With Love from Abroad: Foreign Shocks and Sovereign Default *

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Abstract

Empirically, we document that roughly half of the medium-run volatility of output in emerging economies is accounted for by global disturbances shocks such as commodity shocks and U.S monetary policy shocks. These innovations are equal contributors to the fluctuations in output. After controlling for foreign shocks, exogenous fluctuations in terms of trade explain almost 20% of the medium-run volatility of output. Theoretically, we propose a rich sovereign default model to study the transmission of foreign shocks into default risk and fluctuations in the domestic economy. We then assess the welfare cost of foreign fluctuations in the economy.

Keywords— Sovereign risk, foreign shocks, developing economies, commodity goods

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1 Introduction

Several small open economies (SOE) experienced sovereign default in the recent past. Being actively engaged in international trade and international financial system, the SOE countries are exposed to different external shocks. These shocks most likely originate mostly from global demand, monetary policy in large open economies such as the USA, or from the commodity markets. Different types of external shocks have various implications for the business cycle and imply different optimal responses of the economic policy in these countries. However, the role of external shocks has been largely overlooked in the literature that studies the issue of sovereign default. In this paper, we provide an empirical approach that allows to identify different types of external shocks, and study their implications on a small open economy model with default.

In the empirical section, we analyze the effects of external shocks on business cycles in small open economies. We focus on decomposing the terms of trade dynamics into its exogenous variation and the component due to the global business cycle and monetary policy. We estimate vector autoregressive models for a broad sample of developed and developing economies, use country-specific commodity indexes, and impose the restriction that dynamics of the global business cycle are identical across the countries. This allows to estimate an otherwise highly dimensional VAR, and distinguish between the effects of global business cycle and country-specific terms of trade shocks. Our results suggest that the effects of exogenous terms of trade shocks can be overestimated in the literature, and a larger share of business cycle fluctuations can be originating from global shocks.

In the theoretical section, we propose a SOE model that allows for sovereign default and discipline it quantitatively. We leverage on the estimates of the joint dynamics of aggregate world business cycle and monetary policy, that we obtained in the empirical part, to introduce a realistic structure of external shocks. This allows us to separate the effects of local and foreign shocks on the decision of the country to default. Our preliminary results suggest that a country's decision to default is affected by the external monetary policy and global demand shocks. We compare the obtained implications for business cycles to a setup in which the only source of shocks is local.

1.1 Related Literature

This paper is related to two strains in the literature. First, this is the empirical literature that studies the international transmission of shocks. Second, this is the theoretical and empirical literature that studies the dynamics of small open economies in the context of sovereign default.

Within the large literature devoted to the international transmission of shocks it is important to highlight two specific topics. These are papers studying the effect that global factors, including the dynamics of large open economies, have on the small open economies, and those that focus on commodity or terms of trade shocks.

The established consensus in the literature suggests that there are common driving factors of the global economy, and Akıncı (2013) and more recently Miranda-Agrippino and Rey (2020) suggest that those can be attributed to the global financial factors. Boehm and Kroner (2020) studies the effects of the US monetary policy on this cycle. Ben Zeev (2019) studies the differentiated response of countries with different exchange rate regimes to the financial shocks, and Morelli et al. (2022) provide additional evidence of the role of financial intermediaries in the international transmission of shocks and stress their role as cause of sovereign default. Rey (2016) focuses on the transmission of the US monetary policy instead, and concludes that it challenged the monetary autonomy of countries with flexible exchange rate regimes.

Apart from the global conditions, small open economies are naturally affected by shock in terms of trade, frequently originating from commodity markets. In the early paper Mendoza (1995) establishes that the share of GDP variation explained by terms of trade shocks is in the range $45 - 60\%$ using a small open economy model.

The results of Fernández et al. (2022) suggest that the shocks that are driving commodity supercycle are not the same as the ones explaining economic activity in small open economies. Previously, Schmitt-Grohé and Uribe (2018) discovered that terms of trade shocks explain just a small fraction of fluctuations in economic activity (less than 10%). At the same time Ben Zeev et al. (2017) demonstrates that news commodity terms of trade shock explain more than 50% of variation in output in emerging economies. Fernández et al. (2017) highlights the importance of using different world prices in order to capture terms of trade shocks.

The effect of foreign shocks on the dynamics of was also studied in small open economies framework. The aforementioned Mendoza (1995) and Kose (2002) both find that the fluctuations in world prices explain significant part of business cycle fluctuations. Justiniano and Preston (2010) point to the challenges of modeling the effects of external shocks on local economies. Few papers also consider the effects of foreign shocks on economies that can default. Lizarazo (2013) and Arellano (2008) introduce risk averse foreign investor that can generate sovereign default, and Almeida et al. (2019) models explicitly interest rate shocks.

Hence, our paper leverages the insights of the literature on global shocks, and brings them to the study of models with sovereign default.

2 Evidence

In the part of the paper, we study empirically the effects of external shocks on small open economies. Our main goal is to separate the effects of global shocks associated with business cycle and monetary conditions, and the exogenous shocks to commodity prices.

2.1 The VAR model

To characterize a small open economy, we use a two-block Vector Autoregressive (VAR) model. Let y^f be a column vector of n^f foreign variables that summarize the global economy, $\tau - i$ be the i-country specific commodity terms of trade, and $y^{d,i}$ a column vector of n^d domestic variables for the i-small open economy. Then, country VAR system could be written as:

$$\begin{bmatrix} y_t^f \\ \tau_t^i \\ y_t^{d,i} \end{bmatrix} = A_i\left(\mathbb{L}\right) \begin{bmatrix} y_{t-1}^f \\ \tau_{t-1}^i \\ y_{t-1}^{d,i} \end{bmatrix} + \begin{bmatrix} e_t^f \\ e_t^\tau \\ e_t^d \end{bmatrix} \tag{1}$$

where $\mathbb{L}$ the lag operator such that $\mathbb{L}x_t = x_{t-1}$, and $A(\mathbb{L})$ the matrices of reduced-form coefficients. Importantly, given the assumption of small open economies we restrict the sub-matrices related to the impact of domestic variables to the global ones and terms of trade to be 0_n.

$$A_i(l) = \begin{bmatrix} A_{ff}^{(l)} & 0 & 0 \\ A_{\tau f,i}^{(l)} & A_{\tau\tau,i}^{(l)} & 0 \\ A_{df,i}^{(l)} & A_{d\tau,i}^{(l)} & A_{dd,i}^{(l)} \end{bmatrix} \tag{2}$$

Data

We use the data for emerging and advanced economies that are commodity exporters. Our sample includes Argentina, Australia, Brazil, Canada, Chile, Colombia, Denmark, Mexico, New Zealand, Norway, Peru, Russia, and South Africa. The variables used in the analysis can be divided into three groups by their relation to the economy, and the respective restrictions in the VAR model. **The foreign block (y^f):** The included variables in this block are: 1) gdp^f: The logarithm of the quarterly index of real activity for the G7 economies, published by the OECD. 2) i^f: An indicator of monetary conditions proxied with the quarter average of the monthly effective fed funds rate. Source: FRED. **Terms of trade (τ):** The logarithm of the quarterly country-specific commodity terms of trade published by the IMF. They calculated it with a basket of 45 individual commodities prices deflated by the IMF's index for manufactured exports. **Domestic variables** (y^d)**:** The set of endogenous domestic variables considered is: 1) $reer_{it}$: The effective real exchange rate (in logs) reported by the BIS and measured as foreign-to-local currency ratio (positive movements are appreciations). Source: BIS. 2) i_{it}: The nominal policy rate reported by the BIS that were collected in cooperation with national central banks. 3) The net export-to-GDP ratio (nx_{it}), and the logartihms of real investment (I_{it}), real consumption(c_{it}), and real GDP (y_{it}) were obtained from the national accounts reported by the IMF. In the case that the country did not register their seasonally adjusted version, we use X-12 ARIMA to make the adjustment. In the cases of Colombia, Peru, and South Africa we use open-data from their central banks or national statistic institute.

We use maximum available time range for domestic and global economies, thus the range for which we obtain estimates of the global sector is different comparing to the domestic one. This approach is justified by the assumption of small open economy and the additional assumption that there is no structural break in the non-intersecting periods of time.

Identification and estimation

The models are estimated in levels, with two lags and are specific for each country. To take advantage of the larger sample size in the global block we follow a sequential approach, estimating in the first step the following regression:

$$y_t^f = \alpha^f + A_{ff}^{(1)} y_{t-1}^f + A_{ff}^{(2)} y_{t-2}^f + A_{ff}^{(3)} y_{t-3}^f + A_{ff}^{(3)} y_{t-3}^f + e_t^f \tag{3}$$

with $e_t^f = C_{11}\epsilon_t^f$, where $\epsilon_t^f$are orthogonal innovations and C_{11} is an identification matrix. Given that the first block is only formed by two variables, and the assumption of not contemporaneous impact of monetary policy on real economic activity is sensible, we choose to identify C_{11} by Cholesky factorization.

On the second step we estimate the country specific endogenous block:

$$\begin{bmatrix} \tau_t^i \\ y_t^{d,i} \end{bmatrix} = \alpha^d + \sum_{j=1}^{4} \tilde{A}_i^{(j)} \begin{bmatrix} y_{t-1}^f \\ \tau_{t-1}^i \\ y_{t-1}^{d,i} \end{bmatrix} + \begin{bmatrix} C_{\tau\tau,i} \\ C_{d\tau,i} \end{bmatrix} \hat{\epsilon}_t^f + \begin{bmatrix} e_t^\tau \\ e_t^d \end{bmatrix}, \text{ where } \tilde{A}_i^{(j)} = \begin{bmatrix} A_{\tau f,i}^{(j)} & A_{\tau\tau,i}^{(j)} & 0 \\ A_{df,i}^{(j)} & A_{d\tau,i}^{(j)} & A_{dd,i}^{(j)} \end{bmatrix} \tag{4}$$

, $j = \{1, 2, 3, 4\}$ and $\hat{\epsilon}_t^f$ are the foreign shocks identified in the previous step.

Based on the assumption that terms of trade are not explained by domestic variables, Cholesky decomposition is enough to isolate the terms of trade shocks. It implies $\begin{bmatrix} e_t^\tau \\ e_t^d \end{bmatrix} = \begin{bmatrix} \sigma_\tau & 0 \\ C_{32} & C_{33} \end{bmatrix} \begin{bmatrix} \epsilon_t^\tau \\ \epsilon_t^d \end{bmatrix}$. Note that from this block only ε_t^τ has been identified and that $E[\epsilon\epsilon'] = I$.

Aside from that, in the block corresponding to the economy itself, we identify a set of domestic shocks orthogonal to external conditions. In order to do that, we adopt the approach Uhlig (2003) by finding the shock that explains the maximum of the forecast error variance (FEV) of a particular variable over the time span $[\underline{t} : \bar{t}]$. Then, the maximization problem is:

$$\gamma^* = \text{argmax} \left(\sum_{s=\underline{t}}^{\bar{t}} \sum_{h=0}^{s} R_h \gamma \gamma' R_h{}' \right)_{kxk} \tag{5}$$
$$\text{s.t.} \qquad \gamma' \gamma = 1$$
$$\gamma(j) = 0 \;\; \forall \;\; j \in \text{foreign block}$$

where k is the position of the variable whose FEV we can maximize, R_h is the response matrix at horizon h, and γ^* is an identification vector that allow us to map a ε_k shock into the space of ϵ, where ε_k is such that it explain the highest fraction of FEV of the variable k. The first restriction ensures a unique identification while the second one implies that only the information from the domestic variables is used to extract the shock and that γ has no explanatory power for foreign variables.

The solution for this system consists on finding the eigenvector related to the maximum eigenvalue of a sub-matrix from $\sum_{i=0}^{h} \left((\bar{t} + 1 - max(\underline{t}, i)) R_i^{'(k)} R_i^{(k)} \right)$obtained after deleting the rows and columns associated with the variables y^f and τ, where $R_i^{(k)}$ is the k-row of the response matrix at horizon i. In particular, since $E[\epsilon\epsilon'] = I$, we can use the impulse-response function that comes from our initial Cholesky identification approach to pin down these innovations. We identify the shocks with maximum explanation power on the fluctuations of : (i) domestic output - γ_y , (ii) domestic consumption - γ_c, and (iii) domestic investment -γ_I. Each of the shocks is identified separately from the others, which implies that they are not necessarily orthogonal.

To obtain the confidence set for the impulse response, we use a bootstrap blocks-by-blocks approach which consists in:

1. Let Y_j and X_j represent $T_j \times m$ endogenous variables and $T_j \times k$ regressors (including constants), where $j \in \{foreign, domestic\}$.
2. Define two scalars n_m and l. The former is the number of blocks that will compose our new sample,

while the latter is the number of consecutive observations that we include in each block. In this application we set n_m^j such that we obtain a sample size close to $2T_j$

3. Since we have different sample size between the foreign and the domestic block we split the generation of the new sample in two stages. For the common sample size, which describes the SOE), we define a column vector v_d of size n_m^d by drawing with replacement from 1 to $T_d - l + 1$, then the rows that compose the new sample of Y_d and X_d are $\nu_d = v_d \otimes [1 : l]^T$. For the estimation of A_{11}, and A_{12} we also define an additional column vector v_f of size $(n_m^f - n_m^d)$ by drawing with replacement from the interval $[1 : T_f - l + 1]$, computing $\nu_f = \begin{bmatrix} v_f \\ v_d \end{bmatrix} \otimes \begin{bmatrix} 1 \\ \vdots \\ l \end{bmatrix}$ as the vector of selected rows in the foreign block. With that, we get $\{Y_f^{(i)}, X_f^{(i)}, Y_d^{(i)}, X_d^{(i)}\}$
4. Given the new datasample we follow the sequential estimation to get matrices $A^{(s)}$. If the estimated model is stable keep it, otherwise discard this replication
5. If the replication was kept, estimate the identification vectors and compute IRFs and FEVDs.
6. Repeat 3-5 times until we obtain N stable VARs
7. Compute medians and percentiles of the IRFs and FEVs.

2.2 Preliminary Results

Figure 1 reports some of the preliminary results. We plot IRFs for the shocks that explain most of FEV of global output and of the Fed funds rate fluctuations. The response variable is terms of trade.

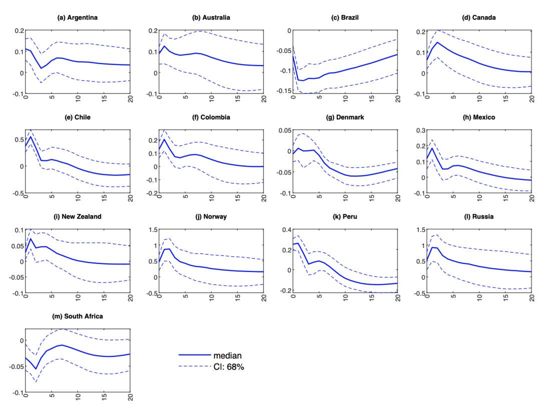
For most of the countries the shocks produce a significant response on terms of trade. Our results stress that terms of trade are an endogenous variable, while the actual origin of the shocks can lie in global output and monetary policy.

More specifically, for the majority of countries in our sample, a positive global output shock leads to a persistent appreciation of the terms of trade (The exceptions are Brazil, Denmark, and South Africa). The impact of a contractionary monetary shock in the US is heterogeneous. For countries such as Argentina, Australia, Brazil, New Zealand, and South Africa, the innovation leads to a short-lived depreciation of the terms of trade. For the remaining countries, terms of trade appreciate following the shock.

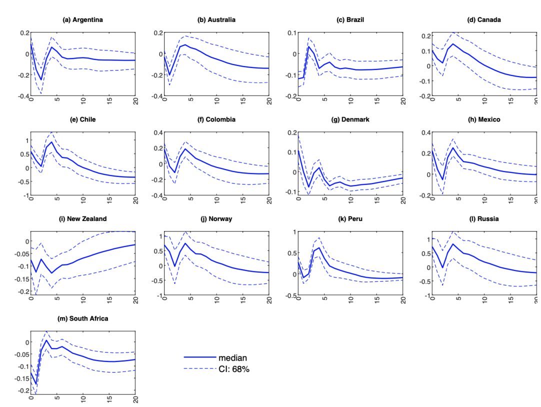
Our FEV analysis suggests that on impact global shocks explain up to 18% of Peru's ToT forecast error variance. In contrast, their effect on Denmark's ToT is negligible. We can see that as time goes by, the global shock becomes more relevant to explain the dynamics of ToT. For example, the global shock explains almost 40% of Brazil's ToT at 3- and 5-year horizons. For most countries, the global shock explains at least 9% of the terms of trade variability in the medium and long run.

Figure 1: Response of terms of trade to Foreign Shocks

(a) Shock explaining maximum FEV of Global Output



(b) Shock explaining maximum FEV of Fed funds rate



We also found that an exogenous appreciation of the terms of trade leads to a highly persistent expansion of domestic output with its maximal impact happening about 10 quarters after the shock. Our results call for rethinking of the approach to modelling small open economies – global shocks explain a significant share of macroeconomic variables' and terms of trade fluctuations, while the regular approach in the literature is to assume the presence of local country-specific shocks as the main drivers of business cycle and default. We provide the detailed results in Appendices A.1 and A.2.

Further, we plan to work on exploiting the cross-sectional dimension of the obtained results. We are planning to determine the factors that produce the cross-sectional differences in responses to the global shocks. Importantly, we would focus on the data related to the characteristics of countries' borrowing – both in extensions of the VAR analysis, and in the analysis of cross-sectional differences across countries.

3 Model

In this part of the paper we introduce a model of small open economy that focuses on the effects of global monetary and business cycle shocks on the local economy when the economy can default. For this purpose we employ a parsimonious two-good production economy that is affected by foreign monetary policy (risk-free rate) and global demand (demand for country's traded good) shocks. We use the estimates for external conditions' processes obtained above, and the rest of the parameters of the economy are matched to Argentina, which is standard for this literature (e.g. Arellano (2008)).

3.1 The environment

In small open economy there's a representative household that maximizes discounted expected utility, where the felicity function is standard:

$$\frac{C_t^{1-\gamma}}{1-\gamma} - \frac{\ell_t^{1+\omega}}{1+\omega}$$

where C is the consumption basket, ℓ_t is labor. There are two goods in the economy. One good is produced domestically, and we denote consumption of this good by domestic households $C_{H,t}$. The second good is produced abroad, and domestic household's consumption of this good is $C_{F,t}$. We assume Armington aggregation between the two:

$$C = \left(a_H C_H^{\frac{1}{\rho}} + (1 - a_H) C_F^{\frac{1}{\rho}} \right)^{\rho}$$

Domestic goods are produced with labor inputs of the domestic household, and there's demand from abroad for these goods that we denote $C_{H,t}^*$ and assume to be proportional to global output Y^*. Thus, demand and supply for domestically produced goods imply

$$A\ell_t^{\alpha} K_t^{1-\alpha} = C_{H,t} + C_{H,t}^*. \tag{6}$$

, where A is productivity. Capital is introduced as in Neumeyer and Perri (2005). The small open economy can borrow on the international financial market and declare an outright default, where the decision to default is denoted with indicator $d_t \in \{0, 1\}$. We introduce long-duration bonds following Hatchondo and Martinez (2009):

$$B_{t+1} = B_t(1-\delta)(1-d_t) - i_t \tag{7}$$

where B denotes the value of outstanding coupon claims, i_t is current-period issuance level, and δ is a parameter that is calibrated based on Macaulay duration $D = \frac{1+r^*}{\delta+r^*}$, and r^* is the constant per-period yield of the bond. Equilibrium in the international market in terms of units of foreign goods implies

$$C_{F,t} + I_t + q_t \left(B_{t+1} - (1-\delta)B_t\right) = p_{H,t} C_{H,t}^* + B_t \tag{8}$$

where $p_{H,t}$ is relative price of domestically produced goods, and the investment is given by

$$I_t = K_{t+1} - (1 - \delta_K)K_t + \Phi(K_{t+1}, K_t) \tag{9}$$

and the price is given recursively:

$$q_t = \frac{1}{1+r_t} p_t(d_{t+1} = 1) + \frac{1-\delta}{1+r_t} \mathbb{E}_t \left[q_{t+1} | d_{t+1} = 1 \right] \tag{10}$$

, where $p_t(d_{t+1} = 1)$ denote probability of the country's default in period $t + 1$ conditional on period t's information set. In case if the country defaults, it loses access to the international financial market and re-enters it in each period of time with exogenous probability θ, as in Arellano (2008). The economy also experiences a loss in case of default, and it is assumed to affect TFP A through the loss function in quadratic form as in Chatterjee and Eyigungor (2012).

Importantly, we incorporate the VAR estimates of the external sector dynamics to quantitatively discipline the shock structure in this economy[1]:

$$\{r_t, p_H, C^*_{H,t}\} \sim VAR \tag{11}$$

3.2 Solution and numerical implementation

The solution of the model is implemented using a combination of value and policy function algorithms, similarly to Arellano (2008). As in Hatchondo and Martinez (2009), we begin with solving a finite horizon problem, and then transitioning to the infinite-horizon economy.

The intertemporal problem of the household does not have a closed-form solution, and thus the sketch of the quantitative algorithm of solution is as follows:

1. Solve for optimal $\{C, C_F, C_H, \ell\}$, given the set of state variables $\{Y^*, r, B, A, d\}$, as well as the future choices of B' and d', in order to evaluate the value function and budget constraint, where x' denotes variable x in the subsequent period of time.

2. Calculate the value of $W = u(C^*, \ell^*) + \beta \mathbb{E} V(Y^{*'}, r', B', A', d)$, where $\mathbb{E}$ denotes mathematical expectation conditional on period t information.

3. Find optimal B' and d, and $V(Y^*, r', B', A', d') = \max_{B',d'} u(C^*, \ell^*) + \beta \mathbb{E} V(Y^*, r', B', A', d')$.

4. Update price function

[1] Detailed description is provided in Appendix .1

The solution and calibration of the model are implemented using CUDA graphical processor language due to the high dimensionality of the problem.

Our preliminary results suggest that the country defaults due to an exogenous increase in the cost of borrowing – a positive shock in interest rate r, as well as due to the contraction of demand for its domestically-produced good and the TFP shocks.

The project aims to expand work in this direction in several aspects. First, it is important to understand the difference in optimal policy – default and borrowing – response to terms of trade and global shocks. Second, we will explore whether implications of models with sovereign default calibrated based on local economic dynamics are consistent with the joint dynamics of the small open economy and the global factors. Third, we would explore quantitatively how matching moments related to the global factors changes the main implications of models with sovereign default, and whether it is possible to match both moments corresponding to local dynamics, and to global factors.

4 Conclusion

In this paper we have demonstrated that the external macroeconomic shocks that are usually associated with unpredictable commodity, in fact largely reflect demand and supply shocks of the United States. Further, we've studied the implications of this insight for modelling the business cycle in small open economies.

Our preliminary results suggest that the defaults originate primarily from the fluctuations of monetary policy and the US business cycle, rather than orthogonal commodity price shocks. This is consistent with existing evidence on the effects of global factors on different macroeconomic variables in small open economies, and has implications both from the economic policy standpoint and from the perspective of investments in developing economies.

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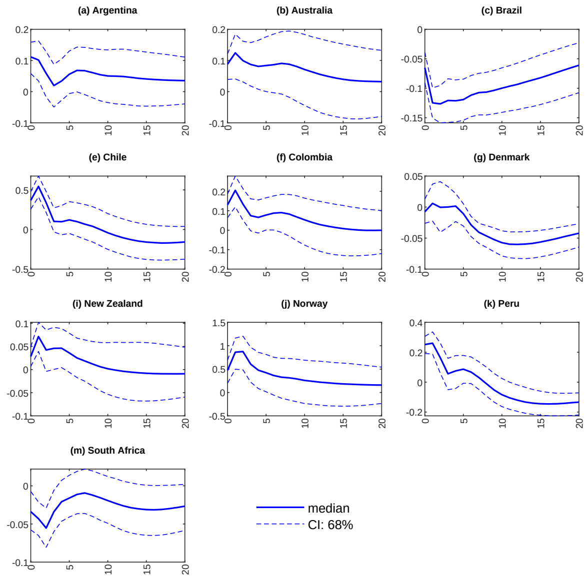
A Appendix

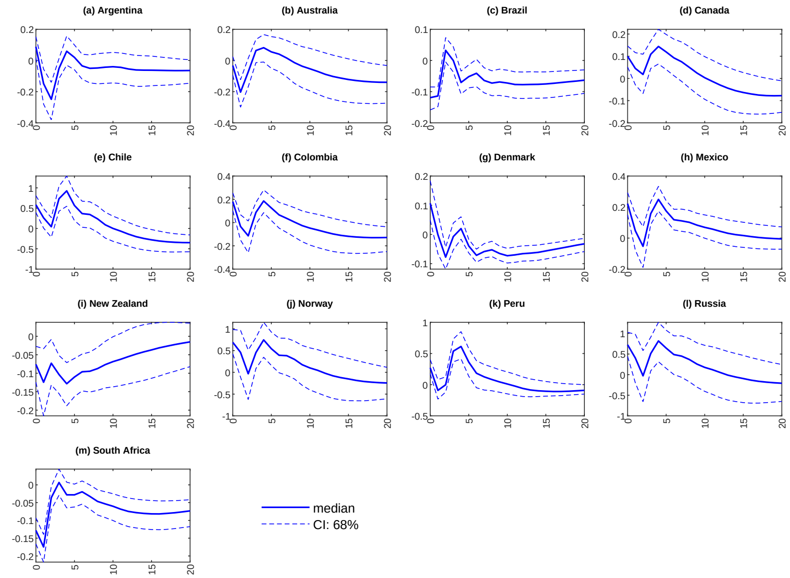
A.1 Response to Foreign Shocks

Figure 2: Response of tot to Foreign Shocks

(a) Global Output



(b) Fed Fund rates



(c) Terms of Trade

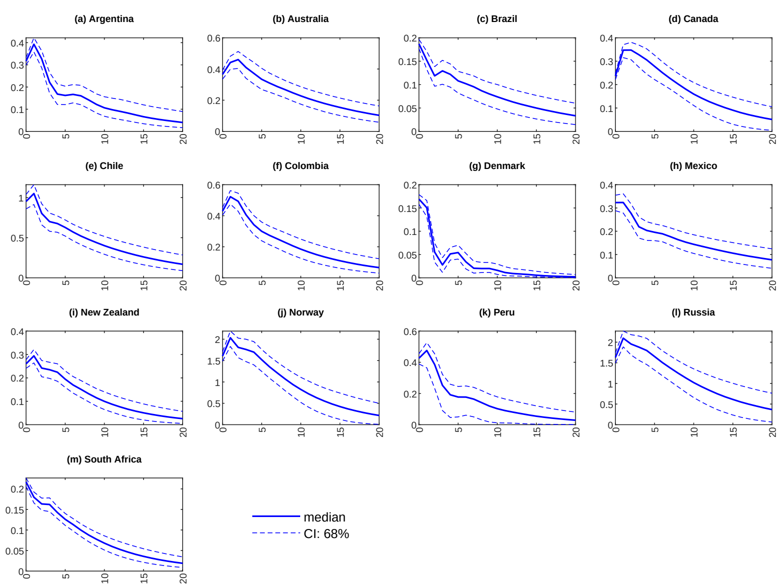
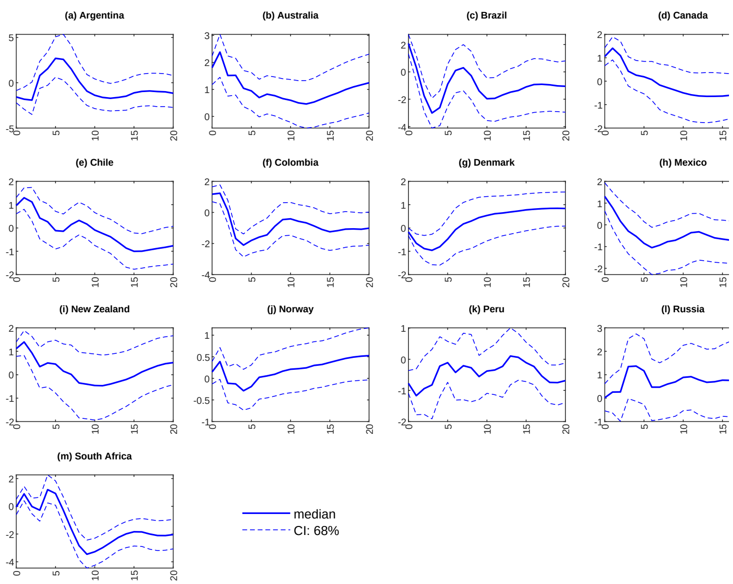
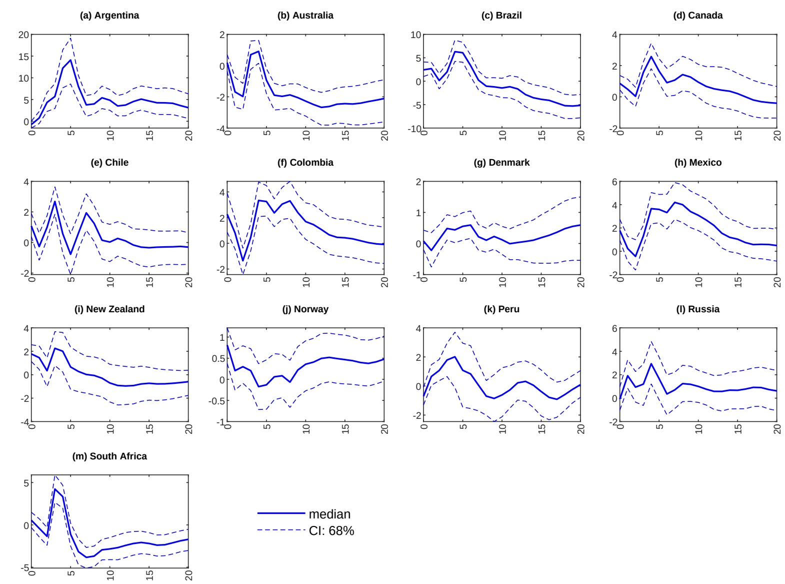


Figure 3: Response of reer to Foreign Shocks

(a) Global Output



(b) Fed Fund rates



(c) Terms of Trade

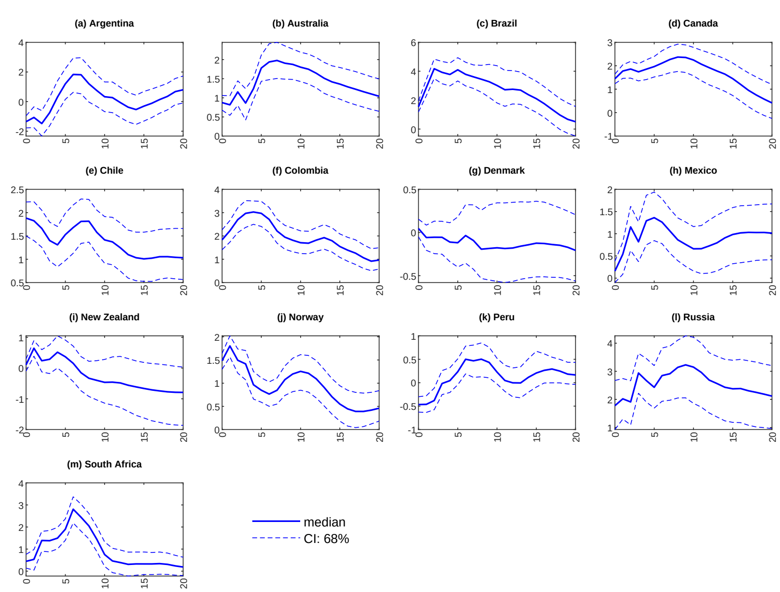
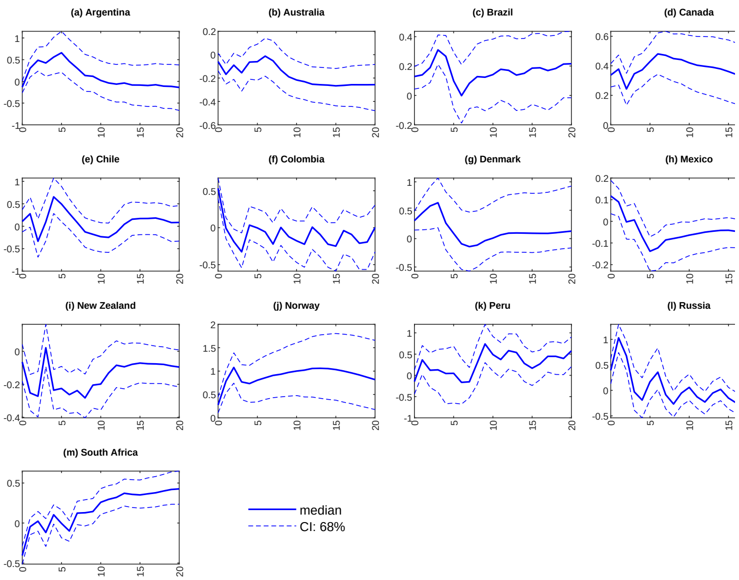
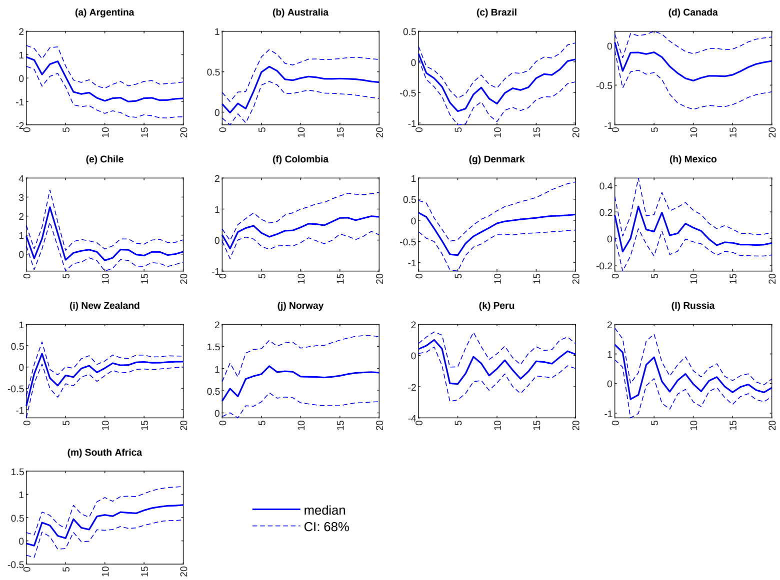


Figure 4: Response of nx to Foreign Shocks

(a) Global Output



(b) Fed Fund rates



(c) Terms of Trade

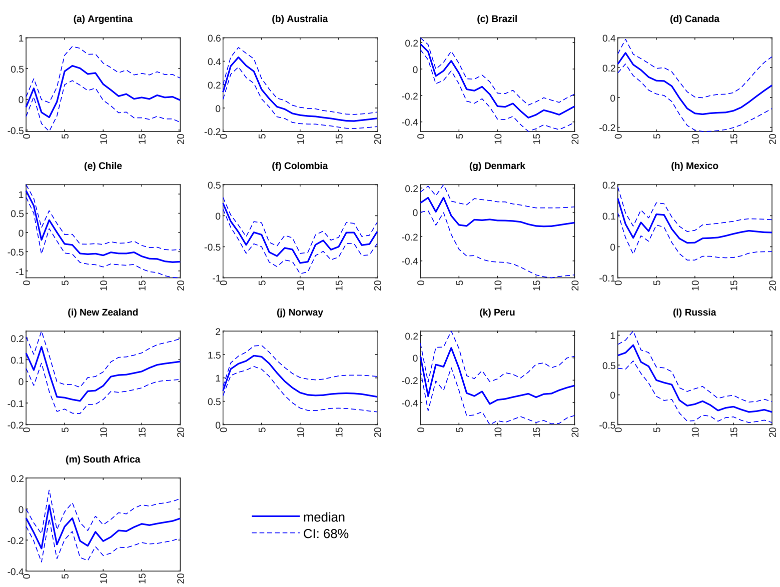
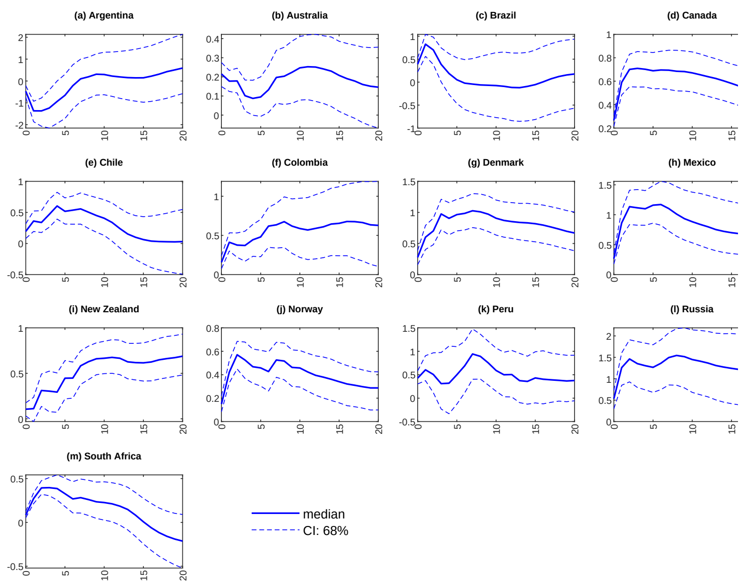
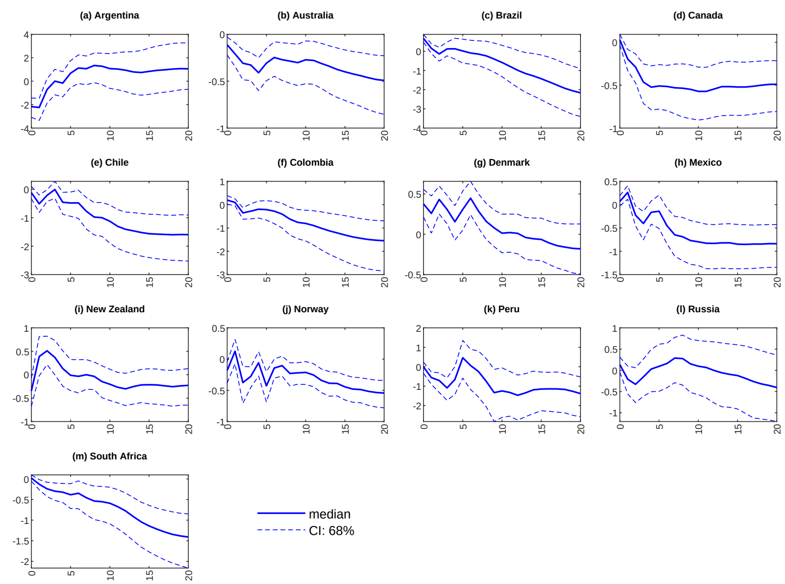


Figure 5: Response of yd to Foreign Shocks

(a) Global Output



(b) Fed Fund rates



(c) Terms of Trade

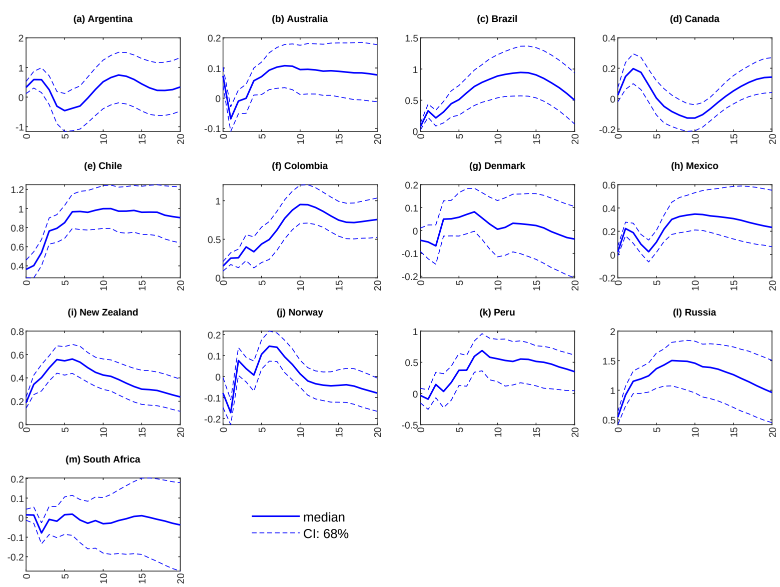


Figure 6: Response of cons to Foreign Shocks

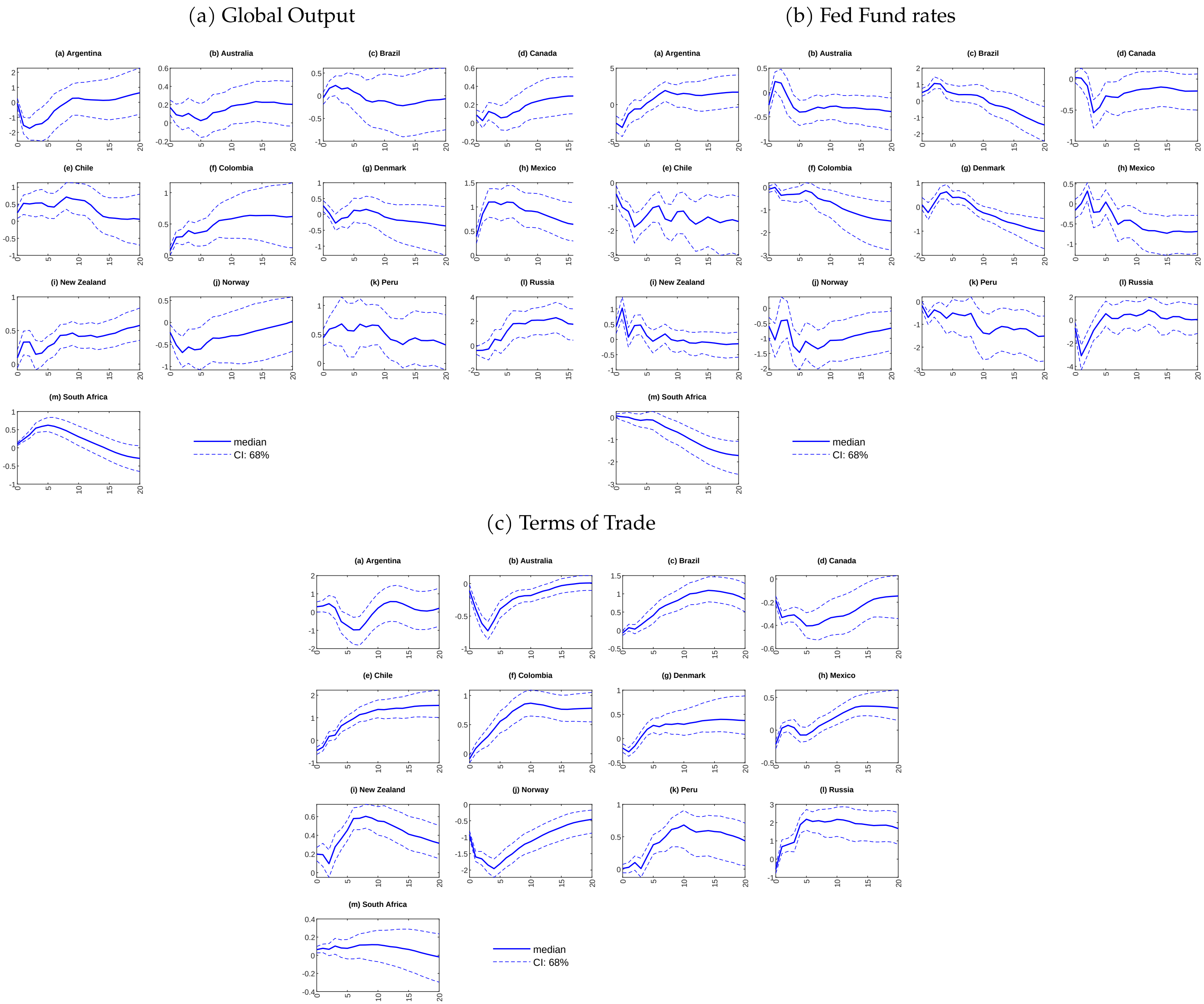
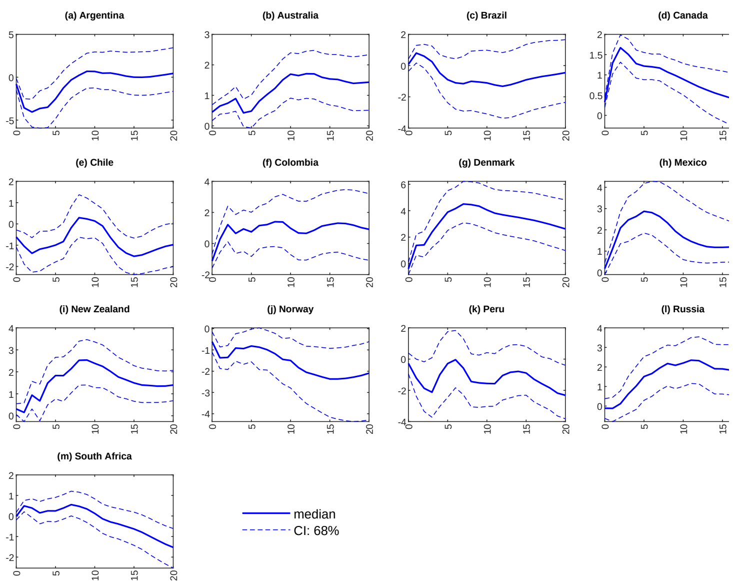
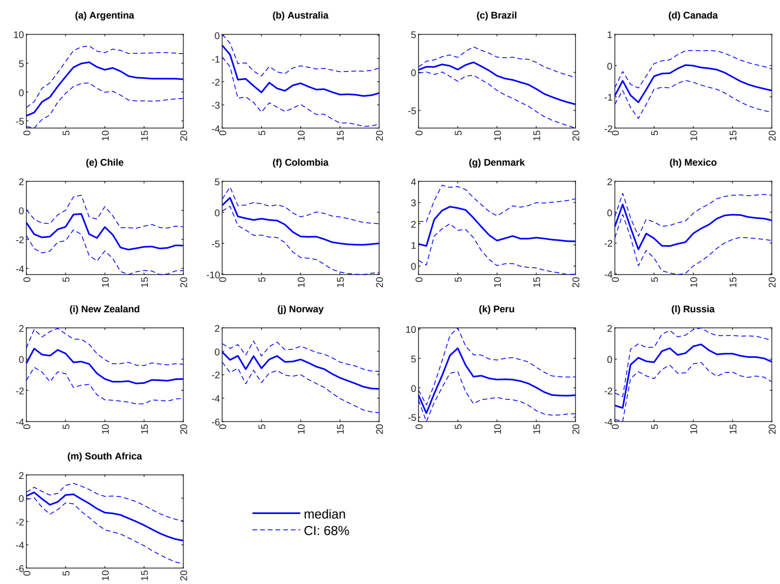


Figure 7: Response of inv to Foreign Shocks

(a) Global Output



(b) Fed Fund rates



(c) Terms of Trade

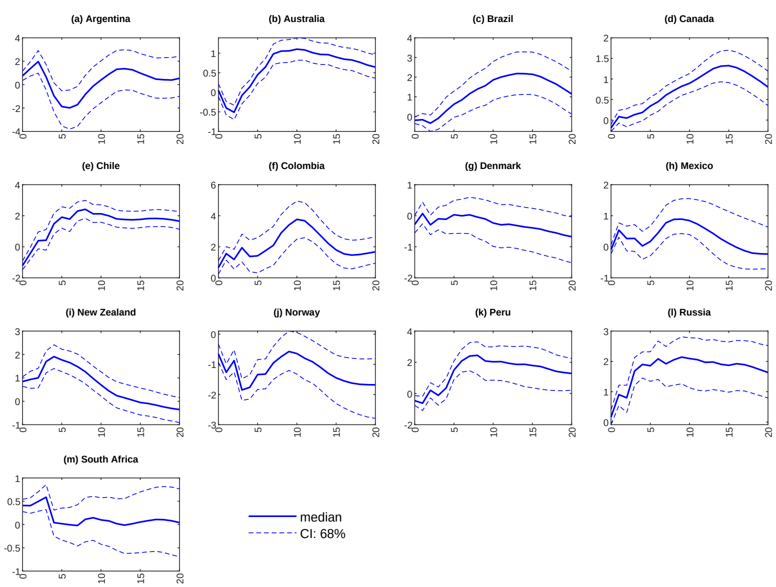
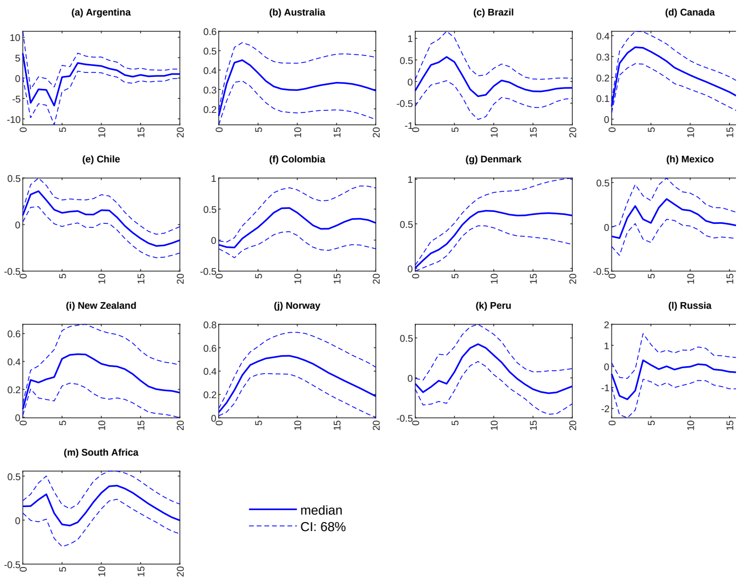
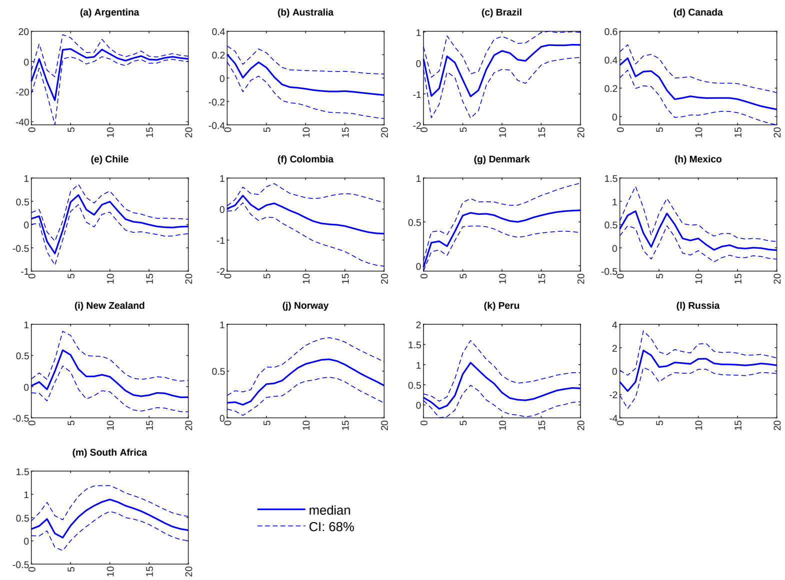


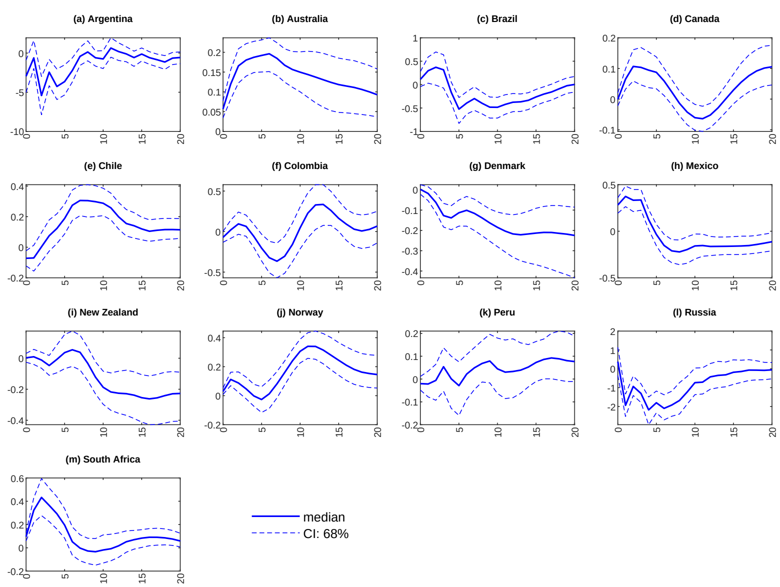
Figure 8: Response of id to Foreign Shocks



(a) Global Output



(b) Fed Fund rates

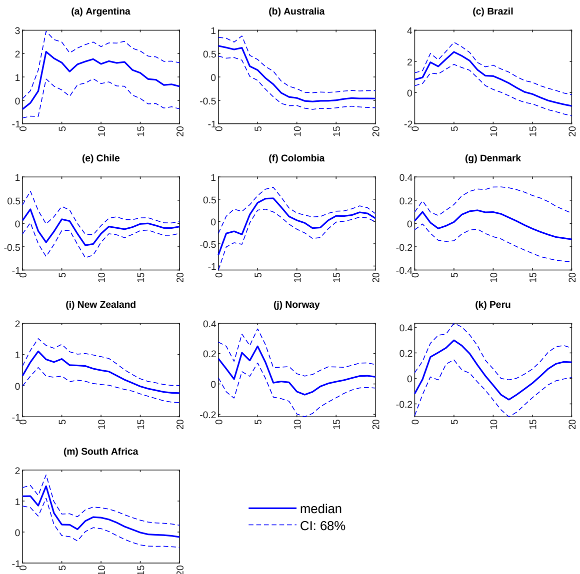


(c) Terms of Trade

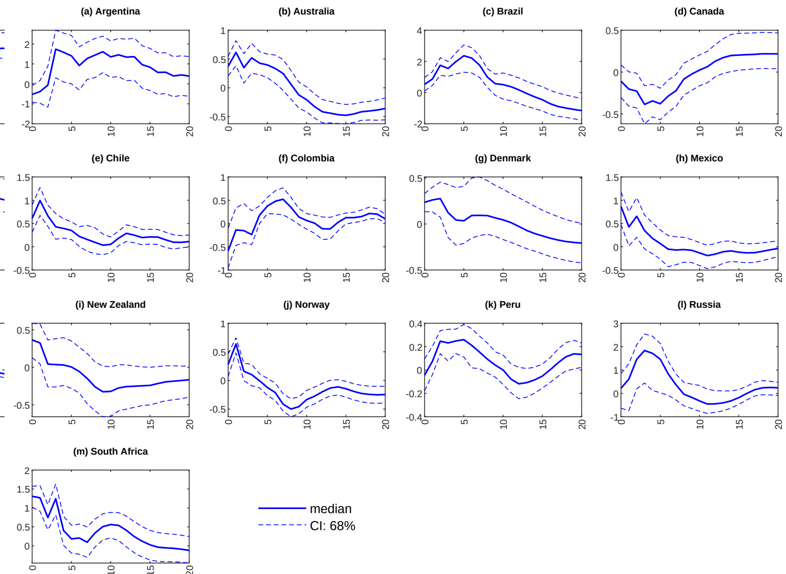
A.2 Response to Domestic Shocks

Figure 9: Response of reer to Domestic Shocks

(a) Max-Fev of Domestic Output



(b) Max-Fev of Consumption



(c) Max-Fev of Investment

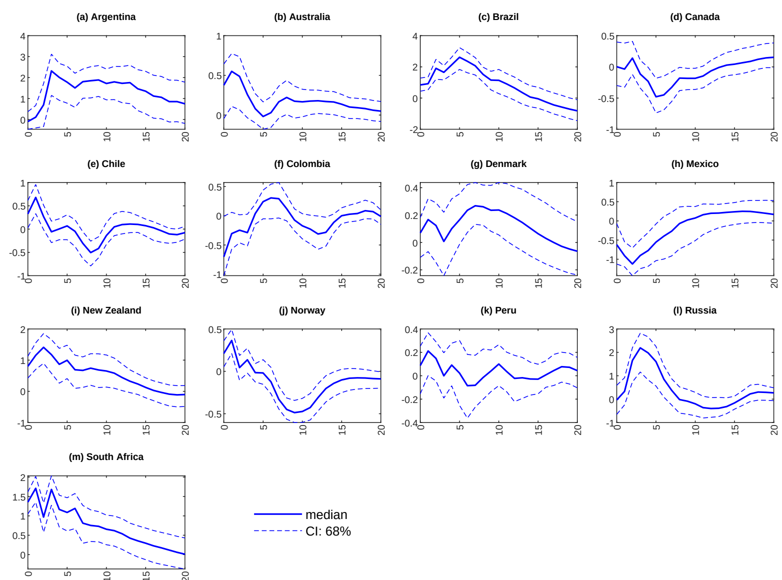
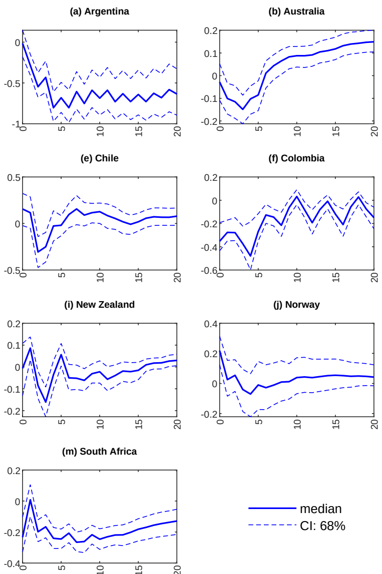
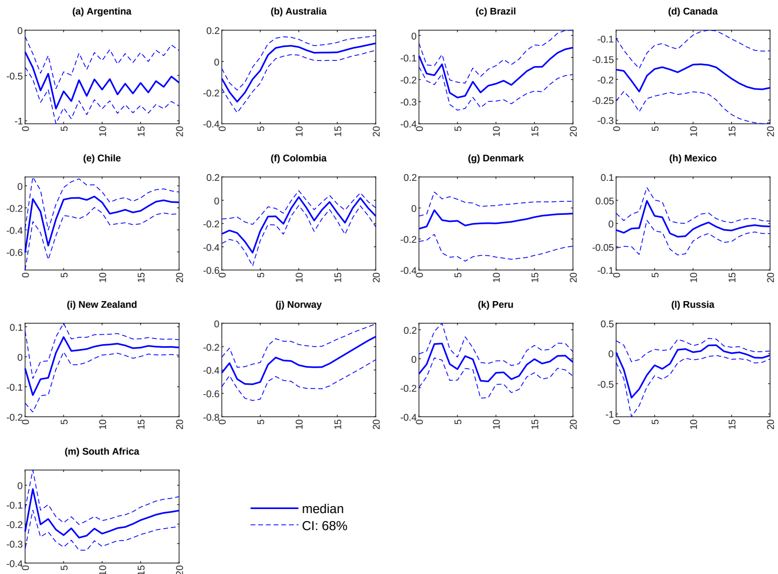


Figure 10: Response of nx to Domestic Shocks

(a) Max-Fev of Domestic Output



(b) Max-Fev of Consumption



(c) Max-Fev of Investment

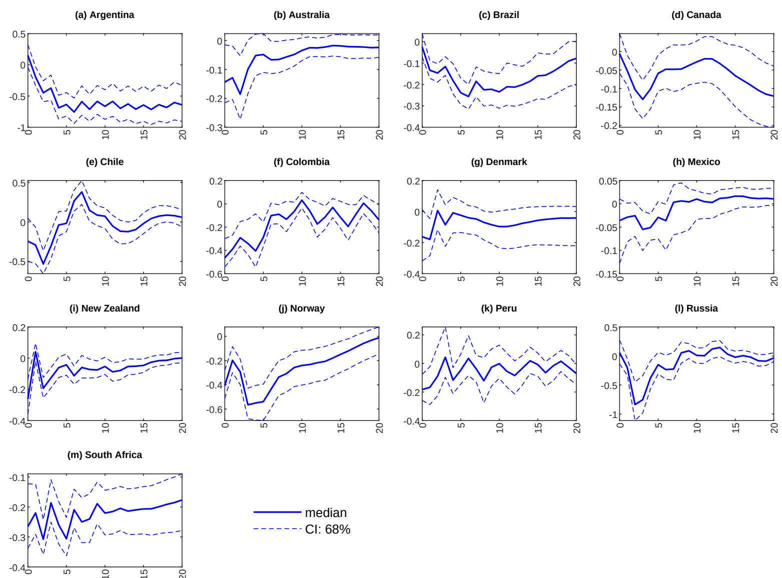
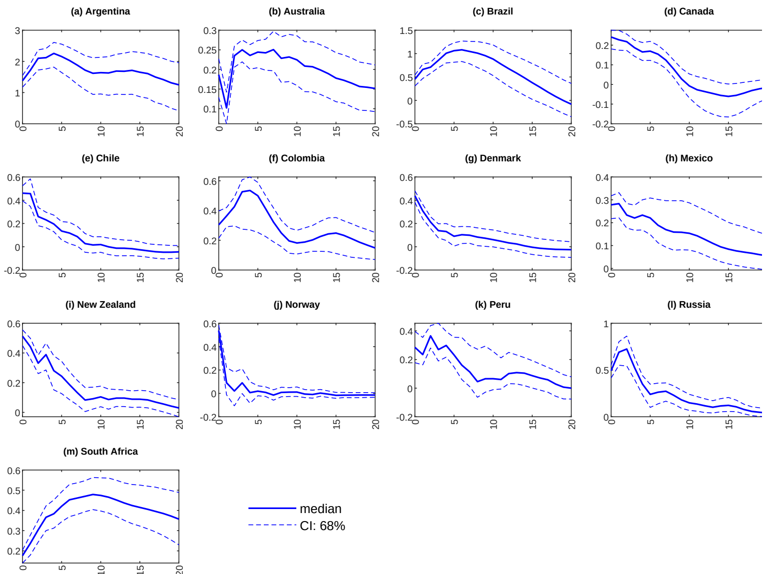
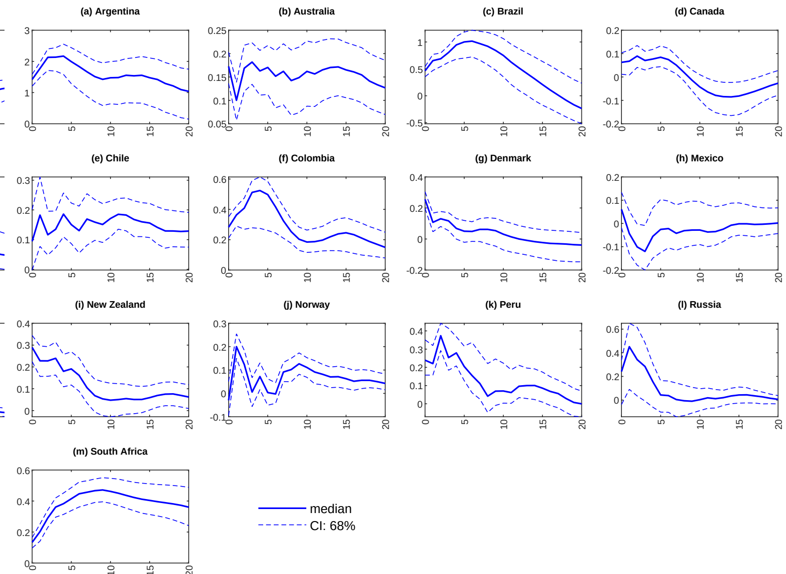


Figure 11: Response of yd to Domestic Shocks

(a) Max-Fev of Domestic Output



(b) Max-Fev of Consumption



(c) Max-Fev of Investment

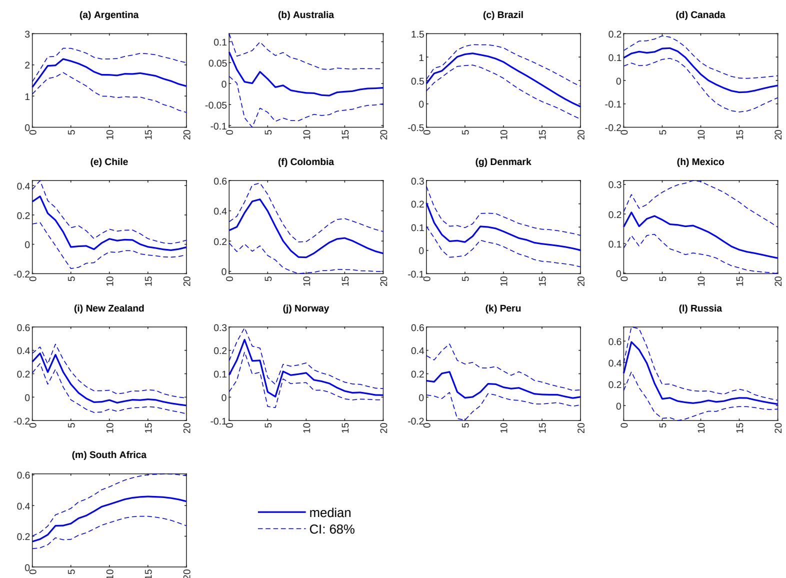
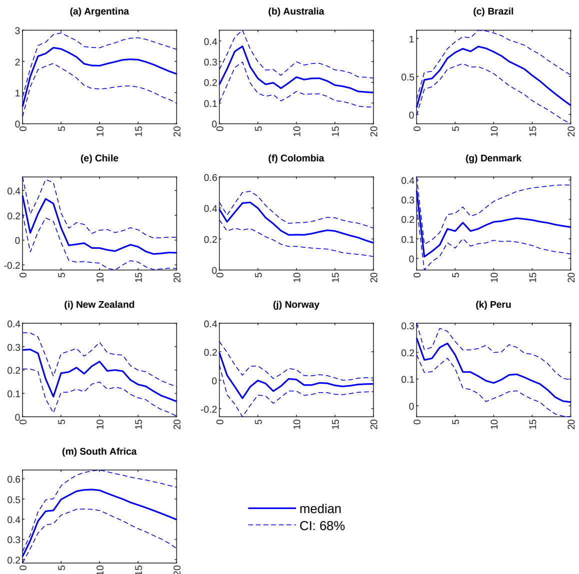
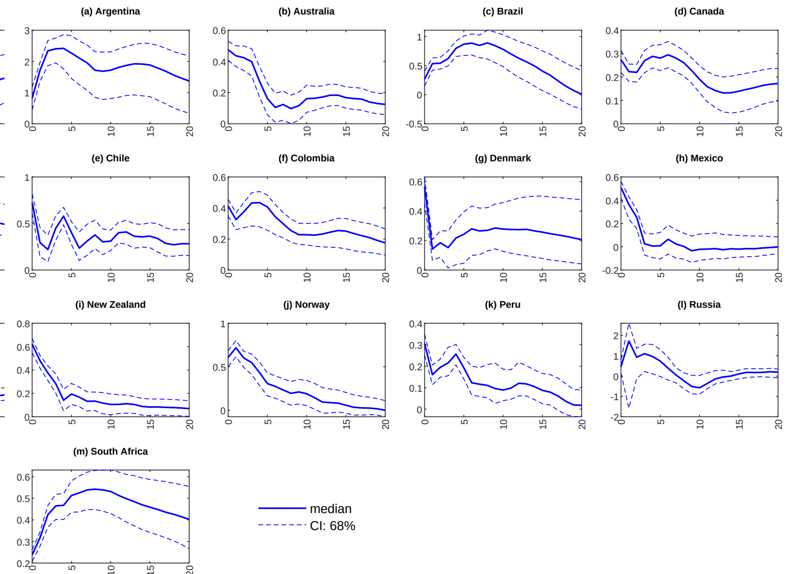


Figure 12: Response of cons to Domestic Shocks

(a) Max-Fev of Domestic Output



(b) Max-Fev of Consumption



(c) Max-Fev of Investment

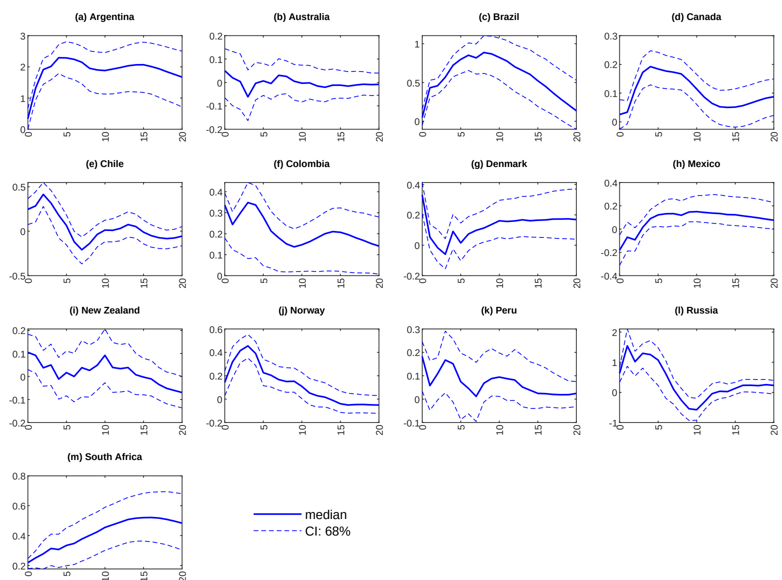
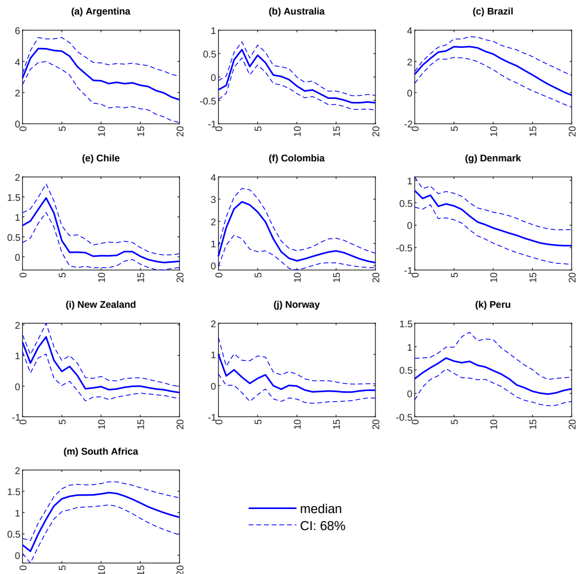
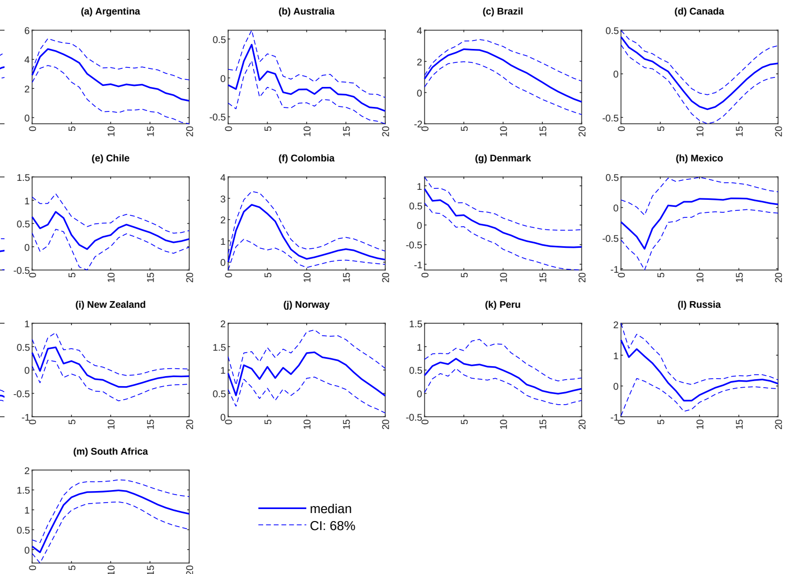


Figure 13: Response of inv to Domestic Shocks

(a) Max-Fev of Domestic Output



(b) Max-Fev of Consumption



(c) Max-Fev of Investment

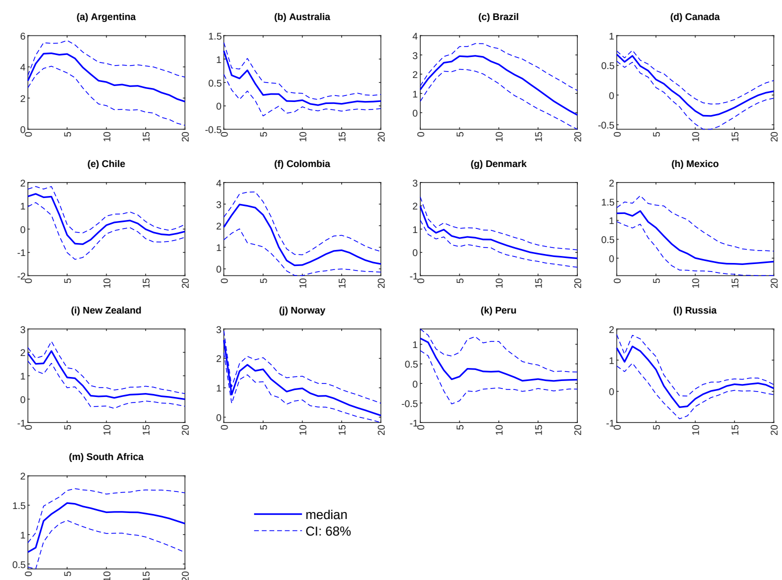
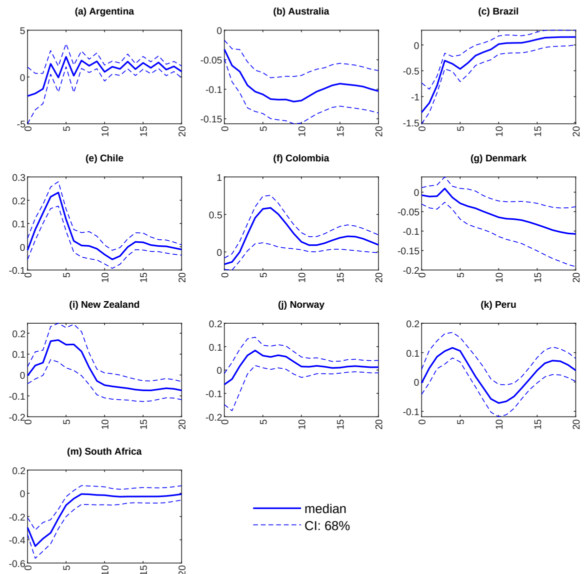
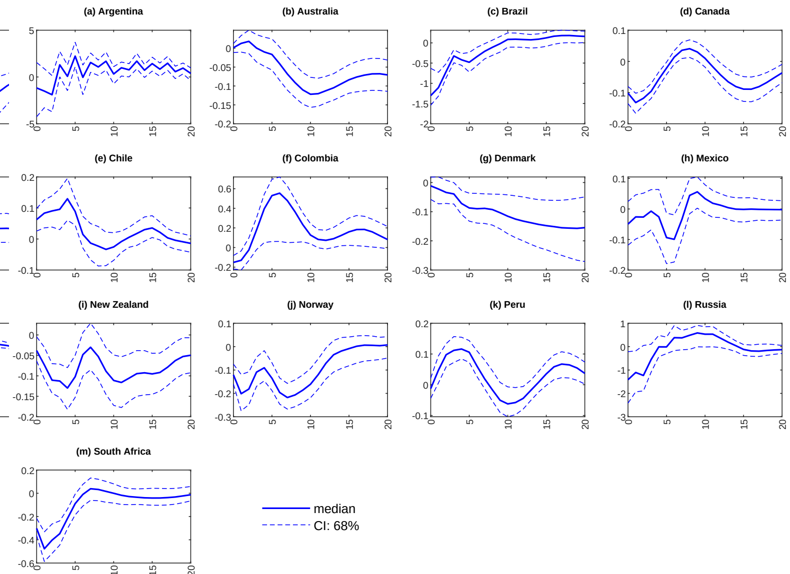


Figure 14: Response of id to Domestic Shocks

(a) Max-Fev of Domestic Output



(b) Max-Fev of Consumption



(c) Max-Fev of Investment

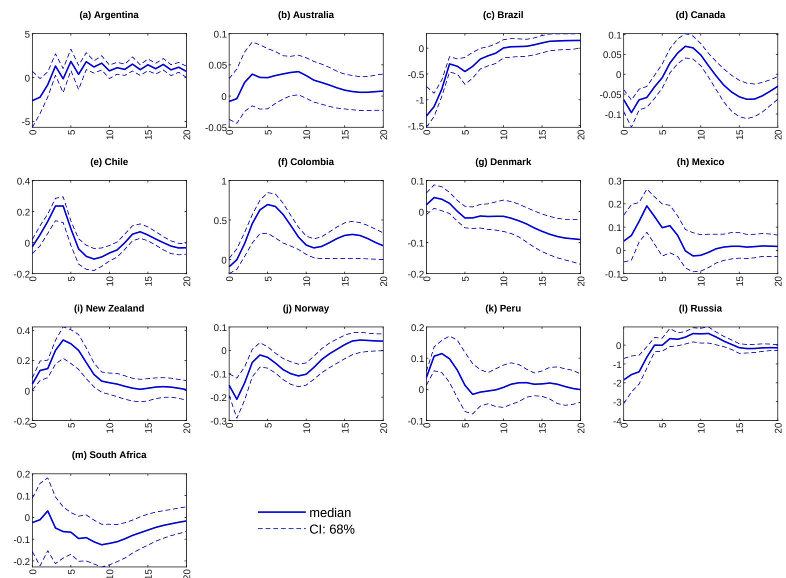


Table 1: Forecast Error Variance Decomposition

FEVD		Global output				Monetary shock				Terms of Trade				Max-Share Investment				Max-Share Consumption				Max-Share Domestic Output			
		REER	I	C	Y	REER	I	C	Y	REER	I	C	Y	REER	I	C	Y	REER	I	C	Y	REER	I	C	Y
Argentina	t = 1	13.8	2.0	0.5	2.8	4.1	49.7	61.5	60.3	10.7	1.6	0.9	1.3	0.5	27.8	1.1	19.9	1.9	24.2	5.3	24.5	1.1	24.6	2.5	23.3
	t =12	7.8	15.0	12.7	12.3	72.9	36.9	34.0	29.9	3.1	5.5	4.9	4.9	4.2	32.4	31.5	40.1	3.1	25.7	34.1	38.6	3.6	30.0	34.2	41.3
	t= 20	9.0	15.1	12.5	12.7	72.5	38.3	35.1	30.9	3.0	6.6	5.8	6.0	4.7	28.5	30.7	36.2	3.3	21.8	31.0	33.1	3.9	25.7	32.2	36.2
Australia	t = 1	44.3	7.9	6.6	29.6	2.1	9.3	15.9	8.8	11.0	0.5	2.7	3.5	3.0	50.4	1.4	3.7	1.8	0.9	52.9	19.2	6.1	3.0	8.0	22.4
	t =12	19.9	17.8	7.0	17.5	39.1	62.3	28.1	42.8	28.3	8.5	33.8	3.6	1.3	4.6	1.2	1.5	1.9	1.0	18.2	11.9	2.7	1.6	13.8	23.8
	t= 20	15.6	21.4	11.7	17.6	49.3	62.3	32.8	50.3	23.8	7.9	24.8	3.4	0.9	2.4	1.1	1.1	1.9	0.9	15.7	10.0	2.6	1.9	13.6	17.1
Brazil	t = 1	14.4	2.6	1.0	14.9	21.0	5.1	32.7	45.9	8.1	1.4	0.7	0.5	2.4	42.2	0.7	18.0	1.0	22.3	7.9	21.0	2.4	39.9	1.2	19.8
	t =12	11.0	13.6	7.0	14.1	33.6	14.8	27.9	16.8	33.6	9.0	19.6	18.2	8.4	43.7	27.8	37.9	6.4	36.3	30.3	32.4	8.3	43.3	28.6	37.9
	t= 20	11.2	13.3	7.7	9.5	44.4	33.0	33.2	42.4	25.7	12.7	28.2	15.9	5.9	23.9	17.7	18.3	5.0	18.8	17.3	14.9	5.9	23.6	17.9	18.2
Canada	t = 1	17.4	6.5	4.3	47.4	11.8	56.2	1.8	1.4	32.7	2.1	18.1	0.8	0.8	26.5	0.9	6.3	0.4	10.5	40.9	2.8	2.6	7.6	0.4	39.2
	t =12	10.3	52.9	8.7	59.9	25.1	18.4	27.5	31.5	51.3	12.6	33.8	2.5	1.2	6.9	5.6	1.6	0.9	2.9	17.7	0.7	2.1	3.8	3.1	3.4
	t= 20	11.8	38.6	16.6	56.9	24.6	18.9	25.6	35.7	49.1	28.8	28.3	2.4	1.1	5.1	4.4	1.2	1.1	2.6	14.2	0.8	1.8	3.1	2.8	2.5
Chile	t = 1	10.0	6.0	4.9	8.3	12.4	14.3	20.2	6.0	37.5	21.7	15.9	27.3	1.3	29.9	4.5	16.3	3.8	5.9	42.6	1.9	0.5	8.5	9.9	44.7
	t =12	10.1	11.7	9.7	13.5	32.1	30.8	53.3	33.9	39.3	33.4	25.8	42.2	2.2	10.2	1.7	1.7	3.4	2.8	5.1	1.6	1.8	6.3	1.3	3.2
	t= 20	15.1	13.7	6.8	7.2	31.3	41.6	50.7	53.0	37.1	28.6	32.4	33.2	1.9	5.8	1.0	0.8	2.9	1.8	3.5	1.1	1.5	3.4	0.9	1.4
Colombia	t = 1	7.1	10.2	2.3	6.4	31.0	10.8	5.4	12.3	17.8	3.1	2.8	5.9	2.7	28.2	40.9	19.7	1.7	0.5	62.8	22.3	2.8	1.8	56.5	25.6
	t =12	12.4	10.8	20.7	23.9	40.7	34.7	21.6	24.8	35.4	24.0	35.2	28.7	0.8	15.6	5.1	6.0	0.9	9.9	10.7	9.8	1.0	11.6	10.2	10.1
	t= 20	14.9	10.5	17.2	18.7	37.1	50.8	43.8	45.2	35.6	19.2	25.8	23.1	0.8	8.1	2.3	2.7	0.8	4.7	4.5	4.3	0.9	5.7	4.4	4.4
Denmark	t = 1	5.9	2.6	12.9	16.7	7.8	17.1	4.6	31.5	0.9	1.3	6.2	0.5	2.4	55.6	17.7	8.7	9.5	12.2	52.1	13.7	0.5	8.0	19.0	42.6
	t =12	52.7	64.0	20.3	81.2	17.9	27.0	34.3	11.3	5.2	1.0	14.2	0.8	3.9	4.4	4.4	1.1	3.8	1.4	16.8	1.3	1.4	1.1	5.7	3.7
	t= 20	51.6	66.1	20.8	83.6	22.8	24.9	45.4	10.4	6.2	1.7	12.9	1.0	3.2	3.1	3.3	0.9	3.7	1.7	9.2	1.2	1.7	1.2	3.9	2.6
Mexico	t = 1	17.3	1.7	25.9	33.3	33.0	32.4	8.9	3.8	0.4	0.6	8.4	0.5	3.8	48.0	4.9	11.1	7.3	2.9	46.3	2.8	1.9	29.7	1.9	36.8
	t =12	9.7	48.4	73.2	67.6	70.9	33.4	16.0	22.1	7.3	4.2	2.1	4.1	3.7	7.2	1.8	2.2	1.4	1.6	3.6	0.6	1.9	4.5	2.2	3.2
	t= 20	11.7	47.6	59.2	54.9	65.9	34.2	27.5	33.7	10.3	5.5	5.2	5.0	3.5	6.1	1.8	1.7	1.4	1.5	2.3	0.4	2.0	4.0	1.9	2.2
New Zealand	t = 1	13.6	1.3	2.1	2.5	35.8	6.7	25.8	23.6	0.3	9.3	5.3	6.8	7.0	52.2	1.5	18.7	1.4	1.8	54.1	16.8	1.2	26.8	11.2	55.6
	t =12	14.8	36.8	18.3	32.5	35.1	17.0	30.5	19.7	4.2	18.0	28.0	27.8	10.9	14.6	1.3	5.6	1.4	1.3	11.5	4.2	6.6	7.3	6.6	10.3
	t= 20	16.5	39.3	25.9	42.6	36.6	24.8	26.2	18.8	8.3	13.9	27.7	22.0	8.7	10.7	1.2	3.7	1.6	1.3	7.8	2.9	5.3	5.4	5.4	6.8
Norway	t = 1	1.1	3.6	2.6	5.4	15.4	2.4	18.5	8.7	51.8	3.6	44.1	1.6	1.0	62.6	1.1	2.3	1.8	7.9	19.0	0.7	0.6	9.9	1.9	75.1
	t =12	7.0	20.4	7.0	58.7	12.4	17.5	30.9	20.1	59.3	17.1	53.2	3.1	4.1	24.4	1.7	4.4	4.9	12.6	4.1	3.0	1.0	3.0	0.3	7.6
	t= 20	11.9	27.1	9.2	48.9	16.5	29.8	34.8	35.7	52.3	15.2	47.7	2.7	3.6	11.9	1.4	2.9	4.5	8.8	3.3	2.3	0.9	1.8	0.3	4.7
Peru	t = 1	28.2	5.5	51.6	50.4	30.5	40.7	11.1	11.8	10.2	4.4	0.5	1.8	1.2	27.9	7.7	6.4	0.4	3.3	23.7	15.7	0.9	2.9	16.0	20.7
	t =12	21.7	13.5	25.0	23.7	67.4	70.2	55.3	58.0	4.2	10.2	11.8	9.6	1.0	1.6	1.0	1.3	1.0	1.4	2.2	2.2	1.1	1.4	2.0	2.5
	t= 20	22.1	15.1	17.0	17.9	67.8	66.2	63.9	65.2	4.3	12.4	12.2	9.9	0.9	1.2	0.6	0.8	0.9	1.0	1.3	1.4	1.0	1.0	1.2	1.6
Russia	t = 1	0.9	0.9	5.3	28.4	2.7	64.5	14.1	2.7	18.4	0.3	8.9	28.7	1.1	13.7	11.6	9.2	1.7	18.9	6.4	6.4	2.6	0.8	9.9	24.5
	t =12	8.7	25.9	22.8	46.0	19.5	24.8	22.6	5.3	42.0	29.4	29.7	40.2	8.1	8.0	8.8	2.3	7.0	7.2	8.8	1.4	6.1	6.4	6.3	4.2
	t= 20	11.0	30.9	29.1	43.9	20.3	20.4	19.5	7.5	45.5	32.6	32.5	40.0	6.0	5.4	5.8	1.5	5.2	4.8	5.8	0.9	4.4	4.3	4.3	2.7
South Africa	t = 1	1.5	0.9	9.7	7.4	6.0	3.9	5.5	2.8	2.0	10.2	3.3	0.5	18.7	29.8	41.8	29.5	17.1	1.0	49.7	19.1	13.1	3.6	40.4	33.7
	t =12	22.3	7.2	29.1	18.5	46.6	25.4	26.0	38.3	13.5	4.0	2.0	1.2	6.7	43.3	17.0	18.8	3.2	33.4	31.0	29.9	3.3	32.7	29.9	31.5
	t= 20	27.7	9.4	11.6	8.4	46.9	50.5	64.6	66.8	10.3	2.7	1.6	1.2	5.3	25.6	12.6	14.3	2.7	20.0	15.3	15.8	2.7	20.2	15.4	16.7
Min Power Explanation	t = 1	0.9	0.9	0.5	2.5	2.1	2.4	1.8	1.4	0.3	0.3	0.5	0.5	0.5	13.7	0.7	2.3	0.4	0.5	5.3	0.7	0.5	0.8	0.4	19.8
	t =12	7.0	7.2	7.0	12.3	12.4	14.8	16.0	5.3	3.1	1.0	2.0	0.8	0.8	1.6	1.0	1.1	0.9	1.0	2.2	0.6	1.0	1.1	0.3	2.5
	t= 20	9.0	9.4	6.8	7.2	16.5	18.9	19.5	7.5	3.0	1.7	1.6	1.0	0.8	1.2	0.6	0.8	0.8	0.9	1.3	0.4	0.9	1.0	0.3	1.4
	All horizo	0.9	0.9	0.5	2.5	2.1	2.4	1.8	1.4	0.3	0.3	0.5	0.5	0.5	1.2	0.6	0.8	0.4	0.5	1.3	0.4	0.5	0.8	0.3	1.4
Max Power Explanation	t = 1	44.3	10.2	51.6	50.4	35.8	64.5	61.5	60.3	51.8	21.7	44.1	28.7	18.7	62.6	41.8	29.5	17.1	24.2	62.8	24.5	13.1	39.9	56.5	75.1
	t =12	52.7	64.0	73.2	81.2	72.9	70.2	55.3	58.0	59.3	33.4	53.2	42.2	10.9	43.7	31.5	40.1	7.0	36.3	34.1	38.6	8.3	43.3	34.2	41.3
	t= 20	51.6	66.1	59.2	83.6	72.5	66.2	64.6	66.8	52.3	32.6	47.7	40.0	8.7	28.5	30.7	36.2	5.2	21.8	31.0	33.1	5.9	25.7	32.2	36.2
	All horizo	52.7	66.1	73.2	83.6	72.9	70.2	64.6	66.8	59.3	33.4	53.2	42.2	18.7	62.6	41.8	40.1	17.1	36.3	62.8	38.6	13.1	43.3	56.5	75.1

Figure 15: Estimation sample by country

Variable	Sample
Foreign block	1962Q1-2019Q4
Domestic block	
Argentina	1996Q1-2019Q4
Australia	1994Q1-2019Q4
Brazil	1996Q1-2019Q4
Canada	1994Q1-2019Q4
Chile	1997Q1-2019Q4
Colombia	1995Q2-2019Q4
Denmark	1995Q1-2019Q4
Mexico	1998Q4-2019Q4
New Zealand	1994Q1-2019Q4
Norway	1994Q1-2019Q4
Peru	2003Q3-2019Q4
Russia	1995Q1-2019Q4
South Africa	1994Q1-2019Q4

B Sensitivity analysis: Model only with terms of trade

To verify out results, we contrast them with a model in which the only foreign variable is the terms of trade:

$$\begin{bmatrix} \tau_t^i \\ y_t^{d,i} \end{bmatrix} = f_0 + \sum_{j=1}^{4} \tilde{F}_i^{(j)} \begin{bmatrix} y_{t-j}^f \\ \tau_{t-j}^i \\ y_{t-j}^{d,i} \end{bmatrix} + + \begin{bmatrix} e_t^\tau \\ e_t^d \end{bmatrix}$$

where $\tilde{F}_i^{(j)} \begin{bmatrix} F_{\tau f,i}^{(j)} & F_{\tau\tau,i}^{(j)} & 0 \\ F_{df,i}^{(j)} & F_{d\tau,i}^{(j)} & F_{dd,i}^{(j)} \end{bmatrix}, j = \{1, 2, 3, 4\}$

Table 2: Contribution of Terms of Trade in Domestic Variables FEV

		Two block VAR model												Model only with Terms of Trade			
		Shock of Global output				Shock of of external Monetary Policy				Shock of Terms of Trade							
		REER	I	C	Y	REER	I	C	Y	REER	I	C	Y	REER	I	C	Y
Argentina	t = 1	13.8	2.0	0.5	2.8	4.1	49.7	61.5	60.3	10.7	1.6	0.9	1.3	12.7	0.6	2.4	2.9
	t =12	7.8	15.0	12.7	12.3	72.9	36.9	34.0	29.9	3.1	5.5	4.9	4.9	7.4	7.1	5.5	10.8
	t= 20	9.0	15.1	12.5	12.7	72.5	38.3	35.1	30.9	3.0	6.6	5.8	6.0	14.9	15.2	12.9	24.3
Australia	t = 1	44.3	7.9	6.6	29.6	2.1	9.3	15.9	8.8	11.0	0.5	2.7	3.5	30.3	0.5	2.0	6.0
	t =12	19.9	17.8	7.0	17.5	39.1	62.3	28.1	42.8	28.3	8.5	33.8	3.6	57.7	13.1	64.7	5.2
	t= 20	15.6	21.4	11.7	17.6	49.3	62.3	32.8	50.3	23.8	7.9	24.8	3.4	72.5	19.5	63.2	9.2
Brazil	t = 1	14.4	2.6	1.0	14.9	21.0	5.1	32.7	45.9	8.1	1.4	0.7	0.5	1.6	3.2	2.1	5.2
	t =12	11.0	13.6	7.0	14.1	33.6	14.8	27.9	16.8	33.6	9.0	19.6	18.2	66.8	16.4	44.6	38.9
	t= 20	11.2	13.3	7.7	9.5	44.4	33.0	33.2	42.4	25.7	12.7	28.2	15.9	68.1	34.9	65.8	53.2
Canada	t = 1	17.4	6.5	4.3	47.4	11.8	56.2	1.8	1.4	32.7	2.1	18.1	0.8	56.2	9.1	21.7	1.5
	t =12	10.3	52.9	8.7	59.9	25.1	18.4	27.5	31.5	51.3	12.6	33.8	2.5	88.0	48.0	51.3	30.2
	t= 20	11.8	38.6	16.6	56.9	24.6	18.9	25.6	35.7	49.1	28.8	28.3	2.4	91.0	59.8	57.1	44.9
Chile	t = 1	10.0	6.0	4.9	8.3	12.4	14.3	20.2	6.0	37.5	21.7	15.9	27.3	60.9	32.0	18.1	37.8
	t =12	10.1	11.7	9.7	13.5	32.1	30.8	53.3	33.9	39.3	33.4	25.8	42.2	83.3	58.6	62.4	86.2
	t= 20	15.1	13.7	6.8	7.2	31.3	41.6	50.7	53.0	37.1	28.6	32.4	33.2	86.7	73.4	78.8	90.1
Colombia	t = 1	7.1	10.2	2.3	6.4	31.0	10.8	5.4	12.3	17.8	3.1	2.8	5.9	22.7	1.2	1.6	10.1
	t =12	12.4	10.8	20.7	23.9	40.7	34.7	21.6	24.8	35.4	24.0	35.2	28.7	80.4	58.6	67.8	64.5
	t= 20	14.9	10.5	17.2	18.7	37.1	50.8	43.8	45.2	35.6	19.2	25.8	23.1	86.2	72.4	80.2	78.5
Denmark	t = 1	5.9	2.6	12.9	16.7	7.8	17.1	4.6	31.5	0.9	1.3	6.2	0.5	1.1	0.8	6.1	0.5
	t =12	52.7	64.0	20.3	81.2	17.9	27.0	34.3	11.3	5.2	1.0	14.2	0.8	29.9	25.4	20.8	28.1
	t= 20	51.6	66.1	20.8	83.6	22.8	24.9	45.4	10.4	6.2	1.7	12.9	1.0	32.5	37.3	24.4	35.6
Mexico	t = 1	17.3	1.7	25.9	33.3	33.0	32.4	8.9	3.8	0.4	0.6	8.4	0.5	8.9	0.3	0.5	19.2
	t =12	9.7	48.4	73.2	67.6	70.9	33.4	16.0	22.1	7.3	4.2	2.1	4.1	27.6	36.9	24.3	30.4
	t= 20	11.7	47.6	59.2	54.9	65.9	34.2	27.5	33.7	10.3	5.5	5.2	5.0	30.3	36.9	35.4	34.3
New Zealand	t = 1	13.6	1.3	2.1	2.5	35.8	6.7	25.8	23.6	0.3	9.3	5.3	6.8	0.3	9.0	10.1	6.8
	t =12	14.8	36.8	18.3	32.5	35.1	17.0	30.5	19.7	4.2	18.0	28.0	27.8	8.5	58.5	60.6	68.9
	t= 20	16.5	39.3	25.9	42.6	36.6	24.8	26.2	18.8	8.3	13.9	27.7	22.0	13.5	62.7	70.8	76.6
Norway	t = 1	1.1	3.6	2.6	5.4	15.4	2.4	18.5	8.7	51.8	3.6	44.1	1.6	57.4	5.5	51.6	0.9
	t =12	7.0	20.4	7.0	58.7	12.4	17.5	30.9	20.1	59.3	17.1	53.2	3.1	75.9	26.0	88.4	9.8
	t= 20	11.9	27.1	9.2	48.9	16.5	29.8	34.8	35.7	52.3	15.2	47.7	2.7	78.9	27.4	88.0	19.6
Peru	t = 1	28.2	5.5	51.6	50.4	30.5	40.7	11.1	11.8	10.2	4.4	0.5	1.8	30.5	2.4	26.4	21.2
	t =12	21.7	13.5	25.0	23.7	67.4	70.2	55.3	58.0	4.2	10.2	11.8	9.6	32.6	75.3	91.6	89.1
	t= 20	22.1	15.1	17.0	17.9	67.8	66.2	63.9	65.2	4.3	12.4	12.2	9.9	42.2	81.3	93.9	91.2
Russia	t = 1	0.9	0.9	5.3	28.4	2.7	64.5	14.1	2.7	18.4	0.3	8.9	28.7	14.8	0.7	16.3	43.5
	t =12	8.7	25.9	22.8	46.0	19.5	24.8	22.6	5.3	42.0	29.4	29.7	40.2	74.3	65.2	63.7	70.0
	t= 20	11.0	30.9	29.1	43.9	20.3	20.4	19.5	7.5	45.5	32.6	32.5	40.0	78.2	65.0	63.9	68.3
South Africa	t = 1	1.5	0.9	9.7	7.4	6.0	3.9	5.5	2.8	2.0	10.2	3.3	0.5	0.8	10.5	2.6	0.4
	t =12	22.3	7.2	29.1	18.5	46.6	25.4	26.0	38.3	13.5	4.0	2.0	1.2	18.0	11.4	6.0	13.6
	t= 20	27.7	9.4	11.6	8.4	46.9	50.5	64.6	66.8	10.3	2.7	1.6	1.2	19.9	25.1	20.0	30.6
Min Power Explanation	t = 1	0.9	0.9	0.5	2.5	2.1	2.4	1.8	1.4	0.3	0.3	0.5	0.5	0.3	0.3	0.5	0.4
	t =12	7.0	7.2	7.0	12.3	12.4	14.8	16.0	5.3	3.1	1.0	2.0	0.8	7.4	7.1	5.5	5.2
	t= 20	9.0	9.4	6.8	7.2	16.5	18.9	19.5	7.5	3.0	1.7	1.6	1.0	13.5	15.2	12.9	9.2
	All horizon	0.9	0.9	0.5	2.5	2.1	2.4	1.8	1.4	0.3	0.3	0.5	0.5	0.3	0.3	0.5	0.4
Max Power Explanation	t = 1	44.3	10.2	51.6	50.4	35.8	64.5	61.5	60.3	51.8	21.7	44.1	28.7	60.9	32.0	51.6	43.5
	t =12	52.7	64.0	73.2	81.2	72.9	70.2	55.3	58.0	59.3	33.4	53.2	42.2	88.0	75.3	91.6	89.1
	t= 20	51.6	66.1	59.2	83.6	72.5	66.2	64.6	66.8	52.3	32.6	47.7	40.0	91.0	81.3	93.9	91.2
	All horizon	52.7	66.1	73.2	83.6	72.9	70.2	64.6	66.8	59.3	33.4	53.2	42.2	91.0	81.3	93.9	91.2

.1 Tauchen approximation for VAR

Here, we describe the implementation of Tauchen (1986).

1. **Initial Setup of the VAR Model**:

   The original VAR(1) model is defined as:

$$Z_t = AZ_{t-1} + C\epsilon_t$$

Table 3: Forecast Error Variance Decomposition: Foreign Variables

FEVD		Global output			Monetary shock			Terms of Trade		
		Global output	Fed Funds	TOT	Global output	Fed Funds	TOT	Global output	Fed Funds	TOT
Argentina	t = 1	100.0	3.1	9.7	0.0	96.9	6.7	0.0	0.0	81.2
	t =12	96.7	21.9	8.4	3.3	78.1	20.4	0.0	0.0	66.4
	t= 20	88.2	21.9	10.5	11.8	78.1	22.9	0.0	0.0	59.8
Australia	t = 1	100.0	3.3	5.3	0.0	96.7	1.4	0.0	0.0	91.7
	t =12	96.5	23.1	7.2	3.5	76.9	9.6	0.0	0.0	80.0
	t= 20	88.6	23.1	8.6	11.4	76.9	14.7	0.0	0.0	71.4
Brazil	t = 1	100.0	3.2	7.9	0.0	96.8	25.8	0.0	0.0	65.5
	t =12	96.6	22.8	38.3	3.4	77.2	18.6	0.0	0.0	40.3
	t= 20	87.8	22.8	39.0	12.2	77.2	23.4	0.0	0.0	34.3
Canada	t = 1	100.0	3.2	5.6	0.0	96.8	14.2	0.0	0.0	78.9
	t =12	97.1	23.1	11.5	2.9	76.9	12.0	0.0	0.0	73.1
	t= 20	89.6	23.2	12.3	10.4	76.8	16.2	0.0	0.0	68.2
Chile	t = 1	100.0	3.2	9.3	0.0	96.8	24.1	0.0	0.0	64.4
	t =12	96.2	22.5	9.6	3.8	77.5	30.3	0.0	0.0	57.1
	t= 20	86.7	22.4	11.9	13.3	77.6	35.5	0.0	0.0	50.9
Colombia	t = 1	100.0	3.2	6.8	0.0	96.8	13.7	0.0	0.0	77.9
	t =12	96.5	23.4	9.4	3.5	76.6	13.2	0.0	0.0	74.9
	t= 20	87.9	23.4	10.9	12.1	76.6	18.5	0.0	0.0	67.4
Denmark	t = 1	100.0	3.0	0.5	0.0	97.0	29.5	0.0	0.0	69.7
	t =12	96.7	22.2	12.5	3.3	77.8	41.7	0.0	0.0	43.8
	t= 20	88.0	22.2	21.1	12.0	77.8	44.5	0.0	0.0	31.9
Mexico	t = 1	100.0	2.9	8.2	0.0	97.1	28.5	0.0	0.0	61.0
	t =12	95.5	21.6	11.0	4.5	78.4	28.7	0.0	0.0	57.1
	t= 20	84.6	21.6	12.1	15.4	78.4	28.0	0.0	0.0	57.2
New Zealand	t = 1	100.0	3.3	1.1	0.0	96.7	7.5	0.0	0.0	90.8
	t =12	96.9	22.7	4.5	3.1	77.3	20.2	0.0	0.0	72.3
	t= 20	89.3	22.7	7.0	10.7	77.3	23.1	0.0	0.0	66.9
Norway	t = 1	100.0	3.3	6.7	0.0	96.7	14.1	0.0	0.0	77.5
	t =12	97.1	22.9	11.7	2.9	77.1	11.5	0.0	0.0	73.8
	t= 20	89.8	23.0	13.5	10.2	77.0	13.8	0.0	0.0	69.5
Peru	t = 1	100.0	2.8	18.4	0.0	97.2	23.3	0.0	0.0	55.2
	t =12	95.7	22.1	12.9	4.3	77.9	51.9	0.0	0.0	33.4
	t= 20	85.2	22.1	18.9	14.8	77.9	50.1	0.0	0.0	29.8
Russia	t = 1	100.0	3.2	7.9	0.0	96.8	14.8	0.0	0.0	74.6
	t =12	96.7	23.2	12.0	3.3	76.8	12.2	0.0	0.0	72.2
	t= 20	88.3	23.2	14.0	11.7	76.8	14.6	0.0	0.0	68.4
South Africa	t = 1	100.0	3.4	2.0	0.0	96.6	25.1	0.0	0.0	72.3
	t =12	97.0	23.1	5.0	3.0	76.9	23.6	0.0	0.0	69.9
	t= 20	89.5	23.2	6.7	10.5	76.8	32.3	0.0	0.0	59.1
Min Power Explanation	t = 1	100.0	2.8	0.5	0.0	96.6	1.4	0.0	0.0	55.2
	t =12	95.5	21.6	4.5	2.9	76.6	9.6	0.0	0.0	33.4
	t= 20	84.6	21.6	6.7	10.2	76.6	13.8	0.0	0.0	29.8
	All horizon	84.6	2.8	0.5	0.0	76.6	1.4	0.0	0.0	29.8
Max Power Explanation	t = 1	100.0	3.4	18.4	0.0	97.2	29.5	0.0	0.0	91.7
	t =12	97.1	23.4	38.3	4.5	78.4	51.9	0.0	0.0	80.0
	t= 20	89.8	23.4	39.0	15.4	78.4	50.1	0.0	0.0	71.4
	All horizon	100.0	23.4	39.0	15.4	97.2	51.9	0.0	0.0	91.7

where:

- Z_t is a 3×1 vector of endogenous variables.
- A is a 3×3 matrix of autoregressive coefficients.
- C is a 3×3 matrix that maps the structural shocks ϵ_t to the variables.
- ϵ_t is a 3×1 vector of uncorrelated structural shocks with $\mathbb{E}[\epsilon_t \epsilon_t'] = I_3$.

The covariance matrix of the shocks ϵ_t is given by:

$$\Sigma = CC'$$

2. **Defining the Transformation Matrix**:

   In this specific case, the matrix P used for transformation is set equal to the matrix C, i.e., $P = C$.

3. **Transformation of the System**:

   The variables are transformed as:

   $$\tilde{Z}_t = P^{-1} Z_t = C^{-1} Z_t$$

   Substituting this into the original VAR model, we obtain:

   $$P\tilde{Z}_t = AP\tilde{Z}_{t-1} + C\epsilon_t$$

   Multiplying both sides by P^{-1}, the transformed system becomes:

   $$\tilde{Z}_t = \tilde{A}\tilde{Z}_{t-1} + \tilde{C}\epsilon_t$$

   where:

   $$\tilde{A} = P^{-1}AP = C^{-1}AC$$

   $$\tilde{C} = P^{-1}C = C^{-1}C = I$$

   Here, $\tilde{C}$ is the identity matrix, indicating that the shocks in the transformed system are orthogonal.

4. **Simulation Setup**:

   The simulation is set up by defining the grid points for the transformed variables $\tilde{Z}_t$. The grid bounds are determined by the variances σ_i^2, which are calculated iteratively.

5. **Iterative Calculation of Variance**:

   The variance matrix $\tilde{\Sigma}_z$ of the transformed system is initialized as the identity matrix I_3 and updated iteratively using the following rule:

$$\tilde{\Sigma}_z = \tilde{A}\tilde{\Sigma}_z\tilde{A}' + I_3$$

   This iteration is repeated for a sufficient number of steps to ensure convergence.

6. **Grid Formation**:

   Using the calculated variances, the lower and upper bounds for the grid points $\tilde{z}_i$ are defined as:

$$\tilde{z}_{i,\text{lower}} = -\sqrt{\tilde{\Sigma}_z(i,i)} \cdot \mu_i, \quad \tilde{z}_{i,\text{upper}} = -\tilde{z}_{i,\text{lower}}$$

   for $i = 1, 2, 3$. The grid points are evenly spaced between these bounds.

7. **Transforming Back to the Original Variables**:

   After calculating the grid points $\tilde{z}_1, \tilde{z}_2, \tilde{z}_3$ in the transformed space, they are converted back to the original space using the matrix P:

$$Z = P\tilde{Z}$$

8. **Projection and Transition Probability Calculation**:

   For each grid point, the projected values are calculated using the transformed matrix $\tilde{A}$:

$$\tilde{Z}_{\text{proj}} = \tilde{A}\tilde{Z}$$

   where $\tilde{Z}$ is a grid point.

   The transition probabilities are then calculated based on the projected values and the grid points. For each component i of Z_t (where $i = 1, 2, 3$), the transition probability p_i is calculated as:

$$p_i = \Phi\left(\frac{\tilde{z}_i + \frac{w_i}{2} - \tilde{Z}_{\text{proj}}(i)}{\sigma_i}\right) - \Phi\left(\frac{\tilde{z}_i - \frac{w_i}{2} - \tilde{Z}_{\text{proj}}(i)}{\sigma_i}\right)$$

   where $\Phi(\cdot)$ is the cumulative distribution function (CDF) of the standard normal distribution, and w_i is the grid width for the i-th component.

   If $i = 1$, the probability is:

$$p_1 = \Phi\left(\frac{\tilde{z}_1 + \frac{w_1}{2} - \tilde{Z}_{\text{proj}}(1)}{\tilde{\Sigma}_z(1,1)}\right)$$

and if $i = N_1$ (the last point), the probability is:

$$p_1 = 1 - \Phi\left(\frac{\tilde{z}_1 - \frac{w_1}{2} - \tilde{Z}_{\text{proj}}(1)}{\tilde{\Sigma}_z(1,1)}\right)$$

Similar calculations are made for p_2 and p_3.

The overall transition probability for moving from one grid point to another is then the product of these probabilities:

$$p_{\text{transition}} = p_1 \times p_2 \times p_3$$