Global Spillover Effects of US Uncertainty*

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Abstract

We study spillover effects of US uncertainty fluctuations using data from fifteen emerging market economies (EMEs) in a panel VAR framework. A US uncertainty shock negatively affects EME stock prices and exchange rates, raises EME country spreads, and leads to capital outflows from them. Moreover, it decreases EME output, while increasing their consumer prices and net exports. The negative effects on output, exchange rates, and stock prices are weaker, but the effects on capital and trade flows stronger, for South American countries compared to other EMEs. We present a model of a small open economy that faces an external shock to interpret our empirical findings. Theoretically and empirically, we link the heterogeneity in effects across the two groups of EMEs to their differential monetary policy response to the US uncertainty shock.

Keywords: US Uncertainty; Panel VAR; Emerging Market Economies; Monetary Policy Response

JEL Classification: C11; C33; E44; E52; E58; F32

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1 Introduction

What are the international spillover effects of fluctuations in US uncertainty? Given the recent integration of the emerging market economies (EMEs) to world financial markets, how does US financial uncertainty transmit to these countries? Does this cross-border transmission differ, depending on the monetary policy stance of the EMEs?

These issues have received increased attention recently. Policy makers in EMEs often cite increases in US uncertainty as a major reason for revising their economic forecasts downward as well as for an increase in the volatility of capital flows. US uncertainty fluctuations in fact could have serious policy implications for EMEs beyond simple negative spillover effects. Rey (2013) highlights how fluctuations in the Chicago Board of Options Exchange (CBOE) VIX index tend to drive a global financial cycle and thereby, affect global asset prices and financial flows. Rey (2013, 2015) argues that for periphery countries like EMEs, the traditional open-economy policy "trilemma" might have morphed into a "dilemma": countries cannot have both independent monetary policy and perfect capital mobility, even with flexible exchange rates. In fact, even the effectiveness of traditional monetary policy of EMEs in mitigating the impact of fluctuations in US uncertainty is not fully understood.

We contribute to this topic on two main fronts. First, we measure empirically and study theoretically the spillover effects on EMEs of fluctuations in US financial uncertainty. Second, we study, again both empirically and theoretically, heterogeneity across EMEs with respect to transmission of this shock and monetary policy responses. Our results provide strong evidence that a rise in US financial uncertainty has substantial financial and macroeconomic effects on EMEs. Moreover, we find that the monetary policy response by EMEs can affect the cross-border transmission of the US uncertainty shock.

We estimate a monthly panel VAR for fifteen EMEs: Chile, Colombia, Brazil, India, Indonesia, Malaysia, Mexico, Peru, Philippines, Russia, South Africa, South Korea, Taiwan, Thailand, and Turkey. The panel VAR includes an unanticipated component of US financial market uncertainty as an external shock. In particular, we take the random coefficient approach to partially pool the cross-sectional information in the data and estimate average effects across EMEs of fluctuations in US uncertainty.

We estimate that unanticipated changes in US financial market uncertainty have significant financial and macroeconomic effects on the EMEs. An unanticipated increase in US uncertainty depreciates the local currency of EMEs, leads to a decline in local stock markets, increases long-term interest rate spreads (vis-à-vis the US), and is followed by capital outflows. Specifically, on average across EMEs, a 1% increase in US financial uncertainty leads to a 0.0035% point increase in the short-term interest rate, a 0.012% point increase in the long-term interest rate compared to the US, a 0.125% fall in the stock prices, a 0.045% depreciation of the local currency, and a 0.0175% point capital outflows relative to GDP. These are peak effects of US uncertainty fluctuations that occur 2-12 months after the impact. The effects on EME financial markets are adverse and significant for a time period of 2 years.

Importantly, we find that these financial effects transmit to the real economy. In response to a 1% increase in US financial market uncertainty, on average, output drops by 0.035% and net exports from these countries to the US rise by about 0.0022% point relative to GDP. These are peak effects, which occur after a delay of 4-8 months. Consumer prices increase persistently and reach about 0.004% higher 24 months after the impact. These effects on EMEs are potentially large and economically meaningful as the standard deviation of unanticipated fluctuations in US uncertainty we estimate is about 14.4%.[1]

The effects on financial variables suggest that a US uncertainty shock triggers a "flight to safety/quality" phenomenon: Investors appear to pull capital out of the emerging markets that are perceived to be riskier than the US despite the increase in uncertainty in the US, thus negatively affecting asset prices such as stock prices and exchange rates, while pushing up their cost of borrowing as country spreads vis-à-vis the US increase. The increase in net exports and decrease in capital inflows illustrates that one of the channels through which the effects of the US uncertainty shock transmits is via a reduction in aggregate spending. Moreover, consumer prices increase, which illustrates that the US uncertainty shock leads to a trade-off for central banks of these countries as it leads to both output contraction and inflation.

We also assess the heterogeneity in responses between South American and the rest of EMEs by allowing the effects of the US uncertainty shock to be different across these subgroups. We find that South American countries suffer less in terms of a decrease in output and asset prices but experience a larger reversal in capital flows and a larger increase in net exports. Intriguingly, compared to South American countries, while the rest of the EMEs get affected more negatively in terms of output (with similar effects in terms of consumer prices), their short-term interest rates do not decrease by more. Given a larger output response, the policy rates of the rest of EMEs can be considered "relatively high" and monetary policy "relatively tight." We conjecture that this is to stem capital outflows, but such an effect comes at the cost of a larger output contraction and drop in asset prices.

To help interpret our empirical findings, we present a simple two-good small open economy (SOE) model that can account qualitatively for our empirical findings: In the model,

[1]Note that as a check, we find that our results do not change even if we include a realized measure of stock market uncertainty of the EMEs themselves in the VAR.

a negative external shock that increases the interest rate spread faced by the SOE produces responses of macroeconomic and financial variables that are consistent with our estimated responses.[2] The increase in the country interest rate spread drives output as well as consumption and investment expenditures down. As the SOE cuts down on expenditure strongly, net exports increase. A reduction in borrowing gets reflected in current account surplus. The model implications for consumer prices and stock prices are also consistent with the empirical evidence.

Finally, the model provides a possible explanation for the heterogeneity in responses across countries. We model monetary policy as a Taylor-type rule where the central bank possibly responds to the country interest rate spread in addition to the usual endogenous reaction to inflation and output. This reflects a desire on the part of policy to stem capital outflows. We show that in case of such a response by central banks, capital flows are less volatile after the shock, but the response of output and asset prices is stronger.

While the model helps provide grounding for our interpretation of the empirical results, we also present results from other validation exercises. First, we show that the spillover effects of a US monetary policy shock are very similar to those of a US uncertainty shock.[3] This is the case for both the aggregate and sub-group results. Second, using indices for capital control measures, we find that South American countries use capital controls to a lesser extent than the rest of EMEs. Thus, the rest of EMEs pay greater attention to capital flows and possibly use both conventional interest rate policy as well as direct capital controls to counteract its volatility. Finally, through reading of central bank minutes and textual analysis, we show that the rest of EMEs are quite concerned about capital flow volatility.

Our paper is related to several strands of the literature. We build on the body of work pioneered by Bloom (2009). Miranda-Agrippino and Rey (2015) provide further econometric evidence for the global financial cycle emphasized by Rey (2013). They document the presence of a global factor that explains a significant fraction of variation in global asset returns and show that the US monetary policy shock affects this global factor as well as global credit and financial variables. Our theme is similar with a focus on spillovers of US financial uncertainty specifically to EMEs.

In terms of empirics, we use a random coefficients Bayesian panel VAR, which builds on Canova (2007) and Canova and Ciccarelli (2013). We use a Gibbs sampling algorithm

[2]We posit an external shock that increases the (level of) spread faced by the SOE, as it is consistent with our empirical findings. Thus we can interpret this shock as capturing fluctuations in the belief of external investors that lending to the SOE is risky. It can also capture a flight to safety/quality phenomenon. As an alternate, we also study a case where the external shock is a second-moment shock to the spread faced by the SOE.

[3]These results on US monetary policy appeared in detail in Bhattarai, Chatterjee, and Park (2017b), which is now subsumed in this paper.

that allows us to estimate a high-dimensional panel VAR while allowing for shocks across the countries to be correlated. This approach allows us to make inference on the average effect across countries of an external shock, while allowing for heterogeneous country-specific effects. Our framework also allows for the average effect to be different across sub-groups of the countries. This exercise led us to study how the differential response in monetary policy by the EMEs might change the transmission of the US uncertainty shock.

In terms of theory, we extend the classic one-good SOE business cycle model with an external financial shock, building on Uribe and Yue (2006) and Neumeyer and Perri (2005). We extend this framework to a two-good setup with nominal rigidities, where external borrowing is in terms of the foreign currency. These extensions allow us to assess implications for the exchange rate as well as consider the role of monetary policy. We use the model to interpret both the aggregate as well as the sub-group empirical results.

Regarding the focus of the paper, our work is related to papers that assess empirically the effects of US shocks on EMEs. Our empirical work has a similar theme as Canova (2005), which studies transmission of US shocks to Latin American countries and Mackowiak (2007), which studies the effects of US monetary policy shocks on EMEs. In a related work, Bhattarai, Chatterjee, and Park (2017a) study the effects of US unconventional monetary policy shocks on EMEs. Aizenman et al (2015) show the correlation of EME policy rates and of exchange rates with policy rates in four center countries.

More closely related are Uribe and Yue (2006), who estimate the effects of foreign interest spread shock on EMEs using a VAR, and Matsumoto (2011), Akinci (2013), and Carriere-Swallow and Cespedes (2013), who study effects of global financial conditions and/or VIX shocks on EMEs. Fink and Schüler (2015) study US systemic financial stress shock transmission to EMEs.

Overall, we contribute to this growing empirical literature in terms of methodology and scope. Instead of focusing on a single country estimation at a time or conducting fully pooled estimation, we use a partial pooling approach, which offers advantages in terms of assessing heterogeneity. Moreover, we study the effects on a large number of macroeconomic and financial variables jointly for a large number of EMEs. An inclusion of a comprehensive set of open economy variables such as exchange rates, capital flows, and trade flows as well as relative variables such as long-term country spreads allows us to study cross-border effects and transmission of US uncertainty. That is, the differential effects on EMEs relative to the US/world economy can be inferred. For instance, while US uncertainty is known to have contractionary domestic macroeconomic effects and both the previous literature and our results also show evidence for contractionary EME effects, we find that the US actually experiences capital inflows and exchange rate appreciation vis-à-vis EMEs.

2 Data and empirical methodology

We next explain the data and the empirical methodology. We first estimate a US VAR to extract unanticipated and exogenous fluctuations in US financial market uncertainty. This shock is then included as an external regressor in a panel VAR for the EMEs (EM panel VAR) to assess spillover effects. Both the US VAR and the EM panel VAR are estimated using the Bayesian approach.[4]

2.1 US uncertainty shock

For the US economy, a VAR model

$$y_t = B_1 y_{t-1} + B_2 y_{t-2} + \cdots + B_k y_{t-k} + \varepsilon_t, \tag{1}$$

is used, where y_t is an $m_y \times 1$ vector of endogenous variables and $\varepsilon_t \sim \mathbb{N}\left(0, I_{m_y}\right)$ with $E\left(\varepsilon_t | y_{t-j} : j \geq 1\right) = 0$. The coefficient matrix B_j for $j = 0, \cdots, k$ is an $m_y \times m_y$ matrix. In the baseline specification, y_t includes: the CBOE VIX index as a proxy of US financial uncertainty, the industrial production (IP) index as a measure of output, and the consumer price index (CPI) as the price level. The baseline specification uses six lags of y_t. In an extended specification, we consider a VAR with eight variables, similar to Bloom (2009). In a robustness exercise, we use the financial uncertainty measure estimated by Ludvigson, Ma, and Ng (2015) in place of VIX.[5]

A shock to the VIX is estimated, which we refer to as the US uncertainty shock, in (1) after we remove the endogenous influences of lags of output and the price level on uncertainty. This is a reduced-form shock and thus we do not focus on impulse responses to this shock of the US economy.[6] Our approach of considering continuous fluctuations in VIX is different from the baseline approach of Bloom (2009), which uses large movements in VIX. We choose to use continuous fluctuations of the VIX index as our baseline measure because of concern with the relatively short sample period. In an extension, however, we follow the large-change

[4] The details are explained in the online Appendix.

[5] Here, to extract the shock, following the uncertainty shock literature, we use just US variables in the VAR. In the panel EM VAR that we use to assess spillover effects on EMEs however, we control for global variables such as OECD output.

[6] Different orthogonalization/ordering schemes to identify structural uncertainty shocks are used in the literature, for example in Bloom (2009) and Rey (2013). In an extension, we show that even if we orthogonalize the shock with a particular ordering, it is quite similar to the one we use in our baseline analysis. In a robustness exercise where we use the same variables as in Bloom (2009), we identify the uncertainty shock following the ordering of Bloom (2009) where VIX is ordered second after stock prices and estimate spillover effects.

approach of Bloom (2009) and find very similar spillover results.[7]

2.2 EM panel VAR

We now present in detail the baseline specification of the EM panel VAR.

2.2.1 Baseline specification

After extracting the surprise component in US financial uncertainty from the US VAR (1), we assess its spillover effects on the EMEs by including it in a system of equations for their economies. Suppose that our sample includes N countries indexed by $i = 1, 2, \cdots, N$. The dynamics of endogenous variables for country i are then represented as

$$z_{i,t} = \sum_{j=1}^{p} B_{i,j} z_{i,t-j} + \sum_{j=0}^{q} D_{i,j} \varepsilon_{VIX,t-j} + C_i x_t + u_{i,t}, \tag{2}$$

where $z_{i,t}$ is an $m_z \times 1$ vector of endogenous variables for country i, $\varepsilon_{VIX,t}$ is the median of the US uncertainty shock estimated in the US VAR, x_t is an $m_x \times 1$ vector of exogenous variables including a constant term, dummy variables, and some world variables, and u_t is an $m_z \times 1$ vector of the disturbance terms.[8] The coefficient matrix $B_{i,j}$ for $j = 1, \cdots, p$ is an $m_z \times m_z$ matrix, $D_{i,j}$ for $j = 0, \cdots, q$ is an $m_z \times 1$ vector, and C_i is an $m_z \times m_x$ matrix. It is assumed that for $\mathbf{u}_t = \left(u'_{1,t}, \cdots, u'_{N,t}\right)'$,

$$\mathbf{u}_t | \mathbf{z}_{t-1}, \cdots, \mathbf{z}_{t-p}, \varepsilon_{VIX,t}, \cdots, \varepsilon_{VIX,t-q}, x_t \sim \mathbb{N}\left(\mathbf{0}_{Nm_z \times 1}, \mathbf{\Sigma}\right), \tag{3}$$

where $\mathbf{z}_t = \left(z'_{1,t}, \cdots, z'_{N,t}\right)'$, $\mathbf{0}_{Nm_z \times 1}$ is an $Nm_z \times 1$ vector of zeros, and $\mathbf{\Sigma}$ is an $Nm_z \times Nm_z$ positive definite matrix.

In the baseline specification, $z_{i,t}$ includes five financial variables and three macroeconomic

[7]Bloom (2009) considers HP-filtered VIX index in a robustness exercise and our method is closer to this approach. Gourio et al. (2013) construct a measure of realized volatility using point-wise averages of several advanced economy volatility measures and then also use that series in a VAR. In our sample period, four major fluctuations in VIX are identified: the financial crisis in 2008-2009 and three European debt crisis events. If we were to follow Bloom (2009), our analysis would be closer to a case/narrative study on spillover effects of financial/debt crisis in advanced economies rather than estimating the effects of general uncertainty fluctuations. In fact we include dummy variables for these events in the EM panel VAR to avoid the concern that our results are driven by financial crises outliers. If these four events are not excluded, the effects on the EMEs will be larger in general.

[8]Since we use the median of the US uncertainty shock estimated in the US VAR and its lags as regressors in (2), our estimation of its effects is subject to the so-called generated regressor problem. As we show in Section 3, however, the US uncertainty shock is very tightly estimated, which suggests that the generated regressor problem is not very severe. As another check on this issue, we use the growth rate of VIX as a measure of US uncertainty shock in the EM panel VAR.

variables. Specifically, we use short-term (policy) interest rates, long-term interest rate spreads of country i with respect to the 10-year Treasury yield in the US, the aggregate stock price, the nominal effective exchange rate of the local currency, capital inflows to country i, industrial production as output, CPI as consumer prices, and net exports to the US relative to GDP. These constitute a core set of financial and macroeconomic variables. Note that we include the short-term (policy) rate to control for monetary policy reaction by these countries, which helps us determine the dynamics of the macroeconomic variables here. Three lags are included for the endogenous variables and the uncertainty shock (p=q=3).

Some of the EMEs in our sample are commodity exporters and so a proxy of the world demand for commodities and a price index of commodities are included in the vector of exogenous variables x_t as control variables. In addition, we control for the world demand proxied by overall industrial production of the OECD countries. Dummy variables to control for the effect of the US financial and European debt crisis (September-Decemeber 2008, May 2010, and February and August 2011) are also included in x_t. In particular, (3) implies that these variables in x_t are assumed exogenous to the system. This is because the EMEs can be considered as small open economies. It is however likely that there are some other common factors that drive their business cycles. No restrictions on $\mathbf{\Sigma}$ in (3) except that it is positive definite are imposed so that the disturbance terms $u_{i,t}$'s are freely correlated across the EMEs and could capture potential effects of other common factors.

Note that the coefficient matrices in (2) are allowed to be different across the EMEs. We allow for such dynamic heterogeneity since the EMEs are certainly not homogeneous. However, they are small open economies and thus are likely to be affected in a similar way by external shocks. To account for potential common effects of the US uncertainty shock, we take the random coefficient approach and assume that the distribution of the coefficient matrices in (2) are centered around a common mean.

Specifically, the random coefficient approach is undertaken following Canova (2007) and Canova and Ciccarelli (2013). Let us collect the coefficient matrices in (2) as $B_i = \begin{pmatrix} B_{i,1} & \cdots & B_{i,p} \end{pmatrix}'$ and $D_i = \begin{pmatrix} D_{i,0} & \cdots & D_{i,q} \end{pmatrix}'$ and let $\gamma_i = \text{vec}\begin{pmatrix} B_i' & D_i' & C_i \end{pmatrix}'$. Note that the size of γ_i is given as $m_\gamma = m_z m_w$ where $m_w = pm_z + (q+1) + m_x$ is the number of regressors in each equation. It is assumed that for $i = 1, \cdots, N$,

$$\gamma_i = \bar{\gamma} + v_i, \tag{4}$$

where $v_i \sim \mathbb{N}\left(\mathbf{0}_{m_\gamma \times 1}, \Sigma_i \otimes \underline{\Sigma}_i\right)$ with $\mathbf{0}_{m_\gamma \times 1}$ an $m_\gamma \times 1$ vector of zeros, Σ_i an $m_z \times m_z$ matrix that is the i-th block on the diagonal of $\mathbf{\Sigma}$, $\underline{\Sigma}_i$ an $m_w \times m_w$ positive definite matrix, and $E\left(v_i v_j'\right) = \mathbf{0}_{m_\gamma \times m_\gamma}$ for $i \neq j$. The common mean $\bar{\gamma}$ in (4) turns out to be the weighted average of the country-specific coefficients γ_i with their variances as weights in the posterior distribution conditional on γ_i's. For a particular value of $\bar{\gamma}$, the pooled estimates of the dynamics effects of the uncertainty shock $\varepsilon_{VIX,t}$ can be computed by tracing out the responses of $z_{i,t}$ to an increase in $\varepsilon_{VIX,t}$ over time with γ_i replaced by $\bar{\gamma}$.

2.2.2 Heterogeneity across subgroups of countries

We also estimate the differential effects of the US uncertainty shock across two subgroups of the EMEs in our sample. Our baseline subgroup estimation consists of South American countries in one group and the rest of the EMEs in another. This choice is motivated by the close connections between the US and South American countries such as the high level of trade and investment between them, the geographical proximity, as well as the existence of previous work that focuses on these countries, such as Canova (2005).[9]

Specifically, the mean of the coefficients, $\bar{\gamma}$ in (4), is now different between two groups of the EMEs, denoted group 1 and 2. So the assumption for the random coefficient approach (4) is modified as follows: For $i = 1, \cdots, N$,

$$\gamma_i = \bar{\gamma}_1 \times I_1(i) + \bar{\gamma}_2 \times [1 - I_1(i)] + v_i, \tag{5}$$

where $I_1(i)$ is an indicator function that takes on 1 if country i is in group 1 and 0 otherwise, $v_i \sim \mathbb{N}\left(\mathbf{0}_{m_\gamma \times 1}, \Sigma_i \otimes \underline{\Sigma}_i\right)$. By comparing the impulse responses to the US uncertainty shock across these two subgroups, using $\bar{\gamma}_1$ and $\bar{\gamma}_2$, respectively, one can study whether these two groups were differentially sensitive to the US uncertainty shock.

2.2.3 Alternative specifications

After estimating the baseline specification, we consider some alternative variables to assess robustness as well as to relate them to our theoretical results. Due to computational burden and sample size issues, we continue to use the baseline specification that includes eight variables but replace one variable of the baseline specification with a new one at a time.

First, we consider different measures of economic activity. In the baseline specification, IP is our measure of economic activity, as it is the usual choice with monthly data. To assess the results based on a broader measure of activity as well as to help guide the theoretical results on measures of spending, we consider data on GDP, consumption, and investment. Their quarterly observations are interpolated to get the monthly observations. Next, we use several alternative financial and open economy variables. We replace long-term interest rate

[9] Mexico, for instance, is the third largest trade partner of the U.S.

spreads with a measure of long-term real interest rate spreads.[10] For open economy variables, we first replace the nominal effective exchange rate with the real effective exchange rate. We then use several alternative measures of external balance. We replace our baseline measure of net exports, which is to the US, with net exports to the rest of the world as well as net foreign asset position with the US. We also use several capital inflow measures from the US, compared with our baseline measure which in principle also incorporates capital inflows from other countries. In particular, we use cumulated net foreign asset position and cumulated foreign asset position of the US with these EMEs. Finally, we include realized volatility of EME stock price index in order to control for both first and second moments of EM stock prices. This will also help establish further that the effects that we estimate are indeed that of an external uncertainty shock, as we would have directly controlled for domestic stock market uncertainty. In this specification, to keep number of variables the same as the baseline, we drop CPI. Table 2 in the online appendix presents all the specifications that we estimate.

2.3 Data

We use monthly US data from January 1990 through November 2014. In addition to VIX, IP, and CPI included in the baseline specification, we also use data on an alternative financial uncertainty measure, as well as on a short-term interest rate as a measure of monetary policy, the S&P 500 index, wages, hours, and employment in extended specifications for the US VAR. The data source for most of the US data is the FRED maintained by the St Louis Fed. The financial uncertainty measure is available from Ludvigson, Ma, and Ng (2015). For the period when the zero lower bound is binding, we use the shadow interest rate from Krippner (2016) as a measure of the short-term interest rate. As an alternative to it, we also use the 2-year Treasury yield.

Our sample includes fifteen EMEs: Brazil, Chile, Colombia, India, Indonesia, Malaysia, Mexico, Peru, Philippines, Russian, South Africa, South Korea, Taiwan, Thailand, and Turkey.[11] Our data for the EMEs is at the monthly frequency for the period from January 2004 through November 2014. We use data on IP, CPI, the trade-weighted effective nominal and real exchange rates, the aggregate stock price, long-term and short-term interest rates,

[10]While using long-term real interest rates requires us to take a stance on how expected inflation is determined, it is still worthwhile to check this specification as in the theoretical model, the relevant spread increase we study is in real terms.

[11]These countries are selected based on the classification by the IMF and Morgan Stanley. We do not include countries that experienced crises during our sample period, such as Argentina and Venezuela, as well as countries that might actively manage their exchange rates, such as China. Countries in the Euro zone are also excluded since due to use of a common currency, they might get affected differently.

long-term interest rate spreads with respect to the US 10-year Treasury yield, net exports to world and US, and capital inflows from the rest of the world. As an alternative measure of output, we also include data on gross domestic product (GDP), investment, and consumption. Moreover, for alternative external balance measures, we use data provided by Bertaut and Judson (2014), which is based on underlying data from US Treasury (TIC). In particular, from that data set, we use net foreign asset position and capital inflows from the US to the EMEs. Net exports and capital flows are normalized by the relevant nominal GDP. The data sources for the other EM country data include Datastream, Bloomberg, EPFR, BIS, IMF, and OECD. A detailed description is provided in the data appendix.[12]

3 Spillover effects of the US uncertainty shock

We start our results with the measure of the US uncertainty shock and then proceed to present the spillover effects on the EMEs.

3.1 US uncertainty shock

Figure 1 presents the posterior median of the estimated US uncertainty shock, along with 90% error bands. For comparison, in Figure 1 we also plot the growth rate of VIX, which is very similar to the shock we estimate. Around some important events that had worldwide effects, and are marked by vertical lines, the US uncertainty shock takes quite large values. To ensure that our results are not driven by these outliers, we include dummy variables for these events in the EM panel VAR.[13]

3.2 Spillover effects

We now present results on the uncertainty shock's spillover effects on the EMEs. The impulse responses presented in this section are the average effects of the US uncertainty shock across all the EMEs in the baseline panel VAR specifications and the average effects among South American countries and the rest of the EMEs, respectively, in the subgroup analysis.

[12]The data is not pre-processed before estimation and that the variables are used in logs, in levels, or in ratios relative to GDP. The exceptions are that we interpolate quarterly nominal GDP to monthly frequency to construct some ratios relative to GDP, and in an extension, interpolate quarterly real GDP, consumption, and investment into monthly series. The interpolation method is also described in the data appendix.

[13]Note again that while this is our baseline measure of the US uncertainty shock, we consider in extensions several different estimation/identification strategies and also use a completely different financial uncertainty measure estimated by Ludvigson, Ma, and Ng (2015) in place of VIX. Our results on spillover effects to EMEs are robust across these various cases as we show in the Appendix.

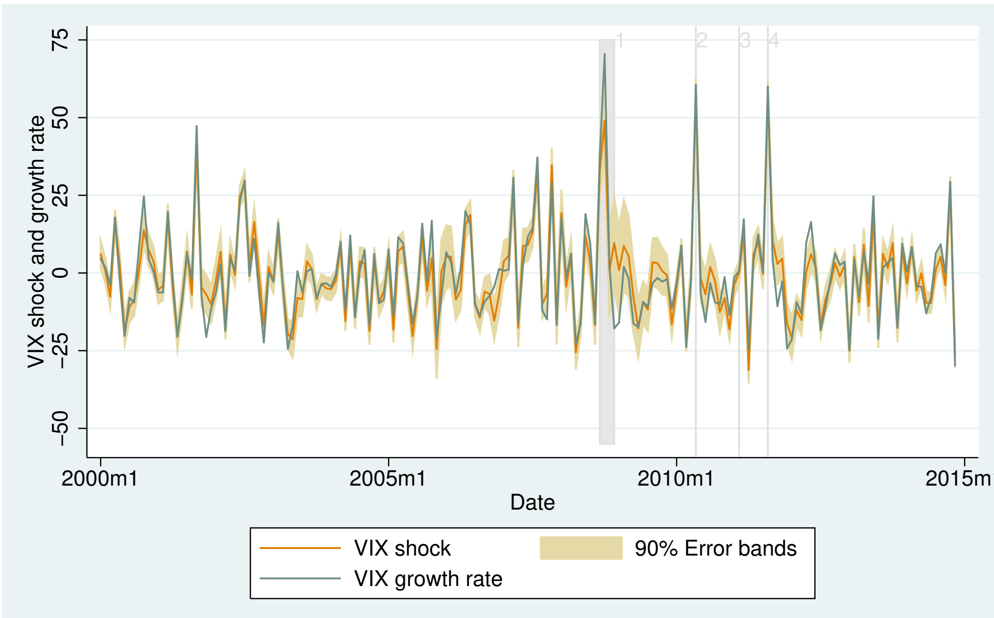

Figure 1: The estimated US uncertainty shock and the growth rate of VIX

Notes: The US uncertainty shock is 100 times the posterior median of the relevant shock in US VAR (1), which is presented together with 90% error bands. The growth rate of VIX is 100 times the first difference of the log of VIX. The vertical lines mark the financial crisis and the three major events of the Euro debt crisis: [1] September 2008 through December 2008 when Lehman Brothers collapsed and subsequently the financial markets were disturbed, [2] May 2010 when the Eurozone members and the IMF agreed on a large bailout package for Greece, [3] February 2011 when the Eurozone bailout fund, the European Stability Mechanism, was set up, and [4] August 2011 when the EC President Jose Manuel Barroso warned that the sovereign debt crisis was spreading beyond the periphery.

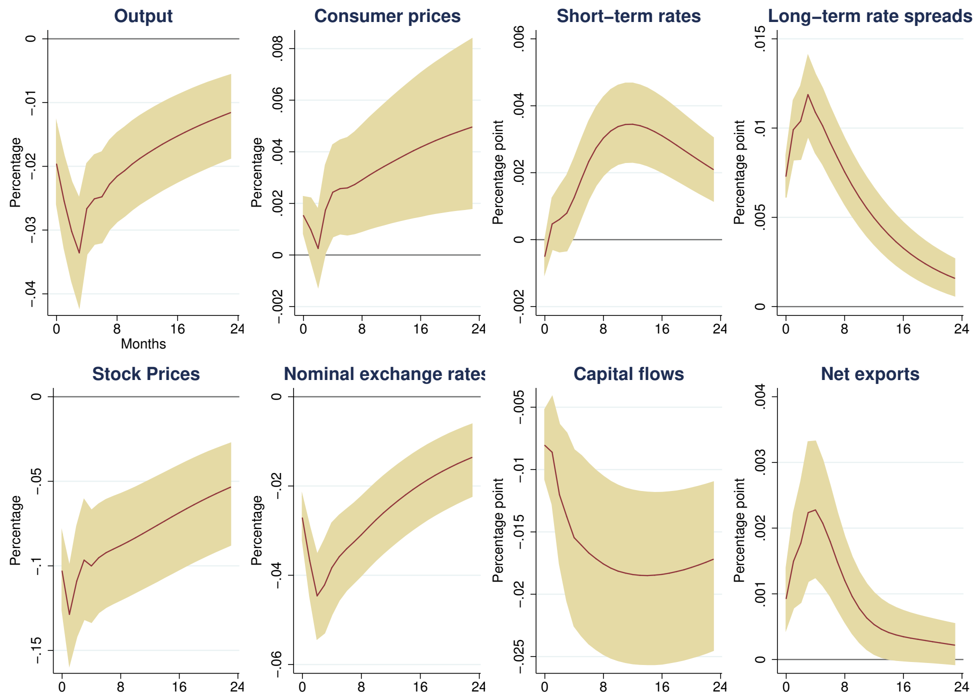

Figure 2: Impulse responses of the EM panel VAR to the US uncertainty shock: macroeconomic and financial variables

Notes: Each plot presents the posterior median of the impulse responses to a 1% increase in the US uncertainty shock along with the 90% error band in the baseline specification that includes the both macroeconomic and financial variables. Output is the industrial production and consumer prices are the CPI in each of the EM countries. Net exports are the ratio of the net exports from the EM countries to the US and GDP of the EM countries. The long-term rate spread is the spread between the 10-year Treasury yields in the US and the long-term interest rate in the EM countries. The stock price is the MSCI. The nominal exchange rate is the effective exchange rate of the EM countries so a decrease in the exchange rate implies depreciation of the local currency. The capital flow is the ratio of the cumulative sum of the equity and bond inflows to GDP of the EM countries.

3.2.1 Benchmark specification

We present results from our baseline specification in Figure 2. We start by describing the results on financial market variables as they provide the first channel of possible transmission to the EMEs. On average, following an increase in US financial uncertainty, short-term interest rates and long-term country spreads (compared to the 10-year Treasury yield in the US) of these countries increase persistently. In addition, stock prices decline and nominal exchange rates depreciate persistently. Capital flows out of them.

Specifically, on average across the EMEs, a 1% increase in US financial uncertainty leads to a 0.0035% point increase in the short-term interest rate, a 0.012 % point increase in the long-term interest rate compared to the US, a 0.125% fall in the stock prices, a 0.045%

depreciation of the local currency, and a 0.0175% point capital outflows relative to GDP. These are peak effects that occur about 2-12 months after the impact. The effects on EME financial markets are uniformly adverse and significant for 2 years after the impact. The effects on financial variables suggest that a US uncertainty shock triggers a flight to safety/quality phenomenon as investors appear to pull capital out of these markets that are perceived to be risky compared to the US, thus negatively affecting asset prices such as stock prices and exchange rates, while increasing their cost of borrowing as country spreads increase.

Our framework can be used to assess the transmission to the real economy. Figure 2 shows that an increase in US uncertainty has significant effects on the macroeconomy of EMEs. Output of these countries drops while net exports increase. Moreover, consumer prices increase in EMEs. Specifically, in response to a 1% increase in US financial uncertainty, output falls by 0.035% and net exports to the US rise by about 0.0022% point relative to GDP. Again, these are peak effects, which occur after 4-8 months. Consumer prices increase persistently and reach about 0.004% higher, 24 months after impact. Since the standard deviation of unanticipated fluctuations in estimated US financial uncertainty is about 14.4%, these effects are economically large as well.

The decrease in output shows that increases in US financial uncertainty lead to a contractionary effect in EMEs. This is consistent with the concurrent financial market effects such as increases in long-term country spreads and decreases in stock prices. The increase in net exports and decrease in capital inflows illustrates that the effects of the US uncertainty shock transmits through these countries via a reduction in spending. It is well-known that EMEs have quite countercyclical net exports/current account, which we show here for a particular shock.

Finally, consumer prices increase, which we conjecture is due to both the exchange rate depreciation that affects the prices of home goods, as well as, a subsequent import price increase. It illustrates that the US uncertainty shock leads to a major trade-off for central banks of these countries as it leads to output contraction together with a price increase.

3.2.2 Subgroup analysis

We now present results where we split the EMEs into two subgroups: South American countries that include Brazil, Chile, Colombia, Mexico and Peru, and the rest. Figure 3 shows that clear heterogeneity is present in responses of both macroeconomic and financial variables. The negative effects on output, stock prices, and exchange rates are bigger and more persistent for the rest of EMEs compared to South American countries. For instance, the peak effects on output and exchange rates are more than double for the rest of EMEs and for all these variables, the effects are more persistent for the rest of EMEs as well. Specifically, output drops less than 0.2% in South American countries while it drops more than 0.4% in the rest of EMEs.

The effects however are bigger and more persistent on capital flows and net exports for South American countries compared to the rest of EMEs. In fact, the peak effects on capital flows and net exports are more than double for South American countries compared to rest of EMEs. The peak effect on capital outflows of a 1 % increase in US financial market uncertainty is estimated to be about 0.002% relative to GDP in South American countries while it is about 0.001% in the rest of EMEs. Also, net exports increases by about 0.004% point relative to GDP at its peak in South American countries but only about 0.001% point in the rest of EMEs. Thus, South American countries suffer less in terms of output, stock prices and the exchange rate but there is a larger increase in net exports and a bigger reversal in capital flows. These differential responses of the two subgroups are statistically significant as shown in Figure 4 where we present the differences of the impulse responses of the rest of the EMEs and South American countries.

Strikingly, the short-term (policy) rate of the rest of EMEs does not decrease by more compared to South American countries, even though the countries get affected much more negatively in terms of output (with similar effects in terms of consumer prices). Thus, the policy rates of the rest of EMEs can be considered to be "relatively high" and monetary policy "relatively more tight" given the larger negative response of output.

To make this sub-group differences even more formal, in Figure 4, we show the differences in the responses of the rest of EMEs compared to South American EMEs. This makes it clear that output responds more negatively for the rest of EMEs, but there is no difference in terms of the policy rates. At the same time, as we emphasized above, the capital flow difference is positive (or net export difference is negative), as the drop in capital inflows is much less for the rest of EMEs.[14]

This (lack of) heterogeneity, especially in response of the policy rates, then suggests an intriguing explanation that might be consistent with differential monetary policy reaction by these two groups of countries.[15] It is well-known that many EMEs are worried about sharp reversals in capital flows, even independently of the effects on output.[16] Then, if the

[14]Taking statistical uncertainty into account, stock prices also respond more negatively in the rest of EMEs, but there are basically no differences in consumer prices or the interest rate spread and even nominal exchange rate.

[15]Note again that in equilibrium, the responses of the policy rates are not very different across the groups. But that precisely is what is intriguing and our point: despite a significantly larger drop in output, the rest of EMEs do not decrease their policy rates.

[16]For example, the Governor of South African Reserve Bank in a speech titled "Challenges to South African Monetary Policy in a World of Volatile Capital Flows" mentions:

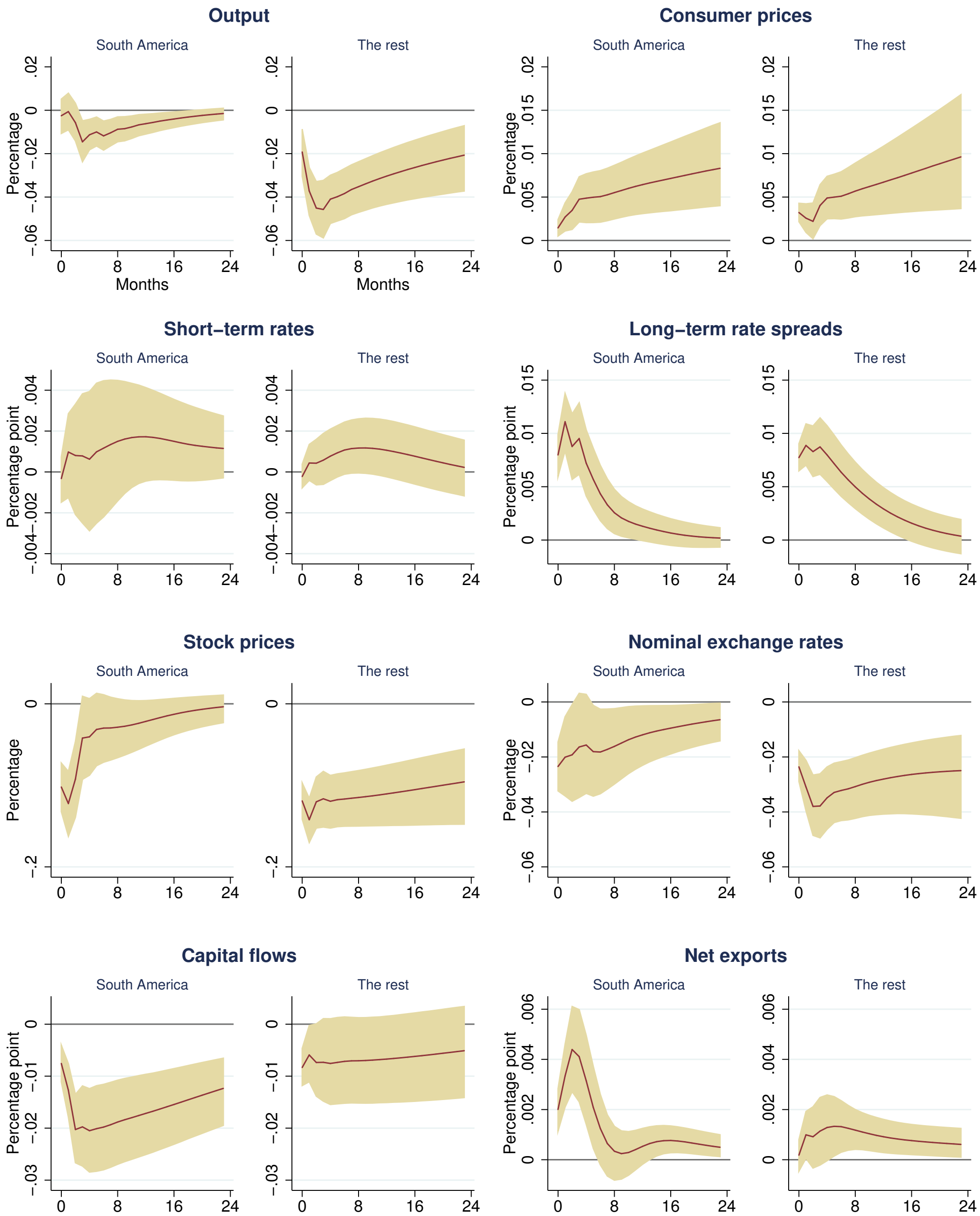

Figure 3: Impulse responses of the EM panel VAR to the US uncertainty shock: macroeconomic and financial variables; South America vs. the rest

Notes: Each plot presents the posterior median of the impulse responses to a 1% increase in the US uncertainty shock along with the 90% error bands in the specification for subgroup analysis that includes both the macroeconomic and financial variables. Subplots are shown for two groups of countries: South America including Brazil, Chile, Colombia, Mexico, Malaysia, and Peru and the rest of the EM economies. See the notes in Figure 2.

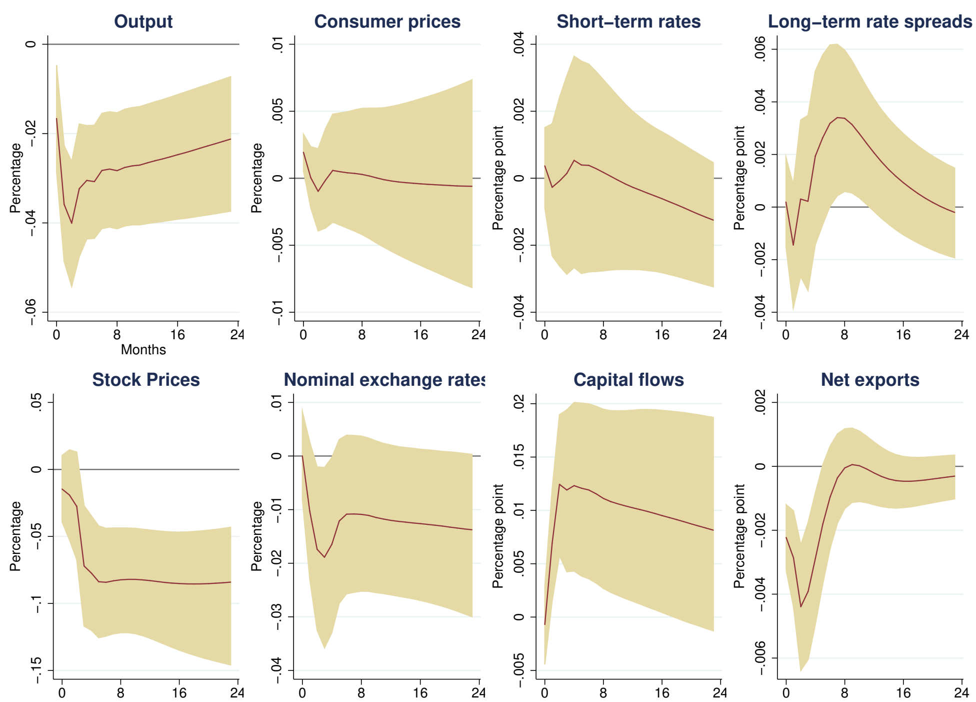

Figure 4: Differential responses of the EM panel VAR to the US uncertainty shock: the rest minus South America

Notes: Each plot presents the posterior median of the impulse responses of the rest of EMEs minus the impulse responses of South American countries, both to a 1% increase in the US uncertainty shock, along with the 90% error bands of the differences in impulse responses. See the notes in Figure 2.

rest of EMEs are more concerned with capital outflows than South American countries, the central banks of these countries might keep their policy rates relatively high, in order to stem such capital outflows. This can be successful, but might come at the cost of larger drops in output as monetary policy will turn out to be unduly contractionary. This kind of trade-off is consistent with our results above and guides the model we present next where we introduce heterogeneity in monetary policy rules.

3.2.3 Extensions and robustness

We estimate several extensions to the baseline specification and do various robustness exercises. Our first set of extensions focus on effects of the baseline uncertainty shock on alternative measures of real economic activity and of open economy variables including measures of external balance. Figure C.1 in the online appendix shows that all these measures of economic activity and aggregate spending decline persistently when US uncertainty increases unexpectedly. The response of investment is bigger than GDP and consumption as expected. The first row of Figure C.2 shows that long-term real interest rate spreads increase, real exchange rates depreciate, and net exports to the world increase. In particular, note that the effects on the real exchange rates are essentially the same as those on the nominal exchange rates presented in Figure 2. The second row of Figure C.2 shows that the net foreign asset position of the US, the cumulated net foreign asset position of the US, as well as the cumulated foreign asset position of the US with these EMEs all decreases. These variables are based on US Treasury data (TIC) and the results are all consistent with net exports from the EMEs to the US increasing and capital inflows to the EMEs decreasing as we find in our baseline specification. Especially, the cumulated foreign asset position of the US is an alternative to our baseline measure for capital inflows from EPFR. As our final sensitivity analysis on the panel VAR, we estimate an eight variable system including realized EME stock price volatility (while dropping CPI) to analyze how robust our results are once we allow for EM stock price volatility to also respond endogenously to the US uncertainty shock. The results are presented in Figure C.3, and our conclusions continue to hold.[17]

Next we conduct a series of robustness exercises for our measure of shock. First, we extend the US VAR to include more financial and real variables as in Bloom (2009), and

> The continued uncertainties in the global economy ... have contributed to periodic bouts of risk aversion, often resulting in a flight to so-called safe havens, despite the fact that the underlying fundamentals in the emerging markets have not changed. The problem ... is one of ... excessively volatile portfolio flows, which respond to the vagaries of global risk aversion. (Address to the Swiss Chamber Southern Africa, May 2012)

Later in the paper, we provide other relevant examples.

[17] We also estimate a slight positive effect, after a delay, of US stock price uncertainty shock on EME stock price volatility itself, which is as expected given a negative effect on the level of EME stock prices.

apply his identification scheme. The results using this measure of US uncertainty shock are in Figure C.4. Second, in the three-variable US VAR, we impose a recursive identification scheme where VIX is ordered last and identify the uncertainty shock. The identified shock is almost identical to the baseline series. So, we do not report the result. Third, we simply use the growth rate of VIX as a measure of uncertainty shock in the EM panel VAR. This partly addresses the generated regressor problem that arises in our two-step estimation procedure. The results are presented in Figure C.5. Fourth, in the three variable VAR specification, we replace VIX with the financial uncertainty measure of Ludvigson, Ma, and Ng (2015). The results are presented in Figure C.6. Lastly, we follow Bloom (2009) and identify only large movements in VIX as the US uncertainty shock. We find very similar spillover results as our baseline results. The results are in Figures C.7.[18]

As a final extension we consider a variance decomposition analysis. The online appendix describes the method we use to compute the contribution of the shock at different horizons in explaining the forecast error variance. We start with the results based on all countries, which is in Table C.1, where for concreteness we focus on the five most salient variables. The US uncertainty shock explains a non-trivial fraction of the variation of these variables, for instance around 15% at the 3 month horizon for output and 20% at the 12 month horizon for long-term interest rate spreads. We then present results based on the sub-group estimation, in Table C.2 for South American countries and in Table C.3 for the rest of EMEs. Consistent with the impulse response results, for South American countries, the US uncertainty shock explains relatively more the variation in capital flows compared to output while for the rest of EMEs, it explains relatively more the variation in output compared to capital flows.

4 Model

There are two countries, home and foreign, and two traded goods, one produced by each country. The home country is a small open economy (SOE) while the foreign country is effectively a closed economy as home country variables have negligible effects on foreign variables.[19] Monetary policy at home is determined by an interest rate feedback rule. The model is a two-good, nominal, foreign currency debt, sticky prices extension of the classic

[18]We also check that our main results are not sensitive to lag length selection in the panel VAR. Results using four lags of the US uncertainty shock in the panel VAR are reported in Figure C.8 for the baseline case and in Figure C.9 for the sub-group analysis in the online appendix. For the sub-group estimation, we have also checked our results on using other activity measures and other financial and open economy variables. As one example, we report results using long-term real rate spreads in Figure C.10 in the online appendix. Overall, all these exercises lead to similar results as our baseline specification.

[19]In terms of our empirical analysis, the home country is essentially an EME while the foreign country is the US.

SOE business cycle model in Neumeyer and Perri (2005) and Uribe and Yue (2006).[20]

4.1 Private sector

We start by describing the environment faced by households and firms.

4.1.1 Households

A representative household at home maximizes expected discounted utility

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(c_t - \mu \tilde{c}_{t-1}, h_t\right), \tag{6}$$

where $0 < \beta < 1$ is the discount factor, $0 < \mu < 1$ is the external habit formation parameter, c_t is household consumption of the composite consumption good, $\tilde{c}_{t-1}$ is aggregate consumption taken as given, and h_t is hours supplied by the household. E_0 is the mathematical expectation operator conditional on period-0 information and $U\left(c_t - \mu \tilde{c}_{t-1}, h_t\right)$ is concave, twice continuously differentiable, and increasing in $c_t - \mu \tilde{c}_{t-1}$ and decreasing in h_t.

The composite consumption good c_t is an aggregate of the home good, $c_{H,t}$, and the foreign good, $c_{F,t}$

$$c_t = \left[(1-\chi)^{\frac{1}{\varepsilon}} c_{H,t}^{\frac{\varepsilon-1}{\varepsilon}} + \chi^{\frac{1}{\varepsilon}} c_{F,t}^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{7}$$

where $\varepsilon > 0$ is the elasticity of substitution between the goods and $0 < \chi < 1$ denotes the weight of the foreign good in the home consumption basket and therefore, also measures the degree of home bias. The home and foreign goods are, in turn, aggregates of a continuum of differentiated varieties indexed by $i \in [0,1]$. The consumption goods are thus defined as: $c_{H,t} = \left[\int_0^1 c_{H,t}(i)^{\frac{\nu-1}{\nu}} di\right]^{\frac{\nu}{\nu-1}}$ and $c_{F,t} = \left[\int_0^1 c_{F,t}(i)^{\frac{\nu-1}{\nu}} di\right]^{\frac{\nu}{\nu-1}}$, where $\nu > 1$ is the elasticity of substitution among the varieties. Both the composite investment good i_t, and the the home investment good $i_{H,t}$ and the foreign investment good $i_{F,t}$, are similar aggregates as the respective consumption goods.

We define the nominal price (in terms of the home currency) of the aggregate consumption and investment good as p_t and the nominal prices (in terms of the home currency) of the home and foreign goods as $p_{H,t}$ and $p_{F,t}$ respectively. The household's flow budget constraint is then given by

[20] Note that the variables that are specific to the home and foreign country are subscripted with H and F, respectively. Those variables that are defined in relation to the composite good of both home and foreign goods are denoted with an $*$ if they are relevant for the foreign country but without an $*$ if they are relevant for the home country.

$$\frac{Q_t}{p_t^*} d_t^* + \frac{I_{t-1}}{\Pi_t} b_{t-1} = \frac{Q_t}{p_t^*} R_{t-1} d_{t-1}^* + b_t + \frac{Q_t}{p_t^*} \Psi\left(d_t^*\right) - w_t h_t - u_t k_t + c_t + i_t - \varphi_t, \tag{8}$$

where d_t^* is the international debt position in terms of the foreign currency, R_{t-1} is the gross nominal interest rate in foreign currency terms, w_t is real wages, u_t is the real rental rate of capital, k_t is the capital stock, and φ_t is profits from home firms which are all held domestically.

In addition, Q_t is the real exchange rate and p_t^* the foreign aggregate price level. Here, $Q_t \equiv S_t p_t^* / p_t$, where S_t is the nominal exchange rate, defined as the price of a unit of the foreign currency in terms of the home currency. Finally, $\Psi\left(d_t^*\right)$ denotes debt-adjustment costs, where $\Psi\left(.\right)$ is a convex function, which induces stationarity of debt position. In addition to international borrowing, the household also can trade in domestic, one-period, non-state contingent nominal bonds. b_t is domestic bond holdings, expressed in real terms $b_t = B_t/p_t$, I_{t-1} is the gross nominal interest rate, and $\Pi_t \equiv p_t/p_{t-1}$ is gross inflation. The household is also subject to a no-Ponzi game condition.

The capital accumulation equation is given by

$$k_{t+1} = \left(1-\delta\right) k_t + k_t \Phi\left(\frac{i_t}{k_t}\right), \tag{9}$$

where $0 < \delta < 1$ is the rate of depreciation and$\Phi\left(i_t/k_t\right)$ represents investment adjustment cost, where $\Phi\left(.\right)$ is an increasing concave function.

The problem faced by the foreign country household is the same as above, but since the home country is a small open economy, the home good will have a negligible weight on the foreign consumption basket.

4.1.2 Firms

There are a continuum of monopolistically competitive firms, indexed by $i \in [0,1]$, that produce differentiated varieties. Firm i produces output $y_t(i)$ using labor and capital as inputs, $y_t(i) = F(k_t(i), h_t(i))$, where the production function $F(.)$ is constant returns to scale, concave, and increasing. Firms rent capital and hire labor in perfectly competitive factor markets. There is a working capital requirement that firms need to hold non-interest bearing assets, $\kappa_t\left(i\right)$, to finance a fraction of wage bill each period

$$\kappa_t(i) \geq \eta w_t h_t(i), \tag{10}$$

where $\eta \geq 0$. (10) represents a simple financial friction on the firm side.

Firm i sets prices $p_{H,t}(i)$ for its goods. Firms face a cost of adjusting prices given by

$d\left(p_{H,t}(i)/p_{H,t-1}(i)\right)$ where $d\left(.\right)$ is a convex function. The demand function for variety i is derived from the cost-minimization problem of the household over differentiated varieties and given by $\frac{y_t(i)}{y_t} = \left(\frac{p_{H,t}(i)}{p_{H,t}}\right)^{-\nu}$, where y_t is aggregate world demand taken as given.

In addition to the non-interest bearing assets $\kappa_t\left(i\right)$, the balance sheet of the firm has one-period interest bearing liabilities, denoted by $d_t^f\left(i\right)$. These one-period riskless liabilities bear gross interest rate R_t^d in terms of price of the home good. Defining the net liabilities of the firm as $a_t\left(i\right) \equiv R_t^d d_t^f\left(i\right) - \frac{p_t}{p_{H,t}}\kappa_t\left(i\right)$, we can derive a law of motion for $a_t\left(i\right)$ as shown in the appendix. The firm is also subject to a no-Ponzi game condition.

The firm maximizes expected discounted profits

$$E_0 \sum_{t=0}^{\infty} \rho_{0,t}\varphi_t\left(i\right), \tag{11}$$

where $\rho_{0,t} = \beta^t \frac{U_c(c_t-\mu\tilde{c}_{t-1},h_t)}{U_c(c_0-\mu\tilde{c}_{-1},h_0)}$ is the stochastic discount factor of the household.

4.1.3 International pricing and market clearing

There is no international price discrimination and thus we have $p_{H,t} = S_t p_{H,t}^*$ and $p_{F,t} = S_t p_{F,t}^*$. We also define the terms of trade $\varsigma_t \equiv p_{F,t}/p_{H,t}$ and a relative price $r_t \equiv p_t/p_{H,t}$. Then, we have $\varsigma_t = \frac{p_{F,t}}{p_{H,t}} = \frac{p_{F,t}^*}{p_{H,t}^*} = \frac{p_t^*}{p_{H,t}^*}$. The goods, factor, and bonds markets clear in equilibrium. Goods market clearing is given by

$$y_t(i) = c_{H,t}(i) + i_{H,t}(i) + c_{H,t}^*(i) + i_{H,t}^*(i) + d\left(\frac{p_{H,t}(i)}{p_{H,t-1}(i)}\right).$$

The foreign demand for the home good $c_{H,t}^*(i) + i_{H,t}^*(i)$ will be a function of the terms of trade and foreign aggregate demand $y_t^* = c_t^* + i_t^*$. Finally, we assume a zero net supply of the home nominal bond, $B_t = 0$.

4.2 Monetary policy

Monetary policy is given by an interest-rate feedback rule

$$\beta I_t = \left[\beta I_{t-1}\right]^{\rho_I} \left[\left(\frac{\Pi_t}{\Pi}\right)^{\phi_\pi} \left(\frac{y_t}{y_{t-1}}\right)^{\phi_y} \left(\beta R_t\right)^{\phi_{RI}}\right]^{(1-\rho_I)}, \tag{12}$$

where $\rho_I \geq 0$ is the interest-rate smoothing parameter, $\phi_\pi \geq 0$, $\phi_y \geq 0$, and $\phi_{RI} \geq 0$ are feedback parameters, and Π is the steady state value of gross inflation.

Thus, the nominal interest rate responds, as is standard, to inflation and output growth, but also could additionally, to the international borrowing rate.[21] The latter aspect of the monetary policy rule will be used to interpret the heterogeneity across countries that we find in the empirical results and reflects a concern that some central banks might have in keeping the home nominal interest rate close to the foreign interest rate, in order for instance to stem rapid movements of capital flows.[22]

4.3 Exogenous processes

We define the interest rate spread $R_t^S \equiv R_t - R_t^*$ as the difference between the domestic household international borrowing rate and foreign interest rate and posit an ARMA (1,3) process for R_t^S

$$R_t^S = \rho_S R_{t-1}^S + \exp(\sigma_0)\varepsilon_{R^S,t} + \exp(\sigma_1)\varepsilon_{R^S,t-1} + \exp(\sigma_2)\varepsilon_{R^S,t-2} + \exp(\sigma_3)\varepsilon_{R^S,t-3}, \tag{13}$$

where $\varepsilon_{R^S,t}, \varepsilon_{R^S,t-1}, \varepsilon_{R^S,t-2}, \varepsilon_{R^S,t-3} \sim N(0,1)$ and $\exp(\sigma_0)$, $\exp(\sigma_1)$, $\exp(\sigma_2)$, $\exp(\sigma_3) > 0$. We posit this more general process to match the hump-shaped response of country spread that we estimate empirically as it is the theoretical counterpart to our empirical measure. This will be the baseline shock, as a proxy for the empirical US uncertainty shock.[23]

In the baseline, we do not consider time varying volatility in the interest rate spread process. In an extension, we consider a stochastic volatility process by making σ_0 time-varying as

$$\sigma_t - \sigma = \rho_\sigma (\sigma_{t-1} - \sigma) + \varepsilon_{\sigma,t}, \tag{14}$$

where $\varepsilon_\sigma \sim N(0,1)$. We then explore implications of a pure second-moment shock that does not change the level of the spread R_t^s.[24] Finally, we assume that foreign output and prices evolve exogenously following AR(1) processes in terms of deviations from their respective

[21] Using output or output growth in the feedback rule leads to very similar results.

[22] In the past, tracking the foreign interest rate to stem large movements in the exchange rate has been termed "fear of floating," of EMEs. Here, our model can be thought of as capturing a "fear of movements in external balance" of EMEs. Simply changing the relative weight on output vs. inflation, without introducing a concern explicitly for the foreign rate, is another possible way to introduce heterogeneity. This approach however, does not capture the notion of "fear of capital flows" that we think is important in the data. We nevertheless explored this approach as well, and found that it does not lead to any discernible differences in the results. Finally, in a different context, Taylor (2007) explores monetary policy rules of this kind for the US and Europe, where interest rate feedback rule contains a feedback to foreign interest rate, and finds some suggestive evidence that this term might matter.

[23] Also, note that we assume a common steady state for R_t and R_t^* and that since we will not model a process for R_t^* separately, we can consider the shock to spread as a shock to the international borrowing rate R_t. We will therefore use them interchangeably.

[24] We adopt this framework of time-varying volatility in the external shock process from Fernandez-Villaverde et al (2011).

deterministic steady-states. Thus,

$$y_t^* - y^* = \rho_{y^*}\left(y_{t-1}^* - y^*\right) + \varepsilon_{y,t}^* \text{ and } p_t^* - p^* = \rho_{p^*}\left(p_{t-1}^* - p^*\right) + \varepsilon_{p,t}^*. \tag{15}$$

In particular, in an extension, we will explore implications of a negative foreign output/demand shock, as another proxy for the US uncertainty shock.

4.4 Results

We formally define in the online appendix the equilibrium and discuss the aggregate optimality and feasibility conditions that characterize it. We here define three variables for later use in the model simulations and results. Net exports as a ratio of output is given by $\frac{nx_t}{y_t} = \frac{y_t - r_t\left[c_t + i_t + \frac{Q_t}{p_t^*}\Psi(d_t^*)\right]}{y_t}$ while the current account as a ratio of output is given by $\frac{ca_t}{y_t} = -r_t\left(\frac{Q_t}{p_t^*}d_t^* - \frac{Q_t}{p_t^*}d_{t-1}^*\right)$. Finally, we price a stock as a claim to the (future) stream of firm profits $\Omega_t = E_t\left[\frac{\rho_{t+1}}{\rho_t}\left(\Omega_{t+1} + \varphi_{t+1}\right)\right]$.

We solve the model non-linearly, where in period 0, an unexpected shock to the interest rate spread, ε_{R^s}, hits the economy, and then the economy evolves deterministically thereafter.[25] As we discussed before, we interpret this shock as proxying for the foreign uncertainty shock in our empirical exercise. Thus, it is used to roughly capture the belief of external investors that lending to the SOE is risky or some "flight to safety/quality" phenomenon.

4.4.1 Functional forms and parameterization

We use the same functional forms as in Uribe and Yue (2006) and a standard specification for price-adjustment costs

$$U\left(c - \mu\tilde{c}, h\right) = \frac{\left[c - \mu\tilde{c} - \omega^{-1}h^{\omega}\right]^{1-\gamma} - 1}{1-\gamma},\ F(k,h) = k^{\alpha}h^{1-\alpha},$$

$$\Phi\left(x\right) = x - \frac{\phi}{2}\left(x - \delta\right)^2, \Psi\left(d\right) = \frac{\psi}{2}\left(d_t^* - \bar{d}\right),\ d(\Pi_H) = \frac{d_1}{2}\left(\Pi_H - \bar{\Pi}_H\right)^2.$$

For the parameters common to Uribe and Yue (2006), we use the same values as theirs, which are given in Table 1.[26] Thus, our goal here is simply to assess model dynamics taking the calibration as given from the previous literature.

[25] We use a non-linear solver to compute this perfect foresight solution. In an extension, when we consider a second-moment shock to the interest rate spread, we use a third-order perturbation solution method.

[26] Note however that our model is calibrated to the monthly frequency and some parameters are modified accordingly. Also, as in Uribe and Yue (2006), we calibrate $\bar{d}$ to achieve a steady-state net exports to GDP ratio of 0.02.

Then for the new parameters in our model, we consider three alternative values for the home-bias, trade elasticity, and price-adjustment costs parameters: χ=0.3, 0.35, 0.4, ε=0.7, 1.5, 4, and d_1=35, 50, 75. Our baseline choices are χ=0.35, ε=1.5, and d_1=35. This parameterization implies a moderate trade elasticity and quite flexible prices. For the elasticity of substitution across differentiated varieties, we use a standard value of 7.

Table 1: Parameterization of the model based on Uribe and Yue (2006)

Parameter	Value	Parameter	Value
μ	0.204	ω	1.455
δ	0.025/3	γ	2
β	0.99	ϕ	72.8
α	0.32	ψ	0.00042
$\frac{\bar{d}}{y}$	1.37	η	1.2

We use parameters for the shock process such that it matches exactly the dynamics of the interest rate spread we estimate in Figure 2. For the monetary policy rule, we consider the usual Taylor rule parameter values: ρ_I= 0.8, ϕ_π= 1.5, and ϕ_y= 0.5/12. Finally, in a model variant to interpret the heterogeneous responses across different sub-groups of countries that we estimate empirically in Figure 3, we allow a response in the monetary policy rule directly to the foreign interest rate spread: ϕ_{RI}= 0.5/12.[27]

4.4.2 Impulse responses

We now present impulse responses when an unexpected shock $\varepsilon_{R^S,t}$ hits the SOE in the initial period, when it is in the deterministic steady-state.[28] The baseline impulse responses from the model are shown in Figure 5, which are all qualitatively consistent with our empirical impulse responses in Figure 2. When the cost of borrowing in international market increases, it generates contractionary macroeconomic effects. Consumption, investment, and output all decrease in the SOE. The mechanism is an increased cost of borrowing, and thus of financing spending, which drives lower consumption as well as investment. Because of the working capital constraint, investment gets additionally negatively affected as wage bill increases with increased interest rates. Output of the home good declines following this reduction in spending.

[27] In this case, since the shock is persistent, we remove interest rate smoothing. We use the same value for this coefficient as the output coefficient for ease of comparison.

[28] Note again that while our baseline is a level shock to the country spread, we do consider a second-moment shock to the country spread in an extension. The qualitative behavior of the model is similar, with the only difference is that when we present impulse responses to a "pure" second-moment shock, by definition, it does not affect the level of the country-spread.

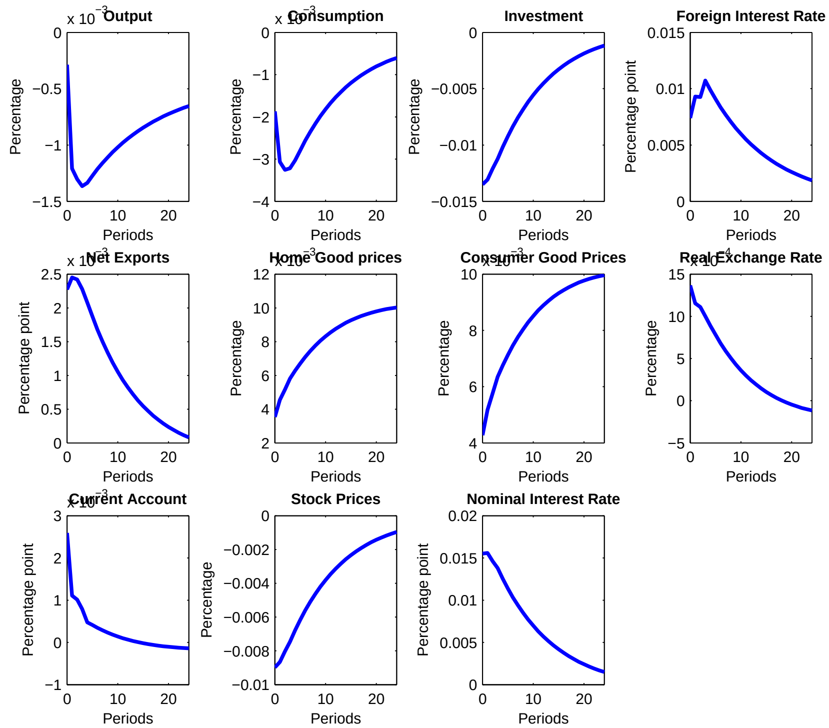

Figure 5: Impulse responses of the small open economy model to a shock to the foreign interest rate spread

Notes: Non-linear impulse responses are those computed when an unexpected foreign interest rate (spread) shock hits in the initial period and then the economy evolves deterministically thereafter. The economy is in the deterministic steady-state initially and the response are presented in terms of % or % points deviation from the steady-state. The economy transitions back to the steady-state in the long-run. The choice of model parameter values, including the size and persistence of the shock, is described in the text.

In our two-good model, there are additional implications for prices that are consistent with our empirical results. First, because of decreased demand, through the market-clearing condition for home goods, a clear prediction is that the real exchange rate depreciates.[29] That is, the relative price of the home good must decline in equilibrium as demand for the good falls strongly. The decline in output, together with a fall in relative price of the home good, leads to a fall in firm profits and thereby, stock prices.

Moreover, associated with the decrease in aggregate demand is also an increase in net exports (as a ratio of GDP), as spending contracts more compared to output. Compared to a one-good model, the contraction in spending gets additionally magnified as the relative

[29]Note that in the model, as is the convention, our notation is such that an increase in the exchange rate constitutes a depreciation. Here we focus on the real exchange rate as the nominal exchange rate is non-stationary, but empirically, as we show in the online appendix, the response of the real exchange rate is basically identical to the nominal exchange rate.

price of the home good declines (or equivalently the real exchange rate depreciates). Thus, net exports is persistently positive for a long period of time following the shock. Finally, as a reflection of the reduction in debt of the SOE following this shock, there is a positive current account balance (as a ratio of GDP).[30] These are consistent with the empirical responses in Figure 2 where net exports increase while capital inflows decline in the EMEs.

Next, consistent with our empirical responses, goods prices increase. What is the mechanism? Because of nominal rigidities and forward looking behavior of firms, in our model, home good inflation is determined by the path of marginal costs faced by home firms. Importantly, the relevant marginal cost is in terms of the home good price. Thus, while components of the marginal cost such as real wages and rental rate of capital decline initially given the large drop in macroeconomic aggregates, because of the real exchange rate depreciation, the marginal cost in terms of the home good prices actually increases.[31] This then leads to an increase in home goods prices. Given the home bias in consumption, consumer good prices are influenced strongly by home good prices, which translates also into consumer good prices increasing in the model.

To help interpret the heterogeneity in responses across sub-groups of countries that we find empirically, we now consider a case where the central bank, in addition to inflation and output, also responds to the foreign interest rate. This is meant to capture an inclination on the part of some central banks to keep the home interest rate at a similar level as the foreign interest rate, in order to avoid large swings in capital flows. The impulse responses from this variation in the model are shown in Figure 6. It is clear that because of such policy, which turns out to be contractionary, output and consumption, and by more limited amount also investment, decline by more.[32] In addition, while the differential effects are smaller, the decline in stock prices is also larger.

On the other hand, the response of current account is lower. Thus the SOE limits the capital outflows from it to the rest of the world as a result of such a policy. Thus, at least qualitatively, for many variables, this is consistent with the heterogeneity in responses we find in Figure 3, where in particular, South American countries suffer less in terms of output and stock prices but there is a larger increase in current account following a US uncertainty shock. Our model based interpretation for this heterogeneity then is that it can arise if the rest of EMEs, compared to South American countries, put a larger weight in the monetary

[30] In our model, the current account is countercyclical for a persistent enough shock.

[31] Note that even though the foreign interest rate increases, in equilibrium, because of the large fall in output, the rental rate of capital actually declines for the initial periods. It later increases above steady-state.

[32] As monetary policy tracks the foreign interest rate/spread, the dynamics of the nominal interest rate and some other variables such as output have a very similar dynamics, with somewhat humped shape response and minor non-monotonicity in the first few periods.

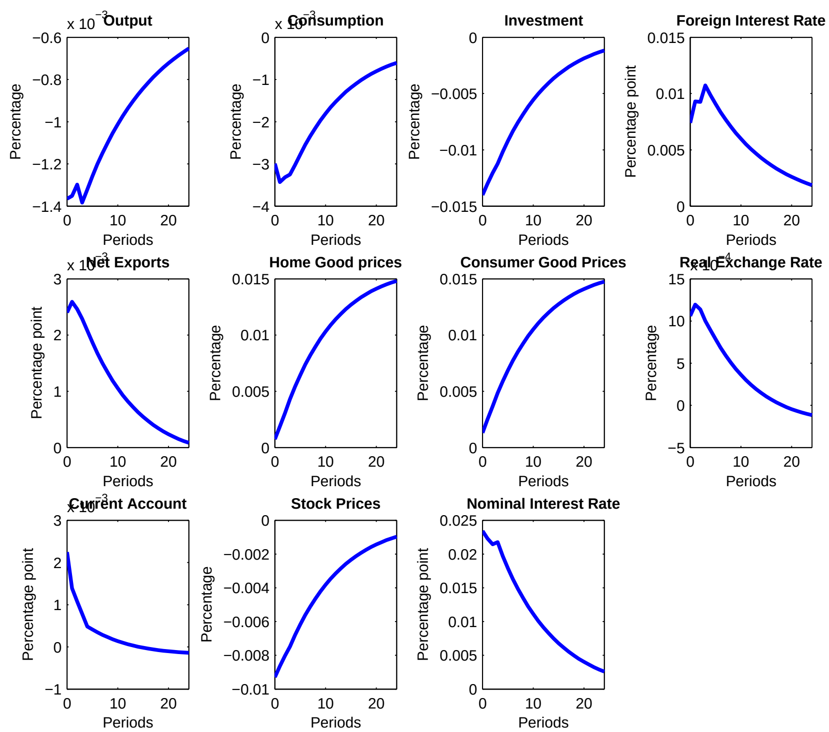

Figure 6: Impulse responses of the small open economy model to a shock to the foreign interest rate spread when the central bank reaction function includes the shock

Notes: Compared to the baseline in 5, the central bank interest rate reaction function now also includes a feedback to the foreign interest rate. Also, see the notes in Figure 5.

policy reaction function to the foreign interest rate.

4.4.3 Extensions and robustness

We consider several extensions and robustness exercises. Importantly, we introduce a second-moment shock to the foreign interest rate process. We then compute the responses of the model variables to a purely second-moment shock, that is, one where we hold the first-moment shock at its steady-state. Figure C.11 in the online appendix shows the results and while the response of most variables are similar qualitatively to our baseline, with magnitudes being smaller, by definition, this shock does not lead to an increase in the level of country spread. This increase in the level of country spread due to the VIX shock is a robust empirical feature.

For the baseline first-moment shock to the foreign interest rate spread case, we show in the online appendix in Figures C.12 and C.13, the results when we use a greater level of price stickiness (d_1=50) and a lower trade elasticity (ε=0.9) respectively. Finally, we also consider a negative foreign income/output shock as a possible proxy for the US uncertainty shock. The results are reported in Figure C.14. Since such a shock constitutes an exogenous drop in demand for the SOE produced good, it does generate a drop in the SOE output, consumption, and investment. But counterfactually, net exports decrease, which is due to the drop in demand for the SOE produced good.

5 Discussion and external evidence

We have so far presented our empirical results, with several robustness exercises, and used a theoretical model to help interpret them. We now present some evidence, external to the baseline empirical and theoretical approach, to provide additional validity to our results and interpretation.

5.1 US monetary policy spillovers

We first discuss results based on spillovers to EMEs of the standard US monetary policy shock.[33] Since our sample period includes the zero lower bound for the US, we use a shadow interest rate computed by Krippner (2016) for this period as a measure of monetary policy. The identification of a US monetary policy is standard, where we use a recursive identification method by ordering the shadow interest rate last.[34] Additionally, for the panel VAR

[33]These results appeared in much more detail in Bhattarai, Chatterjee, and Park (2017b).

[34]The monthly US VAR has five variables: the industrial production (IP) index as a measure of output, PCE index as a measure of consumption, the PCE deflator as a measure of consumer prices, CRB BLS spot

exercise, the specification is identical to the one we have used above where we replace the US uncertainty shock with a US monetary shock.

We present results from our baseline specification in Figure C.15 in the online appendix. On average, following an exogenous increase in US short-term interest rates, EME short-term interest rates and especially, EME long-term country spreads increase persistently.[35] Moreover, capital flows out of these countries. The US monetary policy shock also transmits to the real economy of EMEs: output of these countries drops while net exports increase. These results thus lend validity to our model based interpretation that transmission of foreign shocks to EMEs appear to operate through the country spread channel. Additionally, similar to the US uncertainty shock, central banks of EME countries face a non-trivial trade-off in the face of a US monetary policy shock as well. If our hypothesis that central banks of different EMEs might respond differentially to such a trade-off is correct, then we should observe similar heterogeneous responses in our sub-group estimation here as well.

Figure C.16 in the online appendix presents results based on the subgroup analysis where we split the EMEs in our sample into two subgroups as before. Strikingly, we find similar results: the negative effects on output and exchange rates are bigger and more persistent for the rest of EMEs compared to South American countries while the effects are bigger and more persistent on capital flows and net exports for South American countries compared to the rest of EMEs. Most importantly, the short-term (policy) rate of the rest of EMEs not only does not decrease by more compared to South American countries, even though the countries get affected much more negatively in terms of output, it in fact is significantly positively affected. Thus, our results here provide supporting evidence in favor of "fear of capital flows" in the rest of the EMEs and associated heterogeneity in monetary policy response.

5.2 Capital flow controls

We have interpreted the heterogeneity in responses across sub-groups based on heterogeneity in monetary policy reaction to capital outflows. If these capital flow concerns are more paramount for the rest of EMEs compared to South American EMEs, then it should be reflected in other, non-monetary policy choices as well. In particular, the rest of EMEs are expected to use direct capital flow restrictions measures more extensively. Capital flow control indices computed by Fernandez et al (2015) show that it is indeed the case: South American EMEs have higher capital mobility (or less restrictive capital control policies)

price index as a measure of commodity prices, and a short-term interest rate as the measure of monetary policy instrument. In the baseline specification we use six lags. The sample period is Jan 1984-Nov 2015 and we use a Bayesian approach to estimation. Details are in the online appendix.

[35]Ha and So (2017) also find that US monetary policy plays an important role in monetary transmission in SOE interest rates, presumably hampering the effectiveness of domestic monetary policy.

compared to the rest of EMEs in our sample. The results based on these indices are reported in Table C.4 in the online appendix.

5.3 Analysis of EME central bank minutes

Finally, we turn to narrative evidence from monetary policy committee meeting minutes of EME central banks. Overall, this analysis reveals a picture of fear of capital flows. Moreover, in some instances, considerations for financial stability and fear of capital flows led to changes in monetary policy, despite domestic output and inflation stabilization objectives demanding a different course of policy action. We present more textual evidence on other central banks in the online appendix while focusing on Turkey and Peru to highlight the sub-group differences.

Perhaps the most prominent example of this "fear of capital flows" is the Central Bank of Republic of Turkey (CBRT) law that explicitly includes financial stability together with inflation targeting in their monetary policy framework. In November 2016, despite a decline in aggregate economic activity and a fall in inflation, CBRT undertook substantial monetary tightening to take precautions for the enhancement of the stability in the financial system and to mitigate capital outflows:

> In sum, the slowdown in aggregate demand contributes to the fall in inflation. However, the recent exchange rate movements resulting from increased global uncertainty and high volatility limit the improvement in inflation outlook.... *The increased global uncertainty driven by the US presidential election send emerging financial markets into turbulence, inducing portfolio outflows... The Committee decided to implement monetary tightening* (Monetary Policy Committee, CBRT, Nov 2016).

However, this "fear of capital flows" is not a homogeneous concern among the EMEs. For example, facing similar external considerations, the Board of the Central Reserve Bank of Peru (CRBP) approved to maintain the monetary policy interest rate in their November 2016 meeting:

> This decision is consistent with an inflation forecast in which inflation is gradually converging to 2.0 percent in the monetary policy horizon and takes into account that: i) 12 month inflation expectations are within the target range; ii) The effects of the rise in the prices of some food products and fuels on the rate of inflation in September and October have been transitory, so inflation is expected to converge soon to the inflation target range; iii) Local economic activity has been growing at a rate close to its potential growth level, and iv) *The global economy continues showing mixed signals of recovery in production and employment,*

as well as increased uncertainty in international financial markets. In this scenario, the Peruvian economy maintains sound fundamentals (Monetary Policy Notes, CRBP, Nov 2016).

Thus, there indeed is heterogeneity across EME central banks in terms of the degree of attention and importance they assign to volatility of capital flows and how they tailor monetary policy in response to these concerns.

Given these stark differences in policy focus between emerging economies, we take a further step towards a more rigorous analysis by analyzing the entire text of monetary policy meeting minutes of Brazil, South Africa, Turkey and Peru from 2006-2014.[36] In particular, we measure capital flow concerns as the number of times monetary policy minutes contain words in the group {capital flow(s), capital outflow(s), international capital market, international market, portfolio flow(s), portfolio outflow(s),} and contrast this to the output stabilization concern measured as word count in the group {output, economic activity, employment, unemployment, growth, production}. Because all four central banks are currently official inflation targeting central banks, naturally they are concerned with price stabilization. Hence, we use output stabilization as the appropriate scale to compare with for capital flow concerns. As Figure C.17 in the online appendix confirms, a pervasive fear of capital flows for Turkey and South Africa can be traced, which forms a striking contrast with Peru and Brazil. In Peru, capital flow concerns are generally rarely mentioned, and in fact, the median relative frequency of capital flow words is zero, whereas in Brazil, the median relative frequency is nearly half of that of South Africa and Turkey.[37]

6 Conclusion

We study the spillover effects on emerging market economies (EMEs) of fluctuations in US uncertainty. We find that changes in US financial uncertainty have significant financial and macroeconomic effects on the EMEs. Moreover, we find economically meaningful heterogeneity in responses among the fifteen EMEs and suggestive evidence that the EME monetary policy response can play a critical role in the transmission of the US uncertainty shock. We use a small open economy (SOE) model with financial and nominal frictions to interpret our

[36] This ensures at least two countries each in the two sub-groups that we studied in the empirical section. Very few emerging countries have minutes of monetary policy committee meetings publicly available at a regular frequency over our entire sample period. For example, India has very infrequent minutes in the earlier part of the sample and more frequently only in the last few years. Hence, we chose to restrict the sample to four major countries that regularly release minutes over this time period.

[37] Strikingly enough, Central Bank of Brazil seldom mentions capital flow words even during the global financial crisis period unlike the other countries.

empirical findings.

In future work, we will explore if the spillovers effects of US uncertainty are also important for advanced small open economies, as suggested in Gerko and Rey (2017). Moreover, it will be interesting to understand how US financial uncertainty propagates to EMEs in a general equilibrium global economy with countries of different sizes where an increase in expected volatility in the stock markets of a large economy can lead to a flight to quality episode in EMEs, similar to Caballero and Krishnamurthy (2008). Finally, a comprehensive analysis of the EME central bank minutes to capture the “fear of capital flows”, following analysis like Feroli et al (2017), is part of our future research.

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Online Appendix

-Not for publication-

A Data description

See the data Appendix for the complete list of the data with detailed descriptions and their sources. It also explains how quarterly GDP, consumption, and investment series are interpolated to monthly series for the US and the emerging market countries. For the latter countries, monthly GDP is used to normalize capital flows and net exports.

B Specifications

We list our baseline and all alternative specifications for the EM panel VAR below.

Table 2: Baseline and alternative specifications of the EM panel VAR

Specifications		**Endogenous variables**
Baseline		Short-term interest rates, long-term interest rate spreads with respect to the 10-year Treasury yield in the US, the aggregate stock price, the nominal effective exchange rate of the local currency, capital inflows, Industrial Production, CPI, and net exports to the US
Alternative		The same as the baseline specification except that
	1	Industrial Production is replaced with GDP
	2	Industrial Production is replaced with consumption
	3	Industrial Production is replaced with investment
	4	Long-term interest rate spread is replaced with long-term real interest rate spread
	5	Nominal effective exchange rate is replaced with real effective exchange rate
	6	Net exports to the US is replaced with net exports to the world
	7	Net exports to the US is replaced with net foreign asset position with the US
	8	Capital inflows from the world is replaced with various capital inflow measures from the US
	9	CPI is replaced with the realized volatility of aggregate stock price

Notes: For each of the EMEs in the EM panel VAR the endogenous variables listed above, the US uncertainty shock with its lags, a proxy of the world demand for commodities, a price index of commodities, and the US financial crisis and European debt crisis dummy variables are included.

C Extensions and robustness

C.1 Empirical results

Figure C.1 presents the spillover effects on the alternative measures of economic activity and aggregate spending in EMEs where to conserve space we only present the responses of the alternative measures. GDP, consumption, and investment all respond negatively to the uncertainty shock with investment responding most strongly. Figure C.2 in the first row, reports the spillover effects of the US uncertainty shock on long-term real interest rate spreads, real effective exchange rates, and net exports to the world and in the second row, reports the spillover effects on alternative measures of external balance and capital flows that use TIC data. Again, to conserve space we only present the responses of the alternative variables. Figure C.3 presents our baseline macro and financial variables' impulse responses in a specification which allows for an endogenous response of EM stock price volatility to the US uncertainty shock.

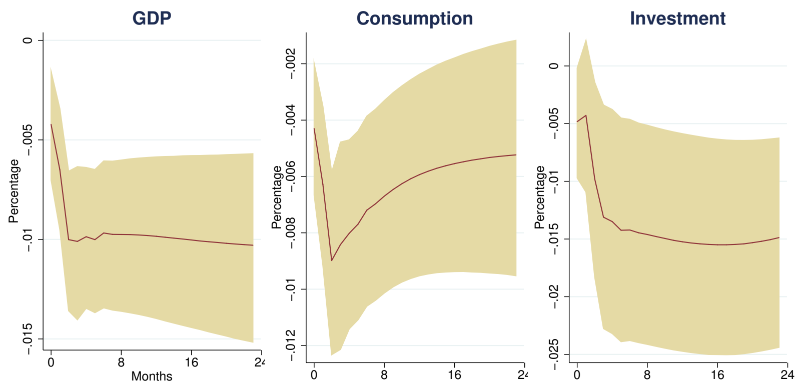

Figure C.1: Impulse responses of the EM panel VAR to the US uncertainty shock: other macroeconomic activity variables

Notes: Each plot presents the posterior median of the impulse responses to a 1% increase in the US uncertainty shock along with the 90% error bands in an alternative specification that includes GDP, consumption and investment as a measure of economic activity. The EM panel VAR includes the baseline seven variables except IP plus an alternative measure of economic activity but only the impulse response of the different measures of economic activity is displayed. Quarterly data on GDP, consumption and investment is interpolated into monthly observations. For the details, see the Data Appendix.

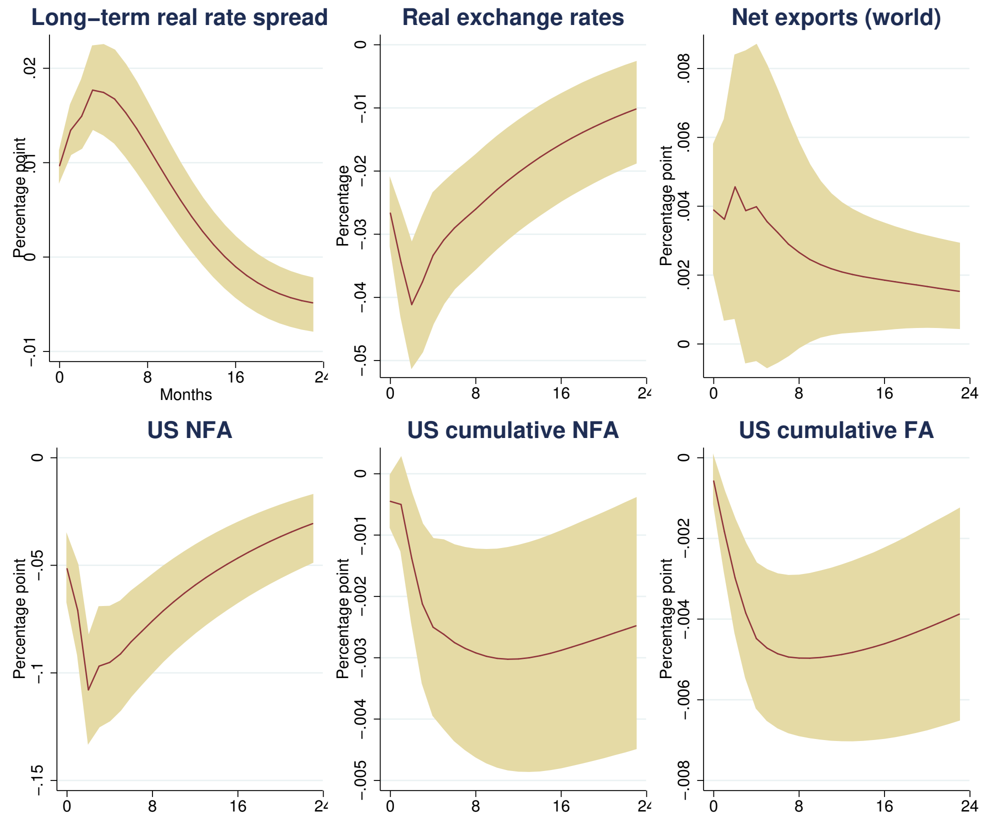

Figure C.2: Impulse responses of the EM panel VAR to the US uncertainty shock: other open economy and financial variables

Notes: Each plot presents the posterior median of the impulse responses to a 1% increase in the US uncertainty shock along with the 90% error bands in alternative specifications. In the first row, these are where the long-term nominal interest rate is replaced with the long-term real interest rate, the nominal effective exchange rate is replaced with the real effective exchange rate, and the net exports to the US is replaced with the net exports to the world, respectively. In the second row, these are where net exports to the US is replaced with net foreign asset position of the US on the EMEs, capital flows is replaced with cumulated net foreign asset position of the US on the EMEs, and capital flows is replaced with cumulated US foreign asset positions. Only the impulse response of the alternative variables is displayed. For the details, see the Data Appendix.

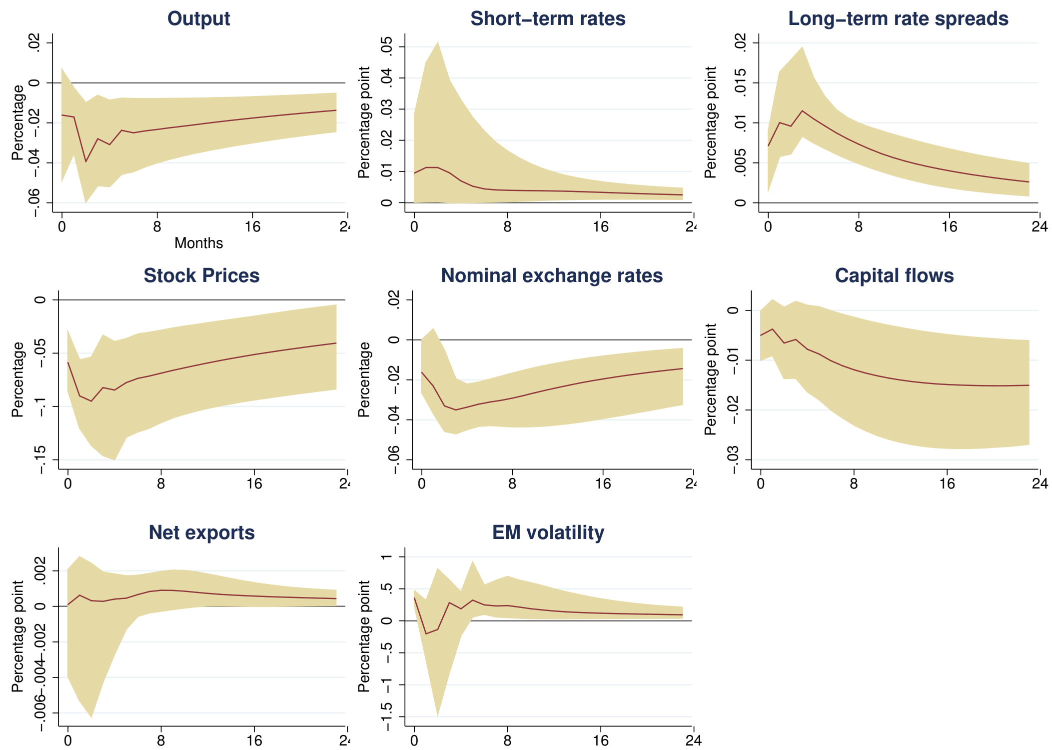

Figure C.3: Impulse responses of the EM panel VAR to the US uncertainty shock: controlling for EM MSCI volatility

Notes: Each plot presents the posterior median of the impulse responses to a 1% increase in the US uncertainty shock along with the 90% error bands in alternative specifications. We display the full set of impulse responses of the 8 variable system for each EM where we add realized EM MSCI volatility and drop CPI from the panel VAR. For the details, see the Data Appendix.

We do some robustness exercises on our measure of shock. First, the US VAR is extended to include eight total variables, as in Bloom (2009). We then identify US VIX shock by ordering VIX second, after S&P 500. This is the order used in Bloom (2009). The results are presented in Figure C.4. Second, we compare the baseline reduced-form shock to the identified shock from the orthogonalization scheme that orders VIX last. The identified shock is very similar to the baseline shock. The largest difference between the two shock series is less than 0.03 while the standard deviation of the two shock series is about 1.05. We do not present the orthogonalized shock since it is hardly distinguishable from the reduced-form shock. Note again that the shock series from ordering VIX first would be identical to our baseline series. Third, we simply use the growth rate of VIX as a measure of uncertainty shock in the EME panel VAR. This partly addresses the generated regressor problem that arises in our two-step estimation procedure. The results are presented in Figure C.5. Fourth, in the three variable VAR specification, we replace VIX with the financial uncertainty measure of Ludvigson, Ma, and Ng (2015). The results are presented in Figure C.6.

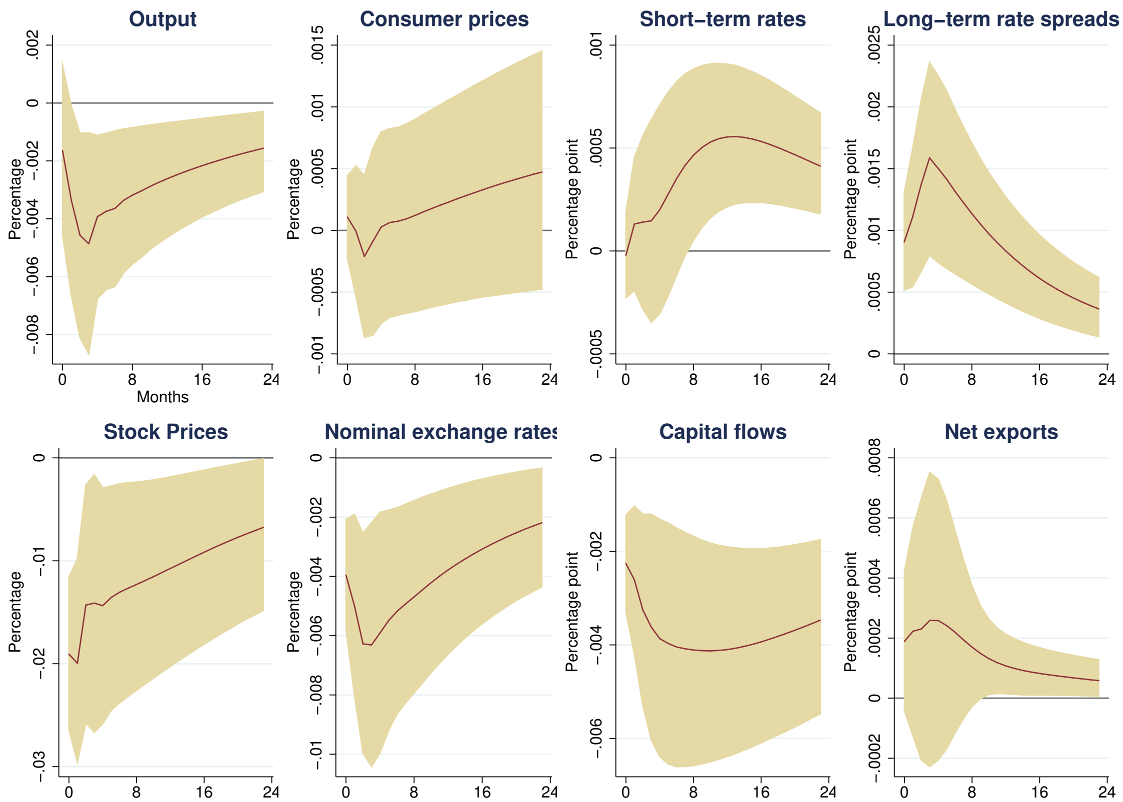

Figure C.4: Impulse responses of the EM panel VAR to the US uncertainty shock: macroeconomic and financial variables

Notes: Each plot presents the posterior median of the impulse responses to a 1% increase in the US uncertainty shock along with the 90% error band in the baseline specification that includes the both macroeconomic and financial variables. The US uncertainty shock is an identified shock in a eight variable US VAR specification where the identification scheme follows Bloom (2009). See notes in Figure 2.

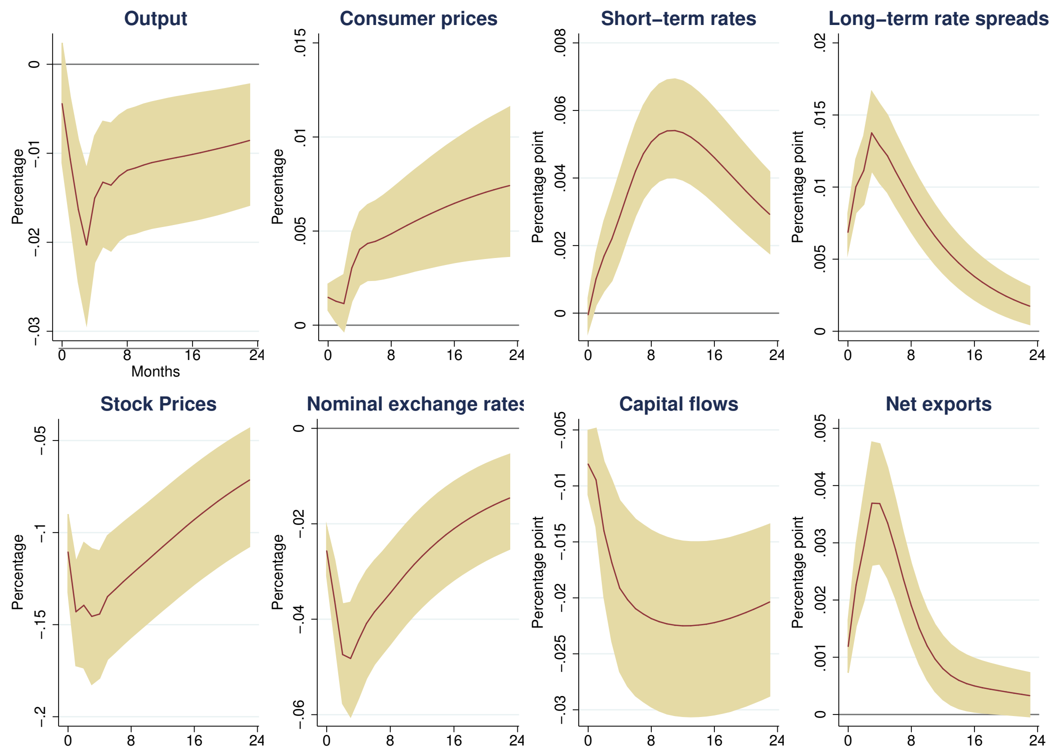

Figure C.5: Impulse responses of the EM panel VAR to the US uncertainty shock: macroeconomic and financial variables

Notes: Each plot presents the posterior median of the impulse responses to a 1% increase in the US uncertainty shock along with the 90% error band in the baseline specification that includes the both macroeconomic and financial variables. The US uncertainty shock is simply the growth rate of VIX. See notes in Figure 2.

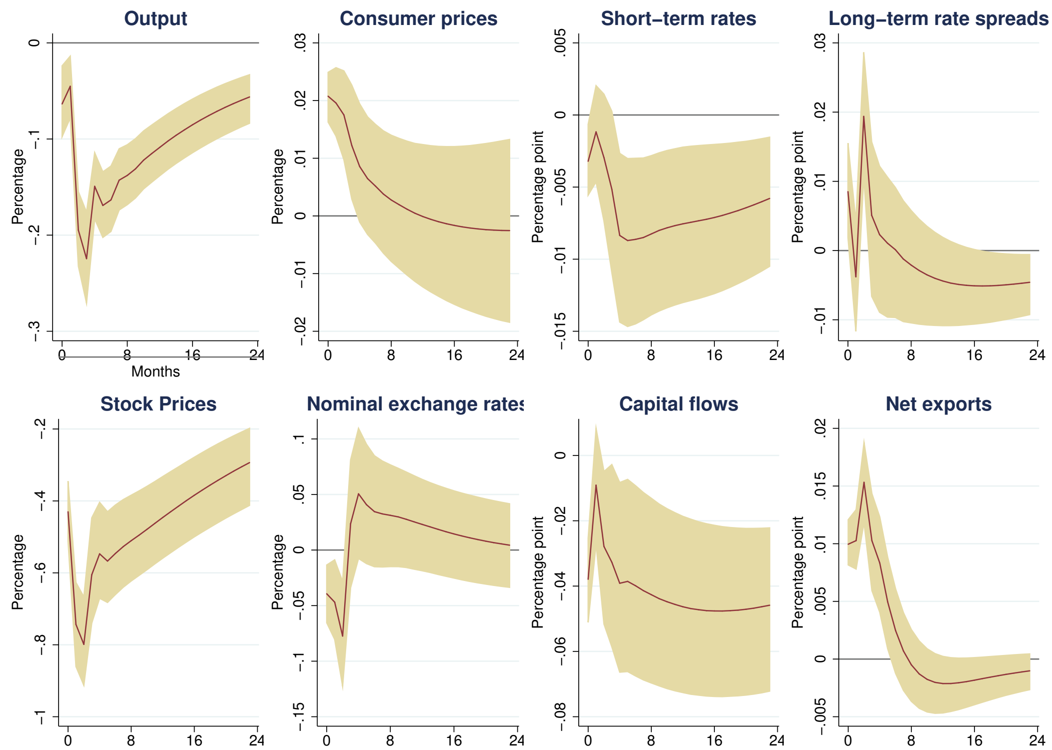

Figure C.6: Impulse responses of the EM panel VAR to the US uncertainty shock: macroeconomic and financial variables

Notes: Each plot presents the posterior median of the impulse responses to a 1% increase in the US uncertainty shock along with the 90% error band in the baseline specification that includes the both macroeconomic and financial variables. The US uncertainty shock is computed from a three variable US VAR specification, like the baseline specification, but uses the financial uncertainty measure of Ludvigson, Ng, and Ma (2015), instead of the VIX. See notes in Figure 2.

Fifth, we follow Bloom (2009) and identify only large movements in VIX as the US uncertainty shock. We first remove the persistent trend in log VIX using HP filter and then we create a dummy variable that takes on 1 in those periods where HP-filtered VIX is more than one standard deviation above the mean of the same series and 0 otherwise. This dummy variable is used in the panel VAR as a measure of the US uncertainty shock. Bloom (2009) identified a shock as one more than 1.65 standard deviations above the mean but we lowered the bar because of the relatively short sample period. If such large shocks are identified for multiple consecutive periods, we choose the period where HP-filtered VIX is greatest among those periods. Specifically, the following six periods are identified when the US uncertainty shock hits: September 2001, September 2002, February 2003, November 2008, May 2010, and September 2011. The results are presented in Figure C.7.

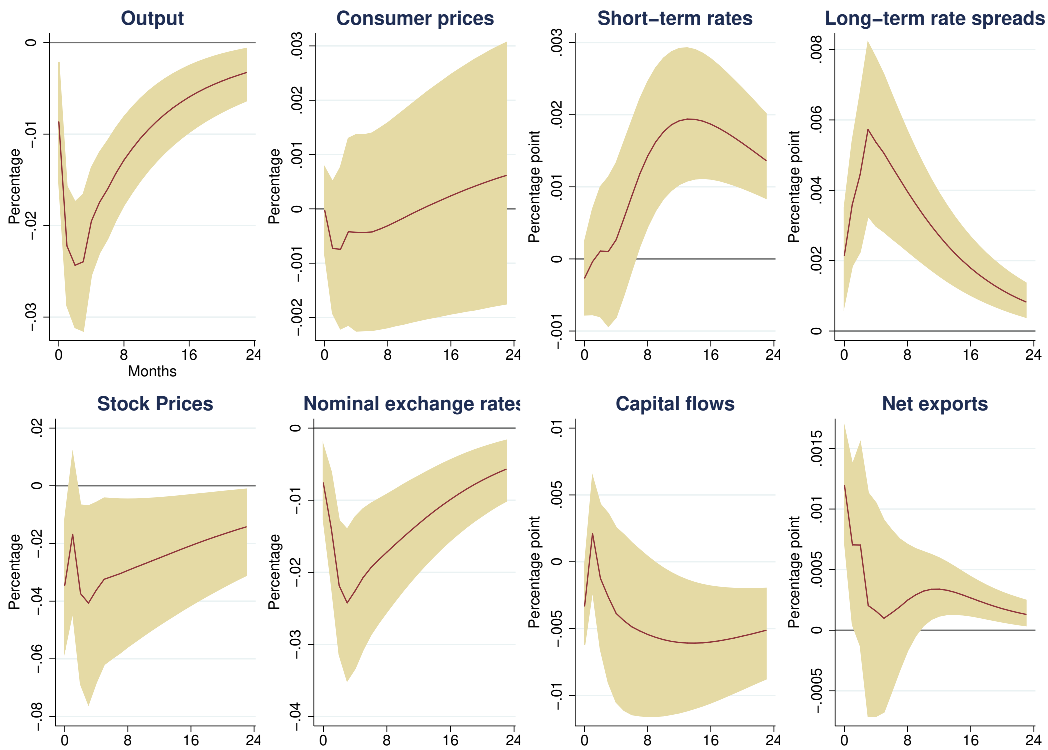

Figure C.7: Impulse responses of the EM panel VAR to the US uncertainty shock: macroeconomic and financial variables

Notes: Each plot presents the posterior median of the impulse responses to a 1% increase in the US uncertainty shock along with the 90% error band in the baseline specification that includes the both macroeconomic and financial variables. The US uncertainty shock is computed as large movements in VIX following Bloom (2009).

Next, we check that our main results are not sensitive to lag length selection in the panel VAR. Results using four lags of the US uncertainty shock in the panel VAR are reported in Figure C.8 and C.9. The results with five and six lags of the US uncertainty shock show similar responses and are available upon request.

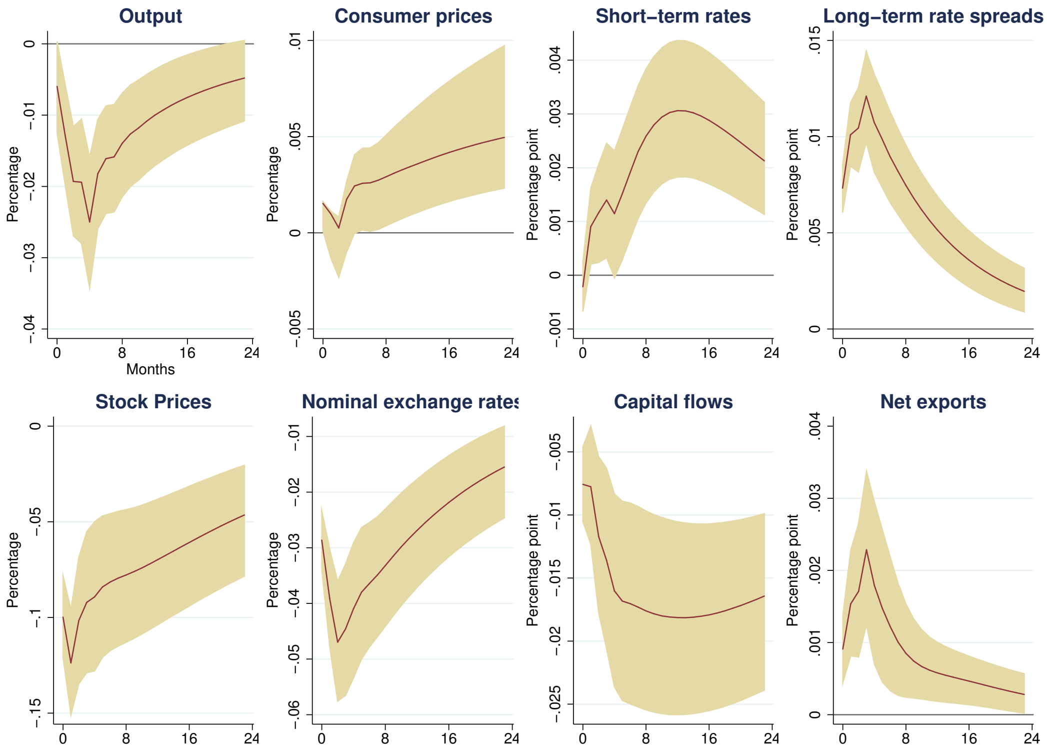

Figure C.8: Impulse responses of the EM panel VAR to the US uncertainty shock: with four lags of the US uncertainty shock

Notes: Each plot presents the posterior median of the impulse responses to a 1% increase in the US uncertainty shock along with the 90% error band in the baseline specification that includes the both macroeconomic and financial variables. Four lags of the US uncertainty shock are included. See notes in Figure 2.

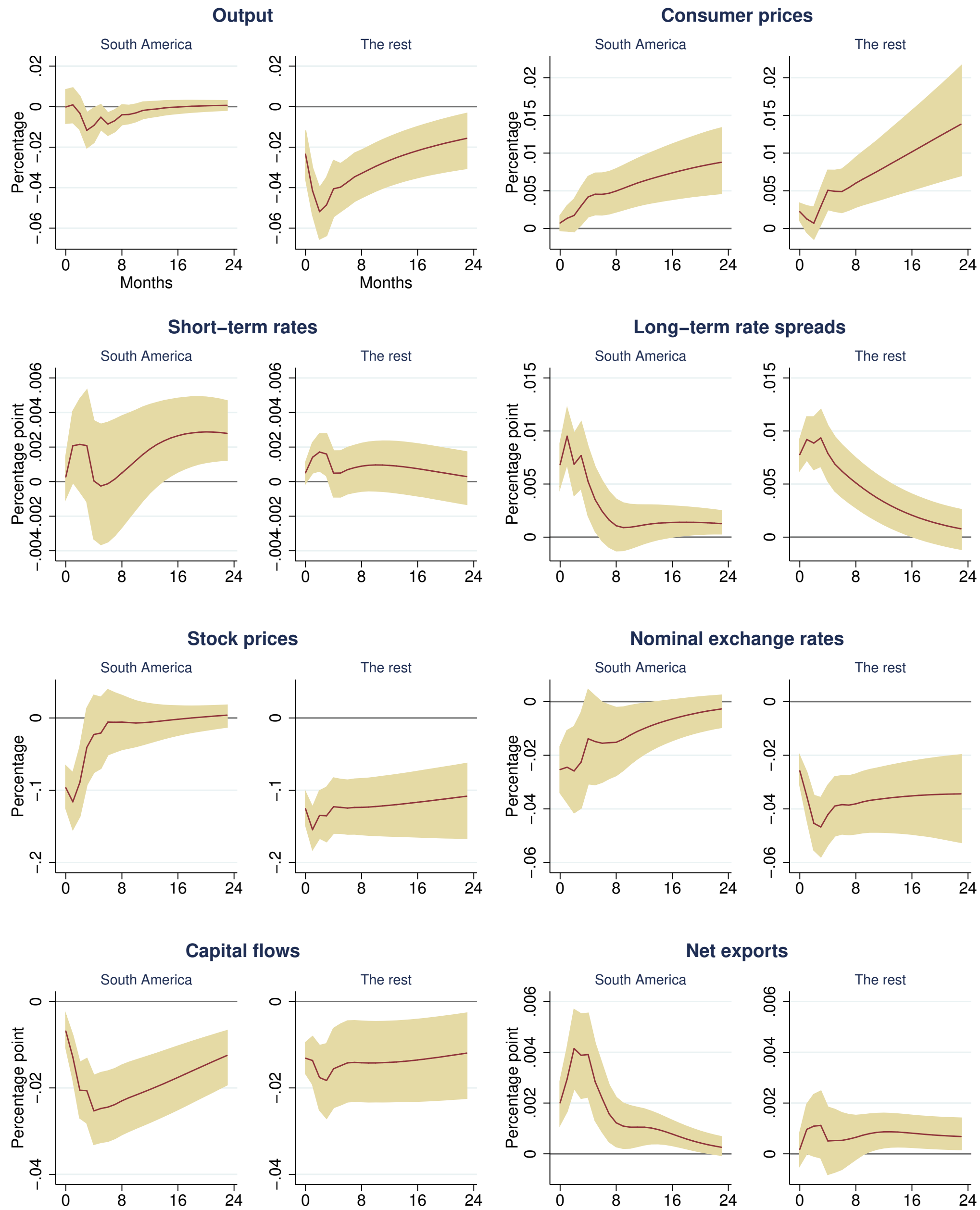

Figure C.9: Impulse responses of the EM panel VAR to the US uncertainty shock: macroeconomic and financial variables; South America vs. the rest; with four lags of the US uncertainty shock

Notes: Each plot presents the posterior median of the impulse responses to a 1% increase in the US uncertainty shock along with the 90% error band in the specification for subgroup analysis that includes both the macroeconomic and financial variables. Four lags of the US uncertainty shock are included. Subplots are arranged by variables and shown for two groups of countries: South America including Brazil, Chile, Colombia, Mexico, Malaysia, and Peru and the rest of the EM economies. See the notes in Figure 2.

For the sub-group estimation, we have also checked our results on using other activity measures and other financial and open economy variables. As one example, we report results using long-term real rate spreads in Figure C.10.

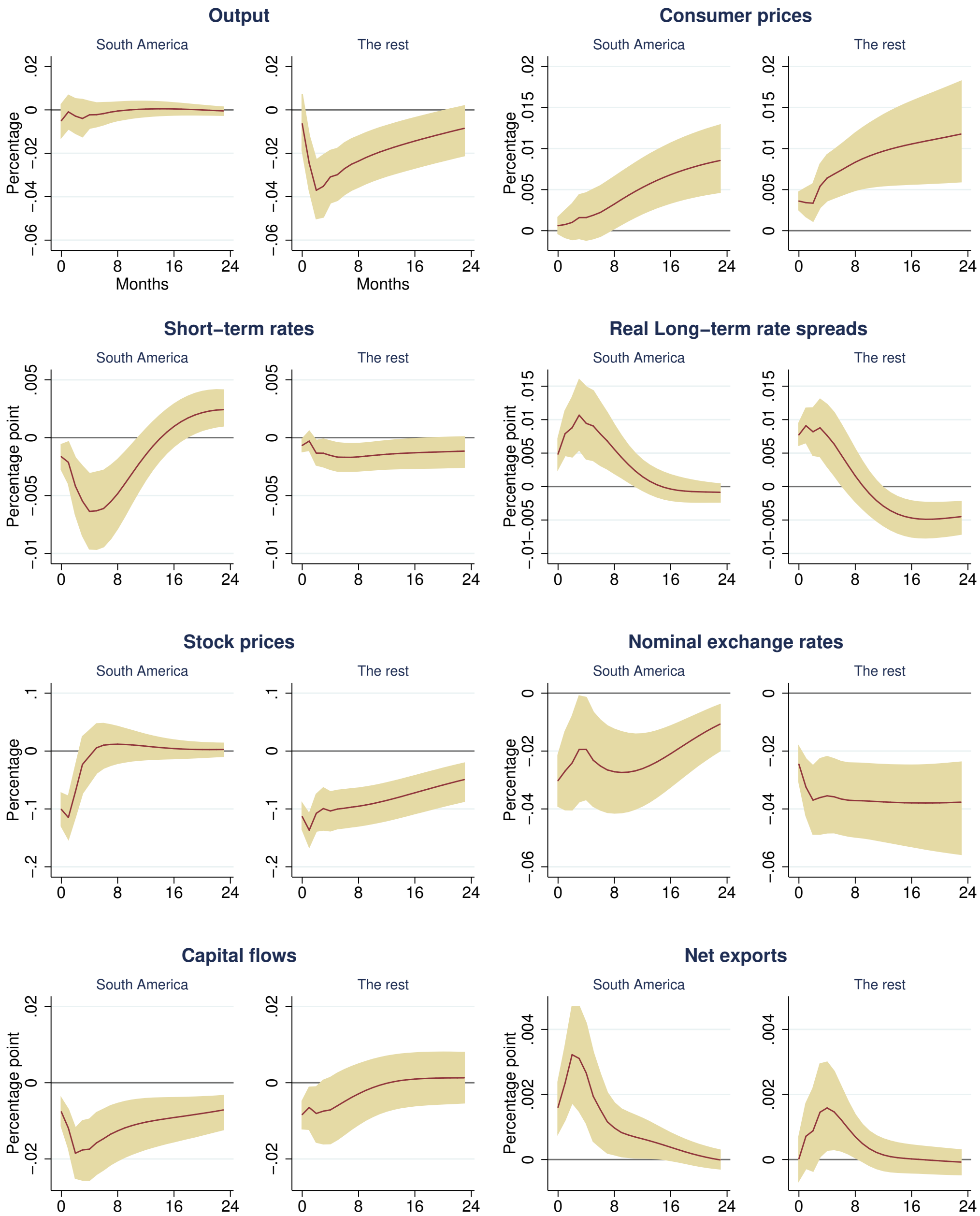

Figure C.10: Impulse responses of the EM panel VAR to the US uncertainty shock: macroeconomic and financial variables; South America vs. the rest; with real long-term rate spreads

Notes: Each plot presents the posterior median of the impulse responses to a 1% increase in the US uncertainty shock along with the 90% error band in the specification for subgroup analysis that includes both the macroeconomic and financial variables. Nominal long-term interest rate spreads are replaced with real long-term interest rate spreads. Subplots are arranged by variables and shown for two groups of countries: South America including Brazil, Chile, Colombia, Mexico, Malaysia, and Peru and the rest of the EM economies. See the notes in Figure 2.

We now present the contribution of the US uncertainty shock in the h-period ahead forecast error variance of the EME variables. The method used to compute these variance decomposition results is described above in the Appendix.

Table C.1: Forecast error variance decomposition (%)

Horizon	Output	Short rate	LR spread	Exch Rate	Cap Flows
1	1.74	0.37	10.67	7.49	2.70
3	15.02	0.63	14.89	12.18	3.39
12	11.62	6.35	20.04	13.49	8.63
24	11.11	9.59	12.52	12.43	12.76

Notes: Forecast error variance decomposition at different horizons in the specification for all EMEs that includes financial and macroeconomic variables. See the Appendix for details on the method used to compute these variance decomposition results.

Table C.2: Forecast error variance decomposition for South American EMEs (%)

Horizon	Output	Short rate	LR spread	Exch Rate	Cap Flows
1	0.48	0.28	6.55	4.39	2.71
3	9.79	0.97	8.88	4.37	13.88
12	12.07	5.42	6.56	8.77	17.75
24	10.85	6.05	5.27	12.96	18.91

Notes: Forecast error variance decomposition at different horizons for South American EMEs in the sub group specification that includes financial and macroeconomic variables. See the Appendix for details on the method used to compute these variance decomposition results.

Table C.3: Forecast error variance decomposition for Rest of EMEs (%)

Horizon	Output	Short rate	LR spread	Exch Rate	Cap Flows
1	1.72	0.40	15.16	6.70	2.91
3	14.71	1.46	14.37	11.71	1.96
12	13.24	5.54	13.07	12.77	3.52
24	11.00	9.88	12.93	13.97	6.84

Notes: Forecast error variance decomposition at different horizons for rest of EMEs in the sub group specification that includes financial and macroeconomic variables. See the Appendix for details on the method used to compute these variance decomposition results.

C.2 Theoretical model and results

In this section we present details of the theoretical model as well as the results from the various extensions that we discuss in the main text.

C.2.1 Maximization problems

We present formally the maximization problems of the household and firms. We start first with the two static expenditure minimization problems. The household chooses $\{c_{H,t}, c_{F,t}\}_{t=0}^{\infty}$ to minimize $p_{H,t}c_{H,t} + p_{F,t}c_{F,t}$ subject to

$$\left[(1-\chi)^{\frac{1}{\varepsilon}} c_{H,t}^{\frac{\varepsilon-1}{\varepsilon}} + \chi^{\frac{1}{\varepsilon}} c_{F,t}^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}} \geq c_t, \tag{C.16}$$

while taking as exogenously given $\{p_{H,t}, p_{F,t}\}_{t=0}^{\infty}$. Then, the shadow price on (C.16) is equal to p_t, the home currency nominal price of the aggregate consumption good. The demand functions take standard forms. Next, the household chooses $\{c_{H,t}(i)\}_{t=0}^{\infty}$ to minimize $\int_0^1 c_{H,t}(i)p_{H,t}(i)di$ subject to

$$\left[\int_0^1 c_{H,t}(i)^{\frac{\nu-1}{\nu}} di\right]^{\frac{\nu}{\nu-1}} \geq c_{H,t}, \tag{C.17}$$

while taking as exogenously given $\{p_{H,t}(i)\}_{t=0}^{\infty}$. Then, the shadow price on (C.17) is equal to $p_{H,t}$, the home currency nominal price of the home consumption good. The demand functions take standard forms. Similar expenditure minimization problems also apply for the foreign consumption goods and the investment good.

Given the two first-stage, static expenditure minimization problems discussed above, the problem of the home household then is to choose $\{c_t, h_t, d_t^*, b_t, k_{t+1}, i_t\}_{t=0}^{\infty}$ to maximize (6) subject to a sequence of constraints (8) and (9), while taking as exogenously given initial wealth, initial capital stock, and $\{\Pi_t,\ \varphi_t,\ R_{t-1},\ \tilde{c}_{t-1},\ w_t,\ u_t,\ Q_t,\ I_{t-1},\ p_t^*\}_{t=0}^{\infty}$.

Now we move to the maximization problem of the firms. In addition to the non-interest bearing assets $\kappa_t(i)$, the balance sheet of the firm has one-period interest bearing liabilities, denoted by $d_t^f(i)$. These one-period riskless liabilities bear gross interest rate R_t^d in terms of price of the home good. The evolution of the liabilities is then governed by

$$\begin{aligned} d_t^f(i) =& R_{t-1}^d d_{t-1}^f(i) - \frac{p_{H,t}(i)}{p_{H,t}} F(k_t(i), h_t(i)) + d\left(\frac{p_{H,t}(i)}{p_{H,t-1}(i)}\right) \\ &+ \frac{p_t}{p_{H,t}}\left[w_t h_t(i) + u_t k_t(i) + \varphi_t(i) - \kappa_{t-1}(i) + \kappa_t(i)\right], \end{aligned}$$

where $\varphi_t(i)$ is profits of the firm. Next, defining the net liabilities of the firm as $a_t(i) \equiv R_t^d d_t^f(i) - \frac{p_t}{p_{H,t}}\kappa_t(i)$ gives a law of motion for $a_t(i)$ as

$$\frac{a_t(i)}{R_t^d} = a_{t-1}(i) - \frac{p_{H,t}(i)}{p_{H,t}} F(k_t(i), h_t(i)) + d\left(\frac{p_{H,t}(i)}{p_{H,t-1}(i)}\right) + \frac{p_t}{p_{H,t}}\left[w_t h_t(i) + u_t k_t(i) + \varphi_t(i)\right]$$
$$+ \frac{p_t}{p_{H,t}} \kappa_t(i)\left(1 - \frac{1}{R_t^d}\right) + \left(\frac{p_{t-1}}{p_{H,t-1}} - \frac{p_t}{p_{H,t}}\right)\kappa_{t-1}(i). \tag{C.18}$$

The problem of firm i at home is to choose $\{a_t(i), h_t(i), k_t(i), p_{H,t}(i)\}_{t=0}^{\infty}$ to maximize (11) subject to a sequence of constraints (10) and (C.18), the production function, and the demand curve, while taking as exogenously given initial net liabilities, non-interest bearing assets, and $\{\frac{p_{t-1}}{p_{H,t-1}}, R_{t-1}^d, p_{H,t}, y_t, \rho_{0,t}, w_t, u_t\}_{t=0}^{\infty}$.

C.2.2 Equilibrium

We next define the equilibrium in our economy and discuss the aggregate optimality and feasibility conditions that characterize it. We briefly also discuss the steady-state of the model.

An equilibrium is a collection of allocations (of goods varieties and aggregates) for the household, $\{c_{H,t}(i),\ c_{F,t}(i),\ i_{H,t}(i),\ i_{F,t}(i),\ c_t,\ ,\tilde{c}_{t-1},\ h_t,\ d_t^*,\ b_t,\ \ k_{t+1},\ i_t\}_{t=0}^{\infty}$, allocations and goods prices for the firms $\{a_t(i),\ h_t(i),\ k_t(i),\ p_{H,t}(i)\}_{t=0}^{\infty}$, a sequence of aggregate prices $\{S_t,$ $p_{H,t},\ p_{F,t},\ p_t,\ R_t,\ w_t,\ u_t,\ \rho_{0,t},\ R_t^d\}_{t=0}^{\infty}$ and output $\{y_t\}_{t=0}^{\infty}$, and monetary policy instrument $\{I_t\}_{t=0}^{\infty}$ such that

(i) Given prices and monetary policy, the allocations are such that they satisfy the maximization problems of the household,

(ii) Given aggregate prices, aggregate output, and monetary policy, the goods prices and allocations are such that they satisfy the maximization problem of the firms,

(iii) The allocations and goods prices across firms are symmetric,

(iv) Individual and aggregate consumption is equal,

(v) The nominal interest rate is determined by the monetary policy rule, and

(vi) Goods, factor, and bonds markets clear,

given the initial capital stock, consumption, household debt, firm net asset position, firm non-interest bearing asset, relative price, aggregate price, interest rates, and an exogenous process for $\{R_t^s, y_t^*, p_t^*, \sigma_t\}_{t=0}^{\infty}$.

We present in detail in the Online Appendix, the non-linear, aggregate equilibrium conditions of the model that determine the dynamics of the seventeen endogenous aggregate variables $\{d_t,\ w_t,\ h_t,\ u_t,\ k_t,\ c_t,\ i_t,\ R_t^d,\ y_t,\ \tilde{c}_t,\ \varphi_t,\ \varsigma_t,\ \Pi_t,\ \Pi_{H,t},\ b_t,\ I_t,\ \xi_t\}$. The economic interpretation of these equilibrium conditions is also relegated to the Online Appendix. We only focus on an equilibrium where R_{t-1}^d is strictly positive. This means that the working capital constraint (10) will always bind. It is assumed that the firms start with no net liabilities.

While the details of the deterministic steady-state are in the online Appendix, it is nevertheless useful to note some properties of the steady-state as for our non-linear impulse responses, we will start the economy in the deterministic steady-state and the economy will transition back to this same steady-state in the long run. First, as is well known, given the debt adjustment cost function, $\bar{d}$ pins down the steady-state external debt of this economy. Moreover, we pick a zero net inflation steady-state. Then, the interest rates are equal to $\frac{1}{\beta}$: $I = R^d = R = \frac{1}{\beta}$. We also normalize the terms-of-trade ς in steady-state to be 1.[38] Together, this implies that all relative prices and exchange rates are also1 in the steady state. The investment to capital stock ratio is equal to δ, which implies $u = \frac{1}{\beta} - (1-\delta)$, and $w = \left[\left(\frac{\varepsilon-1}{\varepsilon}\right)(1-\alpha)^{1-\alpha}\alpha^{\alpha}u^{-\alpha}\right]^{\frac{1}{1-\alpha}}(1+\eta(1-\beta))^{-1}$. Finally, given these solutions for factor prices and the investment to capital stock ratio, variables in levels such as hours, consumption, output, investment, and capital in steady-state can be derived.

C.2.3 Results of extensions

We now consider a second-moment shock to the foreign interest rate and compute the responses of the model variables to a purely second-moment shock, that is, one where we hold the first-moment shock at its steady-state. We use a third-order accurate perturbation solution method to compute the stochastic equilibrium. For the parameterization of the second-moment shock, we use estimates in Fernandez-Villaverde et al (2011) for Brazil and use a simple AR(1) process for the interest rate shock as opposed to an ARMA (1,3), so that it is easily comparable to the literature. Figure C.11 shows the results.

[38] We have this freedom, given that we choose the steady-state of foreign demand to be consistent with the market clearing condition for goods.

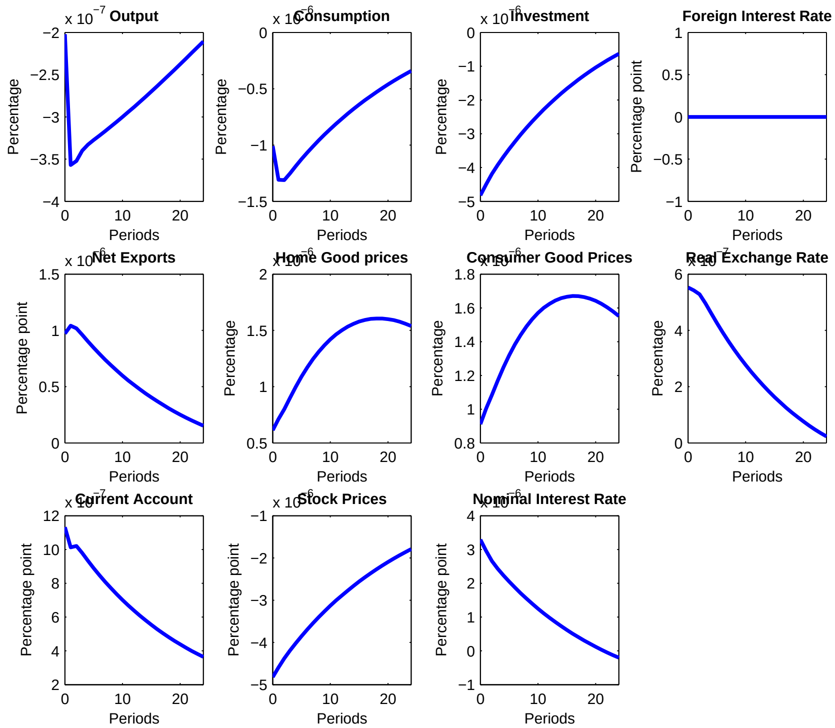

Figure C.11: Impulse responses of the small open economy model to a shock to the volatility of the foreign interest rate spread

Notes: These are non-linear impulse responses to a second-moment shock (volatility shock) to the foreign interest rate spread. The solution method is a third-order perturbation.

For the baseline case, we show in Figures C.12 and C.13, results when we use a greater level of price stickiness (d_1=50) and a lower trade elasticity (ε=0.9) respectively. Finally, we also consider a negative foreign income/output shock as a possible proxy for the US uncertainty shock. We use the same parameters for the size of this shock as the baseline interest rate spread shock and for persistence use a random walk specification that is common in business cycle studies. The results are reported in Figure C.14.

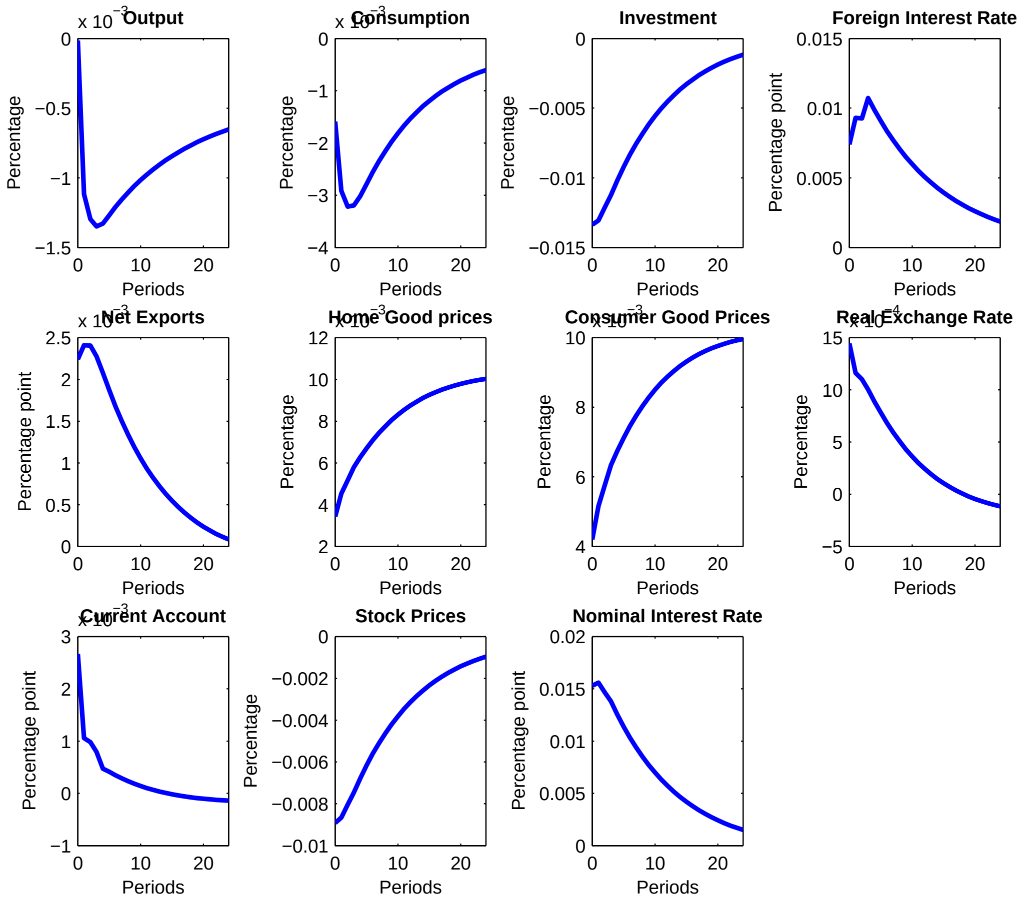

Figure C.12: Impulse responses of the small open economy model to a shock to the foreign interest rate spread with stronger nominal rigidities than baseline

Notes: Compared to the baseline in Figure 5, prices are more sticky. Also, see the notes in Figure 5.

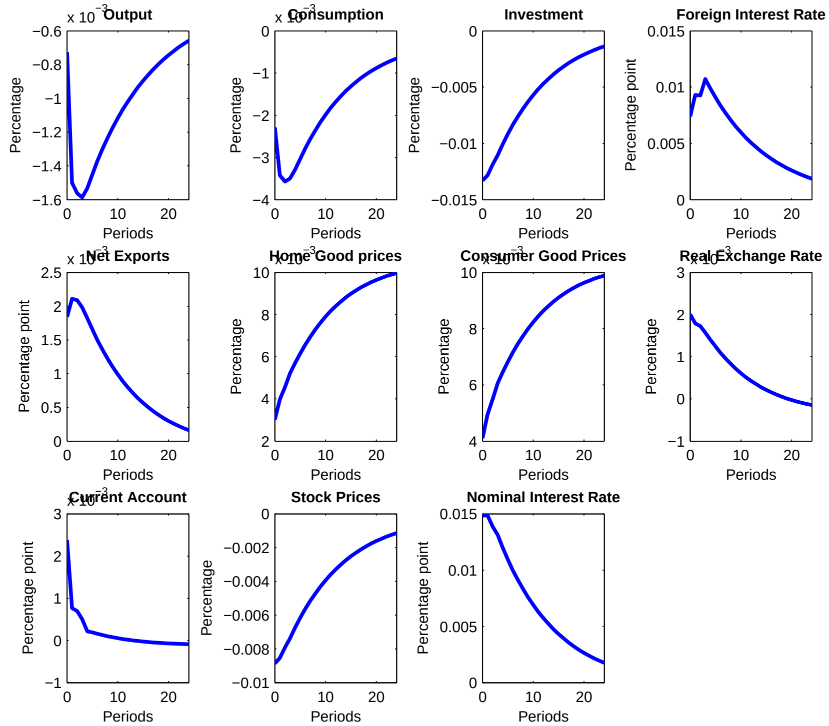

Figure C.13: Impulse responses of the small open economy model to a shock to the foreign interest rate spread with lower trade elasticity than baseline

Notes: Compared to the baseline in Figure 5, the trade elasticity is lower. Also, see the notes in Figure 5.

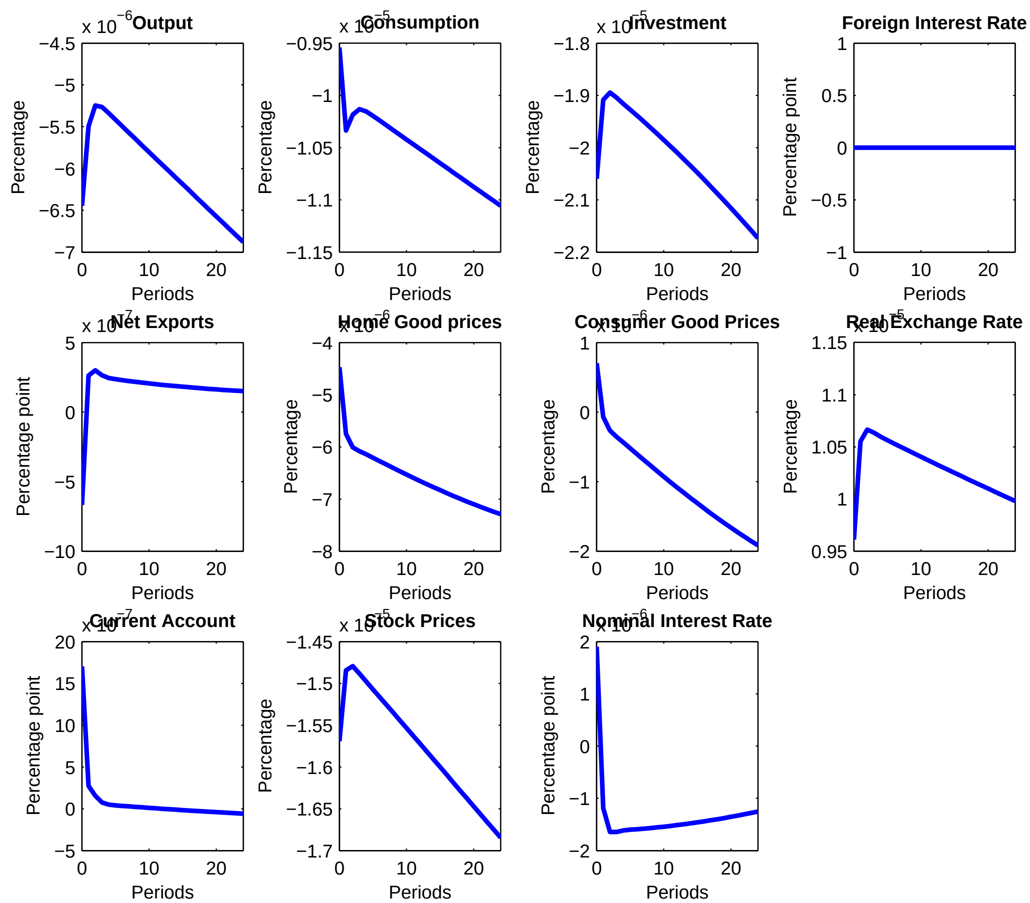

Figure C.14: Impulse responses of the small open economy model to a shock to foreign income

Notes: These are non-linear impulse responses to a shock to foreign income/demand. Also, see the notes in Figure 5.

C.3 US monetary policy spillovers

We present results on spillovers to a standard monetary policy shock.

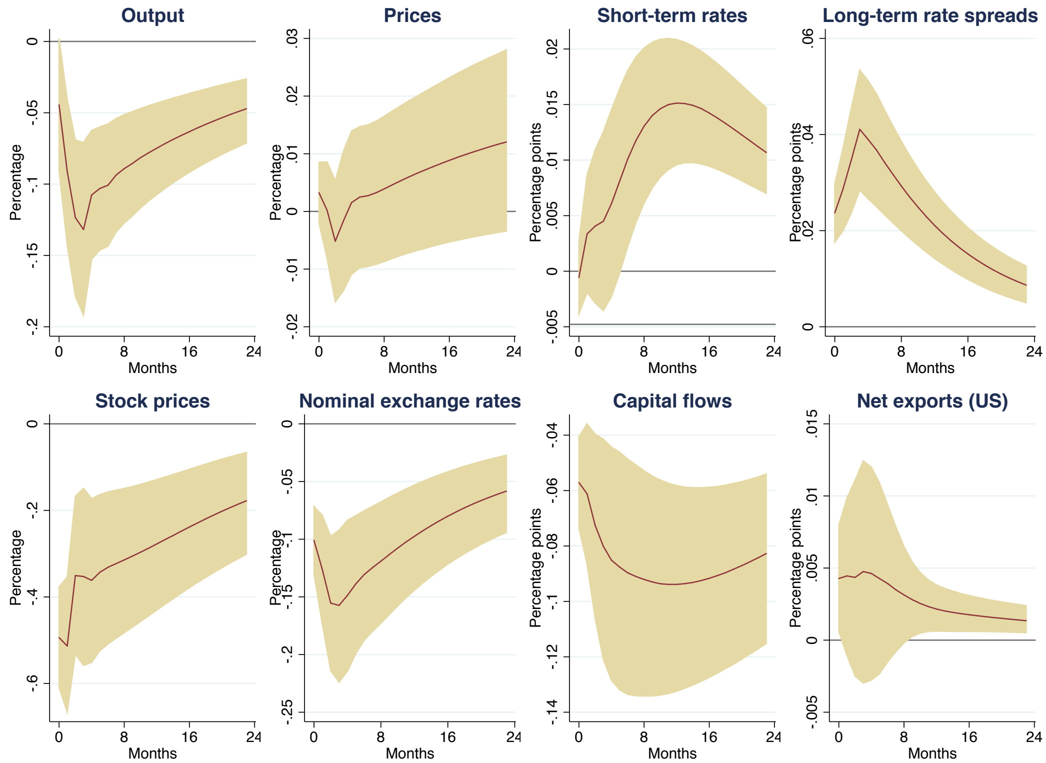

Figure C.15: Impulse responses of the EM panel VAR to the US monetary policy shock: macroeconomic and financial variables

Notes: Each plot presents the posterior median of the impulse responses to a one standard deviation (contractionary) US monetary policy shock along with the 68% error band in the baseline specification that includes the both macroeconomic and financial variables. A one standard deviation increase constitutes an increase of 0.262% points in the US short-term interest rate. Output is the industrial production and consumer prices are the CPI in each of the EM countries. Net exports are the ratio of the net exports from the EM countries to the US and GDP of the EM countries. The long-term rate spread is the spread between the 10-year Treasury yields in the US and the long-term interest rate in the EM countries. Both US and EM interest rates are nominal. The stock price is the MSCI. The nominal exchange rate is the nominal effective exchange rate of the local currency so a decrease in the exchange rate implies depreciation of the local currency. The capital flow is the ratio of the cumulative sum of the equity and bond inflows to GDP of the EM countries.

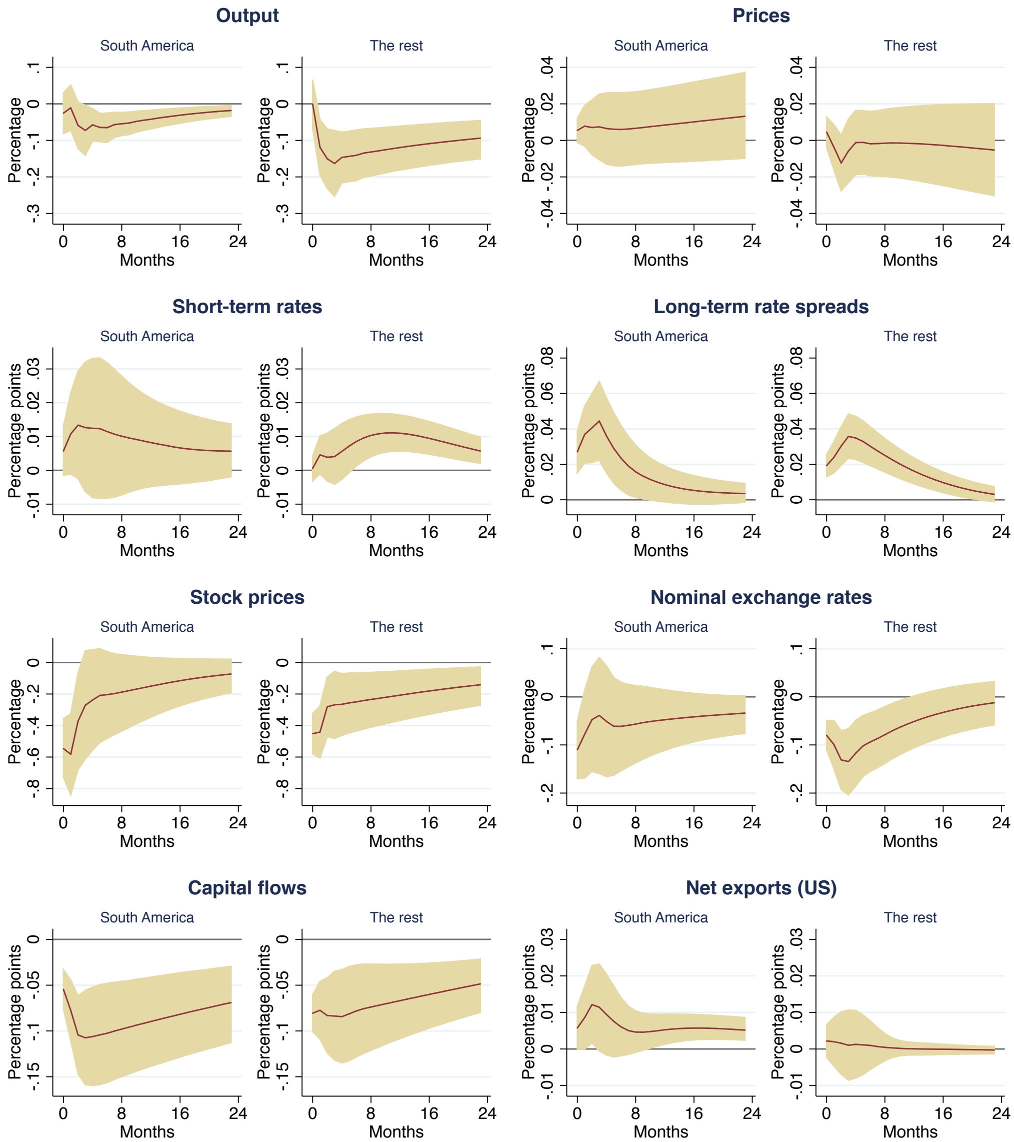

Figure C.16: Impulse responses of the EM panel VAR to the US monetary policy shock: macroeconomic and financial variables; South America vs.The rest

Notes: Each plot presents the posterior median of the impulse responses to a one standard deviation (contractionary) US monetary policy shock along with the 68% error bands in the specification for subgroup analysis that includes both the macroeconomic and financial variables. Subplots are arranged by variables and shown for two groups of countries: South America including Brazil, Chile, Colombia, Mexico, Malaysia, and Peru and the rest of the EM economies. See the notes in Figure C.15.

C.4 Capital control indices

We present results on capital control indices. Fernandez et al (2015) construct these indices based on the de jure information extracted from IMF's Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER). The indices are made available through the NBER. The construction of the indices involves using the narrative description in the AREAER to determine whether or not there are restrictions in international asset transactions (with 1 representing restriction and 0 not).

Table C.4: Capital control indices for the EMEs

Sub-group	Aggregate Flows	Inflows	Outflows
South America	0.46	0.46	0.46
Rest	0.66	0.60	0.72

Notes: The capital control indices are from Fernandez et al (2015), where a higher value represents a greater degree of capital control measures used by the countries. We report the averages across the sub-groups for three different indices, those pertaining to aggregate capital flows, only capital inflows, and only capital outflows. Median across the sub-groups show a similar pattern. The time-period of the data is from 2004-2013, over which we take averages for a country.

C.5 Textual analysis of central bank minutes

We first provide quote-based examples of some additional countries in the group of rest of EMEs where capital flows concerns led to tight monetary policy. For example, the Reserve Bank of India (RBI) decided to maintain their policy rate constant despite decline in output and inflation after the international monetary policy uncertainty and related capital outflows in May, 2013:

> On monetary policy measures, four of the seven Members recommended maintenance of status quo in the policy repo rate. In their view, though growth and inflation are projected to move down, we still have to guard against high inflation expectations that can destabilize the momentum of the economy. *Moreover, the external front is fragile and warrants that we do not do anything that can send wrong signals about our discounting the possibility of capital outflows* (Minutes of Monetary Policy Technical Advisory Committee Meetings, RBI, July 2013).

In a similar instance, the Reserve Bank of South Africa (RBS) raised its policy rate despite economic slowdown out of concerns for external financial market uncertainty:

> Since the previous meeting of the Monetary Policy Committee the global environment has been dominated by heightened uncertainty relating to the debt crisis in

> Greece and the sharp decline in equity prices in China. While the tail risks from these events appear to have dissipated somewhat, uncertainties still remain. *At the same time, the risks associated with financial market volatility related to the timing of the first increase in the US policy rate persist. Domestically, the growth outlook remains weak, as both the supply and demand sides remain constrained amid declining business and consumer confidence. The MPC has therefore decided ... the repurchase rate will increase by 25 basis points to 6 per cent per annum with effect from Friday 24 July 2015* (Monetary Policy Committee, RBS, July 2015).

We next take a further step towards a more rigorous analysis by analyzing the entire text of monetary policy meeting minutes of Brazil, South Africa, Turkey and Peru from 2006-2014. In particular, we measure capital flow concerns as the number of times monetary policy minutes contain words in the group {capital flow(s), capital outflow(s), international capital market, international market, portfolio flow(s), portfolio outflow(s),} and contrast this to the output stabilization concern measured as word count in the group {output, economic activity, employment, unemployment, growth, production}.

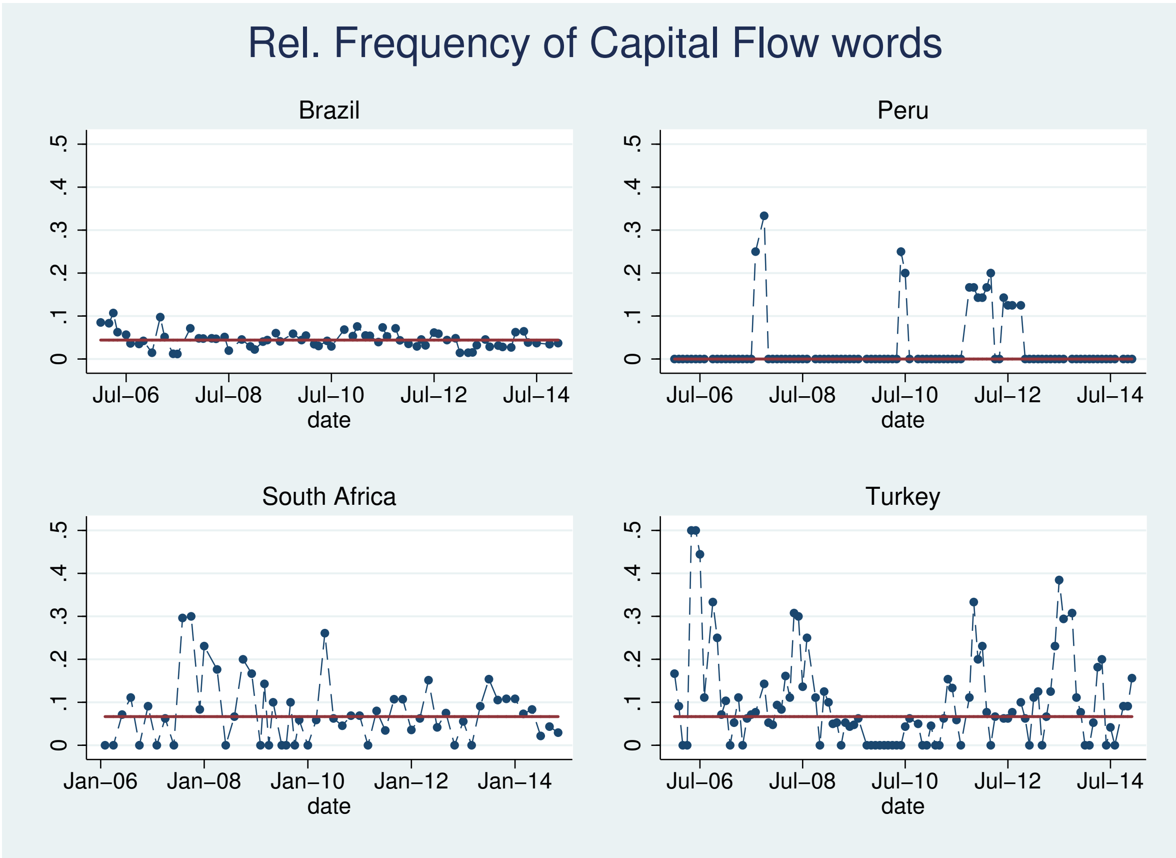

Figure C.17: Word counts reflecting concerns about output vs. capital flows in monetary policy minutes for Brazil, South Africa, Turkey and Peru

Notes: We use the policy minutes as given in the document "Monetary Policy Notes." for Peru, "Statement of the Monetary Policy Committee" for South Africa, "Summary of the Monetary Policy Committee Meetings." for Turkey and "Minutes of the Meeting of the Monetary Policy Committee" for Central Bank of Brazil. We count the number of times the monetary policy minutes contain words in two groups: {capital flow(s), capital outflow(s), international capital market, international market, portfolio flow(s), portfolio outflow(s),} and {output, economic activity, employment, unemployment, growth, production}. The dotted line in each panel represents the relative frequency of the capital flow words over time and the solid line represents the median relative frequency for that country over the entire sample period.