.93	0.00	0.00	0.83	0.01	0.39
Brazil	0.98	1.00	0.86	0.98	0.04	0.81
South Africa	0.92	0.99	0.22	0.73	0.99	1.00
Korea	0.88	0.46	0.00	0.21	0.60	0.83
Mexico	1.00	1.00	0.00	0.86	1.00	0.40
Philippines	0.70	0.03	-	0.87	0.69	-

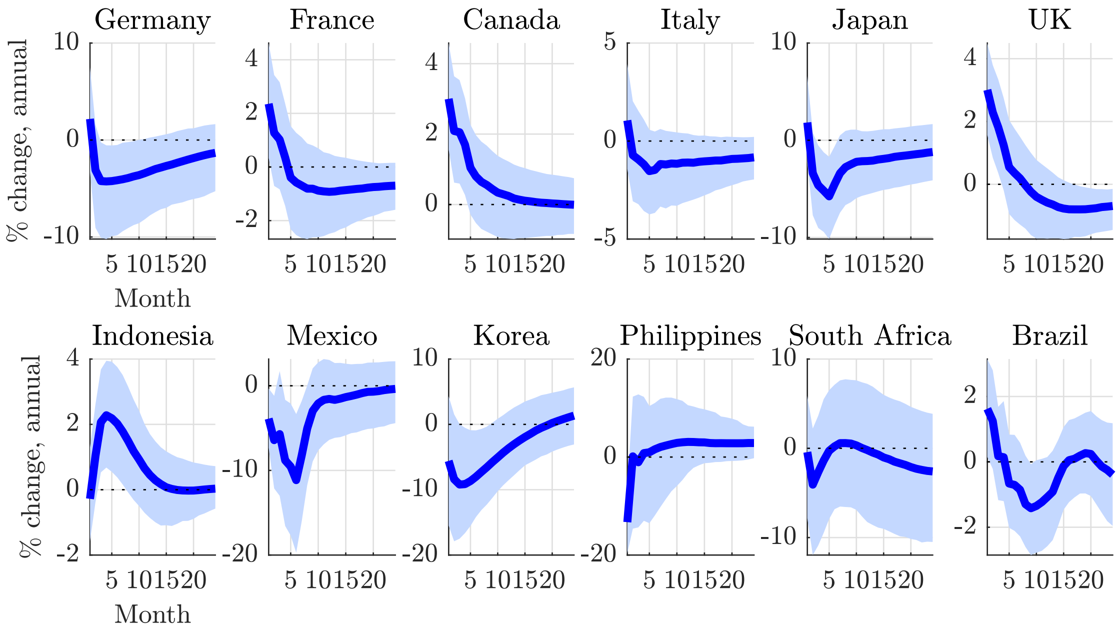
Table B.1: Granger causality test

Notes: The table reports the p-values of the F-statistic of a regression of Federal Funds rate and HP-filtered U.S. industrial production on up to 36 lags of the domestic shock series identified using recursive ordering for each country. The p-value for Philippines is not reported for 36 lags because of its limited sample size.

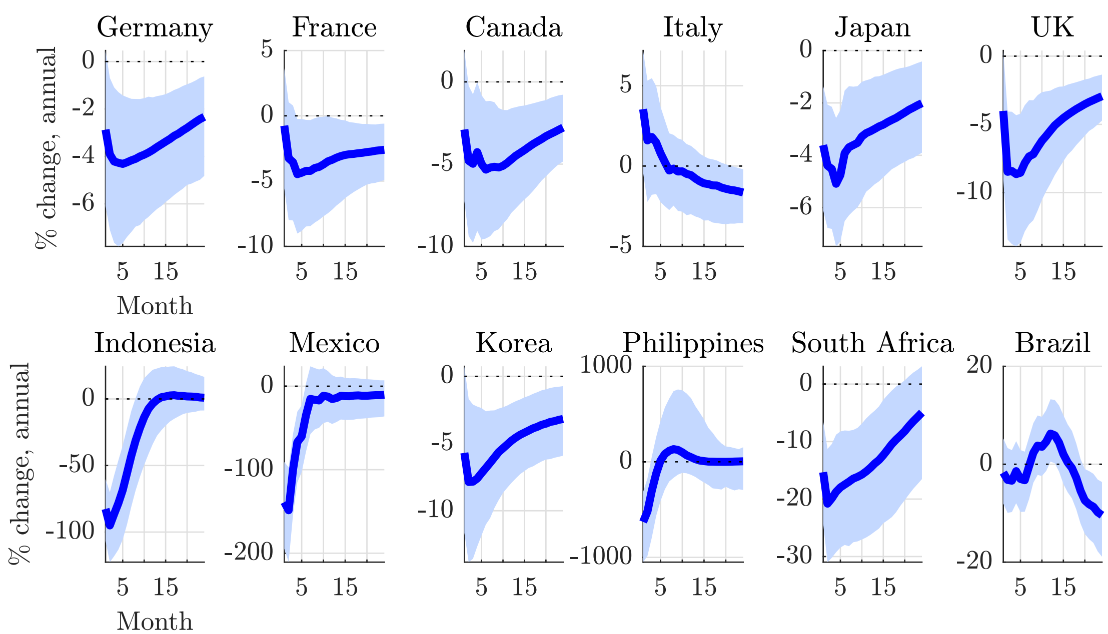
	P-value of F-statistic						
	P.C. =1	*P.C. = 3*	*P.C. =5*		*P.C. =1*	*P.C. = 3*	*P.C. =5*
Germany	0.27	0.51	0.61	Indonesia	0.99	0.99	1.00
Canada	0.24	0.57	0.68	Brazil	0.72	0.97	0.87
Italy	0.21	0.17	0.33	South Africa	0.42	0.82	0.44
France	0.88	0.93	0.47	Korea	0.09	0.36	0.10
Japan	0.30	0.19	0.22	Mexico	0.74	0.52	0.55
United Kingdom	0.83	0.81	0.47	Philippines	0.80	0.97	0.82

Table B.2: Information sufficiency test (cf. Forni and Gambetti, 2014)

Notes: The table reports the p-values of the F-statistic of a regression of the identified anticipated external shock on up to 5 principal components (P.C.) of a large data set capturing all the relevant U.S. macroeconomic information, described in Appendix A.



(a) Domestic shock



(b) External shock

Figure B.1: Currency excess returns

Note: The figure shows the response of one-year ahead ex ante excess returns to domestic (Panel B.1a) and external (Panel B.1b) shocks. The lines denote IRFs with corresponding 90% confidence intervals from 1000 bias-corrected bootstrap replications of the reduced-form VAR. Domestic shocks are normalized to deliver a 1% impact increase in the home interest rate, while external shocks are normalized to deliver a 1% increase in the Fed Funds rate at one-year horizon.

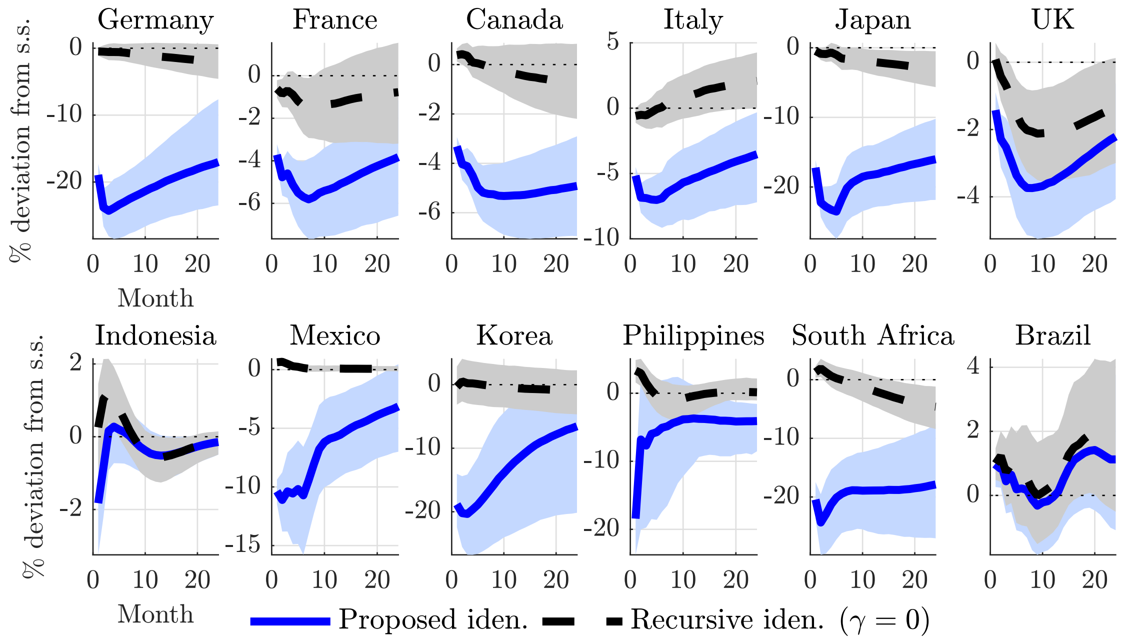


Figure B.2: Exchange rate response to a domestic shock across identification approaches

Note: The blue solid lines are the estimated exchange rate IRFsto domestic shock from the baseline three-variable VAR identified using our proposed identification. The black dashed lines are the estimated exchange rate IRFs to domestic shock from the baseline three-variable VAR identified using a recursive scheme. The shaded areas are the 90% confidence intervals from 1000 bias-corrected bootstrap replications of the reduced-form VAR. Impulse responses are normalized to deliver a 1% impact increase in the domestic interest rate.

C Additional model details

C.1 Traders's decision problem

This section shows that a CRRA utility has a mean-variance representation. The problem of the international trader reads as follows:

$$\max_{d_{t+1}} \mathrm{E}_t \left[\frac{(T^\star + \widetilde{R}_{t+1} d_{t+1})^{1-\omega_t^\star}}{1-\omega_t^\star} \right] = \mathrm{E}_t \left[\frac{\exp\left\{ (1-\omega_t^\star) \log(T^\star + \widetilde{R}_{t+1} d_{t+1}) \right\}}{1-\omega_t^\star} \right] \tag{17}$$

where $T^\star$ is such that $(T^\star + \widetilde{R}_{t+1} d_{t+1}) > 0$.

Take second order Taylor expansion around $\widetilde{R} = 0$:

$$\log(T^\star + \widetilde{R}_{t+1} d_{t+1}) \approx \log(T^\star) + \frac{d_{t+1}}{T^\star} \widetilde{R}_{t+1} - \frac{d_{t+1}^2}{2\,(T^\star)^2} \widetilde{R}_{t+1}^2$$

$$\approx \log(T^\star) + \frac{d_{t+1}}{T^\star}\widetilde{R}_{t+1} - \frac{d_{t+1}^2}{2\left(T^\star\right)^2}\,\mathrm{Var}_t(\widetilde{R}_{t+1})$$

where $\widetilde{R}_{t+1}^2$ is replaced by the conditional variance of $\widetilde{R}_{t+1}$.[40,41] Then Eq. (17) is approximated by:

$$\max_{d_{t+1}}\ \mathrm{E}_t\left[\frac{\exp\left\{(1-\omega_t^\star)\left(\log(T^\star) + \frac{d_{t+1}}{T^\star}\widetilde{R}_{t+1} - \frac{d_{t+1}^2}{2(T^\star)^2}\,\mathrm{Var}_t(\widetilde{R}_{t+1})\right)\right\}}{1-\omega_t^\star}\right]$$

$$\approx \max_{d_{t+1}}\ \exp\left\{(1-\omega_t^\star)\left(\log(T^\star) - \frac{d_{t+1}^2}{2\left(T^\star\right)^2}\,\mathrm{Var}_t(\widetilde{R}_{t+1})\right)\right\}\mathrm{E}_t\left[\exp\left\{(1-\omega_t^\star)\left(\frac{d_{t+1}}{T^\star}\widetilde{R}_{t+1}\right)\right\}\right].$$

Assume normal distribution of $\widetilde{R}_{t+1}$, then

$$\approx \max_{d_{t+1}}\ \log(T^\star) - \frac{d_{t+1}^2}{2\left(T^\star\right)^2}\,\mathrm{Var}_t(\widetilde{R}_{t+1}) + (1-\omega_t^\star)\frac{d_{t+1}^2}{2\left(T^\star\right)^2}\,\mathrm{Var}_t(\widetilde{R}_{t+1}) + \frac{d_{t+1}}{T^\star}\,\mathrm{E}[\widetilde{R}_{t+1}]$$

$$\approx \max_{d_{t+1}}\ \mathrm{E}_t[\widetilde{R}_{t+1}]d_{t+1} - \frac{\omega_t^\star}{2T^\star}\,\mathrm{Var}_t(\widetilde{R}_{t+1})d_{t+1}^2$$

In equilibrium, the individual trader's asset decisision reads

$$d_{t+1} = \frac{T^\star\,\mathrm{E}_t[\widetilde{R}_{t+1}]}{\omega_t^\star\,\mathrm{Var}_t(\widetilde{R}_{t+1})}$$

Without loss of generality, we set $T^\star = 1$. Then, aggregating over the m_t measure of traders, the overall demand for domestic bonds from traders is

$$\widetilde{D}_{t+1} = \frac{m_t}{\omega_t^\star}\frac{\mathrm{E}_t\,\widetilde{R}_{t+1}}{\mathrm{Var}_t(\widetilde{R}_{t+1})}$$

which is Eq. (10) in the text.

[40] Note that $\mathrm{E}_t[\widetilde{R}_{t+1}]^2 \approx 0$.

[41] As the time interval shrinks, the higher order terms that are dropped from (17) become negligible relative to those that are included, and the deviation of $\widetilde{R}_{t+1}^2$ from $\mathrm{Var}_t(\widetilde{R}_{t+1})$ also become negligible. In particular in the limit of continuous time the approximation is exact and can be derived using Ito's Lemma.

C.2 Model equilibrium equations

Besides each country's Phillips Curve, the model's equilibrium equations in levels are given by:

$$\beta^\star \, \mathrm{E}_t \left[\left(C^\star_{t+1}\right)^{-\omega^\star \exp(\omega^\star_{t+1})} \frac{R^\star_t}{\Pi^\star_{t+1}} \right] = \left(C^\star_t\right)^{-\omega^\star \exp(\omega^\star_t)}$$

$$\frac{R^\star_t}{R^\star} = \left(\frac{R^\star_{t-1}}{R^\star} \right)^{\rho_R} \left(\frac{\Pi^\star_t}{\Pi^\star} \right)^{(1-\rho_R)\phi} \exp\left(\varepsilon_{r^\star,t}\right)$$

$$\beta \, \mathrm{E}_t \left[\left(C_{t+1}\right)^{-\omega} \frac{R_t}{\Pi_{t+1}} \right] = \left(C_t\right)^{-\omega}$$

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R} \right)^{\rho_R} \left(\frac{\Pi_t}{\Pi} \right)^{(1-\rho_R)\phi} \exp\left(\varepsilon_{r,t}\right)$$

$$\Pi_t = \left(\Pi_{H,t}\right)^{1-\lambda} \left(\frac{S_t}{S_{t-1}} \Pi^\star_t \right)^{\lambda}$$

$$Y_t = Q_t^{\frac{\theta\lambda}{1-\lambda}} \left\{ (1-\lambda) C_t + \lambda Q_t^\theta C^\star_t \right\}$$

$$\frac{B_{t+1}/P_{H,t}Y_t}{R_t} - B_t/P_{H,t-1}Y_{t-1} \frac{1}{\Pi_{H,t} Y_t/Y_{t-1}} = 1 - Q_t^{-\frac{\lambda}{1-\lambda}} \frac{C_t}{Y_t}$$

$$S_t = Q_t \frac{P_t}{P^\star_t}$$

$$-B_{t+1}/P_{H,t}Y_t = \frac{\mu \, \mathrm{E}_t \left(R_t - R^\star_t \frac{S_{t+1}}{S_t} \right)}{\mathrm{Var}_t \left(R_t - R^\star_t \frac{S_{t+1}}{S_t} \right)}$$

C.3 Model solution

We can represent the model outlined in Appendix C.2 as the following system of equations:

$$\mathrm{E}_t \left[f(X_{t+1}) \right] = 0$$

where X_{t+1} contains all the variables in the model (including variables dated at time t and $t-1$) and f has as many rows as endogenous variables in the model. The risky steady state (Coeurdacier et al., 2011) is obtained by taking a second-order approximation of f around $\mathrm{E}_t X_{t+1}$:

$$\Phi\left(\mathrm{E}_t X_{t+1}\right) = f\left(\mathrm{E}_t X_{t+1}\right) + \mathrm{E}_t\left[f''\left[X_{t+1} - \mathrm{E}_t X_{t+1}\right]^2\right]$$

where f'' is also evaluated at $\mathrm{E}_t X_{t+1}$. The risky steady state, $\mathtt{X}$, is then characterized by $\Phi\left(\mathtt{X}\right) = 0$, and the second moments $\mathrm{E}_t\left[f''\left[X_{t+1} - \mathrm{E}_t X_{t+1}\right]^2\right]$ are generated by the linear dynamics around $\mathtt{X}$.

The model's solution thus consists in a log-linear approximation around a risky steady state that is consistent with the second moments generated by the log-linear dynamics around it. This is achieved through an iterative algorithm, along the lines of Coeurdacier et al. (2011).