INTERNATIONAL MONETARY FUND

An Estimated DSGE Model for Integrated Policy Analysis

Kaili Chen, Marcin Kolasa, Jesper Linde, Hou Wang,
Pawel Zabczyk, and Jianping Zhou

WP/23/135

2023
JUN

WORKING PAPER

 WP/23/135

IMF Working Paper
Monetary and Capital Markets Department

An Estimated DSGE Model for Integrated Policy Analysis

Prepared by Kaili Chen, Marcin Kolasa, Jesper Lindé, Hou Wang, Pawel Zabczyk, Jianping Zhou

Authorized for distribution by Jesper Lindé
June 2023

ABSTRACT: We estimate a New Keynesian small open economy model which allows for foreign exchange (FX) market frictions and a potential role for FX interventions for a large set of emerging market economies (EMEs) and some inflation targeting (IT) advanced economy (AE) countries serving as a control group. Next, we use the estimated model to examine the empirical support for the view that interest rate policy may not be sufficient to stabilize output and inflation following capital outflow shocks, and the extent to which FX interventions (FXI) can improve policy tradeoffs. Our results reveal significant structural differences between AEs and EMEs—in particular FX market depth—leading to different transmission of capital outflow shocks which justifies occasional use of FXI in some EMEs in certain situations. Our analysis also highlights the critical importance of accounting for the endogeneity of FXI behavior when assessing FX market depth and policy tradeoffs associated with volatile capital flows in past episodes.

JEL Classification Numbers:	C6, F4, E5, O5
Keywords:	Integrated Policy Framework; Emerging Markets; Monetary Policy; Foreign Exchange Intervention; Endogenous Risks; Incomplete Financial Markets; Bayesian Estimation
Author's E-Mail Address:	kchen4@imf.org,mkolasa@imf.org, jlinde@imf.org, hwang2@imf.org, pzabczyk@imf.org, jzhou1@imf.org

* The authors would like to thank seminar participants at the IMF for very valuable discussions and comments. A special thank you to Atet Wijoseno at the Bank of Indonesia who contributed strongly to an earlier version of the model. The views expressed herein are those of the authors and should not be attributed to the IMF, its Executive Board, or its management.

Contents

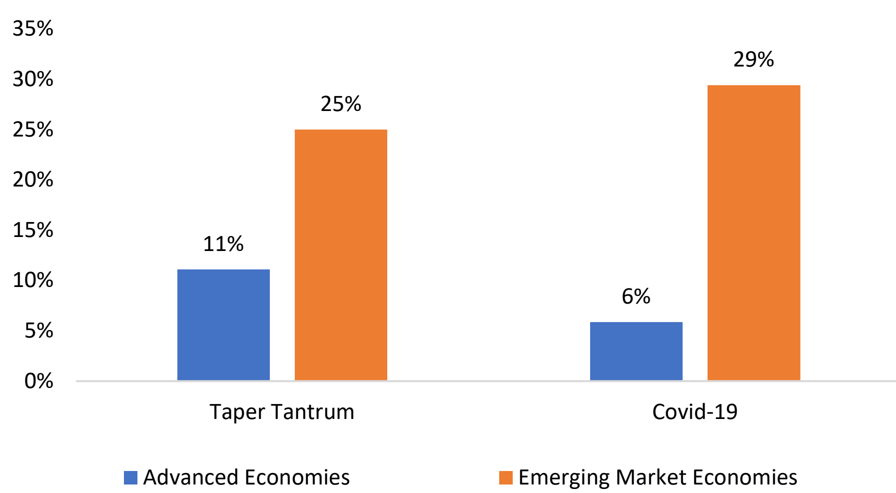
* The authors would like to thank seminar participants at the IMF for very valuable discussions and comments. A special thank you to Atet Wijoseno at the Bank of Indonesia who contributed strongly to an earlier version of the model.

APPENDIX TABLES

I. Introduction

Over the last two decades, many emerging market economies (EMEs) and developing countries have moved away from fixed exchange rate regimes and adopted a monetary policy framework based on inflation targeting (IT). The IT framework, first introduced in New Zealand in 1990 and then in many other advanced economies (AEs), was found to be very successful in stabilizing both inflation and real aggregates (Svensson, 2010). However, unlike their advanced economy counterparts, many EME central banks with IT frameworks have continued to rely on foreign exchange interventions (FXIs) in their monetary policy operations. This was particularly evident during episodes of volatile capital flows (Hofmann et al., 2019), like the Taper Tantrum and the COVID-19 crisis (Kalemli-Ozcan et al, 2022). We illustrate this point in Figure 1, which shows that FX sales during these two episodes were much more prevalent in EMEs than in AEs. A very similar picture emerges if we restrict the sample to inflation targeting countries.

Figure 1. FX Interventions during Risk-off Episodes



Source: Own calculations based on monthly data from Adler et al. (2021). The figure presents the share of countries within each group that intervened during the two considered episodes. A country is classified as intervening if it was selling FX reserves (broad measure) in the month following the shock (June 2013 for Taper Tantrum, April 2020 for Covid-19), and the total transaction volume was at least 0.5% of its annual GDP.

As explored in depth by e.g., Adrian et al (2020, 2021) and Basu et al. (2020), one reason for more frequent use of FXIs in EMEs is that these countries face more difficult stabilization tradeoffs because of several (often related) economic characteristics that set them apart from AEs. EMEs typically have relatively larger net foreign liabilities and more limited access to international financial markets, which makes them more vulnerable to sudden changes in global financial conditions. Their FX and domestic financial markets are often not as deep as in AEs, implying that swings in international capital flows may lead to large undesirable movements in the exchange rate. Moreover, exchange rate volatility tends to have more adverse effects in EMEs because of their limited ability to hedge currency mismatches and larger and more persistent exchange rate pass-through to inflation.

This reasoning has recently found support from the theoretical literature, which identified frictions warranting the use of FX interventions in certain circumstances as more likely to emerge in EMEs than in AEs. One of the key frictions is FX market shallowness, which leads to inefficient movements in uncovered interest rate parity (UIP) premia that can be at least partially offset by appropriate use of FXI (see, e.g., Gabaix and Maggiori, 2015; Cavallino, 2019; Amador et al., 2019; Fanelli and Straub, 2021). Another consideration is the presence of currency mismatches that may precipitate a sharp rise in the borrowing spreads when the exchange rate depreciates, possibly leading to severe financial crises often referred to as 'sudden stops' (see, e.g., Jeanne and Korinek, 2010; Mendoza, 2010; Basu et al., 2020). In a recent and more quantitatively oriented study, Adrian et al. (2021) argue that these frictions may create a particularly difficult tradeoff for central banks in economies with strong price and wage indexation mechanisms, fast pass-through of exchange rate to consumer prices, and high stickiness of export prices in foreign currency, the last two features stressed by the dominant currency paradigm literature (Gopinath et al., 2020).

The goal of this paper is to test the empirical relevance of these mechanisms and quantitatively verify their implications, including the conditions under which FXI can be useful, by embedding them in a microfounded macroeconomic framework that can be taken directly to the data. To this end, we develop a dynamic stochastic general equilibrium (DSGE) model that can be seen as an empirical formulation of the two-country model described in Adrian et al. (2021). The model is a New Keynesian small open economy setup with potentially shallow FX markets, FX mismatches and a range of nominal rigidities considered in the DSGE literature, including sticky prices and wages with indexation to past inflation and possibly also exchange rate movements. Prices are set in local currency, which lets the data speak to the degree of exchange rate pass-through. Additionally, to address the well-known forward-guidance puzzle implied by models with fully rational agents (Giannoni et al., 2015), we allow for a modest degree of bounded rationality by using the framework developed by Gabaix (2020) and extended to an open economy setting in Kolasa et al. (2022).

Most importantly, and in contrast to previous papers microfounding the deployment of FXI, we *estimate* the model for a set of EMEs as well as a set of small open AEs that we use as a control group. We use Bayesian methods, drawing on the large literature dealing with open economy DSGE models (e.g., Adolfson et al., 2007; Justiniano and Preston, 2010). A critical assumption in the estimation is that we adopt the same priors for EMEs and the control group of AEs. This implies that any posterior differences in the parameters, and consequently any differences in shock transmission, are driven by cross-country variation in the time series used in estimation. Taking the model directly to the data allows us to assess and compare the quantitative implications of international differences in the transmission mechanism and could easily be complemented by scenario analyses assessing country-specific policy tradeoffs.

Importantly, apart from including the standard set of macroeconomic time series as observables when estimating the model, we use the Adler et al. (2019) estimate of FX interventions as an additional observable. By doing so, we overcome a significant obstacle in identifying FX market depth in macroeconomic models, wherein countries with shallow FX markets may seem to have deep markets since their central banks have systematically relied on FX interventions to mitigate exchange rate volatility during the sample period. The addition of the FXI proxy as observable in estimation thus facilitates joint identification of FXI policies and FX market depth, especially in countries where we find strong evidence for active FX interventions. Moreover, we also estimate a variant of our model in which we relax the assumption that FX market depth and the systematic part of the FXI rule are constant and instead allow for the possibility that they vary over time using regime switching methods advocated in Maih (2015).

Our analysis confirms the empirical relevance of frictions in EMEs, which may warrant the use of FXI in certain circumstances. The model estimates show that FX markets are shallower on average in EMEs than AEs, implying that UIP premium shocks can lead to larger movements in the exchange rate. Inflation expectations are also less well-anchored in EMEs, which can pose difficult output-inflation tradeoffs following exchange rate depreciations. The model estimates also suggest that a few EMEs have used FXI to respond to exchange rate movements in a systematic and rule-based manner. By limiting exchange rate depreciation due to capital outflows, FXI – in the form of FX sales – reduce the need to raise interest rates to contain inflation, and therefore improve policy tradeoffs. A final model extension featuring regime switching provides evidence for time-varying market depth and, consequently, greater impact of FXI in periods when markets are shallow.

The rest of the paper is organized as follows. Section II presents the DSGE model. Section III describes the model estimation procedure and reports our estimation results. Section IV presents impulse responses to key shocks to quantify shock transmission and policy tradeoffs. In Section V we assess empirical support for the view that FX market depth and the systematic part of the endogenous FXI rule are time-varying by estimating the model using regime-switching methods. The last section concludes.

II. The DSGE Model

We start by describing an empirical small open economy formulation of the fully fledged two-country model in Adrian et al. (2021), which in turn draws on the model in Adrian et al. (2020). The framework is estimated using a set of standard macroeconomic time series for 12 emerging market countries and 5 small open advanced economies that all pursue independent monetary policy (some variant of inflation targeting). It draws heavily on the two-country model, but makes a number of simplifying assumptions and introduces a number of data-driven add-ons meant to enhance its empirical properties. The first of these is the small open economy assumption—we posit that the size of the domestic (home) economy (ζ) is arbitrarily small relative to the foreign economy (ζ^*), which means that the foreign economy is essentially exogenous. Second, we attempt to capture trade in intermediate goods by assuming that exporting firms combine domestically produced goods with imported goods before selling them abroad. This way the model can reconcile very volatile exports and imports with a relatively stable trade balance (as a share of GDP). Third, and in another important twist on the two-country model above, we allow for household discounting in the spirit of Gabaix (2020) and Kolasa et al. (2022), which helps mitigate the forward guidance puzzle (see Del Negro et al., 2008). Fourth, since we consider a (log-)linearized formulation of the model, we do not allow for the occassionally binding external debt limit, and the Lagrange multiplier $\Theta_t \geq 0$ on the bank's borrowing constraint is hence set to nil to begin with.

Before turning to Bayesian estimation, we next provide more details on the empirical model and highlight its relationship to the microfounded DSGE model of Adrian et al. (2021).

II.1. Aggregate Demand

The home economy resource constraint can (under conditions discussed in Appendix A.1) be expressed as a share-weighted average of home consumption c_t, government spending g_t, and "net exports" (the difference between exports m_t^* and imports m_t) weighted by the (steady-state) trade share m_y

$$y_t = c_y c_t + g_y g_t + m_y (m_t^* - m_t). \tag{1}$$

Consumption demand is determined by the consumption Euler equation linking the marginal utility of consumption $\lambda_{c,t}$ to future marginal utility of consumption and short-term real interest rates faced by consumers $r_{b,t}$,

$$\lambda_{c,t} = \delta_c \mathrm{E}_t \lambda_{c,t+1} + r_{b,t}. \tag{2}$$

In equation (2), $0 < \delta_c \leq 1$ is the discounting parameter in the spirit of the behavioral New Keynesian model of Gabaix (2020) and its open economy extension (Kolasa et al., 2022).[1] The marginal utility of consumption varies inversely with current consumption, but rises with past consumption, with the latter reflecting habit persistence in consumption,

$$\lambda_{c,t} = -\frac{1}{\hat{\sigma}}(c_t - \varkappa_c c_{t-1} - \upsilon_{c,t}), \tag{3}$$

where $\hat{\sigma} = \sigma(1 - \varkappa_c)$ and $\upsilon_{c,t}$ is an exogenous consumption demand shock which is assumed to follow an AR(1) process:

$$\upsilon_{c,t} = \rho_\upsilon \upsilon_{c,t-1} + \varepsilon_{c,t}. \tag{4}$$

Taken together, these equations imply that consumption demand depends on a long-term real interest rate $r_{b,t}^L$, but with an important caveat that this borrowing rate depends on a *discounted* sum of future short-term rates:

$$c_t - \varkappa_c c_{t-1} - \upsilon_{c,t} = -\hat{\sigma}\mathrm{E}_t \sum_{j=0}^{\infty} \delta_c^j r_{b,t+j} = -\hat{\sigma} r_{b,t}^L. \tag{5}$$

The inclusion of discounting (i.e., allowing for $\delta_c < 1$) implies that future short-term real interest rates have more muted effects on current consumption demand.[2]

In addition to allowing for discounting, our model departs from the standard New Keynesian setup by assuming that the borrowing rate facing home consumers includes a time-varying "private borrowing spread" Ψ_t:

$$r_{b,t}^L = \mathrm{E}_t \sum_{j=0}^{\infty} \left\{\delta_c^j\left(i_{t+j} - \pi_{c,t+j+1}\right) + \delta_c^j(i_{b,t+j} - i_{t+j})\right\} = r_t^L + \Psi_t. \tag{6}$$

Hence, r_t^L is the effective long-term real interest rate on government bonds, and the interest rate spread Ψ_t is a discounted sum of future gaps between the nominal borrowing rate and policy rate, i.e., $\Psi_t = \mathrm{E}_t \sum_{j=0}^{\infty} \delta_c^j (i_{b,t+j} - i_{t+j}) = \mathrm{E}_t \sum_{j=0}^{\infty} \delta_c^j \psi_{t+j} = \frac{1}{1-\delta_c \rho_\psi} \psi_t$ where the last equality follows from the fact that we assume that the short-term borrowing spread follows an AR(1) process:

$$\psi_t = \rho_\psi \psi_{t-1} + \varepsilon_{\psi,t}. \tag{7}$$

Fisher (2015) shows that this Smets and Wouters (2007) domestic risk-premium shock can be interpreted as a structural shock to the demand for safe and liquid assets. In the theoretical two-country model by Adrian et al. (2021), a spread between interest rates faced by households ($i_{b,t}$) and the central bank policy rate (i_t) only arises when the home economy hits the borrowing limit. Our specification in eq. (6) allows this spread to be positive even when the home economy is not

[1] In general, assuming behavioral expectations as in Gabaix (2020) may introduce additional terms to the intertemporal optimality conditions. For example, Kolasa et al. (2022) show that eq. (2) should also contain net foreign assets. To preserve tractability of the model, we disregard these additional features whenever their quantitative implications are small.

[2] Accordingly, forward guidance about future monetary policy actions would have much smaller effects in this setup than in the standard workhorse New Keynesian model.

at the borrowing limit, which would arguably be the case with a more fully articulated model of the banking sector, for example (e.g., Gertler and Karadi, 2011).

We now turn to discuss the contribution of net exports to aggregate demand y_t in eq. (1). Following Christiano et al. (2011), and as noted earlier, we allow exporting firms to combine domestically produced goods and imported goods in the production of export goods. Thus, exports involve a continuum of exporters with some degree of monopoly power who combine a homogeneous domestically produced good and a homogeneous good from imports. To a first-order approximation, demand for domestically produced ($m^*_{d,t}$) and imported ($m^*_{m,t}$) goods used to produce exports is then given by

$$m^*_{d,t} = y^*_t - \eta_x \gamma^{x,*}_t + \omega_x \eta_x \gamma^{m,d}_t, \tag{8}$$

$$m^*_{m,t} = y^*_t - \eta_x \gamma^{x,*}_t - \eta_x(1-\omega_x)\gamma^{m,d}_t + \hat{\hat{\vartheta}}_{m^*,t}, \tag{9}$$

where ω_x is the share of imported goods directed towards the export sector in the steady state, $\gamma^{x,*}_t$ is the relative price of exported goods (produced by home exporters) to that of their foreign competitors, and $\gamma^{m,d}_t$ is the relative price between imported and domestic goods, i.e. $\gamma^{m,d}_t = p_{m,t} - p_t$. In the export demand for imported goods, we allow for a stationary exogenous shock $\hat{\hat{\vartheta}}_{m^*,t} = d\vartheta_{m^*,t}/1$, where $\vartheta_{m^*,t}$ follows an AR(1) process (as deviation from its deterministic mean of unity):

$$\vartheta_{m^*,t} - 1 = \rho_{m^*}\left(\vartheta_{m^*,t-1} - 1\right) + \varepsilon_{m^*,t}, 0 \le \rho_{m^*} < 1, \varepsilon_{m^*,t} \sim i.i.d.\ N\left(0, \sigma^2_{m^*}\right).$$

This shock will tend to shift both exports and imports in parallel, without affecting the trade balance. The demand equations above imply that total export demand $m^*_t = (1-\omega_x)m^*_{d,t} + \omega_x m^*_{m,t}$ can be be expressed as:

$$m^*_t = y^*_t - \eta_x \gamma^{x,*}_t + \omega_x \hat{\hat{\vartheta}}_{m^*,t}. \tag{10}$$

Hence, total export demand m^*_t rises with foreign output y^*_t and falls with the relative price of goods exported to the foreign economy, i.e., $\gamma^{x,*}_t = p_{x,t} - p^*_t$. So, allowing for imported goods to be used in the export sector does not affect the final export demand equation, but relative price changes between imported and domestically produced goods would change the relative share of those two types of goods used in producing exports. Finally, notice that in the special case when foreign currency prices of home products move inversely one-to-one with the nominal exchange rate, we have $\gamma^{x,*}_t$ equal to the negative of the product real exchange rate $q_{p,t}$, which is given by

$$q_{p,t} = s_t + p^*_t - p_t. \tag{11}$$

Similarly, total imports equal $m_t = (1-\omega_x)m_{c,t} + \omega_x m^*_{m,t}$ where import demand for domestic consumption purposes expands as domestic consumption rises and falls in response to an increase in their relative price,

$$m_{c,t} = c_t - \eta_c \gamma_t^{m,c} + \hat{\vartheta}_{m,t}, \tag{12}$$

where $\gamma_t^{m,c} = p_{m,t} - p_{c,t}$ is the price of a bundle of imported goods relative to that of a consumption basket comprising both domestically-produced and imported goods and $\hat{\vartheta}_{m,t} = d\vartheta_{m,t}/1$. The specification with private consumption rather than government spending means that we maintain the assumption that government spending has a negligible import content. Importantly, domestic import demand is also subject to an exogenous transient preference shifter, $\vartheta_{m,t}$ which follows an AR(1) process (as a deviation from its deterministic mean of unity):

$$\vartheta_{m,t} - 1 = \rho_m\left(\vartheta_{m,t-1} - 1\right) + \varepsilon_{m,t}, 0 \leq \rho_m < 1, \varepsilon_{m,t} \sim i.i.d.\ N(0, \sigma_m^2).$$

Furthermore and finally, note that the relative price $\gamma_t^{m,c}$ under the assumption of full pass-through from exchange rates to import prices reduces to the consumption-based real exchange rate

$$q_{c,t} = s_t + p_t^* - p_{c,t}. \tag{13}$$

II.2. Aggregate Supply

Turning to the supply side, the price-setting equation for domestically produced goods takes the form of a modified New Keynesian Phillips Curve:

$$\pi_t - \iota_d \pi_{t-1} = \beta \delta_c \mathrm{E}_t(\pi_{t+1} - \iota_d \pi_t) + \kappa_p mc_t + \varepsilon_{\pi,t}. \tag{14}$$

This specification is based on Calvo-style price setting, with the sensitivity of domestic producer price inflation π_t to marginal cost mc_t determined by the slope coefficient

$$\kappa_p = \frac{(1-\xi_p)(1-\beta\xi_p)}{\xi_p}, \tag{15}$$

which varies inversely with the mean duration of price contracts ξ_p. The Phillips Curve specification in (14) allows for the possibility of some structural persistence that is determined by the indexation parameter $0 \leq \iota_d \leq 1$. This persistence may be interpreted as reflecting dynamic indexation as in Christiano et al. (2005), so that non-optimizing firms index their new price to past inflation and the inflation target according to $P_t^{new} = (1+\pi)^{1-\iota_p}(1+\pi_{t-1})^{\iota_p} P_{t-1}$, which implies that the steady-state embeds no price distortions. But it is also empirically consistent with the view that inflation expectations feature an adaptive component, as in Clarida et al. (1999). Either way, when $\iota_p > 0$ i.i.d. cost-push shocks like $\varepsilon_{\pi,t}$ may exert persistent "second round" effects on inflation.

Marginal cost mc_t rises with an increase in the producer real wage ζ_t, and falls with a decline in the marginal product of labor mpl_t

$$mc_t = \zeta_t - mpl_t, \tag{16}$$

and with our Cobb-Douglas production function with variable labor and fixed capital, Appendix A.3 establishes that linearized marginal cost can be expressed as

$$mc_t = \zeta_t + \frac{\alpha}{1-\alpha} y_t. \tag{17}$$

Turning to labor supply, the marginal rate of substitution mrs_t between consumption and leisure—which determines the cost of working an additional hour in terms of consumption goods—is given by

$$mrs_t = \frac{\chi}{1-\alpha} y_t - \lambda_{c,t}, \tag{18}$$

and hence rises as hours worked increase or as the marginal utility of consumption declines.

To highlight how an exchange rate depreciation can put upward pressure on (product) wages and hence firms' marginal costs, it's helpful to consider the special case in which wages are fully flexible and there is full pass-through of exchange rate changes to consumer prices (i.e, producer currency pricing). In this case, the product real wage facing firms can be expressed as

$$\zeta_t = \omega_c \gamma_t^{m,d} + \zeta_{c,t} = \frac{\omega_c}{1-\omega_c} q_{c,t} + mrs_t, \tag{19}$$

where $\gamma_t^{m,d} = p_{m,t} - p_t$ and $\zeta_{c,t}$ is the linearized consumption-based real wage. Thus, exchange rate depreciation boosts the relative price of imported goods, causing households to demand a higher real wage in terms of the home produced good ζ_t to keep their purchasing power intact (as required to induce them to work the same number of hours and leave their mrs_t unchanged). The extent of upward pressure on firms' costs rises with the openness of the economy, but is dampened if pass-through from exchange rates to import prices is muted (as in our benchmark calibration, which assumes local currency pricing).

With this in mind, wage formation in the model follows Erceg et al. (2000) and assumes that nominal wages are sticky and set according to Calvo-style wage contracts, so that the wage Phillips curve takes the following form

$$\pi_{w,t} - \tilde{\pi}_{w,t-1} = \beta\delta_c \mathrm{E}_t\left(\pi_{w,t+1} - \tilde{\pi}_{w,t}\right) + \kappa_w\left(mrs_t - \zeta_{c,t}\right) + \varepsilon_{w,t}. \tag{20}$$

This establishes that nominal wage inflation $\pi_{w,t}$ depends on future wage inflation and the gap between the marginal cost of work and the consumption real wage κ_w, with the elasticity of the wage schedule to the labor wedge given by

$$\kappa_w = \frac{(1-\xi_w)(1-\beta\xi_w)\phi_w}{\xi_w(\chi(1+\phi_w)+\phi_w)},$$

where ξ_w is the probability of not being able to reoptimize wages, χ is the inverse of the Frisch elasticity of labor supply, and ϕ_w is the net wage markup. Moreover, we allow for a flexible specification of wage indexation for non-optimizing wage setters in which the relevant inflation measure indexing wages is a long moving average of either past realized inflation, or of exchange rate changes:

$$\tilde{\pi}_{w,t} = \iota_w \pi_{w,t} + (1 - \iota_w)\pi_{L,t}, \tag{21}$$

$$\pi_{L,t} = (1 - \nu)\pi_{L,t-1} + \frac{\nu}{m_y}\Delta s_t. \tag{22}$$

This indexation scheme where $\pi_{L,t}$ depends on past exchange rate changes allows for substantial second round effects through a wage channel. At the same time, the setup allows for a standard wage indexation scheme to past wage inflation when $\iota_w > 0$ and $\nu = 0$. [3]

The product real wage is determined by the identity:

$$\zeta_t = \zeta_{t-1} + \pi_{w,t} - \pi_t \tag{23}$$

with the consumption real wage $\zeta_{c,t}$ given by equation (19), i.e. $\zeta_{c,t} = \zeta_t - \omega_c \gamma_t^{m,d}$.

Our model allows for deviations from the law of one price in both the import and export sector. Thus, there are Phillips curves for determining import prices and export prices, under Calvo-style pricing assumptions. Specifically, price-setting for both consumer-goods import (m) and domestic export (x) sectors is given by

$$\pi_{j,t} - \iota_j \pi_{j,t-1} = \beta\delta_c \mathrm{E}_t\left(\pi_{j,t+1} - \iota_j \pi_{j,t}\right) + \kappa_j mc_{j,t} + \varepsilon_{j,t}, \tag{24}$$

where $\pi_{j,t}$, $j \in \{m, x\}$, denotes the deviation in quarter t of the log of gross inflation from its steady state ($\pi_{j,t} \equiv d\Pi_{j,t}/\Pi_j$, where $\Pi_{j,t} \equiv P_{j,t}/P_{j,t-1}$ is gross inflation, $P_{j,t}$ is the price level, and Π_j is the steady-state gross inflation rate in sector j). Here, $mc_{j,t}$ denotes the real marginal cost of firms in sector j; and $\varepsilon_{j,t}$ denotes a time-varying markup in the import sector m, assumed to be i.i.d. and $N\left(0, \sigma_j^2\right)$. We do not allow for a cost-push shock in the export sector. The slope of the Phillips curve in sector j, κ_j is given by

$$\kappa_j = \frac{(1-\xi_j)(1-\beta\xi_j)}{\xi_j(1+\phi_j\epsilon_j)}.$$

This slope differs from that in the domestic production sector in eq. (15) as it allows for Kimball aggregation (via $\phi_j\epsilon_j$ where ϕ_j is the net price markup and ϵ_j the Kimball curvature parameter) in these sectors. We do this to allow for very flat slopes of the Phillip curve in the export and import sectors without having to resort to unreasonable degrees of price stickiness (i.e., high ξ_j values). The parameter ι_j controls indexation: firms in sector j that do not optimize their price in a given quarter are assumed to index them to a linear combination of previous quarter's inflation and the

[3] Notice that we scale the impact of Δs_t on $\pi_{L,t}$ by$1/m_y$ so that this indirect channel may be potent in an economy with a lower degree of openness (smaller m_y). Ceteris paribus, this means that this channel will be less material in a more open economy with larger m_y, but in that case there will be larger direct effects of a depreciation via $\zeta_{c,t}$.

steady state inflation target, according to $P_{j,t}^{new} = \Pi_j^{1-\iota_j}\Pi_{j,t-1}^{\iota_j}P_{j,t-1}$. Moreover, firms' marginal costs are defined as

$$mc_{x,t} = (1-\omega_x)p_t + \omega_x p_{m,t} - s_t - p_{x,t} \;\; = -q_{p,t} + \gamma_t^{x,*} + \omega_x \gamma_t^{m,d}, \tag{25}$$

$$mc_{m,t} = p_t^* + s_t - p_{m,t} \;\; = q_{p,t} - \gamma_t^{m,d}, \tag{26}$$

where the two relative prices $\gamma_t^{x,*}$ and $\gamma_t^{m,d}$ are given by

$$\gamma_t^{x,*} = p_{x,t} - p_t^* \;\; = \;\; \gamma_{t-1}^{x,*} + \pi_{x,t} - \pi_t^*, \tag{27}$$

$$\gamma_t^{m,d} = p_{m,t} - p_t \;\; = \;\; \gamma_{t-1}^{m,d} + \pi_{m,t} - \pi_t. \tag{28}$$

Finally, consumer price inflation is defined as

$$\pi_{c,t} = (1-\omega_c)\pi_t + \omega_c \pi_{m,t}, \tag{29}$$

where $\omega_c = m_y(1-g_y)(1-\omega_x)$. The adjustment of the overall import share m_y by the the factor $(1-g_y)$ reflects the fact that there is only trade in private consumption goods while the adjustment by $(1-\omega_x)$ accounts for a share of total imports being directed to exports, with $\pi_{m,t}$ denoting the local currency inflation of imported goods. In the special case of full pass-through, eq. (29) simplifies to $\pi_{c,t} = \pi_t + m_c \Delta q_{c,t}$. Notably, our modeling of imperfect pass-through of exchange rate movements to export and import prices nests both local, producer and a simplified variant of dominant currency pricing as special cases.

II.3. International Financial Markets

As noted earlier, financial markets are segmented and incomplete. The Adrian et al. (2021) model mentioned above contains two key financial frictions, one related to an occasionally binding constraint for the banking sector following Chang (2018), and another arising on account of the moral hazard problem in the FX market motivated by the analysis of Gabaix and Maggiori (2015).

As described in Adrian et al. (2021), the complete markets variant of the uncovered interest parity (UIP) does not hold in the short run. However, the model features a risk-augmented UIP equation and an equation for the evolution of the home economy's net foreign liabilities. The two risk-wedges in the UIP equation are due to the financiers' agency friction and the occasionally binding collateral constraint for banks. Hence, we derive the following retail rate-based UIP condition:

$$\underbrace{(1-\tau_{F,t})I_t^b = \mathbb{E}_t\left\{I_t^* \frac{S_{t+1}}{S_t}\right\}}_{\text{Standard UIP Condition}} + \underbrace{\Gamma_t I_t \frac{B_{F,t}}{YP_{D,t}}}_{\text{GM wedge}} + \underbrace{(1-\tau_{F,t})\Theta_t}_{\text{Chang wedge}}, \tag{30}$$

which clearly highlights the two key frictions accounting for deviations from uncovered interest rate parity in our model (and where Θ_t is strictly positive only when the occassionally binding credit constraint is active). Since occassionally binding credit constraints are challenging to handle in linearized models–and also because Adrian et al. (2021) show their welfare implications to be more muted–they are assumed away in the remainder of this paper.

In equilibrium, positions taken by financiers $B_{F,t}$ must match home agents' net demand for foreign currency. This implies that private debt holdings by home households net of demand from foreign portfolio investors, and net of sterilization bonds issued by the monetary authority satisfy

$$B_{F,t} = -B_t - B_{P,t} + B_{M,t}. \tag{31}$$

By consolidating the budget constraints of all agents in the economy, we derive the following law of motion for net foreign assets (B_t is expressed in the home currency):

$$\begin{aligned} B_t = & \left[(1-\omega_F)I_{t-1} + \omega_F I^*_{t-1}\frac{S_t}{S_{t-1}}\right]B_{t-1} \\ & +(1-\omega_B)\left(I^b_{t-1} - I_{t-1}\right)B_{t-1} + \left(I_{t-1} - I^*_{t-1}\frac{S_t}{S_{t-1}}\right)\left[(\omega_P-\omega_F)B_{P,t-1} - (1-\omega_F)B_{M,t-1}\right] \\ & +\tau_{F,t-1}I_{t-1}\left[(1-\omega_F)B_{F,t-1} + (1-\omega_P)B_{P,t-1}\right] \\ & +TB_t, \end{aligned} \tag{32}$$

where TB_t is the nominal trade balance. Importantly, this formula takes into account the fact that that home households own fraction ω_F of financiers, fraction ω_B of banks, and fraction ω_P of portfolio investors.

In Appendix A.2, we establish that equation (30) without the Chang friction (i.e., with $\Theta_t = 0$ for all t) implies the following log-linearized UIP condition:

$$q_{p,t} = \delta_c \mathrm{E}_t q_{p,t+1} + (i^*_t - \mathrm{E}_t\pi^*_{t+1}) - \frac{1+r}{1+r^*}(i_t - \mathrm{E}_t\pi_{t+1}) + \frac{1+r}{1+r^*}\Gamma\left[b_{F,t} + b_F(i_t - \mathrm{E}_t\pi_{t+1})\right] + \frac{1+r}{1+r^*}\tau_{F,t}. \tag{33}$$

Equation (33) shows that the product-based real exchange rate in eq. (11) depreciates (i.e., $q_{p,t}$ rises) when the foreign real interest rate rises relative to the domestic real interest rate, or when the volume of funds intermediated by financiers rises; likewise, the product-based real exchange rate depreciates in response to a rise in the capital inflow tax $\tau_{F,t}$ (which we will assume is nil for all *t* when estimating the model, but its effects are discussed in more detail in Adrian et al., 2021). Even so, the presence of the discounting parameter $\delta_c \leq 1$ implies that the evolution of real rates in the short run matters more for exchange rate dynamics than implied by a standard UIP condition without discounting ($\delta_c = 1$). This feature is consistent with the theoretical predictions of Kolasa et al. (2022) and the empirical evidence provided by Gali (2005).[4]

[4] Kolasa et al. (2022) also argue that δ_c should multiply expected inflation in eq. (33), the consumption Euler equation (2) as well as in the pricing Phillips curves (eqs. 14 and 24). The discounting mechanism should also affect the expectational terms in the wage-setting equation (20). We have muted these channels in order not to attenuate

(continued…)

The presence of $\frac{1+r}{1+r^*}$ in front of the domestic real rate captures an adjustment to equalize returns in case there is a steady state differential between home and foreign real rates. However, when funds intermediated by financiers are positive in the steady state (i.e., $b_F > 0$), an increase in the domestic real rate will exert a depreciationary impact on the real exchange rate. In this case, the partial impact of the change in the home real rate on the exchange rate equals $\frac{1+r}{1+r^*}(\Gamma b_F - 1)$. This means, ceteris paribus, that shallower financial markets (i.e., a larger Γ) and more funds intermediated by financiers mitigate a policy hike-induced exchange rate appreciation.

More funds intermediated by financiers relative to steady state ($b_{F,t} > 0$), will also tend to depreciate the home exchange rate, especially with a shallower financial market (large Γ). The log-linearized version of funds intermediated by financiers (eq. 31) is simply

$$b_{F,t} = -b_t - (1/\Gamma)\tilde{b}_{P,t} + b_{M,t}, \tag{34}$$

where all variables are scaled relative to quarterly output. This equation implies that funds intermediated by financiers rise when net foreign liabilities ($-b_t$) rise or when portfolio investors withdraw funds ($b_{P,t}$ is negative). Funds that have to be intermediated by financiers fall whenever the central bank steps in and conducts FX intervention to support the currency (i.e., lowers its reserves relative to the steady state stock of reserves, implying $b_{M,t} < 0$). One important difference between eq. (34) and the underlying nonlinear equation (31) is that we have scaled the portfolio investment variable by $1/\Gamma$, so that $\tilde{b}_{P,t} = \Gamma b_{P,t}$. This is to ensure that deviations of (exogenous) portfolio investment capital flows from their steady state (b_P) always enter additively in the linearized UIP condition (33). We do this rescaling so that the variance of the portfolio flow shock $b_{P,t}$ does not affect the exchange rate when financial markets are deep (i.e., Γ is low). In turn, $\tilde{b}_{P,t}$ follows a simple stationary AR(1) process:

$$\tilde{b}_{P,t} = \rho_{b_p}\tilde{b}_{P,t-1} + \varepsilon_{b_p,t}, 0 \le \rho_{b_p} < 1, \varepsilon_{b_p,t} \sim i.i.d.\ N\left(0, \sigma^2_{b_p}\right). \tag{34b}$$

We will discuss the process for central bank reserves in Section II.4.

As shown in Appendix A.2, the log-linearized formulation of the net foreign asset accumulation equation can be written as

$$\begin{aligned} b_t = {} & \frac{\tilde{I}}{1+\pi_D} b_{t-1} + \frac{b}{1+\pi_D}\left[(1-\omega)I i_{t-1} + \omega I^* \Delta_S (i^*_{t-1} + \Delta s_t) - \tilde{I}\pi_{D,t}\right] \\ & - \frac{1-\omega}{1+\pi_D} b_M [I i_{t-1} - I^* \Delta_S (i^*_{t-1} + \Delta s_t)] - \frac{(1-\omega)(I - I^*\Delta_S)}{1+\pi_D}\left(b_{M,t-1} - b_M \pi_{D,t}\right) \end{aligned} \tag{35}$$

inflation dynamics when estimated δ_c is significantly negative. As an alternative, we could allow for these additional mechanisms but tighten the prior on δ_c to ensure the latter remains closer to unity.

$$+\frac{(1-\omega)I}{1+\pi_D}[b_F + b_P]\tau_{F,t-1}$$

$$+tb_t.$$

To derive this equation, we have made three key assumptions. First, we have retained the assumption that τ_F is 0 in the steady state. Second, we have imposed $\omega_B = 1$, i.e. that all banks are domestically owned. Third and finally, we have assumed that $\omega_F = \omega_P = \omega$, i.e., we posited the same degree of home ownership of financial intermediaries and exogenous financial investors.

There are a number of composite parameters in eq. (35). These parameters typically reflect the possibility that the home real rate (r) and inflation rate (π_D) differ from their foreign counterparts (r^* and π^*, respectively). These parameters are carefully discussed in the appendix outlining the derivation of this relationship. In addition, $\tilde{I} = (1-\omega)I + \omega I^* \Delta_S$ is a weighted nominal gross interest rate, so that $\frac{\tilde{I}}{1+\pi_D}$ represents a gross real interest rate, while $I - I^* \Delta_S$ is the differential in nominal returns between purchasing a home bond and foreign bond (Δ_S is the steady state nominal depreciation rate of the home economy).

The economics of the log-linearized NFA equation (35) is straightforward. The right-hand-side terms on the first line are related to debt service costs. The terms on the second line are related to costs of reserves and interventions, while the terms on the third row relate to capital flow measures. Finally, we have the log-linearized trade balance on the fourth row, which is shown in Appendix A.2 to equal

$$tb_t = m_y(m_t^* - m_t + \gamma_t^{x,*}), \tag{36}$$

which is a common expression for the trade balance as a share of nominal trend GDP: it is determined by real net exports ($m_t^* - m_t$) and the terms of trade $\gamma_t^{x,*}$.

II.4. Monetary and Fiscal Policy

Following a large empirical literature, including Brandao-Marques et al. (2020), we characterize monetary actions using simple policy rules that often provide a good empirical characterization of actual central bank behavior in advanced economies. Thus, for interest rate setting the central bank is assumed to follow a Taylor-style policy rule

$$i_t = \max\{-i, (1-\gamma_i)\left[(1+\gamma_\pi)\bar{\pi}_{c,t+4|t} + \gamma_y y_t\right] + \gamma_i i_{t-1} + \varepsilon_{i,t}\}, \tag{37}$$

where i is the steady-state nominal interest rate (since variables are measured relative to steady state levels, $i_t = -i$ implies that the policy rate reaches its assumed lower bound of zero). The rule specifies that the central bank responds to the expected four quarter change in the core CPI inflation rate around its target, noting that $\bar{\pi}_{c,t+4|\mathrm{t}} = \mathrm{E}_t(\pi_{c,t+1} + \pi_{c,t+2} + \pi_{c,t+3} + \pi_{c,t+4})/4$. It also takes domestic output (measured as deviation from its trend path) into account. Our assumption that the central bank responds to core CPI inflation in essence means that it puts some weight on responding to import price inflation $\pi_{m,t}$. The parameter γ_i allows for interest rate smoothing and $\varepsilon_{i,t}$ is an interest rate shock. The rule is not meant to capture fully optimal policy but for certain admissible parameterizations it provides a reasonably close approximation to it.

As we are considering the potential empirical support for integrated use of several policy instruments, we consider foreign exchange interventions as a policy instrument. FX interventions involve changing the stock of reserves, so we first define

$$fx_t = b_{M,t} - b_{M,t-1}. \tag{38}$$

Equation (38) implies that $fx_t > 0$ is an increase in the central banks' holdings of foreign reserves. Ceteris paribus, such an increase in reserves will put upward pressure on the amount of funds $b_{F,t}$ that financiers have to intermediate (eq. 34), and hence put upward pressure on the UIP risk premium (eq. 33). Accordingly, if portfolio investors are pulling out of the home currency (i.e., $b_{P,t}$ is negative in eq. 34), the central bank may want to sell reserves (i.e. set $fx_t < 0$) to defend the currency by leaning against risk premium-induced upward exchange rate pressure.

To gauge the extent to which FX interventions are systematically used in different countries, we estimate the model under two alternative assumptions on the conduct of FX interventions. First, we assume that FX interventions are not systematically related to the state of the economy and follow an exogenous error-correction specification

$$fx_t = \rho_{\Delta R} fx_{t-1} - \rho_R b_{M,t-1} + \varepsilon_{fx,t}, \tag{39}$$

which in levels becomes

$$b_{M,t} = (1 + \rho_{\Delta R} - \rho_R) b_{M,t-1} - \rho_{\Delta R} b_{M,t-2} + \varepsilon_{fx,t}.$$

Hence, by imposing $\rho_{\Delta R} > 0$, the exogenous FX rule allows for persistent yet stationary deviations of the central banks' stock of foreign exchange reserves from its steady state.
Second, we consider an FX intervention rule which allows for the possibility that FX interventions are systematically related to changes in the nominal exchange rate, that is

$$fx_t = \rho_{\Delta R} fx_{t-1} - \rho_R b_{M,t-1} - (1 - \rho_{\Delta R}) \frac{\gamma_{\Delta s}}{1-\gamma_{\Delta s}} \Delta s_t + \varepsilon_{fx,t}. \tag{40}$$

The rule in eq. (40) implies that when $\gamma_{\Delta s} > 0$, a depreciation of the home exchange rate ($\Delta s_t > 0$) will cause a selloff of reserves—that is $fx_t < 0$—which will tend to moderate the depreciationary pressure on the exchange rate.[5] A given sized FX intervention will be more effective when Γ is larger (i.e., when the currency market is shallower). The parameter $\frac{\gamma_{\Delta s}}{1-\gamma_{\Delta s}}$ in front of the exchange rate is intended to capture a very large spectrum of FX regimes; a small value for $\gamma_{\Delta s}$ implies an essentially non-systematic FX policy framework, whereas a value of $\gamma_{\Delta s}$ closer to unity implies a very active policy regime. As will be discussed in Section III.1 in greater detail, the formulation of rule was choosen on empirical grounds: from a normative perspective both the Basu et al. (2020) and Adrian et al. (2021) papers imply that central banks should use FXIs to lean against exogenous movements in the UIP risk premium driven by risk-off/on shocks $\tilde{b}_{P,t}$, but not by other shocks for which exchange rate adjustment is warranted. Even so, consistent with a sizeable empirical literature on the exchange rate disconnect puzzle (see Meese and Rogoff, 1983, Obstfeld and Rogoff, 2001, and Itskhoki and Mukhin, 2021), our estimated model implies that $\tilde{b}_{P,t}$ accounts for a sizeable share of exchange rate fluctuations. Consequently, the endogenous rule eq. (40) is also sensible from a more normative perspective. Finally, in both specifications in eqs. (39) and (40), a shock ($\varepsilon_{fx,t}$) is added to the rules to allow for temporary discretionary actions of the central bank.[6]

The model implies that FX interventions will affect the currency via a portfolio balance channel, but also through interactions with interest rate policy via a signalling channel emphasized by Menkhoff et al. (2021) and by Fratscher et al. (2019). For example, an interest rate tightening communicated by the home central bank will tend to put appreciation pressure on the currency and when FXIs are related to changes in the nominal exchange rate (i.e. $\gamma_{\Delta s} > 0$ in eq. 40), this means that the central bank is expected to take the opportunity to build more FX reserves, which will undo some of that appreciation pressure.[7]

To measure the contribution of central bank reserves and FX interventions to net foreign assets, we compute the contribution of reserves to the net foreign asset position in eq. (32) under the maintained assumption that $\omega_F = \omega_P = \omega$:

$$B_t = \left[(1-\omega)I_{t-1} + \omega I^*_{t-1}\frac{S_t}{S_{t-1}}\right]B_{t-1} - (1-\omega)\left(I_{t-1} - I^*_{t-1}\frac{S_t}{S_{t-1}}\right)B_{M,t-1}, \tag{41}$$

The log-linearized variant of eq. (41) can then be written as

[5] Although we do not explicitly model central banks' preferences, an endogenous FXI rule like eq. (40) will help limit exchange rate volatility in our model, which is one of the key objectives of FXI as Patel and Cavallino (2019) argue based on survey results.

[6] One way to interpret these i.i.d. shocks in the FXI rule is that they allow for deviations from the systematic part of the rule in eq. (40) in case it is in fact optimal to let the exchange rate adjust.

[7] We have also studied the correlation between the smoothed innovations in the interest rate policy rule (eq. 37) and the endogenous FXI rule (eq. 40), but found the average correlation to be close to 0 in both EMEs and AEs.

$$b_t = \frac{\tilde{I}}{1+\pi_D} b_{t-1} \underbrace{- \frac{1-\omega}{1+\pi_D} b_M \left[I i_{t-1} - I^* \Delta_S (i^*_{t-1} + \Delta s_t) - (I - I^* \Delta_S) \pi_{D,t} \right]}_{\text{Revaluation effect}} \underbrace{- \frac{(1-\omega)(I - I^* \Delta_S)}{1+\pi_D} b_{M,t-1}}_{\text{Intervention effect}}, \tag{42}$$

As eq. (42) makes clear, the impact of reserves on the NFA position can be attributed to a revaluation and intervention effect. When a negative risk-off $b_{P,t}$ shock hits the economy and the currrency depreciates, the ”revaluation effect” will typically be benign given that reserves $b_{M,t}$ are kept constant. But if the central bank leans against the depreciation by selling foreign reserves ($\Delta b_{M,t} < 0$), then the less beneficial revaluation effect will offset the positive “interaction effect” stemming from the fact that the FX reserve sell-off brings domestic capital to the home economy and thereby strengthens the NFA position.

Which of these two effects dominates will largely depend on the calibration of the steady state stock of reserves b_M and $I - I^* \Delta_S$.[8] We will use eq. (42) to dynamically assess the contribution of central bank reserves to net foreign assets following various shocks, and to measure the cost of an FX intervention as the evolution of b_t when $b_{M,t}$ changes (i.e., when b_t reflects both revaluation and intervention effects) against a counterfactual simulation, in which $b_{M,t} = 0$ for all t (so that movements in b_t only reflect revaluation effects driven by $b_M > 0$).

Government expenditure g_t in eq. (1) is assumed to follow an exogenous AR(1) process:

$$g_t = \rho_g g_{t-1} + \varepsilon_{g,t}. \tag{43}$$

The steady-state level of g is financed by labor income taxes, but any variations in government spending around its steady state are assumed to be paid for via lump-sum taxes. Since Ricardian equivalence holds, this simplifying assumption allows us to abstract from dynamic aspects of fiscal policy.

II.5. The Foreign Economy

The foreign economy is essentially a closed economy variant of the model described above, and consists of the following equations (see e.g. Erceg and Linde, 2013):

$$y^*_t = \left(1 - g^*_y\right) c^*_t + g^*_y g^*_t, \tag{44}$$

$$\lambda^*_{c,t} = \delta^*_c \lambda^*_{c,t+1} + r^*_t, \tag{45}$$

$$\lambda^*_{c,t} = -\frac{1}{\hat{\sigma}^*} \left(c^*_t - \varkappa^*_c c^*_{t-1} - \upsilon^*_{c,t} \right) \tag{46}$$

[8] Notice that equation $(\mathrm{A}.21)$ implies that the effective interest rate differential equals $I - I^* \Delta_S = \Gamma I b_F$ which is positive if funds intermeditated by financiers $b_F > 0$ in the steady state.

$$\pi_t^* - \iota_p^* \pi_{t-1}^* = \beta^* \delta_c^* \left(\pi_{t+1|t}^* - \iota_p^* \pi_t^*\right) + \kappa_p^* \left(\zeta_t^* + \frac{\alpha^*}{1-\alpha^*} y_t^*\right) + \varepsilon_{\pi,t}^* \quad (47)$$

$$\zeta_t^* = \zeta_{t-1}^* + \pi_{w,t}^* - \pi_t^* \quad (48)$$

$$\pi_{w,t}^* - \iota_w^* \pi_{w,t-1}^* = \beta^* \delta_c^* (\pi_{w,t+1|t}^* - \iota_w^* \pi_{w,t}^*) + \kappa_w^* (\lambda_{mrs}^* y_t^* - \lambda_{c,t}^* - \zeta_t^*) + \varepsilon_{w,t}^* \quad (49)$$

$$i_t^* = \max\left\{-i^*, (1-\gamma_i^*)\left[(1+\gamma_\pi^*)\pi_t^* + \gamma_y^* y_t^*\right] + \gamma_i^* i_{t-1}^* + \varepsilon_{i,t}^*\right\} \quad (50)$$

where $\hat{\sigma}^*$, λ_{mrs}^*, κ_p^*, and κ_w^* are composite parameters defined as:

$$\hat{\sigma}^* = \sigma^*(1 - \varkappa^*), \quad (51)$$

$$\lambda_{mrs}^* = \frac{\chi^*}{1-\alpha^*}. \quad (52)$$

$$\kappa_p^* = \frac{(1-\xi_p^*)(1-\beta^*\xi_p^*)}{\xi_p^*}, \quad (53)$$

$$\kappa_w^* = \frac{(1-\xi_w^*)(1-\beta\xi_w^*)\phi_w^*}{\xi_w^*(\chi^*(1+\phi_w^*)+\phi_w^*)}, \quad (54)$$

$$\lambda_{mrs}^* = \frac{\chi^*}{1-\alpha^*}. \quad (55)$$

All variables are measured as percent or percentage point deviations from their steady state levels.[9] In addition, g_t^* is a foreign government spending shock, $\upsilon_{c,t}^*$ is a foreign consumption demand shock, $\varepsilon_{\pi,t}^*$ and $\varepsilon_{w,t}^*$ are price and wage cost-push shocks, whereas $\varepsilon_{i,t}^*$ is a monetary policy shock, while π^* denotes the inflation target. Both g_t^* and $\upsilon_{c,t}^*$ are assumed to follow stochastic AR(1) processes, whereas the cost-push and monetary policy shocks are assumed to be white noise.

III. Model Estimation

The model is estimated on quarterly data for 17 small open economies individually. These comprise 12 emerging market economies and 5 small open advanced economies, all of which have adopted flexible inflation targeting with interest rates as the primary monetary policy tool. Following Smets and Wouters (2003, 2007), Bayesian techniques are adopted to estimate the parameters. Bayesian inference starts out from a prior distribution that describes the available information prior to observing the data used in the estimation. The observed data is subsequently used to update the prior, via Bayes' theorem, to arrive at a posterior distribution of the model's parameters, which can be summarized using standard measures of location (e.g., mode or mean) and spread (e.g., standard deviation and probability intervals).

[9] We use the notation $y_{t+j|t}$ to denote the conditional expectation of a variable y at period $t+j$ based on information available at t, i.e., $y_{t+j|t}$ = E $_t y_{t+j}$.

Below we first list the countries that we have estimated the model on and the observables we include in the estimation for any given country. Section III.2 presents the priors we have adopted for each country. We also describe in some detail the implications of our priors for the propagation of a shock $b_{P,t}$ to foreign portfolio investors' demand for domestic currency in eq. (34), which is akin to a UIP risk premium shock. Next, in Section III.3 we present the estimation results.

III.1. Countries and Data

Table 1 lists the countries and sample periods included in the estimation. As noted previously, we include 12 emerging economies and 5 small open advanced economies, all of which practice flexible inflation targeting with the short-term interest rate as their main monetary policy tool.[10] These five small open economies effectively serve as a control group, allowing us to verify that our estimation procedure classifies them as having deep currency markets and not relying on systematic FX interventions.

Table 1. Countries and Sample Periods included in Estimation

Emerging Market Economies		Advanced Economies	
Brazil	1998Q1-2022Q1	Australia	1994Q1-2022Q1
Chile	2000Q1-2022Q1	Canada	1992Q2-2022Q1
Colombia	2005Q1-2022Q1	New Zealand	1999Q3-2022Q1
Indonesia	2003Q4-2022Q1	Norway	2003Q2-2022Q1
Kazakhstan	2003Q1-2022Q1	Sweden	1997Q1-2022Q1
Malaysia	2000Q4-2022Q1		
Mexico	2003Q1-2022Q1		
Peru	2003Q3-2022Q1		
Philippines	2000Q2-2022Q1		
South Africa	2002Q2-2022Q1		
Thailand	2000Q4-2022Q1		
Turkey	2003Q1-2019Q4		

For each of the countries, estimation proceeds in two steps. First, we estimate a foreign bloc (a closed economy with 5 observables and shocks) using data from the U.S. The shocks and observables included in the foreign bloc are listed in Panel B in Table 2.[11] Since in the model

[10] Of course, during the global financial crisis and its aftermath, and during the COVID pandemic some of the advanced economies undertook large scale asset purchases of domestic government bonds to lower term premiums, but neither one of them intervened in foreign exchange markets.

[11] For convenience we list an observable and shock in the same row in the table, but the shock is not to be interpreted to be a key determinant of the observable in a given row.

the domestic economy is assumed to be small relative to the large foreign economy, it is without loss of estimation efficiency to pre-estimate the foreign economy parameters and keep them fixed for each small open domestic economy. And had we estimated both the domestic and foreign economy parameters jointly, the estimation results would have been unaffected.[12]

Next, contingent on the posterior mean parameters for the foreign economy, the domestic economy bloc is estimated. The latter comprises 10 observables and 11 structural shocks, all of which are summarized in Panel A of Table 2.

Table 2. All Observables and Shocks Used in Estimation

Panel A: Domestic Economy			Panel B: Exogenous Foreign Economy		
Observables	**Shocks**		**Observables**	**Shocks**	
Output gap	$\upsilon_{c,t}$	Domestic demand	Output gap	$\upsilon_{c^*,t}$	Domestic demand
Core inflation	$\vartheta_{m,t}$	Import demand	Core inflation	$\varepsilon_{\pi^*,t}$	Domestic price mark-up
Real exports	$\vartheta_{m^*,t}$	Export demand	Nominal wage growth	$\varepsilon_{w^*,t}$	Wage mark-up
Real imports	$\varepsilon_{\pi,t}$	Domestic price mark-up	Real government expenditure	$\varepsilon_{i^*,t}$	Interest rate policy
Real government expenditure	$\varepsilon_{m,t}$	Import price mark-up	Policy rate	g_t^*	Government spending
Nominal wage growth	$\varepsilon_{w,t}$	Wage mark-up			
Real exchange rate	$b_{p,t}$	Global risk appetite			
Policy rate	$\varepsilon_{\psi,t}$	Domestic term premium			
Long-term interest rate	$\varepsilon_{i,t}$	Interest rate policy			
Foreign exchange intervention	g_t	Government spending			
	$\varepsilon_{fx,t}$	FXI			

Notes: Core inflation data is taken from the WEO database. Quarterly foreign exchange intervention data is based on Adler et al. (2021). The remaining domestic observables are from Haver Analytics. The foreign observables – approximated by the U.S. economy – are calculated based on seasonally adjusted real U.S. gross domestic product, real government consumption expenditures and PCE less food & energy, nonfarm business sector hourly compensation, and the federal funds rate (% p.a.). All the data used in the estimation are available upon request.

As we can see from Panel A in Table 2, the data for the domestic economy includes real GDP, real government expenditure, real imports and exports, core inflation, wage inflation, the policy rate, a long-term interest rate represented by the 10-year government bond yield, the real exchange rate, and a measure of FXI. Since our model does not include supply-side shocks, which can explain the upward trend in real GDP and its components, we detrended all quantities (in logs) using the GDP trend approximated by the HP filter with a smoothing parameter of 6400. By deducting the same trend based on GDP for all quantities, we ensure that the relative fluctuations and correlations remain unaffected by the detrending. Below we refer to detrended GDP as the output gap, with the implicit understanding that this series essentially measures output as deviation from trend. All the nominal variables including interest rates and price and wage inflation are left untouched, and their sample means are matched by their model consistent (calibrated) steady state levels. Consistent with the stationarity assumption of the real exchange rate in the model, we measure it as a percent deviation from its sample mean. As we choose the U.S. as the representative foreign economy, we also include U.S. variables as observables in the estimation and calculate the real exchange rate based on the bilateral

[12] Still, when we estimate the domestic economy, we include the foreign variables as observables to ensure that the estimation results for the domestic economy incorporate information about the foreign business cycle.

exchange rate vis-à-vis the U.S. dollar. FXI is taken from the quarterly broad estimates from Adler et al. (2021) and divided by trend GDP measured in U.S. dollars (calculated using an HP filter with the smoothing parameter λ set to 6400).[13]

Figure 2. Key Macroeconomic Variables Included in Estimation

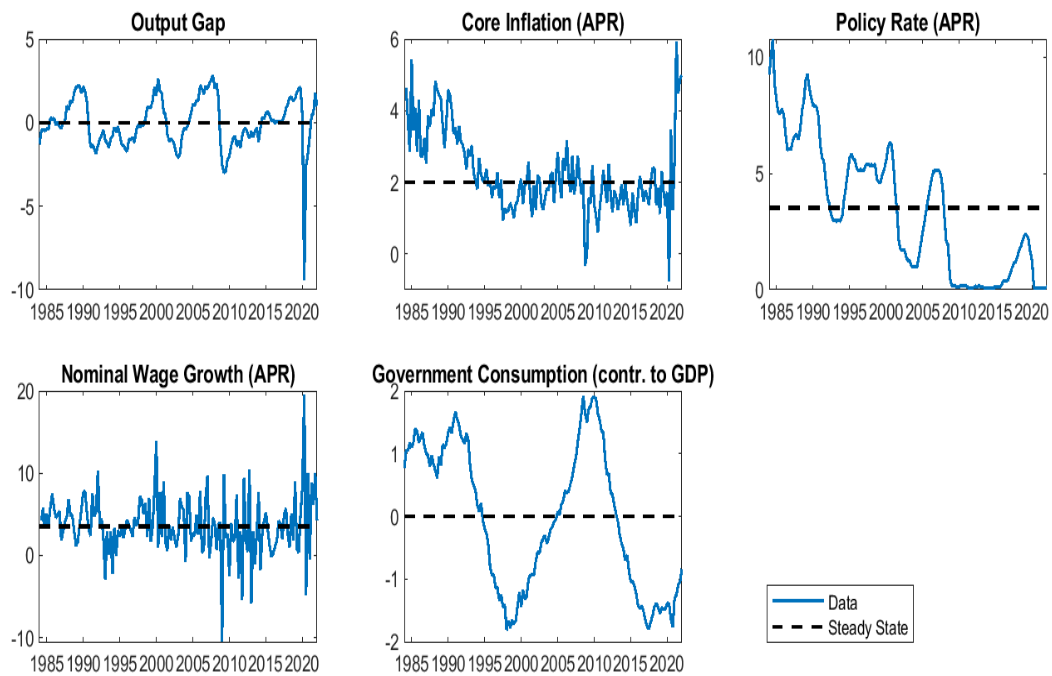
To get a better sense of some key observables and their behavior in emerging markets versus our control group of advanced economies, Figure 2 compares some of the macroeconomic

[13] Many countries still do not publish official FXI data despite the growing transparency of FXI operations over time. Adler et. al. (2021) construct proxies for FXI at the quarterly frequency based on BOP data whenever available, and based on the change in the stock of reserves adjusted for valuation effects if BOP data is not available.

observables in EMEs and AEs. On average, output is more volatile in EMEs compared to AEs. Core CPI inflation also has a higher volatility in EMEs, although in recent years volatility has declined. AEs had on average lower policy rates, and in many of them the rates approached their effective lower bounds during the sample period. The real exchange rate appears to be volatile for both groups, while FX interventions were notably bigger in EMEs relative to AEs. Interestingly, FX interventions appear to be largely unsynchronized across EM economies.

Figure 3 depicts the U.S. variables included in the estimation. We measure the variables in the U.S. economy in the same way as described above for the domestic economy case. We see that the COVID pandemic implied a large temporary negative deviation of output from trend, and that the contribution of government consumption to GDP started to rise following the acute phase of the pandemic. As the focus is not on the US economy, we, for simplicity, estimate using the actual US federal funds rate without imposing the ZLB. But we checked that replacing the actual federal funds rate with a measure of an unconstrained shadow rate yielded similar results.

Figure 3. U.S. Variables Included in the Estimation



The model is estimated under two alternative specifications for FXI for each country in our sample. In the first specification, we assume that FXI is not systematically related to any macroeconomic variable and is only characterized by an exogenous AR(1) process with a small error correction term to ensure stationarity of central bank FX reserves. Notice that this specification approximates a unit root specification of FXIs as a special case. Even so, a unit root specification for FXI (i.e., the change in CB FX reserves) is at odds with the empirical evidence suggesting that FX reserves as share of GDP appear to be roughly stationary in most countries. We will henceforth refer to this rule as the exogenous FXI rule. In the second specification, we replace the exogenous process with an endogenous rule that responds systematically to the current state of the economy. After running a correlation analysis between FX interventions and alternative macroeconomic variables included in our model, and after experimenting with alternative explanatory variables – like the lagged change in the nominal exchange rate or the real exchange rate – we found that the current change in the nominal exchange rate provided the best explanation of variations in FX interventions when estimating the full model.[14] The coefficient determining the strength of interventions to changes in the exchange rate is estimated jointly with other parameters. We will refer to this as the endogenous FXI rule. As described in Section II.4, both the exogenous and endogenous FXI rule specifications in eqs. (39) and (40) include an error correction term where the coefficient $\rho_{fx,2}$>0 ensures that FX reserves go back to the steady state in the long run.

III.2. Priors

Following standard practice in the estimation of DSGE models, see e.g. Adolfson et al. (2007), Christiano, Eichenbaum and Evans (2005), and Smets and Wouters (2003, 2007), we estimate the parameters that we think are well-identified by the observable series, and calibrate (i.e., impose strict priors) for parameters that we believe are either not well-identified or would just capture the sample means of certain series had they been included. To save space, the calibrated parameters are reported in Appendix B (Tables B.1 and B.2). The steady-state ratios of government expenditure, exports, imports, and central bank FX reserves to GDP, are calibrated to reflect the country-specific sample averages. The steady states of price and wage inflation, as well as interest rates, are consistent with countries' official inflation targets and sample averages. The few calibrated values of parameters affecting behavior are in line with the existing empirical literature. For example, the intertemporal elasticity of substitution in consumption is set to 1, the Frisch elasticity of labor supply is set to 0.5, and the capital income share in the Cobb-Douglas production function equals 0.33. The export and import relative price elasticities are calibrated at 0.8. Consistent with Adrian et al. (2021), the ownership share of financial intermediaries is set to 0.8 for all countries, and the steady-state net foreign asset (NFA) position for EMEs is calibrated to be -22.5 percent of GDP (i.e., emerging markets are assumed to have the same liabilities in the steady state), reflecting their sample average. For the advanced economies, we set the NFA position to nil.

The priors for the 35 estimated parameters, which mostly pertain to the nominal and real frictions (12), policy rule parameters (6), as well as the exogenous shock processes (6

[14] Among other variables, we experimented by including the risk off/on shock ($b_{P,t}$ in eq 34) in levels and in first differences in the rule instead of the change in the nominal exchange rate and obtained a notable reduction in the log marginal likelihood for most economies relative to our final specification.

persistence parameters and 11 standard deviations of innovations), are provided in Table 3. The first three columns in the table show the assumptions for the prior distribution of the estimated parameters, with the prior specifications similar to those used in the existing literature. We use the beta distribution for all parameters bounded between 0 and 1.[15] For parameters assumed to be positive, we use the inverse gamma distribution. The exact location and uncertainty of the prior is reported in the table. For a more comprehensive discussion of choices regarding the prior distributions we refer the reader to the papers listed above that we largely follow.

Importantly, the priors are identical for all economies, so any differences in the posterior distributions will be entirely driven by differences in the data, as well as differences in calibrated parameters for government spending, trade shares, size of central bank reserves, and the assumption of positive net foreign liabilities for EMEs.

To show that the priors do not impose differences among EMEs and AEs for the propagation of shocks $b_{P,t}$ to foreign portfolio investors' demand for domestic currency in eq. (34), we now describe in some detail the implications of our priors for the propagation of outflow realizations, which cause the domestic currency to depreciate and the UIP risk premium to rise. We conduct a prior analysis following Del Negro and Schorfheide (2008). Specifically, contingent on the calibrated parameters, we sample 10,000 draws from the prior of all estimated parameters in Table 3, and we compute the impulses to a risk-off foreign portfolio investors shock. We then plot the 90th, 95th and 99th percentiles along with the median response from the sample of 10,000 impulse response functions for each period t=1,2,…,20 in Figure 4. The first two columns in the figure show results for an EME economy in the variant of the model with exogenous (first column) FX interventions (eq. 39) and endogenous (second column) endogenous FXI rule (eq. 40), whereas the last two columns report the corresponding results for a typical advanced economy.[16]

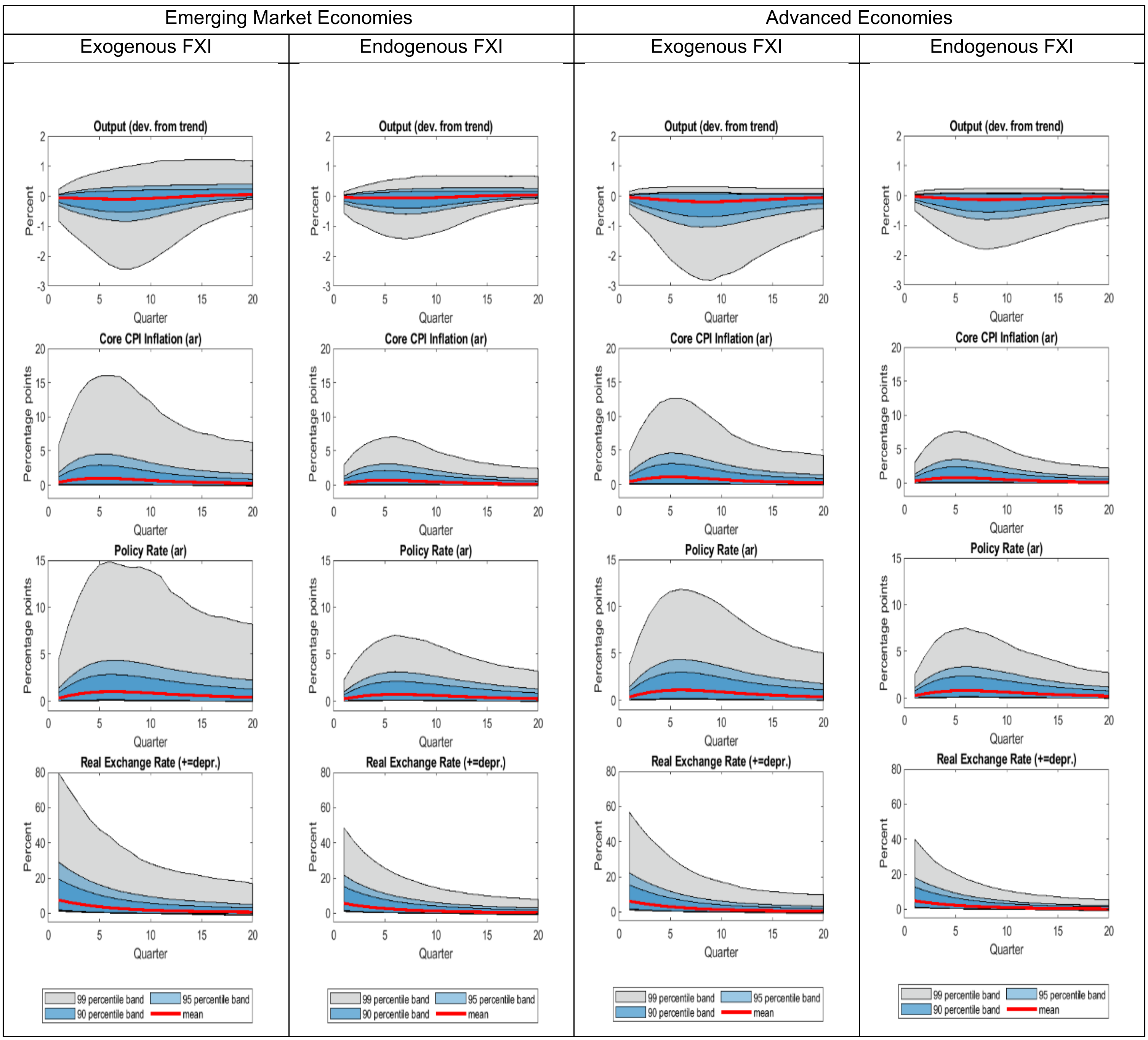
There are many interesting features of the simulated impulse distributions in Figure 4, though here we only highlight the two key ones. First, by comparing the EME impulses with their AE counterparts, we see that our assumed priors and calibrated parameters in no way impose the responses to a risk-off shock (i.e., depreciated domestic exchange rate) to have contractionary effects in EMEs and expansionary effects in AEs. If anything, the prior suggests that such shocks may be associated with even sharper contractionary effects in AEs compared to EMEs. This implies that if we find that depreciations are associated with a larger contraction in output in EMEs, it is not a finding driven by the prior but rather by the information in the data (likelihood). Second, comparing the columns corresponding to exogenous FX Intervention (i.e., no

[15] The only exception is the behavioral parameter δ_c. For this parameter we impose a conservative truncated normal prior centered around 0.985 with standard error 0.0075 so that rational expectations can be obtained as a special case in the estimation of the model.

[16] The two economies used as examples to show how the risk-off shock propagation can differ between typical EMEs and AEs in Figure 4 were chosen since they both have relatively large trade shares.

systematic intervention) with their “endogenous” counterparts reveals that leaning against the depreciation by selling off some FX reserves improves the output-inflation trade-offs following an adverse outflow shock. This is not surprising given that the prior for the FX market depth parameter, Γ, is centred around 0.05, which implies that FX interventions can have a sizeable impact. With deep markets we would expect a notably lower estimate of this key parameter and in this case the effectiveness of an FX intervention would be correspondingly pared down.

Figure 4. Prior Distributions



III.3. Estimation Results

Given the calibrated parameters in Tables B.1 and B.2 in Appendix B and the priors in Table 3, we obtain the joint posterior distribution mode for the parameters in Table 3 in two steps. First, the posterior mode and an approximate covariance matrix, based on the inverse Hessian matrix evaluated at the mode, are obtained by numerical optimization on the log posterior density for each country. Second, the posterior distribution is subsequently explored by generating draws using the Metropolis-Hastings algorithm in separate chains. The proposed distribution is taken to be the multivariate normal density centered at the previous draw with a covariance matrix proportional to the inverse Hessian at the posterior mode; see Schorfheide (2000) and Smets and Wouters (2003) for further details. The results in Table 3 show the averages of all EMEs' and AEs' posterior means for all the estimated parameters. The standard deviations measure the dispersion of the posterior among the 12 EMEs and 5 AEs.[17]

Table 3. Prior and Posterior

Parameter		Prior distribution			Posterior distribution							
					Endogenous FXI rule				Exogenous FXI rule			
		type	mean	std. dev.	EMEs		AEs		EMEs		AEs	
					average	std	average	std	average	std	average	std
Calvo parameter for import prices	ξ_m	beta	0.75	0.05	0.77	0.08	0.85	0.08	0.77	0.07	0.85	0.08
Calvo parameter for export prices	ξ_x	beta	0.75	0.05	0.85	0.07	0.89	0.08	0.84	0.07	0.89	0.09
Calvo parameter for domestic prices	ξ_p	beta	0.75	0.05	0.92	0.03	0.84	0.04	0.92	0.03	0.84	0.03
Calvo parameter for wages	ξ_w	beta	0.75	0.05	0.72	0.07	0.79	0.07	0.72	0.07	0.79	0.08
Imported goods price indexation	ι_m	beta	0.7	0.2	0.74	0.16	0.73	0.23	0.77	0.15	0.79	0.22
Domestic price indexation	ι_p	beta	0.7	0.2	0.48	0.26	0.54	0.21	0.48	0.27	0.58	0.25
Exported goods price indexation	ι_x	beta	0.7	0.2	0.66	0.17	0.79	0.25	0.66	0.15	0.79	0.25
Wage indexation	ι_w	beta	0.7	0.2	0.57	0.29	0.36	0.37	0.55	0.30	0.33	0.36
Wage sensitivity to exchange rate	ν	beta	0.1	0.05	0.05	0.03	0.00	0.00	0.05	0.04	0.00	0.00
Habit formation	$\varkappa_c$	beta	0.7	0.15	0.37	0.18	0.23	0.06	0.37	0.18	0.22	0.05
Discount factor	δ_c	norm	0.985	0.0075	0.97	0.00	0.97	0.01	0.97	0.00	0.97	0.01
FX market friction	Γ	beta	0.05	0.0125	0.03	0.02	0.02	0.01	0.01	0.01	0.02	0.00
Domestic riskpremium shock persistence	ρ_ψ	beta	0.75	0.1	0.75	0.08	0.83	0.07	0.75	0.08	0.83	0.06
Consumption demand shock persistence	ρ_υ	beta	0.85	0.05	0.91	0.03	0.94	0.02	0.91	0.03	0.95	0.02
Govt. expenditure shock persistence	ρ_g	beta	0.85	0.05	0.85	0.05	0.92	0.04	0.85	0.05	0.92	0.04
Import demand shock persistence	ρ_m	beta	0.85	0.05	0.80	0.06	0.81	0.04	0.81	0.06	0.81	0.04
Export demand shock persistence	ρ_{m^*}	beta	0.85	0.05	0.86	0.05	0.93	0.03	0.86	0.04	0.93	0.03
Exchange riskpremium shock persistence	ρ_{b_p}	beta	0.85	0.05	0.91	0.03	0.91	0.02	0.92	0.03	0.90	0.01
Consumption demand shock	σ_c	invgamma	0.5	200	3.55	1.26	2.50	0.54	3.49	1.28	2.38	0.57
Import markup shock	σ_{π_m}	invgamma	0.1	200	0.51	0.72	0.55	0.23	0.52	0.69	0.47	0.33
Domestic markup shock	σ_π	invgamma	0.1	200	0.51	0.34	0.42	0.36	0.52	0.33	0.47	0.33
Wage markup shock	σ_{π_w}	invgamma	0.1	200	1.86	1.01	0.71	0.42	1.84	1.00	0.70	0.43
Domestic riskpremium shock	σ_ψ	invgamma	0.1	200	1.32	0.67	0.48	0.11	1.33	0.60	0.48	0.10
Govt. expenditure shock	σ_g	invgamma	0.5	200	3.31	1.82	1.03	0.13	3.31	1.81	1.03	0.13
Import demand shock	σ_m	invgamma	1	200	4.95	1.11	3.23	1.04	4.96	1.08	3.20	1.07
Export demand shock	σ_{m^*}	invgamma	1	200	30.03	18.21	17.06	8.56	30.16	18.31	17.02	8.45
Exchange riskpremium shock	σ_{b_p}	invgamma	1	200	0.82	0.19	0.78	0.18	0.76	0.27	0.82	0.15
Interest rate policy shock	σ_i	invgamma	0.1	200	0.17	0.14	0.08	0.02	0.17	0.14	0.07	0.02
FXI policy shock	σ_{fx}	invgamma	1	2	6.00	6.93	2.01	1.05	4.52	3.20	1.85	0.92
Interest rate reaction to CPI inflation	γ_π	norm	0.5	0.34	0.62	0.19	1.10	0.26	0.69	0.27	1.19	0.26
Interest rate reaction to output gap	γ_y	beta	0.125	0.05	0.09	0.04	0.10	0.08	0.09	0.04	0.07	0.03
Interest rate smoothing	γ_i	beta	0.75	0.05	0.82	0.05	0.85	0.05	0.82	0.05	0.84	0.04
FXI response to change in exchange rate	$\gamma_{\Delta S}$	beta	0.5	0.125	0.45	0.29	0.13	0.06				
FXI persistence	$\rho_{\Delta R}$	beta	0.5	0.15	0.45	0.13	0.25	0.06	0.36	0.08	0.19	0.05
FXI rule error correction	ρ_R	beta	0.05	0.025	0.02	0.01	0.04	0.02	0.02	0.01	0.05	0.02

Note: For EMEs, the average refers to the average of the 12 posterior means, and std refers to the standard deviation of the 12 posterior means. The same applies to the 5 advanced economies.

[17] In Tables B.3-B.5 in Appendix B we report the posterior mean for all the estimated parameters along with the approximate posterior standard deviation obtained from the Metropolis-Hastings chain for each country.

The estimates point to significant differences in structural characteristics across the economies considered. For EMEs, on average, domestic prices are stickier (higher ξ_p), wages have higher indexation (higher ι_w) and are more sensitive to the exchange rate (higher ν). This increases the likelihood and severity of the wage-price spiral that creates persistently high inflation following currency depreciations. Import prices are more flexible (ξ_m) in EMEs, consistent with a higher degree of dominant (or producer) currency pricing in their imports. The shocks hitting EMEs are larger, in particular shocks to components of GDP, domestic and wage inflation, and the domestic risk premium.

The interest rate reaction function coefficients in Table 3 are largely similar for EMEs compared to AEs, with the exception of the response coefficient on inflation, which is noticeably lower in EMEs, suggesting the use of other instruments (or lower priority) to fight inflation and anchor inflation expectations. Moreover, we notice that the average posterior for σ_i in AEs is notably lower (0.08) compared to EMEs (0.17). This implies that the fit of the policy rule as measured by adjusted R2s is somewhat better in AEs (0.967) relative to EMEs (0.909) on average.[18] Thus, while the simple rule fits somewhat better for AEs than the typical EME country, the estimates suggest that many EMEs have made good progress in adopting IT policy rules in policy formulation, consistent with the empirical work of Brandao-Marquez et al. (2020).

An important finding is that the mean value of the inverse of market depth parameters Γ is notably higher in EMEs than in AEs, provided that we allow for a systematic response of FX interventions to currency movements. Even so, the standard deviation indicates that there is noticeable dispersion in this parameter in EMEs, while in AEs the value is quite similar for the five included countries. Another interesting feature is that in the variant of the model which does not allow for an endogenous FXI rule, and instead assumes that FXI movements are unrelated to exchange rate, we find that EMEs FX markets are indeed deeper than the five AEs on average. This finding highlights the key importance of properly accounting for systematic FX interventions when assessing market depth. This, in turn, also implies that a precise measure of FX interventions is critical when assessing historical levels of market depth. The findings in Table 3 also beg the question if the model with an endogenous FXI rule has a higher log-marginal likelihood than the variant with non-systematic FXIs.

To shed more light on this issue, Table 4 compares model fit under the two alternative specifications. It shows that the model with systematic FX interventions fits the data better for more than half of the EMEs, but not for any of the AEs in the sample. On the contrary, for the AEs, the exogenous FXI specification always fits better. We highlight in bold the individual best-fitting models where the improvement in log marginal likelihood is substantial according to the Bayesian posterior odds ratio (assuming that both model variants are a priori equally likely), taking into account the well-known problem that the Bayesian posterior odds tend to concentrate on a single model, which implies that only sufficiently large differences in LML

[18] There is, however, notably more dispersion in the interest rate rule fit in EMEs than for the AEs. In the five AEs, the adjusted R2 is in no case lower than 0.93, whereas the lowest value among the 12 EMEs is about 0.75.

should be indicative of one model specification outperforming the other. Following the advice in Kass and Raftery (1995) and the DSGE implementation in Oelrich et al. (2020), we use a conservative yardstick and interpret a difference exceeding 10 as strong evidence for one variant relative to the other. According to this criterion, EME 3, 4, 5, 6 and 12 are countries where data strongly favor an endogenous (systematic) FXI rule to the non-systematic alternative, whereas AE4 is a country where the data strongly point towards an exogenous FXI rule. We also see that allowing for a systematic FX intervention rule can significantly affect the estimated market depth parameter Γ. In particular, when we find evidence in favor of a systematic FX intervention rule (i.e., large LML gains associated with $\gamma_{\Delta s}/(1-\gamma_{\Delta s})\,\Delta s_t$ in eq. 40), we see that the FX market is typically estimated to be notably shallower. Again, this highlights that accounting for endogeneity issues when assessing market depth is critical. Expressed alternatively, one cannot simply infer market depth from various past currency markets spreads, as those spreads may have been kept small by past systematic foreign exchange market interventions undertaken by the central bank.

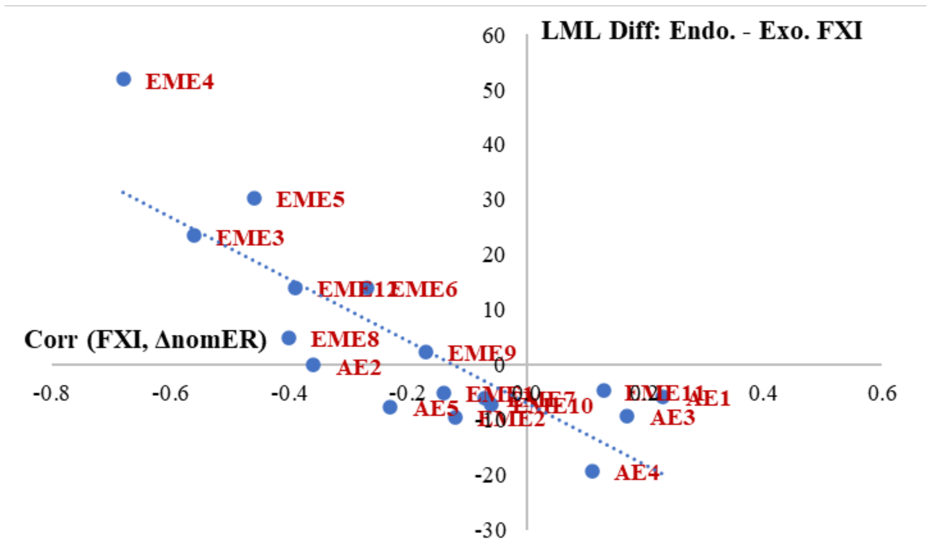
Table 4. Comparison of Model Estimates with Different FXI Specifications

	LML		Γ		$\gamma_{\Delta s}/(1-\gamma_{\Delta s})$	$\rho_{\Delta R}$	σ_{fx}
	Endogenous	Exogenous	Endogenous	Exogenous	Endogenous	Endogenous	Endogenous
EME1	-2241.21	-2236.23	0.035	0.029	0.20	0.59	1.35
EME2	-2106.46	-2097.06	0.023	0.020	0.20	0.39	3.19
EME3	**-2541.52**	-2565.02	0.008	0.006	2.26	0.42	5.61
EME4	**-2461.10**	-2512.96	0.060	0.007	6.04	0.53	5.86
EME5	**-2300.37**	-2330.63	0.045	0.009	4.80	0.38	8.60
EME6	**-2565.04**	-2579.08	0.042	0.006	12.75	0.40	26.91
EME7	-2001.87	-1995.90	0.035	0.028	0.26	0.50	1.96
EME8	-2786.25	-2791.23	0.009	0.007	0.58	0.23	6.62
EME9	-2076.38	-2078.84	0.027	0.019	0.49	0.31	3.52
EME10	-2093.22	-2086.01	0.017	0.008	0.31	0.73	1.83
EME11	-2609.22	-2604.50	0.022	0.018	0.35	0.50	3.40
EME12	**-2920.16**	-2934.15	0.038	0.021	0.48	0.45	3.17
EMEs mean			***0.030***	***0.015***	***2.39***	***0.45***	***6.00***
AE1	-2358.92	-2353.14	0.033	0.021	0.26	0.30	3.30
AE2	-2506.03	-2506.02	0.015	0.014	0.21	0.15	2.32
AE3	-2034.56	-2025.36	0.025	0.022	0.15	0.28	2.47
AE4	-2796.33	**-2777.12**	0.025	0.024	0.04	0.24	0.56
AE5	-2791.96	-2784.31	0.024	0.022	0.12	0.30	1.40
AEs mean			***0.024***	***0.021***	***0.16***	***0.25***	***2.01***

Note: The coefficients in the table are defined in Table 3 and discussed in more detail in eqs. (34) and (40). LML denotes log marginal likelihood. Notice also that countries in this table are not ordered as in Table 1, i.e. the mapping of countries in Table 1 to Table 4 cannot be inferred from the two Tables.

Moreover, it is important to understand that the estimated market depth parameter Γ is not driven by the fact that FXIs are more volatile in EMEs than in AEs as can been seen from Figure 1. Rather, Γ is identified as it shapes the transmission of all shocks in the model. For instance, when Γ is low (FX markets are "deep"), a consumption demand shock $\upsilon_{c,t}$ which drives up domestic absorption will tend to increase inflation and put upward pressure on real rates. Higher real rates in the small open economy relative to the rest of the world will appreciate the real producer exchange rate $q_{p,t}$ via the UIP condition (eq. 33), and also the consumption-based RER $q_{c,t}$. However, when FX markets are estimated to be "shallow" (Γ is higher), stronger domestic consumption demand worsens the NFA position as the trade balance deteriorates and puts depreciationary pressure on the RER.

Figure 5. Difference in Log Marginal Likelihood versus Correlation between FXI and NER Change



The correlation between FXI and nominal exchange rate changes seems to be a good predictor for the best-fitting model—countries where LML is in favor of the endogenous FXI rule specification also tend to be countries where FXI correlates more strongly with the change in the nominal exchange rate. Figure 5 shows a clear relationship between the improvement in model fit on the y-axis (which plots the difference in LML between the variant of the model with an endogenous FXI rule and the variant with an exogenous FX rule) and the correlation between FXI and nominal exchange rate change on the x-axis. In other words, for countries with a strong negative correlation between FX interventions and changes in the exchange rate, our estimation procedure is more likely to suggest systematic interventions moderating exchange movements. Still, we find exceptions to this general prediction: for instance, AE2 has a more negative correlation between FX interventions and changes in the exchange rate (almost -0.4) than EME6 (about -0.3), yet we find no evidence in favor of an endogenous FXI rule for AE2, in contrast to EME6 where that evidence is strong.

All told, considering the country-specific best-fitting models, it is clear that more EMEs—but by far not all—have shallower FX markets than the five small open AEs used as a control group. In our model, this means that FX interventions have more traction in some of the EMEs which may therefore warrant more frequent use of FXIs. Consistent with this empirical finding, our estimation results also suggest that many EMEs use FXIs systematically, more forcefully (as indicated by a larger response coefficient), and that these interventions are more persistent (as indicated by a higher autocorrelation coefficient). That said, even if the systematic component can explain a large part of FX interventions in the data, the unexplained component still accounts for a large share in EMEs—and an even larger one in AEs—as shown by the large standard error of FXI shocks. In the next section, we thus explore how different country-specific frictions and the conduct of FXI affect the transmission of shocks and policy responses.

IV. Posterior Predictive Analysis

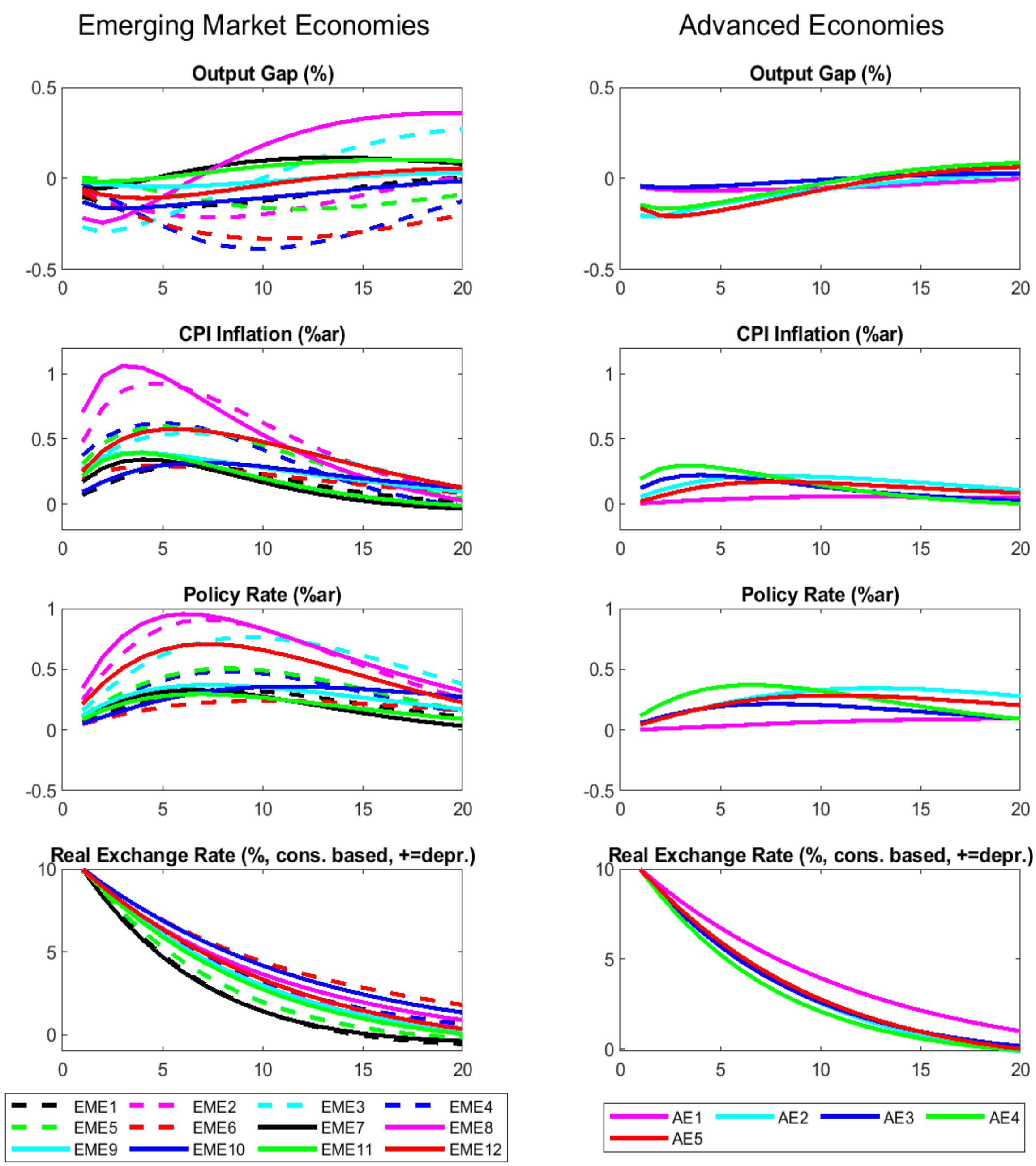
In this section, we undertake posterior predictive analysis with the country-specific models. We focus on impulse response function (IRF) analysis to understand and quantify shock transmission channels and policy tradeoffs. Our focus on policy tradeoffs leads us to focus on shocks that drive unexpected large depreciations of the currency, and that necessitate monetary policy interventions in the form of short-term interest rate changes and FX interventions.[19] In what follows, we always use the best-fitting model specification to construct the IRFs for any given country.

IV.1. Transmission of Foreign Investors Portfolio Outflow Shocks

To begin with, we study the impact of a portfolio investors' outflow shock, i.e., a negative realization of $\tilde{b}_{P,t}$ in eq. (34b). This shock is akin to a UIP risk premium shock in our model and while it has a country-specific standard deviation and propagation, we size the shock so that it induces the real exchange rate to depreciate by 10 percent in all countries. We report the results of this experiment in Figure 6. In the figure, the left column reports results for the 12 EMEs, and the right columns report the results for the 5 AEs. While for each economy we use the posterior parameters which maximize the LML, we set the coefficient $\gamma_{\Delta s}$ = 0 in the rule in eq. (40) whenever the best-fitting model features an endogenous FXI rule. We do this mainly to get a sense of exchange rate pass-through and policy tradeoffs for monetary policy in case a tightening by raising the policy rate is the only option. So for all countries in Figure 6, FXI=0 always.

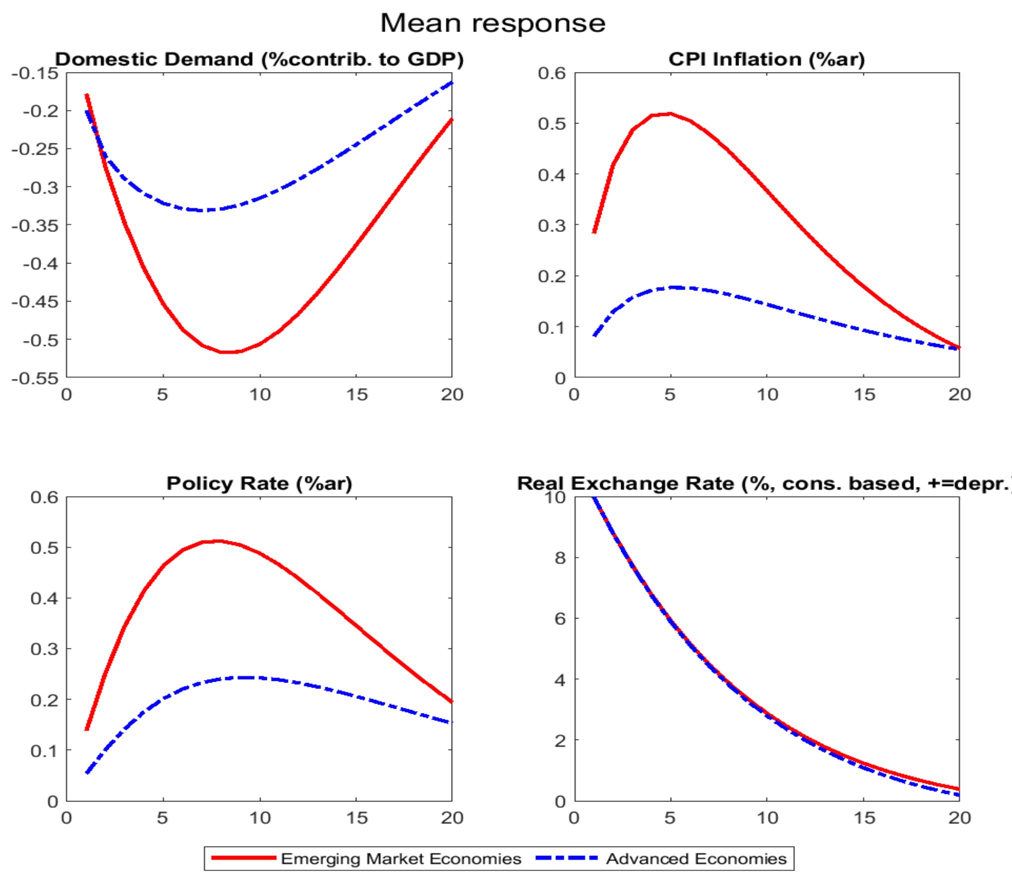
[19] In a rich model like ours, we could have focused on the propagation of several other shocks including foreign shocks, but while we believe that such an analysis is very important, our focus is on understanding the transmission of exchange rates shocks and their interaction with FX interventions and traditional interest rate policy.

Figure 6. Country-Specific Impulses to Foreign investors Portfolio Outflow Shocks



There are many interesting and noteworthy features of Figure 6. First of all, we see that there is much more dispersion in the impulses among the EMEs than in the AEs. This is interesting as we are studying the propagation of a roughly same-sized real exchange rate depreciation in both sets of economies, as can be seen by comparing the real exchange rate paths in the bottom panels. Second, we see that some EMEs face a particularly challenging trade-off, with sizeable and persistent declines in output and large and persistent run-ups in core CPI inflation, which necessitate marked interest rate hikes when FX interventions are not on the table. Third, the effects are qualitatively similar in AEs in the sense that output contracts, and inflation rises, but the effects are quantitatively smaller and therefore associated with more muted interest rate hikes by the AE central banks.

Figure 7. Average Impulses to Foreign investors Portfolio Outflow Shocks

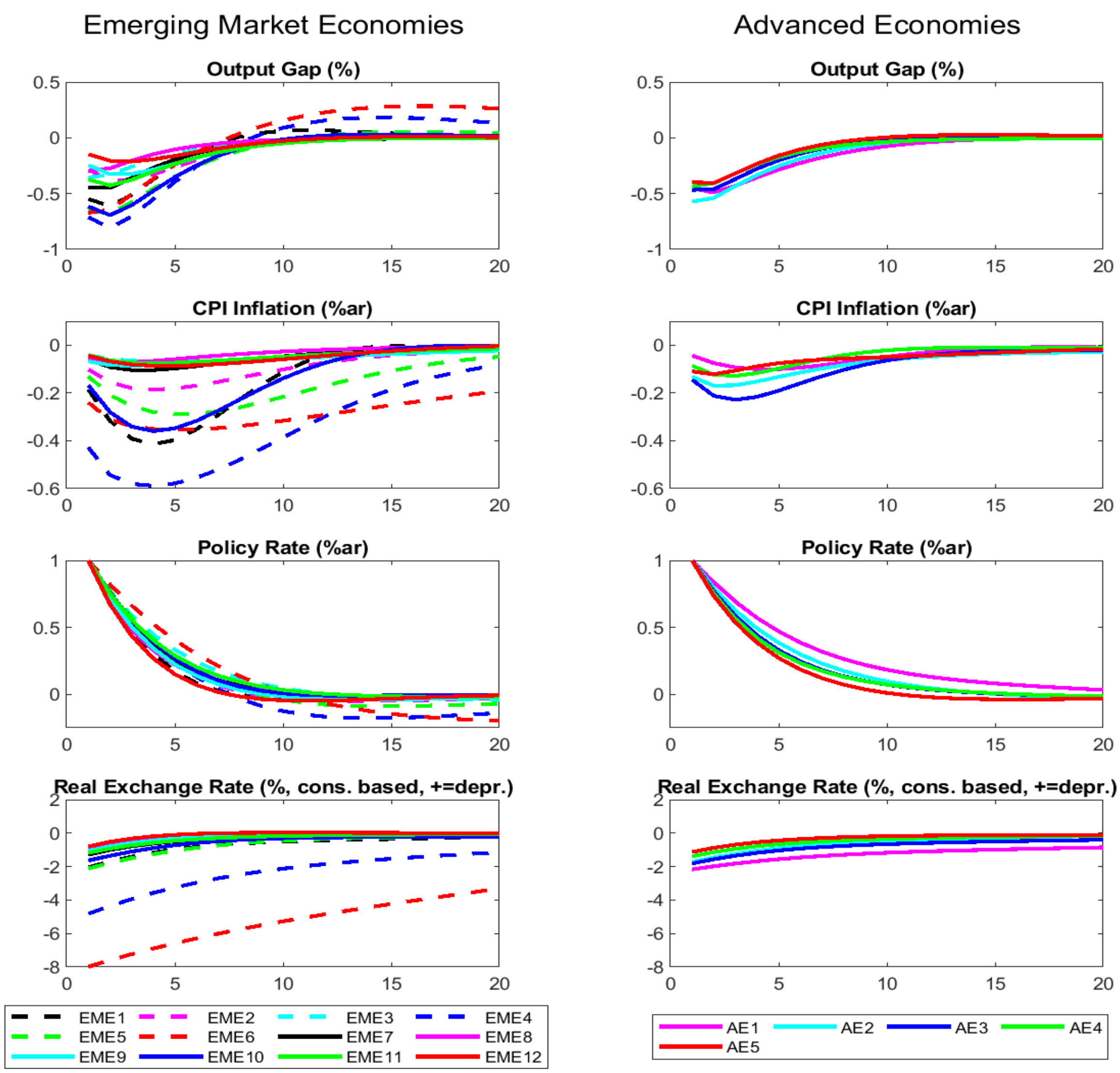


As it is difficult to get a good sense of the average differences between the impulses in the EMEs and AEs, Figure 7 reports the average responses for both sets of countries. It clarifies that the average increase in core CPI inflation is more than 0.5 percentage points for EMEs and only 0.2 percentage points for AEs. The larger run-up in inflation in the EMEs necessitates a policy rate hike of more than twice the magnitude. Arguably, with an unchanged economic structure and unchanged central bank credibility, an even more elevated interest rate path would be needed to limit the transmission from the weaker exchange rate to core CPI inflation to levels like those in AEs. Hence the depreciation poses a notably more difficult policy tradeoff in EMEs when FXIs are ruled out, as even without attempting to ensure AE-like pass-through to inflation, the contraction in domestic demand in EMEs is almost double that experienced in Advanced Economies.

IV.2. Transmission of Interest Rate Policy Shocks

We now move on to consider an unexpected tightening of the short-term interest rate in period 1 (i.e., a shock $\varepsilon_{i,1}$ in eq. 37), again assuming that the central bank adheres to the monetary policy rule in eq. (37). As in Section IV.1, we use the posterior parameters which maximize the LML and simply set the coefficient $\gamma_{\Delta s}$ = 0 in in the rule eq. (40) in case the best-fitting model features an endogenous FXI rule. As before, we do this to get a sense of the impact of an interest rate tightening without at the same time having FX interventions attempting to lean against the resulting appreciation pressure on the exchange rate. In Section IV.3 we will, however, study the potential for FX interventions to influence the transmission of traditional interest rate policy.

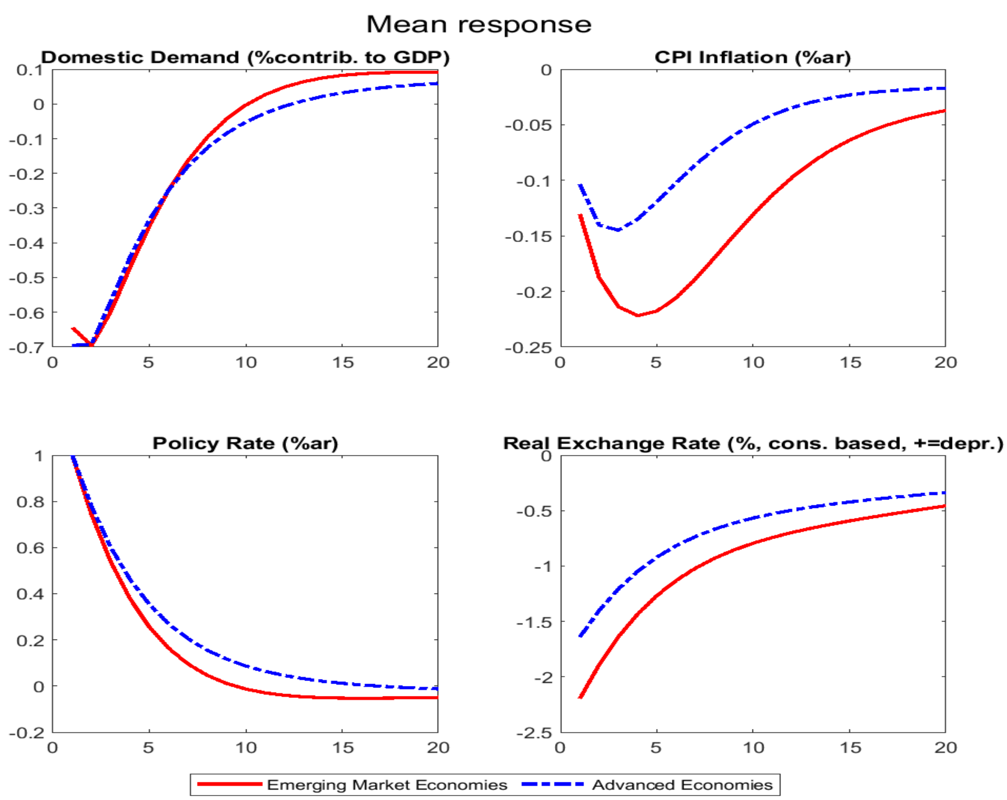
Figure 8. Impulses to an Unexpected Interest Rate Tightening



Regardless of the estimated standard deviation of historical transient deviations $\varepsilon_{i,t}$ from the systematic part of the policy rule in eq (37), Figure 8 reports the effects of a shock $\varepsilon_{i,1}$ that causes the nominal interest rate to rise 100 basis points in period 1 in all countries. Thereafter, the systematic part of the policy rule dictates the outcomes.

By comparing the outcomes for EMEs (left column) with the AEs in the right column, it is clear that the interest rate hike generates a more powerful response of the output gap and core CPI inflation in some EMEs compared to AEs. For two EMEs, Figure 8 shows that the appreciation of the exchange rate following policy tightening is substantial, reflecting that the two countries are estimated to have shallow currency markets (i.e. high Γ, see Table 4) and normally offset swings in their currency through systematic FX interventions captured by high $\gamma_{\Delta s}/(1-\gamma_{\Delta s})$ coefficients. Hence, when we counterfactually restrict interventions, we find very substantial appreciation to an unexpected interest policy tightening, with noticeable effects on the output gap and core CPI inflation. The driver behind this seemingly counterintuitive finding is that tighter monetary policy triggers an improvement in the NFA position (importantly, via reduced important demand), and when FX markets are shallow this leads to a larger decline in the UIP risk premium which strengthens the currency appreciation. For the other countries, the effects in EMEs and in AEs are much more similar, except for the tendency for the interest rate tightening to have a larger impact on core CPI inflation in EMEs.

Figure 9. Mean Impulses to an Unexpected Interest Rate Tightening



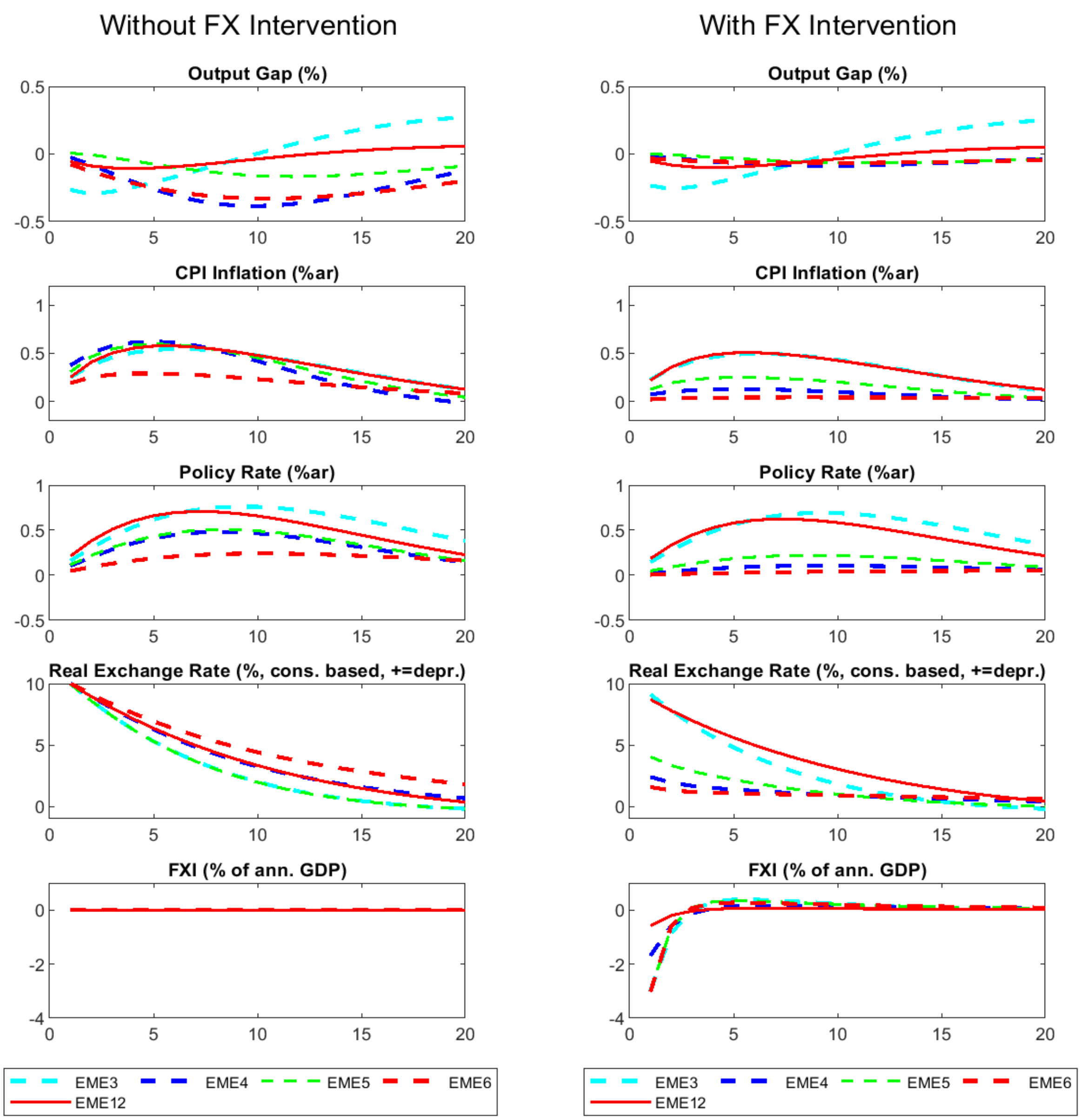
To get a better sense of the average differences between EMEs and AEs, Figure 9 reports the mean effects for each quarter *t*=1 ,2,…,20. The figure shows that monetary tightening contracts domestic demand by a similar magnitude in EMEs and AEs, but that core CPI inflation falls notably more in EMEs. The larger impact on core CPI inflation in the estimated model is largely driven by the stronger real exchange rate appreciation through two main channels. First, the appreciated real exchange rate drives down imported inflation more (the estimated import price stickiness parameter ξ_m is lower in EMEs than in AEs as can be seen in Table 3), and second, domestic wage inflation tends to fall more (Table 3 shows that the estimated parameter ν measuring the indexation of wage inflation to exchange rate movements is higher in EMEs than in AEs). Quantitatively, raising the policy rate by 100 basis points contracts domestic demand by about 0.7 percentage point for both EMEs and AEs on average, and lowers inflation slightly more in EMEs (nearly ¼ percentage points versus about 0.15 percentage points in AEs).

IV.3. Transmission of FX Interventions

In Sections IV.1-2, we maintained the assumption that FX interventions were not used systematically in response to a foreign investor risk-off shock and unexpected interest rate tightening. But, and as shown in Table 4, for some EMEs an endogenous FXI specification is strongly preferred by the data. For those countries, it is more realistic to assume that the central bank relies on FX interventions when facing a large risk-off shock which puts depreciationary pressure on the exchange rate. Accordingly, we shall now study how the systematic use of FXIs can alter the transmission of shocks. To begin with, we focus on the subset of countries for which the evidence in Table 4 points to systematic use of FXIs (i.e., a subset of 5 economies). Now, there are two important things to notice. First, out of these 5 countries, one is estimated to have rather deep currency markets (i.e., a posterior mean for Γ below 0.01, see Table 4). This implies that FX interventions will not have a lot of traction. Second, another country is estimated to respond weakly to movements in exchange rates ($\gamma_{\Delta s}/(1-\gamma_{\Delta s}) = 0.48$, translating into a $\gamma_{\Delta s}$ of around 1/3). Even if currency markets are shallow, such a weak response will tend to bias downwards the overall impact of FX interventions. Irrespective, we include these two countries in the set of economies we study henceforth.

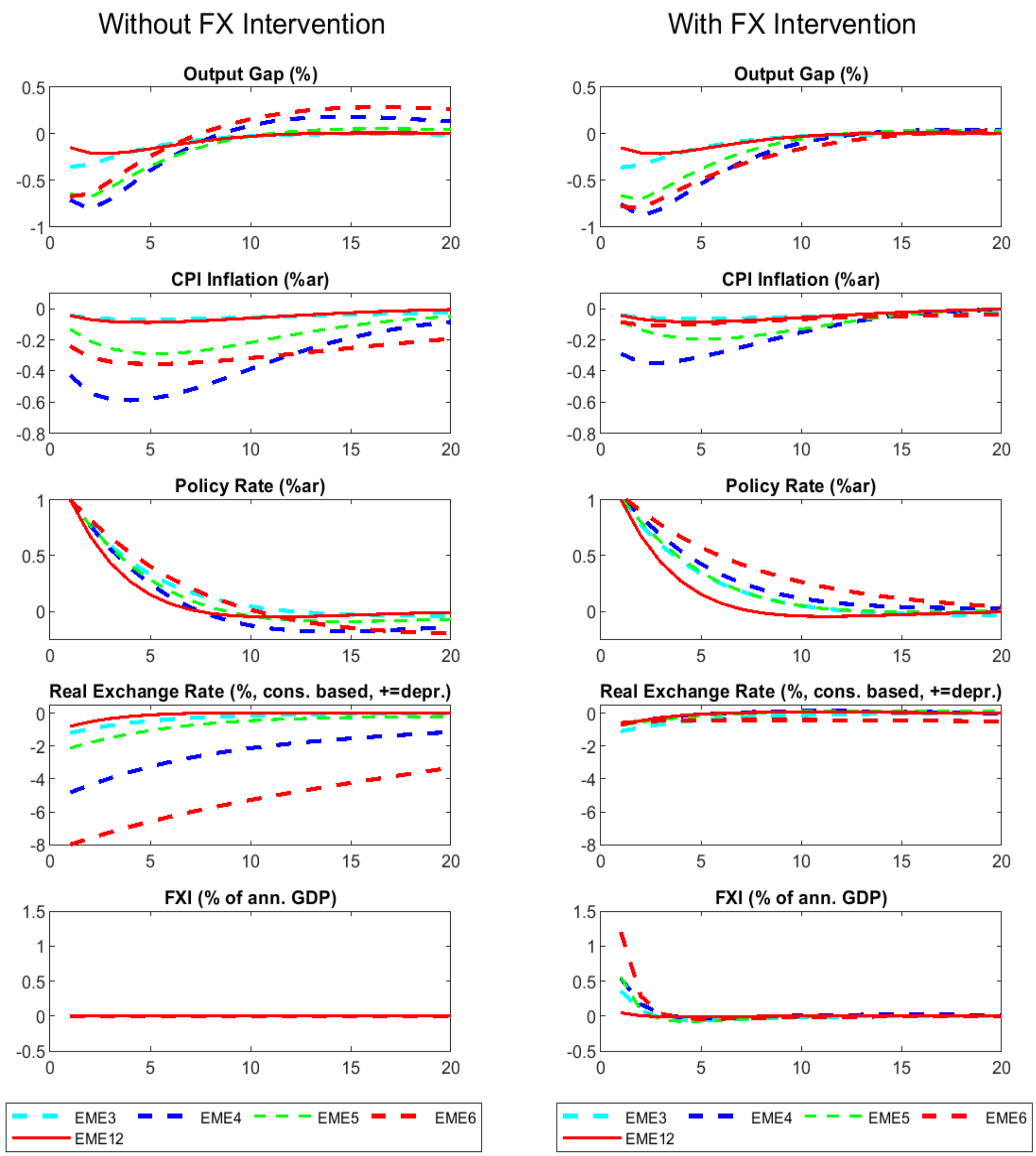
Figure 10 compares the macroeconomic outcome for the foreign investor risk-off shock for these 5 selected economies without FXI (left column, obtained by setting $\gamma_{\Delta s} = 0$) and when the FX intervention coefficient $\gamma_{\Delta s}$ is kept at the posterior mean in each country (right column). All other parameters are set to their country-specific posterior means, implying that currency market depth varies by country. In line with Figure 6, the risk-off shock is sized to cause the real exchange rate to depreciate by 10 percent when FXI is not deployed in each country. By comparing the left and right columns of Figure 10, we see that when FXI is deployed through the sale of FX reserves, the currency depreciates notably less for three countries, which in these economies reduces the increase in core CPI inflation and the need to hike the short-term interest rate. In the remaining two countries, the impulses in the left and right columns are similar. As alluded to above, this is explained by either deep currency markets or weak systematic interventions in response to exchange rate movements. The size of FXI ranges from 0.5 to 3 percent of GDP, reflecting the individually-estimated endogenous FXI rules. All told, the reduction in the depreciation of the exchange rate varies across countries according to FX market depth and the intervention size.

Figure 10. Impact of FXIs on Transmission of Foreign investors Portfolio Outflow Shocks



We now turn to study how FX interventions interact with the unexpected interest rate hike we studied in Figure 8. As in Figure 10, we report results for a subset of 5 EMEs for which there is evidence in favor of systematic FXI behavior, with the setup used to generate the impulses in Figure 11 otherwise identical to that underlying Figure 10.

Figure 11. How FXIs Impact Transmission of an Unexpected Interest Rate Tightening



Turning to the results in Figure 11, it is clear that FXI can notably dampen the transmission of a policy rate hike to the exchange rate. If the central bank reacts to the appreciationary pressure of a policy rate hike by increasing its FX reserves, this has the potential to offset movements in the exchange rate, which, in some cases, implies a weakened interest rate transmission, especially to core CPI inflation. This is evident by comparing the left and right columns in Figure 11. With an endogenous FXI rule, the 100 basis point interest rate hike translates into a much smaller appreciation in the exchange rate when currency markets are shallow and the FXI rule is aggressive, as the central bank, in this case, can successfully fight the appreciation by accumulating FX reserves. While the decline in output is similar with and without FXI, the reduction in core CPI inflation is notably lower.

In summary, these results point to the possibly highly important interactions between interest rate and FX policies. Moreover, they beg the question of the conditions under which the central bank would prefer to lean against domestic currency appreciation pressure induced by a nominal policy rate hike. It may seem more natural, for example, for FX interventions to be used as a substitute for interest rate policy and deployed when an unfavorable risk-off capital outflow shock hits the economy and currency markets dry up. In the next section, we therefore explore a formulation of the model with regime-switching in currency market depth and the central bank's intervention strategy.

V. Regime-Switching Estimation Results

So far, we have analyzed the empirical properties of the model under the assumption that all parameters are constant over time, which allowed us to use standard Bayesian estimation methods. In this section we relax this assumption for two key parameters; first the parameter Γ governing currency market depth, and second, the parameter $\gamma_{\Delta S}$ governing the strength of the systematic response of FXIs to exchange rate movements. The depth of the FX market determines the sensitivity of UIP premium to fluctuations in capital flows. In their seminal work, Gabaix and Maggiori (2015), show that if financiers have mean-variance preferences, the market depth parameter Γ should be related to the conditional exchange rate volatility. Consistent with the implications of their model, empirical evidence suggests that the UIP premium tends to be more elevated in times of financial stress, which suggests that market depth could be state-contingent.

Now, if FX markets are indeed best characterized as being typically liquid, but occasionally drying up, then central bank FX intervention could be more effective in affecting the exchange rate when markets are shallow. There are thus reasons to believe that if currency market depth Γ varies over time, then so could the central bank response to exchange rate pressures $\gamma_{\Delta S}$

(although FXI is more effective when Γ is higher for any given $\gamma_{\Delta S}$ coefficient).[20] For this reason, and since Table 4 documents that these two parameters are often correlated empirically, we also present regime-switching results when both parameters are assumed to follow a two-state Markov process following Leeper and Zha (2006, 2007) and Farmer, Waggoner and Zha (2011). The probability of switching between regimes is assumed to be exogenous and to not be endogenously related to the filtered state of the economy. This appears to be a reasonable approximation when looking for empirical support for potential time-variation in the functioning of the economy but would be considered a serious drawback if the model is used for policy simulations. We use the toolbox RISE written by Junior Maih (see e.g. Maih, 2015) to implement the regime switching estimation.

In the first experiment, it is assumed that only the market depth parameter Γ is time-varying. R_1 denotes the regime where we center the prior for Γ to imply a deep FX market (Γ is low), and R_2 represents a regime where the prior for Γ is set to imply shallower markets (Γ is higher). Uninformative priors are used for the transition probabilities between these regimes. The left columns in Table 5 summarize the priors for the two regimes. When estimating the regime-switching variant of the model, we use the same sample as in Table 4 so that we can compare the LML of the regime-switching model with the variant, which assumes that all parameters are time-invariant.

Table 5. Regime-Switching Estimation – Time-Varying FX Market Depth Only

	Prior distribution					Posterior distribution									
						R_1: Deep Markets (Low Γ)					R_2: Shallow Markets (High Γ)				
		R_1: Deep		R_2: Shallow		EME3		EME4		EME5		EME6		EME12	
Parameter	type	mean	std	mean	std	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow
Γ - FX Market Depth	beta	0.01	0.005	0.075	0.01	0.001	0.072	0.001	0.072	0.008	0.070	0.001	0.072	0.008	0.072
Trans. Probabilities. (R_1 to R_2 & R_2 to R_1)	beta	0.5	0.2	0.5	0.2	0.01	0.63	0.00	0.68	0.18	0.62	0.01	0.63	0.26	0.64
Probability of Deep FX Markets						0.99		0.99		0.77		0.99		0.71	
Change in Log Marginal Likelihood						4.0		-14.8		-2.4		14.7		-0.1	

Note: Change in Log Marginal Likelihood is the change in LML between the model variant allowing for regime-switching in Γ and the constant parameter model with an endogenous FX rule in Table 4.

As the regime switching estimation is time-consuming, we focus on the subset of countries for which we found evidence of endogenous conduct of FX interventions (see Table 4), and the columns to the right in Table 5 report the corresponding regime-switching estimation results. The first row in the table shows the posterior for Γ in the “deep” (R_1) and “shallow” (R_2) regimes, and the second row the corresponding transition probabilities, that is $p(R_2|R_1)$ and $p(R_1|R_2)$. The third row reports the implied unconditional probability of a deep FX market (based on posterior

[20] Note that an FX intervention is not necessarily desirable when markets are shallow, but may be desirable when markets are shallow *and* there is a risk-off capital outflow shock. In practice, however, it is likely that the “shallow” regime proxies for a joint occurrence of shallow FX markets and capital outflow shocks, rather than just FX market shallowness.

transition probabilities), while the final row reports the change in LML between the regime switching model and the constant parameter model (so a positive number implies that the regime switching model is associated with a higher log marginal data density).[21] We learn from Table 5 that the data supports time-varying FX market depth for two out of five countries, as the log marginal likelihood improves relative to the no-switching assumption. But only weakly so in one country using the conservative posterior odds ratio criterion discussed earlier. So, taken together, the results in the table provide limited support for the time-varying FX market depth specification. However, as noted above and when discussing the results in Table 4, there is a strong connection between the estimated market depth and the systematic conduct of FX intervention. Hence, in the next experiment we allow these two parameters to comove. In the first regime, which we still label "deep", the prior is centered around a deep FX market and a fairly passive FX intervention policy (i.e., $\gamma_{\Delta S}$ is low). In the second regime, we center the prior on a shallow FX market and an active role for systematic FX intervention. Thus, the second regime switching estimation exercise is compatible with consistently low UIP risk premiums either due to a deep FX market (low Γ) or, even if the FX market is shallow (high Γ), to the central banks FX intervention strategy (i.e., large $\gamma_{\Delta S}$), which keeps the UIP risk premium compressed.

Table 6. Regime-Switching Estimation – Time-Varying FX Market Depth and FXI Rule

	Prior distribution					Posterior distribution									
						R_1: Deep Markets (Low Γ and $\gamma_{\Delta S}$)					R_2: Shallow Markets (High Γ and $\gamma_{\Delta S}$)				
		R_1: Deep		R_2: Shallow		EME3		EME4		EME5		EME6		EME12	
Parameter	type	mean	std	mean	std	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow
Γ - FX Market depth	beta	0.01	0.005	0.075	0.01	0.001	0.067	0.006	0.081	0.008	0.075	0.002	0.061	0.007	0.070
$\gamma_{\Delta S}$ - FXI sensitivity to ΔS_t	beta	0.1	0.1	0.5	0.125	0.560	0.827	0.082	0.868	0.078	0.845	0.448	0.912	0.093	0.497
Trans. Probabilities. (R_1 to R_2 & R_2 to R_1)	beta	0.5	0.2	0.5	0.2	0.01	0.60	0.17	0.04	0.51	0.06	0.03	0.28	0.22	0.59
Probability of Deep FX Markets						0.98		0.21		0.10		0.92		0.73	
Change in Log Marginal Likelihood						14.3		-5.0		-7.0		30.7		9.3	

Note: Change in Log Marginal Likelihood is the change in LML between the model variant allowing for regime-switching in Γ and the constant parameter model with an endogenous FX rule in Table 4.

The regime switching results for this joint hypothesis are reported in Table 6, which is identical to Table 5, except for an added row reporting the FX intervention parameter $\gamma_{\Delta S}$. By comparing the change in LML relative to the constant parameter model, we see that the results in Table 6 are notably more supportive of the idea that these parameters may vary over time. In particular, the model fit is significantly improved for all the countries except for one. So, the hypothesis that the FXI response coefficient $\gamma_{\Delta S}$ is bigger when markets are shallower is generally supported, possibly on account of FX interventions being more effective during times of stress, which also tend to coincide with sharp exchange rate movements. In three of the five EMEs considered, the data supports the notion of time-varying parameters, and in two of those the data strongly supports the hypothesis of occasionally shallow FX markets and a more active FXI response

[21] If we let p_{12}= p(R2|R1) and p_{21}= p(R1|R2), then the expected duration of a spell (ES henceforth) in regimes 1 and 2 equal $ES_1 = 1/p_{12}$ and $ES_2 = 1/p_{21}$ and we can then calculate the unconditional probability of regime 1 (i.e. the deep FX markets regime) as $ES_1/(ES_1 + ES_2)$.

when markets are shallow. Although the prior is that the two regimes are equally likely, the posterior transition probabilities show that a majority (three) of the economies often have deep markets, but for two economies we find that they predominantly have shallow FX markets.

VI. Conclusion

Motivated by the observation that many EME central banks rely heavily on FXIs in their monetary policy operations, we have estimated a state-of-the-art New Keynesian small open economy model with FX market frictions and a potential role for FXI for a set of EMEs and AEs. The model is an empirical formulation of the quantitative microfounded model developed by Adrian et al. (2021), which embedded Gabaix and Maggiori (2015) FX market frictions.

Our estimated country-specific results suggest different transmission of risk appetite shocks in some EMEs relative to a control group comprising advanced economies. In particular, we find that these shocks generate a sizeable tradeoff between output and inflation stabilization for some EMEs, and the differences in their transmission reflect structural differences in price and wage formation and depth of FX markets. Under the assumption that currency market depth is not affected by FX interventions, these differences in the transmission of risk appetite shocks justify more frequent and systematic use of FXIs in EMEs with shallow markets, as interventions help stabilize the exchange rate and improve policy tradeoffs. When relaxing the assumption that market depth is constant, however, our regime-switching estimation results support the notion that FX market liquidity varies over time, suggesting that FX interventions can be non-effective sometimes but occasionally very effective in episodes when market liquidity dries up.

Following Gabaix and Maggiori (2015), we assume that the central bank undertakes sterilized interventions in the spot FX market and that it needs adequate foreign currency reserves for its operations. It would be useful to extend the model in a number of directions to allow the study of non-sterilized interventions and interventions in derivative markets. It would also be of interest to delve deeper into the issue of whether an effective FX intervention strategy necessitates large FX reserves, or if fiscal backing and solid public finances suffice.

A central estimated parameter in our model is currency market depth, which governs the sensitivity of the UIP risk premium to capital flows. Our estimated model suggests that currency markets are fairly deep in our control group of five small open advanced economies, while we find evidence of more shallower currency markets in 6 of the 12 studied emerging market economies. In future work it would be of interest to compare our estimated shallowness with empirical, externally-validated market depth measures in different countries. However, when computing external FX market depth measures for different countries, our paper stresses the importance of taking into account the endogeneity of FX policy, because FX markets may seem deep while in fact they are not due to the systematic use of FXI.

We leave an additional number of prominent issues for future work. First, the current formulation of the model focuses on the demand side and abstracts from shocks stemming from the supply side. This led us to detrend the quantities prior to estimation, which we did in a way aimed at preserving the trade balance and government spending to GDP ratios. In ongoing work, we have introduced an endogenous, stochastic, supply-driven sources of business cycle fluctuations in the economy. This removes the need to prefilter the data before estimation and allows us to study the implication of productivity shocks, which are important in many developing economies. Second, it would be of interest to examine whether the results hold up when we allow for commodities and a more elaborate fiscal sector. Such an extension will allow us to better evaluate and quantify multiple policy tools including different types of fiscal policy and commodity subsidies. Third and finally, it would also be of interest to include a more developed banking sector, along with durable goods (i.e., housing) to allow for both bank- and borrower-based macroprudential tools and how they interact with FX and interest rate policies in an open economy framework.

References

Adler, Gustavo, Noemie Lisack, and Rui C. Mano, 2019, “Unveiling the effects of foreign exchange intervention: A panel approach," Emerging Markets Review 40(C), 100620.

Adler, Gustavo, Rui Mano, Kyun Suk Chang, and Yuting Shao, 2021, "Foreign Exchange Intervention: A Dataset of Public Data and Proxies," IMF Working Papers 2021/047, International Monetary Fund.

Adolfson, Malin, Stefan Laseen, Jesper Linde, and Mattias Villani, 2007, “Bayesian estimation of an open economy DSGE model with incomplete pass-through,” Journal of International Economics 72, 481–511.

Adrian, Tobias, Christopher Erceg, Jesper Lindé, Pawel Zabczyk, and Jianping Zhou, 2020, “A Quantitative Model for the Integrated Policy Framework,” IMF Working Paper No. 20/122 (Washington DC: International Monetary Fund).

Adrian, Tobias, Christopher Erceg, Marcin Kolasa, Jesper Lindé, and Pawel Zabczyk, 2021, “A Quantitative Microfounded Model for the Integrated Policy Framework,” IMF Working Paper No. 21/292 (Washington DC: International Monetary Fund).

Amador, Manuel, Javier Bianchi, Luigi Bocola, and Fabrizio Perri, 2020, "Exchange Rate Policies at the Zero Lower Bound," Review of Economic Studies 87(4), 1605-1645.

Basu, Suman S., Emine Boz, Gita Gopinath, Francisco Roch, and Filiz D. Unsal, 2020, "A Conceptual Model for the Integrated Policy Framework," IMF Working Papers 2020/121, International Monetary Fund.

Blanchard, Olivier, Gustavo Adler, and Irineu de Carvalho Filho, 2015, “Can Foreign Exchange Intervention Stem Exchange Rate Pressures from Global Capital Flow Shocks?” IMF Working Paper No. 15/159 (Washington DC: International Monetary Fund).

Brandao-Marques, Luis, Gaston Gelos, Thomas Harjes, Ratna Sahay, and Yi Xue, 2020, “Monetary Policy Transmission in Emerging Markets and Developing Economies,” IMF Working Paper No. 20/35 (Washington DC: International Monetary Fund).

Cavallino, Paolo, 2019, “Capital Flows and Foreign Exchange Intervention," American Economic Journal: Macroeconomics 11, 127-170.

Chang, R., 2019, “Foreign Exchange Intervention Redux," in Monetary Policy and Financial Stability: Transmission Mechanisms and Policy Implications, ed. by A. Aguirre, M. Brunnermeier, and D. Saravia, Central Bank of Chile, vol. 26, chap. 7, 205-247.

Christiano, Lawrence J., Martin Eichenbaum, and Charles L. Evans, 2005, “Nominal rigidities and the dynamic effects of a shock to monetary policy.” Journal of political Economy 113(1), 1-45.

Christiano, L., M. Trabandt, and K. Walentin (2011): "Introducing Financial Frictions and Unemployment Into a Small Open Economy Model," Journal of Economic Dynamics and Control 35(12), 1999—2041.

Clarida, R., J. Gali, and M. Gertler, 1999, “The Science of Monetary Policy: A New Keynesian Perspective," Journal of Economic Literature 37, 1661-1707.

Davig, Troy and Eric M. Leeper (2006), “Fluctuating Macro Policies and the Fiscal Theory”, in NBER Macroeconomics Annual 21, eds. Acemoglu, Rogoff, and Woodford.

Davig, Troy, and Eric M. Leeper (2007). "Generalizing the Taylor Principle." American Economic Review 97(3), 607-635.

Del Negro, Marco & Schorfheide, Frank, 2008, "Forming priors for DSGE models (and how it affects the assessment of nominal rigidities)," Journal of Monetary Economics 55(7), 1191-1208,

Erceg, Christopher J., Dale W. Henderson, and Andrew T. Levin, 2000, "Optimal monetary policy with staggered wage and price contracts." Journal of monetary Economics 46(2), 281-313.

Erceg, Christopher J. and Jesper Lindé, 2014, "Is there a fiscal free lunch in a liquidity trap?," Journal of the European Economic Association 12, 73-107.

Fanelli, Sebastián, and Ludwig Straub, 2021, “A Theory of Foreign Exchange Interventions.” Review of Economic Studies 88, 2857-2885.

Farmer, R. F., Waggoner, D. F., and Zha, T. (2011). “Minimal State Variable Solutions to Markov Switching Rational Expectations Models,” *Journal of Economics Dynamics and Control* 35(12), 2150-2166.

Fisher, Jonas D.M. (2015), "On the Structural Interpretation of the Smets--Wouters "Risk Premium" Shock," Journal of Money, Credit and Banking 47(2-3), 511-516.

Fratzscher, Marcel, Oliver Gloede, Lukas Menkhoff, Lucio Sarno and Tobias Stöhr (2019), "When Is Foreign Exchange Intervention Effective? Evidence from 33 Countries." American Economic Journal: Macroeconomics 11(1),132-156.

Gabaix, Xavier, 2020, "A Behavioral New Keynesian Model," American Economic Review 110(8), 2271-2327.

Gabaix, Xavier, and Matteo Maggiori, 2015, “International Liquidity and Exchange Rate Dynamics,” The Quarterly Journal of Economics 130, 1369-1420.

Gali, Jordi and Tommaso Monacelli, 2005, “Monetary Policy and Exchange Rate Volatility in a Small Open Economy,” Review of Economic Studies 72(3), 707–734.

Giannoni, Marc, Christina Patterson, and Marco Del Negro, 2015, "The Forward Guidance Puzzle," 2015 Meeting Papers 1529, Society for Economic Dynamics.

Gopinath, Gita, Emine Boz, Camila Casas, Federico J. Díez, Pierre-Olivier Gourinchas, and Mikkel Plagborg-Møller, 2020, "Dominant Currency Paradigm." American Economic Review 110(3):

677-719.

Hoffmann, Mathias, Michael U. Krause, and Peter Tillmann, 2019, “International capital flows, external assets and output volatility," Journal of International Economics 117, 242-255.

Itskhoki, Oleg & Dmitry Mukhin (2021), "Exchange Rate Disconnect in General Equilibrium," Journal of Political Economy 129(8), 2183-2232.

Jeanne, Olivier, and Anton Korinek, 2010, “Excessive Volatility in Capital Flows: A Pigouvian Taxation Approach," American Economic Review 100, 403-407.

Justiniano, Alejandro, and Bruce Preston, 2010, “Monetary policy and uncertainty in an empirical small open-economy model,” Journal of Applied Econometrics 25, 93–128.

Kalemli-Ozcan, Sebnem, Mitali Das, and Gita Gopinath, 2022. “Preemptive Policies and Risk-Off Shocks in Emerging Markets,” IMF Working Paper No. 2022/003, Washington, DC: International Monetary Fund.

Kolasa, Marcin, Sahil Ravgotra, and Pawel Zabczyk, 2022, "Monetary Policy and Exchange Rate Dynamics in a Behavioral Open Economy Model," IMF Working Papers 2022/112, International Monetary Fund.

Maih, Junior, 2010, “Efficient perturbation methods for solving regime-switching DSGE models,” Working Paper 2015-1, Norges Bank.

Meese, R., and K. Rogoff (1983): "Empirical Exchange Rate Models of the Seventies: Do They Fit Out of Sample?," Journal of International Economics 14(1), 3--24.

Mendoza, Enrique G., 2010, “Sudden Stops, Financial Crises, and Leverage," American Economic Review 100, 1941-1966.

Menkhoff, Lukas, Malte Rieth, and Tobias Stöhr (2021), "The Dynamic Impact of FX Interventions on Financial Markets", Review of Economics and Statistics 103(5), 939--953.

Obstfeld, M., and K. Rogoff (2001): "The Six Major Puzzles in International Macroeconomics: Is There a Common Cause?," in NBER Macroeconomics Annual 2000, 339--390.

Patel, Nikhil and Paolo Cavallino, 2019, “FX intervention: goals, strategies and tactics,” BIS Papers No. 104.

Smets, Frank, and Raf Wouters, 2003, "An estimated dynamic stochastic general equilibrium model of the euro area." Journal of the European economic association 1(5), 1123-1175.

Smets, Frank, and Rafael Wouters, 2007, "Shocks and frictions in US business cycles: A Bayesian DSGE approach." American economic review 97(3), 586-606.

Svensson, Lars E.O., 2010. "Inflation Targeting," Handbook of Monetary Economics, in: Benjamin M. Friedman & Michael Woodford (ed.), Handbook of Monetary Economics, edition 1, volume 3, chapter 22, pages 1237-1302, Elsevier

Appendix A. Derivations of Linearized Relationships

This appendix documents some of the key derivations of the linearized model equations in the small open economy formulation of the two-country Q-IPF model.

A.1 Resource Constraint

The equilibrium resource constraint in the small open economy (ignoring price and wage dispersion terms) is given by

$$Y_t = C_{D,t} + G_t + M^*_{D,t}, \tag{A.1}$$

where aggegate foreign total export demand M^*_t, is given by

$$M^*_t = m_y \left[\frac{P^x_t}{P^*_t}\right]^{-\eta_x} Y^*_t, \tag{A.2}$$

and where Y^*_t and P^*_t are the foreign output and price level, respectively, and P^x_t is the price charged by exporting firms. Notice that the specification in $(\mathrm{A.}2)$ allows for short run deviations from the law of one price which occur because export prices (in the local currency) are sticky. Aggregate consumption is assumed to be given by a CES index of domestically produced and imported goods according to:

$$C_t = \left[(1-\omega_c)^{1/\eta_c}\left(C_{D,t}\right)^{(\eta_c-1)/\eta_c} + \omega_c^{1/\eta_c}\left(\frac{M_{C,t}}{\vartheta_{m,t}}\right)^{(\eta_c-1)/\eta_c}\right]^{\eta_c/(\eta_c-1)}, \tag{A.3}$$

where $C_{D,t}$ and $M_{C,t}$ denote consumption of the domestic and imported good, respectively. ω_c is the share of imports in consumption, η_c is the elasticity of substitution between domestic and foreign consumption goods, and $\vartheta_{m,t}$ is an exogenous demand shifter which satisfies $\mathrm{E}(\vartheta_{m,t}) = 1$. By maximizing $(\mathrm{A.}3)$ subject to the budget constraint $P_t C_{D,t} + P_{M,t} M_{C,t} = P_{C,t} C_t$, we obtain the following consumption demand functions

$$C_{D,t} = (1-\omega_c)\left[\frac{P_t}{P_{C,t}}\right]^{-\eta_c} C_t, \tag{A.4}$$

$$\frac{M_{C,t}}{\vartheta_{m,t}} = \omega_c \left[\frac{P_{M,t}}{P_{C,t}}\right]^{-\eta_c} C_t, \tag{A.5}$$

where the CPI price index (defined as the minimum expenditure required to buy one unit of C_t) is given by

$$P_{C,t} = \left[(1-\omega_c)(P_t)^{1-\eta_c} + \omega_c\left(P_{M,t}\right)^{1-\eta_c}\right]^{1/(1-\eta_c)}. \tag{A.6}$$

By adding and subtracting imports $M_{C,t}$ to eq. $(\mathrm{A}.1)$, to import of goods used for exports, we arrive at a specification, which resembles a gdp identity

$$Y_t = C_{D,t} + M_{C,t} + G_t + M^*_{D,t} + M^*_{M,t} - \left(M_{C,t} + M^*_{M,t}\right). \tag{A.7}$$

By substituting $(\mathrm{A}.4)$ and $(\mathrm{A}.5)$ into $(\mathrm{A}.7)$, we then obtain

$$Y_t = (1-\omega_c)\left[\frac{P_{C,t}}{P_t}\right]^{\eta_c} C_t + \omega_c \left[\frac{P_{M,t}}{P_{C,t}}\right]^{-\eta_c} C_t + G_t + M^*_t - M_t,$$

where we have also used that

$$M^*_t = M^*_{D,t} + M^*_{M,t}, \tag{A.8}$$

$$M_t = M_{C,t} + M^*_{M,t}. \tag{A.9}$$

Introducing the notation

$$\Gamma^{C,D}_t \equiv \frac{P_{C,t}}{P_t}, \tag{A.10}$$

$$\Gamma^{x,*}_t \equiv \frac{P_{X,t}}{P^*_t}, \tag{A.11}$$

$$\Gamma^{M,D}_t \equiv \frac{P_{M,t}}{P_t}, \tag{A.12}$$

we can rewrite this equation as follows:

$$Y_t = (1-\omega_c)\left(\Gamma^{C,D}_t\right)^{\eta_c} C_t + \omega_c\left(\Gamma^{M,D}_t\right)^{-\eta_c}\left(\Gamma^{C,D}_t\right)^{\eta_c} C_t + G_t + M^*_t - M_t.$$

Totally differentiating this equation, we obtain

$$\begin{aligned} dY_t = {} & (1-\omega_c)\left[\eta_c(\Gamma^{C,D})^{\eta_c-1} d\Gamma^{C,D}_t C + (\Gamma^{C,D})^{\eta_c} dC_t\right]\ldots \\ & +\omega_c\left[-\eta_c(\Gamma^{M,D})^{-\eta_c-1}(\Gamma^{C,D})^{\eta_c} C d\Gamma^{M,D}_t + (\Gamma^{M,D})^{-\eta_c}\eta_c(\Gamma^{C,D})^{\eta_c-1} C d\Gamma^{C,D}_t + (\Gamma^{M,D})^{-\eta_c}(\Gamma^{C,D})^{\eta_c} dC_t\right]\ldots \\ & +dG_t + dM^*_t - dM_t, \end{aligned} \tag{A.13}$$

and collecting terms, assuming that all relative prices equal unity in the non-stochastic steady state, the above simplifies to

$$\begin{aligned} dY_t = {} & (1-\omega_c)C\left[\eta_c \frac{d\Gamma^{C,D}_t}{\Gamma^{C,D}} + \frac{dC_t}{C}\right]\ldots \\ & +\omega_c C\left[-\eta_c \frac{d\Gamma^{M,D}_t}{\Gamma^{M,D}} + \eta_c \frac{d\Gamma^{C,D}_t}{\Gamma^{C,D}} + \frac{dC_t}{C}\right]\ldots \\ & +dG_t + dM^*_t - dM_t. \end{aligned}$$

Now, dividing by Y, and defining $x_t = dX_t/X$, we have

$$y_t = (1-\omega_c)\frac{C}{Y}\left[\eta_c \gamma^{c,d}_t + \hat{c}_t\right] + \omega_c \frac{C}{Y}\left[-\eta_c \gamma^{m,d}_t + \eta_c \gamma^{c,d}_t + c_t\right]\ldots$$

$$+\frac{G}{Y}g_t+\frac{M}{Y}(m_t^*-m_t),$$

where we have used a balanced trade assumption ($M+M^*=0$). If we let $x_y=X/Y$, we can then rewrite and simplify the above equation as

$$y_t=(1-\omega_c)c_y\left[\eta_c\gamma_t^{c,d}+\hat{c}_t\right]+\omega_c c_y\left[-\eta_c\gamma_t^{m,d}+\eta_c\gamma_t^{c,d}+c_t\right]+g_y g_t+m_y\left(m_{d,t}^*-\widehat{m}_{c,t}\right),$$

or equally, using that $c_y+g_y=1$,

$$y_t=c_y c_t+c_y\eta_c\left(\gamma_t^{c,d}-\omega_c\gamma_t^{m,d}\right)+\left(1-c_y\right)g_t+m_y\left(m_{d,t}^*-m_{c,t}\right). \quad \text{(A.14)}$$

This differs a bit relative to the aggregate resource constraint (1) because we now have two relative prices in the resource constraint. Hence we continue to see if we can eliminate these two. To that effect, we have $\gamma_t^{m,d}$ which from eq. $(A.12)$ simply equals

$$\gamma_t^{m,d}=\pi_{m,t}-\pi_t+\gamma_{t-1}^{m,d}.$$

We can get $\gamma_t^{c,d}$ from eq. (A.6). Dividing this eq by P_t and rearranging, we obtain

$$\Gamma_t^{C,D}=\frac{P_{C,t}}{P_t}=\left[\left((1-\omega_c)(P_t)^{1-\eta_c}+\omega_c\left(P_{M,t}\right)^{1-\eta_c}\right)P_t^{-(1-\eta_c)}\right]^{1/(1-\eta_c)}$$

$$=\left[(1-\omega_c)+\omega_c\left(\Gamma_t^{M,D}\right)^{1-\eta_c}\right]^{1/(1-\eta_c)}.$$

Totally differentiating the last equation,we get

$$d\Gamma_t^{C,D}=\frac{1}{1-\eta_c}[(1-\omega_c)+\omega_c(\Gamma^{M,D})^{1-\eta_c}]^{1/(1-\eta_c)-1}\omega_c(1-\eta_c)(\Gamma^{M,D})^{1-\eta_c}\frac{d\Gamma_t^{M,D}}{\Gamma^{M,D}}$$

$$=[(1-\omega_c)+\omega_c(\Gamma^{M,D})^{1-\eta_c}]^{1/(1-\eta_c)-1}\omega_c(\Gamma^{M,D})^{1-\eta_c}\frac{d\Gamma_t^{M,D}}{\Gamma^{M,D}},$$

and using the fact that

$$\Gamma^{C,D}=[(1-\omega_c)+\omega_c(\Gamma^{M,D})^{1-\eta_c}]^{1/(1-\eta_c)}, \quad \text{(A.15)}$$

this simplifies to

$$\gamma_t^{c,d}=\frac{\omega_c\left(\Gamma^{M,D}\right)^{1-\eta_c}}{(1-\omega_c)+\omega_c(\Gamma^{M,D})^{1-\eta_c}}\gamma_t^{m,d}. \quad \text{(A.16)}$$

Assuming that $\Gamma^{M,D}=1$, we then have that

$$\gamma_t^{c,d}=\omega_c\gamma_t^{m,d}. \quad \text{(A.17)}$$

Similarly, it follows that

$$\Gamma_t^{C,M}=\frac{P_{C,t}}{P_{M,t}}=\left[\left((1-\omega_c)(P_t)^{1-\eta_c}+\omega_c\left(P_{M,t}\right)^{1-\eta_c}\right)\left(P_{M,t}\right)^{-(1-\eta_c)}\right]^{1/(1-\eta_c)}$$

$$= \left[(1-\omega_c)\left(\Gamma_t^{M,D}\right)^{-(1-\eta_c)} + \omega_c\right]^{1/(1-\eta_c)},$$

and so

$$\gamma_t^{c,m} = -\frac{(1-\omega_c)\left(\Gamma^{M,D}\right)^{-(1-\eta_c)}}{(1-\omega_c)(\Gamma^{M,D})^{-(1-\eta_c)}+\omega_c}\gamma_t^{m,d},$$

which if $\Gamma^{M,D} = 1$ reduces to

$$\gamma_t^{c,m} = -(1-\omega_c)\gamma_t^{m,d}.$$

It follows that

$$\gamma_t^{m,c} = (1-\omega_c)\gamma_t^{m,d}. \tag{A.18}$$

Plugging eq. $(\mathrm{A}.17)$ into equation $(\mathrm{A}.14)$, we finally have

$$\begin{aligned} y_t &= c_y c_t + c_y \eta_c\left(\omega_c \gamma_t^{m,d} - \omega_c \gamma_t^{m,d}\right) + \left(1-c_y\right)g_t + m_y(m_t^* - m_t) \\ &= c_y c_t + \left(1-c_y\right)g_t + m_y(m_t^* - m_t), \end{aligned}$$

which is the log-linerized resource constraint in the main text (eq. 1). Importantly, this derivation rests on the assumption that all relative prices are unity in the steady state. Strictly speaking, this assumption is only fulfilled if all substitution elasticities and markups are parameterized symmetrically for both imported and domestically produced goods, see the discussion in Adolfson et al. (2007) for further details.

Finally, note that m_t^* can be computed from equation $(\mathrm{A}.8)$ as

$$\frac{dM_t^*}{M^*} = \frac{M_D^*}{M^*}\frac{dM_{D,t}^*}{M_D^*} + \frac{M_M^*}{M^*}\frac{dM_{M,t}^*}{M_M^*}$$

$$\Leftrightarrow$$

$$m_t^* = (1-\omega_x)m_{d,t}^* + \omega_x m_{m,t}^*,$$

where the second equality follows from defining the import share of export goods in the steady state as ω_x. Likewise, equation $(\mathrm{A}.9)$ implies that m_t is given by

$$\frac{dM_t}{M} = \frac{M_C}{M}\frac{dM_{C,t}}{M_C} + \frac{M_M^*}{M}\frac{dM_{M,t}^*}{M_M^*}$$

$$\Leftrightarrow$$

$$m_t = (1-\omega_x)m_{c,t} + \omega_x m_{m,t}^*,$$

where the second equality follows from our maintained balanced trade assumption.

A.2 UIP and Net Foreign Asset Dynamics

In this section, we derive the log-linearized UIP and net foreign asset equations.

A.2.1 The Linearized UIP Condition

We first proceed to log-linearize and derive the real UIP condition. The UIP condition, (30), can be rewritten as

$$(1-\tau_{F,t})\frac{I_t^b}{1+\pi_{t+1|t}}=\left\{\frac{I_t^*}{1+\pi_{t+1|t}^*}\frac{1+\pi_{t+1|t}^*}{1+\pi_{t+1|t}}\frac{S_{t+1|t}}{S_t}\right\}+\Gamma_t\frac{I_t}{1+\pi_{t+1|t}}\frac{B_{F,t}}{P_tY}+(1-\tau_{F,t})\frac{\Theta_t}{1+\pi_{t+1|t}},$$

or equivalently, recognizing that I_t^b, I_t^* and I_t are gross nominal interest rates,

$$(1-\tau_{F,t})(1+r_t^b)=\left\{(1+r_t^*)\frac{Q_{P,t+1|t}}{Q_{P,t}}\right\}+\Gamma_t(1+r_t)\frac{B_{F,t}}{P_tY}+(1-\tau_{F,t})\frac{\Theta_t}{1+\pi_{t+1|t}},\tag{A.19}$$

and evaluating this in the steady state, where $\Gamma_t=\Gamma>0$ and the product real exchange rate $Q_P=\bar{S}_t\bar{P}_t^*/\bar{P}_t$ is constant, and also recalling $\Theta=0$, $r^b=r$, and $\tau_F=0$, equation $(A.19)$ implies that

$$(1+r)=(1+r^*)+\Gamma(1+r)b_F.\tag{A.20}$$

Equation $(A.20)$ shows that when $r=r^*$, then $b_F=0$ since $\Gamma>0$. When $r\neq r^*$, we have

$$b_F=\frac{r-r^*}{\Gamma(1+r)}.\tag{A.21}$$

With the solution for b_F at hand, we can solve for Δ_S from eq. (30) which, conditional on our steady state assumptions, gives

$$I=I^*\Delta_S+\Gamma I b_F$$

$$\Leftrightarrow$$

$$\Delta_S=\frac{I-\Gamma I b_F}{I^*}=\frac{I}{I^*}\left(\frac{1+r^*}{1+r}\right)=\frac{1+\pi}{1+\pi^*}.\tag{A.22}$$

With these considerations in mind, totally differentiating the real UIP equation $(A.19)$, ignoring the final / non-smooth term, and exploiting SS assumptions (including $\tau_F=0$), we get

$$d(1+r_t)-d\tau_{F,t}(1+r)$$
$$=d(1+r_t^*)+(1+r^*)\left(\frac{dQ_{P,t+1|t}}{Q_P}-\frac{dQ_{P,t}}{Q_P}\right)+\Gamma(1+r)db_{F,t}+\Gamma b_F d(1+r_t),$$

$$\Leftrightarrow$$

$$\frac{d(1+r_t)}{1+r}-d\tau_{F,t}=\frac{(1+r^*)}{(1+r)}\frac{d(1+r_t^*)}{(1+r^*)}+\frac{(1+r^*)}{(1+r)}\left(\frac{dQ_{P,t+1|t}}{Q_P}-\frac{dQ_t}{Q_P}\right)+\Gamma db_{F,t}+\Gamma b_F\frac{d(1+r_t)}{(1+r)},$$

so that

$$r_t - \tau_{F,t} = \frac{1+r^*}{1+r} r_t^* + \frac{1+r^*}{1+r}\left(q_{p,t+1|t} - q_{p,t}\right) + \Gamma b_{F,t} + \Gamma b_F r_t,$$

or equivalently

$$q_t = q_{t+1|t} - \frac{1+r}{1+r^*} r_t + \frac{1+r}{1+r^*}\tau_{F,t} + r_t^* + \frac{1+r}{1+r^*}\Gamma b_{F,t} + \frac{1+r}{1+r^*}\Gamma b_F r_t.$$

This equation is convenient, as it allows us to do discounting directly in the UIP equation.

A.2.2 Linearized Financial Flow Equations

Now, we also have equation (31), which relates aggregate net foreign assets (B_t) to financiers debt ($B_{F,t}$), exogenous private portfolio flows ($B_{P,t}$) and the central banks reserves ($B_{M,t}$) according to $B_t = -B_{F,t} - B_{P,t} + B_{M,t}$. This means that a positive value of $B_{P,t}$ represents a currency outflow, and a positive value of $B_{M,t}$ means that the CB has a stock of foreign reserves. Log-linearizing this equation after scaling with $1/P_tY$, we have

$$b_{F,t} = -b_t - b_{P,t} + b_{M,t}. \tag{A.23}$$

A.2.3 Linearized Net Foreign Asset and Trade Balance Equations

We now derive the log-linerized representation of the net foreign asset equation (32). To begin with, we make the following two assumptions:

1. $\omega_B = 1$ i.e. all banks domestically owned,

2. $\omega_F = \omega_P = \omega$ i.e. same degree of home ownership of profits of financial intermediaries and exogenous financial investors.

With these two assumption, eq. (32) simplifies to

$$B_t = \left[(1-\omega)I_{t-1} + \omega I_{t-1}^* \tfrac{S_t}{S_{t-1}}\right] B_{t-1} - (1-\omega)\left(I_{t-1} - I_{t-1}^* \tfrac{S_t}{S_{t-1}}\right) B_{M,t-1}$$
$$+(1-\omega)\tau_{F,t-1} I_{t-1}\left[B_{F,t-1} + B_{P,t-1}\right] + TB_t,$$

and scaling this by P_tY, we have

$$b_t = \left[(1-\omega)I_{t-1} + \omega I_{t-1}^* \tfrac{S_t}{S_{t-1}}\right] \tfrac{1}{1+\pi_t} b_{t-1} - (1-\omega)\left(I_{t-1} - I_{t-1}^* \tfrac{S_t}{S_{t-1}}\right) \tfrac{1}{1+\pi_t} b_{M,t-1} \tag{A.24}$$
$$+(1-\omega)\tfrac{\tau_{F,t-1} I_{t-1}}{1+\pi_t}\left[b_{F,t-1} + b_{P,t-1}\right] + tb_t.$$

Totally differentiating eq. (A.24), and defining

$$\tilde{I} = (1-\omega)I + \omega I^* \Delta_S,$$

we have

$$db_t = \frac{\tilde{I}}{1+\pi} db_{t-1} + \frac{b}{1+\pi}\left[(1-\omega)I\frac{dI_{t-1}}{I} + \omega I^* \Delta_S\left(\frac{dI^*_{t-1}}{I^*} + \frac{dS_t}{\bar{S}_t} - \frac{dS_{t-1}}{\bar{S}_{t-1}}\right) - \tilde{I}\frac{d(1+\pi_t)}{1+\pi}\right]$$
$$-\frac{1-\omega}{1+\pi} b_M\left[I\frac{dI_{t-1}}{I} - I^*\Delta_S\left(\frac{dI^*_{t-1}}{I^*} + \frac{dS_t}{\bar{S}_t} - \frac{dS_{t-1}}{\bar{S}_{t-1}}\right)\right] - \frac{(1-\omega)(I-I^*\Delta_S)}{1+\pi}\left(db_{M,t-1} - b_M\frac{d(1+\pi_t)}{1+\pi}\right)$$
$$+\frac{(1-\omega)\tau_F I}{1+\pi}\left[(b_F+b_P)\left(\frac{dI_{t-1}}{I} - \frac{d(1+\pi_t)}{1+\pi_t}\right) + db_{F,t-1} + db_{P,t-1}\right] + \frac{(1-\omega)I}{1+\pi}[b_F+b_P]d\tau_{F,t-1}$$
$$+dtb_t.$$

If we denote $x_t = dX_t/X$, and $x_t = dx_t$ for variables already expressed in percentage rates, and recognizing that $1+\bar{r} = \frac{I}{1+\pi}$, we finally obtain

$$b_t = \frac{\tilde{I}}{1+\pi} b_{t-1} + \frac{b}{1+\pi}[(1-\omega)Ii_{t-1} + \omega I^*\Delta_S(i^*_{t-1} + \Delta s_t) - \tilde{I}\pi_t] \tag{A.25}$$
$$-\frac{1-\omega}{1+\pi} b_M[Ii_{t-1} - I^*\Delta_S(i^*_{t-1} + \Delta s_t)] - \frac{(1-\omega)(I-I^*\Delta_S)}{1+\pi}\left(b_{M,t-1} - b_M\pi_t\right)$$
$$+\frac{(1-\omega)\tau_F I}{1+\pi}\left[(b_F+b_P)(i_{t-1}-\pi_t) + b_{F,t-1} + b_{P,t-1}\right] + \frac{(1-\omega)I}{1+\pi}[b_F+b_P]\tau_{F,t-1}$$
$$+tb_t,$$

and when $b=0$ and $\tau_F = 0$, this simplifies to

$$b_t = \frac{\tilde{I}}{1+\pi} b_{t-1} \tag{A.26}$$
$$-\frac{1-\omega}{1+\pi} b_M[Ii_{t-1} - I^*\Delta_S(i^*_{t-1} + \Delta s_t)] - \frac{(1-\omega)(I-I^*\Delta_S)}{1+\pi}\left(b_{M,t-1} - b_M\pi_t\right)$$
$$+\frac{(1-\omega)I}{1+\pi}[b_F+b_P]\tau_{F,t-1}$$
$$+tb_t.$$

In the case where $b \neq 0$ (but τ_F is still assumed to be 0 in steady state), we obtain equation (35).

Now, we also need an expression for the trade balance. The trade balance in levels is given by

$$TB_t = S_t P^X_t M^*_t - S_t P^*_t M_t, \tag{A.27}$$

and scaling with $P_t Y$ we obtain

$$\frac{TB_t}{P_t Y} = \frac{S_t P^X_t}{P_t}\frac{M^*_t}{Y} - \frac{S_t P^*_t}{P_t}\frac{M_t}{Y},$$

or equivalently

$$tb_t = \Gamma_t^{X,D} \frac{M_t^*}{Y} - Q_{P,t} \frac{M_t}{Y}.$$

Totally differentiating this expression, we obtain

$$dtb_t = d\Gamma_t^{X,D} \frac{M_t^*}{Y} + \Gamma^{X,D} \frac{dM_t^*}{Y} - dQ_{P,t} \frac{M}{Y} - Q_P \frac{dM_t}{Y},$$

and using the balanced trade assumption $M = M^*$ and $m_y = M/Y$, and also $\Gamma^{X,D} = Q_P$, we have

$$dtb_t = Q_P m_y \left(\frac{d\Gamma_t^{X,D}}{\Gamma^{X,D}} + \frac{dM_t^*}{M^*} - \frac{dQ_{P,t}}{Q_P} - \frac{dM_t}{M} \right),$$

and further

$$tb_t = Q_P m_y \left(\gamma_t^{x,d} + m_t^* - q_{p,t} - m_t \right).$$

Now, one further simplification is possible, by recognizing that

$$\gamma_t^{x,d} - q_{p,t} = s_t + p_t^x - p_t - (s_t + p_t^* - p_t)$$
$$= p_t^x - p_t^*$$

which equals $\gamma_t^{x,*}$ in eq. $(A.11)$. Accordingly, the log-linearized trade balance equation can be written as in equation (36) in the main text.

Finally, we end this section with some steady state considerations w.r.t. to net foreign assets and portfolio flows. First, recalling our assumption that $\tau_F = 0$, we notice that equation $(A.24)$ implies that in the steady state

$$b = [(1-\omega)I + \omega I^* \Delta_S] \frac{1}{1+\pi_D} b - (1-\omega)(I - I^* \Delta_S) \frac{1}{1+\pi_D} b_M + tb,$$

and since $I - I^* \Delta_S = \Gamma I b_F$, with $I^{eff} = (1-\omega)I + \omega I^* \Delta_S$ being the effective steady state nominal interest rate, we have

$$b = \frac{I^{eff}}{1+\pi_D} b - (1-\omega)\Gamma \frac{Ib_F}{1+\pi_D} b_M + tb.$$

Now, if we want to impose a given b then we need to apply the following trade balance as share of GDP identity

$$tb = \left(1 - \frac{I^{eff}}{1+\pi_D}\right) b + (1-\omega)\Gamma \frac{Ib_F}{1+\pi_D} b_M.$$

We set $b_M = 1.2$ (which corresponds to 30 percent of annualized GDP) to match CB average currency reserves (as share of GDP) for many EMEs. For $-b = b_M$, we have that

$$tb = \left(\frac{I^{eff}}{1+\pi_D} - 1 + (1-\omega)\Gamma \frac{Ib_F}{1+\pi_D}\right) b_M,$$

and using eq. $(A.21)$, this simplifies as

$$tb = \left(\frac{I^{eff}}{1+\pi_D} - 1 + (1-\omega)(r - r^*)\right) b_M$$

which clearly demonstrates that the economy under these assumptions needs to sustain a relatively large trade balance surplus to cover effective debt service costs. If we assume

$$\frac{I^{eff}}{1+\pi_D} - 1 = \frac{1.06^{1/4}}{1.03^{1/4}} - 1 = 0.0072,$$

$$(1-\omega)(r-r^*) = (1-0.8)\left(1.04^{1/4} - 1 - 1.02^{1/4} + 1\right) = 9.7809e - 04$$

we would end up with the following

$$tb = (0.0072 + 9.7809e - 04) \times 1.2 = 0.0098,$$

which means that the country would need to run a surplus of approximately one percent (as a share of quarterly GDP) to balance debt service costs.

This would be one way to go, and to do this properly we would need to have exports exceed imports in the steady state, and incorporate this consistently in the model. An alternative would be to start from eq. (31), and note that with all variables expressed as shares of steady state quarterly GDP we have that

$$b_{P,t} = -b_t - b_{F,t} + b_{M,t},$$

and imposing the steady state for b_F from equation $(\mathrm{A}.21)$ and assuming that $-b = b_M$, we then arrive at

$$b_P = -\frac{r-r^*}{\Gamma(1+r)} + 2b_M.$$

This corresponds to a steady state, in which foreign investor' portfolio flows are large enough to finance net foreign liabilities and the currency reserve adjusted for funds intermediated by the financiers. This latter approach is notably simpler and is hence the one we use.

Notably, in the special case, in which b is assumed to equal zero, we can solve for b_P from eq. (31):

$$b_P = b_M - b_F. \tag{A.28}$$

A.3 Wage and Pricing Schedules

In this section, we focus on wage and pricing schedules.

A.3.1 Marginal Costs

We have the following production function

$$Y_t = e^{z_t} K^{\alpha} N_t^{1-\alpha}, \tag{A.29}$$

and hence the following marginal cost equation in the model

$$\frac{MC_t}{P_t} = \frac{W_t^r}{MPL_t} = \frac{W_t^r}{(1-\alpha)e^{z_t}K^{\alpha}N_t^{-\alpha}}. \tag{A.30}$$

Totally differentiating eq. $(\mathrm{A}.30)$, we obtain

$$d\left(\frac{MC_t}{P_t}\right) = \frac{dW_t^r}{(1-\alpha)K^{\alpha}N^{-\alpha}} + \frac{W^r\alpha}{(1-\alpha)K^{\alpha}N^{-\alpha}}\frac{dN_t}{N} - \frac{W^r}{(1-\alpha)K^{\alpha}N^{-\alpha}}dz_t,$$

where dividing through both sides by eq. (A.30) evaluated in the steady state, we get

$$\frac{d\frac{MC_t}{P_t}}{\frac{MC}{P}} = \left(\frac{W^r}{(1-\alpha)K^{\alpha}N^{-\alpha}}\right)^{-1}\left[\frac{dW_t^r}{(1-\alpha)K^{\alpha}N^{-\alpha}} + \frac{W^r\alpha}{(1-\alpha)K^{\alpha}N^{-\alpha}}\frac{dN_t}{N} - \frac{W^r}{(1-\alpha)K^{\alpha}N^{-\alpha}}dz_t\right]$$

$$= \left[\frac{dW_t^r}{W^r} + \alpha\frac{dN_t}{N} - dz_t\right].$$

Letting $mc_t \equiv d\left(\frac{MC_t}{P_t}\right) / \left(\frac{MC}{P}\right)$ and $\zeta_t \equiv \frac{dW_t^r}{W^r}$, we arrive at

$$mc_t = \zeta_t + \alpha n_t - z_t. \tag{A.31}$$

Now, totally differentiating the production function $(\mathrm{A}.29)$, we obtain

$$dY_t = K^{\alpha}N^{1-\alpha}dz_t + (1-\alpha)K^{\alpha}N^{1-\alpha}\frac{dN_t}{N},$$

so that

$$\frac{dY_t}{Y} = dz_t + (1-\alpha)\frac{dN_t}{N}$$

$$\Leftrightarrow$$

$$y_t = z_t + (1-\alpha)n_t,$$

or equivalently,

$$n_t = \frac{1}{1-\alpha}(y_t - z_t). \tag{A.32}$$

Inserting this into eq. $(\mathrm{A}.31)$, we have

$$mc_t = \zeta_t + \frac{\alpha}{1-\alpha}y_t - \frac{1}{1-\alpha}z_t,$$

which is the linearized marginal cost equation in (17) with the technology shock $z_t = 0$.

A.3.2 Labour Wedge

We now derive the relevant labor wedge in the wage Phillips curve, which builds on Erceg, Henderson and Levin (2000). From the households' first order conditions, we have the following relationships

$$\frac{\chi_0 N_t^{\chi}}{\Lambda_{Ct}} = \left(1 - \tau_{N,t}\right)\frac{W_t}{P_{Ct}}, \tag{A.33}$$

$$\Lambda_{Ct} = \frac{\left(C_t - \varkappa C_{t-1} - C\upsilon_{c,t}\right)^{-\frac{1}{\sigma}}}{1+\tau_{C,t}}. \tag{A.34}$$

The marginal rate of substitution, MRS_t, is defined as

$$MRS_t \equiv \frac{MU_{L,t}}{MU_{C,t}} = \frac{\chi_0 N_t^{\chi}}{\left(C_t - \varkappa C_{t-1} - C\upsilon_{c,t}\right)^{-\frac{1}{\sigma}}},$$

and using the first order conditions we can write this as

$$MRS_t = \frac{\chi_0 N_t^{\chi}}{(1+\tau_{C,t})\Lambda_{Ct}}. \tag{A.35}$$

The last equation, together the first-order condition for leisure choice (eq. A.33), implies the following optimal wage setting schedule:

$$MRS_t = \frac{1-\tau_{N,t}}{1+\tau_{C,t}} \overline{W}_t^C. \tag{A.36}$$

The above equation constitutes the labor wedge which should be closed in the economy.

Totally differentiating eq. $(A.35)$, we obtain

$$dMRS_t = \frac{\chi_0 N^{\chi}}{(1+\tau_C)\Lambda_C}[\chi \frac{dN_t}{N} - (1+\tau_C)^{-1} d\tau_{C,t} - \frac{d\Lambda_{Ct}}{\Lambda_{Ct}}],$$

where variables without time subscripts denoting steady state values. Letting small letters denote percent deviation (percentage points for $\tau_{C,t}$) from the steady state, and noting that $MRS = \frac{\chi_0 N^{\chi}}{(1+\tau_C)\Lambda_C}$ it follows that

$$mrs_t = \chi n_t - (1+\tau_C)^{-1}\tau_{C,t} - \lambda_{C,t},$$

which is equation (18) in main text with $\tau_{C,t} = 0$ for all t. Now, substituting eq. $(A.32)$ into this expression, we obtain

$$mrs_t = \chi \left[\frac{1}{1-\alpha} y_t - z_t\right] - (1+\tau_C)^{-1}\tau_{C,t} - \lambda_{C,t.} \tag{A.37}$$

Totally differentiating eq. $(A.36)$ gives

$$dMRS_t = \frac{1-\tau_N}{1+\tau_C} \overline{W}^C \left[\frac{d\overline{W}_t^C}{\overline{W}^C} - \frac{d\tau_{N,t}}{1-\tau_N} - \frac{d\tau_{C,t}}{1+\tau_C}\right],$$

which, after exploiting that $MRS = \frac{1-\tau_N}{1+\tau_C}\overline{W}^C$ and the notation $\zeta_{c,t} = \frac{d\overline{W}_t^C}{\overline{W}^C}$, can be written as

$$mrs_t = \zeta_{c,t} - \frac{\tau_{N,t}}{1-\tau_N} - \frac{\tau_{C,t}}{1+\tau_C}. \tag{A.38}$$

From the last equation, we can can define the labor wedge, which drives nominal wage inflation as

$$lwedge_t = mrs_t - \zeta_{c,t} + \frac{\tau_{N,t}}{1-\tau_N} + \frac{\tau_{C,t}}{1+\tau_C},$$

and inserting for eq. $(\mathrm{A}.37)$ into this last equation, we obtain

$$lwedge_t = \chi\left[\frac{1}{1-\alpha}y_t - z_t\right] - (1+\tau_C)^{-1}\tau_{C,t} - \lambda_{C,t.} - \zeta_{c,t} + \frac{\tau_{N,t}}{1-\tau_N} + \frac{\tau_{C,t}}{1+\tau_C}$$

$$= \chi\left[\frac{1}{1-\alpha}y_t - z_t\right] - \lambda_{C,t.} + \frac{\tau_{N,t}}{1-\tau_N} - \zeta_{c,t}.$$

This is the model-consistent labor wedge that should enter the wage setting equation. Now, in the model we neither allow for time-varying technology shocks z_t nor time-varying labor taxes $\tau_{N,t}$ so the labor wedge reduces to equation (18) in the main text.

Appendix B. Calibrated Parameters and Full Estimation Results

Table B.1 contains a complete list of calibrated parameters that are assumed to be the same for all emerging market economies and advanced economies. Often, we assume the same values in EMEs and AEs. A notable exception is the NFA position in the steady state, which we assume to be negative in the EMEs and to be nil in the small open advanced economies.

Appendix B. Table B.1: Parameters Calibrated to Match EME and AE Characteristics

Parameter	Description	EMEs	AEs
α	Labor elasticity in Cobb-Douglas production function	0.3	0.3
χ	Frisch elasticity of substitution (FELS)	2	2
η_c	Import price elasticity	0.8	0.8
η_x	Export price elasticity	0.8	0.8
$\chi/(1-\alpha)$	Marginal rate of consumption/leisure substitution	2.8571	2.8571
σ	Coefficient of relative risk aversion	1	1
θ_x	Wage mark-up	0.333	0.333
ω	Ownership share of financial intermediaries/investors	0.8	0.8
$\bar{b}$	NFA relative to Quarterly GDP	-1.012	0
$1+\phi$	gmarkup	2	1.5
ϵ	Kimball curvature	50	50

In Table B.2 we report the country-specific calibrated parameters in the EMEs and in the AEs. As discussed in the main text, they are all set to match country-specific characteristics.

Appendix B. Table B.2: Parameters Calibrated to Country-Specific Characteristics

Parameter	Description	BRA	CHL	COL	IDN	KAZ	MEX	MYS	PER	PHL	THA	TUR	ZAF
$\overline{b_M}$	Reserves relative to Quarterly GDP	0.496	0.608	0.492	0.464	0.680	0.460	1.500	1.076	0.916	1.476	0.464	0.464
β	Household subjective discount factor	0.9867	0.9975	0.9975	0.9950	0.9902	0.9963	0.9970	0.9963	0.9950	0.9975	0.9902	0.9926
$\bar{\pi}$	Steady-State Inflation (ann. perc. points)	4.5	3.0	4.0	3.0	4.0	3.0	2.5	2.0	3.0	2.0	5.0	4.5
$\bar{r}$	Steady-State Real Rate (ann perc points)	5.39	1.00	1.00	2.01	3.96	1.49	1.20	1.49	2.01	1.00	3.96	2.98
g_y	Share of Government Expenditure in GDP	0.190	0.130	0.143	0.080	0.090	0.120	0.110	0.160	0.109	0.145	0.138	0.050
ω_x	Share of Import in Export	0.107	0.160	0.095	0.150	0.130	0.270	0.400	0.130	0.240	0.370	0.180	0.214
m_y	Share of Exports & Imports in GDP	0.120	0.290	0.184	0.200	0.520	0.310	0.610	0.230	0.290	0.690	0.238	0.290
ω_c	Share of Import Goods in Consumption	0.13	0.28	0.19	0.18	0.50	0.26	0.41	0.24	0.25	0.51	0.23	0.24
$\overline{tp}$	Term Premium (ann. perc. points)	1.0	1.5	2.5	1.0	1.0	1.5	1.0	2.0	2.0	1.0	1.5	1.0
$\bar{I}$	Gross Steady-State Nominal Interest Rate	1.025	1.010	1.013	1.013	1.020	1.011	1.009	1.009	1.013	1.008	1.023	1.019

Parameter	Description	AUS	CAN	NOR	NZL	SWE	For. Economy (US)
$\overline{b_M}$	Reserves relative to Quarterly GDP	0.168	0.148	0.564	0.368	0.352	N/A
β	Household subjective discount factor	0.9975	0.9975	0.9975	0.9975	0.9975	0.9962
$\bar{\pi}$	Steady-State Inflation (ann. perc. points)	2.5	2.0	2.0	2.0	2.0	2.0
$\bar{r}$	Steady-State Real Rate (ann perc points)	1.00	1.00	1.00	1.00	1.00	1.53
g_y	Share of Government Expenditure in GDP	0.180	0.230	0.230	0.190	0.290	0.216
ω_x	Share of Import in Export	0.110	0.210	0.180	0.150	0.300	N/A
m_y	Share of Exports & Imports in GDP	0.215	0.320	0.340	0.310	0.370	N/A
ω_c	Share of Import Goods in Consumption	0.23	0.33	0.36	0.33	0.36	N/A
$\overline{tp}$	Term Premium (ann. perc. points)	0.5	1.5	1.0	1.0	1.0	N/A
$\bar{I}$	Gross Steady-State Nominal Interest Rate	1.009	1.008	1.008	1.008	1.008	N/A

Finally, in Tables B.3-B.4 we report the country-specific posterior distributions for all EMEs in with endogenous (Table B.3) and exogenous (Table B.4) rules, and in Table B.5 we report AEs posteriors for both rules.

Appendix B. Table B.3: Country-Specific Posterior and Log Marginal Likelihoods with Endogenous FXI Rule in EMEs

Parameter		Prior distribution			Posterior distribution																							
		type	mean	std. dev.	EME1		EME2		EME3		EME4		EME5		EME6		EME7		EME8		EME9		EME10		EME11		EME12	
					mh mean	mh std	mh mean	mh std	mh mean	mh std	mh mean	mh std	mh mean	mh std	mh mean	mh std	mh mean	mh std	mh mean	mh std	mh mean	mh std	mh mean	mh std	mh mean	mh std	mh mean	mh std
Calvo parameter for import prices	ξ_m	beta	0.75	0.05	0.83	0.03	0.70	0.05	0.83	0.02	0.86	0.03	0.72	0.05	0.95	0.01	0.75	0.04	0.70	0.03	0.74	0.05	0.80	0.04	0.72	0.05	0.69	0.04
Calvo parameter for export prices	ξ_x	beta	0.75	0.05	0.88	0.02	0.75	0.05	0.79	0.04	0.94	0.01	0.88	0.02	0.95	0.01	0.77	0.04	0.85	0.05	0.91	0.02	0.84	0.03	0.91	0.01	0.73	0.04
Calvo parameter for domestic prices	ξ_p	beta	0.75	0.05	0.86	0.02	0.94	0.01	0.94	0.01	0.89	0.02	0.94	0.01	0.93	0.01	0.90	0.02	0.95	0.01	0.92	0.01	0.89	0.01	0.96	0.00	0.94	0.01
Calvo parameter for wages	ξ_w	beta	0.75	0.05	0.58	0.04	0.67	0.04	0.71	0.04	0.72	0.04	0.69	0.04	0.74	0.04	0.80	0.03	0.73	0.04	0.84	0.02	0.63	0.04	0.79	0.03	0.76	0.03
Imported goods price indexation	ι_m	beta	0.7	0.2	0.92	0.06	0.62	0.17	0.96	0.03	0.79	0.14	0.48	0.16	0.96	0.03	0.80	0.13	0.58	0.09	0.62	0.10	0.73	0.09	0.55	0.20	0.82	0.11
Domestic price indexation	ι_p	beta	0.7	0.2	0.82	0.09	0.53	0.14	0.22	0.09	0.21	0.09	0.83	0.07	0.23	0.08	0.64	0.17	0.19	0.09	0.19	0.09	0.79	0.08	0.57	0.10	0.58	0.11
Exported goods price indexation	ι_x	beta	0.7	0.2	0.51	0.17	0.48	0.18	0.52	0.17	0.78	0.05	0.76	0.05	0.66	0.09	0.59	0.17	0.60	0.18	0.94	0.05	0.76	0.12	0.89	0.03	0.43	0.16
Wage indexation	ι_w	beta	0.7	0.2	0.52	0.17	0.65	0.15	0.43	0.13	0.75	0.12	0.43	0.15	0.25	0.11	0.21	0.10	0.77	0.16	0.95	0.02	0.11	0.05	0.79	0.12	0.96	0.02
Wage sensitivity to exchange rate	ν	beta	0.1	0.05	0.03	0.03	0.08	0.04	0.08	0.05	0.07	0.04	0.03	0.02	0.07	0.04	0.00	0.00	0.09	0.06	0.03	0.02	0.01	0.00	0.01	0.01	0.06	0.03
Habit formation	$\varkappa_c$	norm	0.7	0.15	0.38	0.06	0.59	0.08	0.16	0.06	0.36	0.07	0.25	0.07	0.18	0.06	0.28	0.07	0.21	0.07	0.62	0.07	0.32	0.07	0.37	0.07	0.72	0.05
Discount factor	δ_c	beta	0.985	0.0075	0.98	0.01	0.97	0.01	0.97	0.01	0.97	0.01	0.98	0.01	0.98	0.01	0.98	0.01	0.97	0.01	0.97	0.01	0.97	0.01	0.97	0.01	0.98	0.01
FX market friction	Γ	beta	0.05	0.0125	0.04	0.01	0.02	0.01	0.01	0.00	0.06	0.01	0.05	0.01	0.04	0.01	0.04	0.01	0.01	0.00	0.03	0.01	0.02	0.01	0.02	0.01	0.04	0.01
Domestic riskpremium shock persistence	ρ_ψ	beta	0.75	0.1	0.68	0.05	0.76	0.06	0.70	0.07	0.85	0.03	0.79	0.05	0.82	0.06	0.67	0.06	0.80	0.06	0.66	0.07	0.80	0.04	0.88	0.03	0.65	0.06
Domestic demand shock persistence	ρ_υ	beta	0.85	0.05	0.91	0.02	0.93	0.03	0.90	0.02	0.96	0.01	0.88	0.03	0.89	0.03	0.88	0.03	0.90	0.03	0.91	0.04	0.94	0.02	0.89	0.03	0.94	0.02
Govt. expenditure shock persistence	ρ_g	beta	0.85	0.05	0.93	0.02	0.77	0.06	0.89	0.03	0.89	0.03	0.83	0.04	0.81	0.04	0.82	0.04	0.82	0.05	0.80	0.05	0.92	0.02	0.88	0.03	0.89	0.03
Import demand shock persistence	ρ_m	beta	0.85	0.05	0.76	0.05	0.77	0.05	0.85	0.04	0.70	0.06	0.76	0.04	0.89	0.04	0.74	0.05	0.81	0.04	0.79	0.05	0.92	0.03	0.82	0.04	0.81	0.04
Export demand shock persistence	ρ_{m^*}	beta	0.85	0.05	0.79	0.05	0.80	0.05	0.87	0.03	0.87	0.03	0.79	0.05	0.90	0.03	0.88	0.03	0.86	0.04	0.86	0.04	0.93	0.02	0.90	0.03	0.90	0.02
Exchange riskpremium shock persistence	ρ_{b_p}	beta	0.85	0.05	0.87	0.03	0.93	0.02	0.90	0.02	0.93	0.03	0.90	0.03	0.92	0.03	0.87	0.03	0.95	0.02	0.92	0.02	0.89	0.04	0.91	0.02	0.94	0.02
Consumption demand shock	σ_c	invgamma	0.5	200	1.99	0.26	3.30	0.66	4.61	0.45	3.69	0.44	4.96	0.51	4.16	0.38	3.42	0.39	5.99	0.71	1.55	0.24	3.13	0.58	3.34	0.45	2.42	0.39
Import markup shock	σ_{π_m}	invgamma	0.1	200	0.61	0.17	0.07	0.04	0.26	0.04	0.46	0.21	0.07	0.04	0.19	0.06	0.41	0.25	2.47	0.22	0.10	0.09	1.36	0.14	0.10	0.07	0.08	0.04
Domestic markup shock	σ_π	invgamma	0.1	200	0.63	0.06	1.28	0.13	0.40	0.05	0.60	0.07	0.20	0.02	0.63	0.06	0.21	0.08	0.07	0.04	0.61	0.06	0.08	0.05	0.79	0.07	0.55	0.05
Wage markup shock	σ_{π_w}	invgamma	0.1	200	2.14	0.24	2.19	0.25	2.93	0.28	1.38	0.20	2.73	0.30	2.68	0.29	0.56	0.05	3.50	0.40	0.55	0.07	1.63	0.16	0.44	0.05	1.64	0.21
Domestic riskpremium shock	σ_ψ	invgamma	0.1	200	1.20	0.20	2.08	0.61	1.13	0.23	0.85	0.14	1.07	0.22	0.49	0.16	1.12	0.20	1.64	0.36	1.38	0.31	1.15	0.21	0.72	0.12	3.01	0.56
Govt. expenditure shock	σ_g	invgamma	0.5	200	0.80	0.07	3.75	0.35	2.89	0.23	4.75	0.38	4.62	0.37	3.78	0.29	1.00	0.08	7.02	0.58	4.67	0.38	2.41	0.22	2.59	0.20	1.49	0.11
Import demand shock	σ_m	invgamma	1	200	5.63	0.50	5.94	0.55	4.78	0.39	3.88	0.32	6.74	0.58	3.70	0.30	3.98	0.35	5.79	0.49	3.24	0.28	5.95	0.60	4.38	0.32	5.34	0.41
Export demand shock	σ_{m^*}	invgamma	1	200	21.32	1.74	24.77	2.30	12.63	0.98	20.57	1.61	40.81	3.38	9.05	0.75	17.72	1.59	73.35	5.86	23.90	2.14	47.09	4.17	24.66	2.04	44.48	3.26
Exchange riskpremium shock	σ_{b_p}	invgamma	1	200	1.08	0.21	1.00	0.22	0.58	0.09	0.62	0.11	0.56	0.10	0.79	0.19	0.99	0.19	0.91	0.15	0.64	0.11	1.02	0.30	0.79	0.15	0.91	0.15
Interest rate policy shock	σ_i	invgamma	0.1	200	0.08	0.01	0.46	0.06	0.05	0.01	0.08	0.01	0.13	0.01	0.03	0.00	0.08	0.01	0.21	0.02	0.13	0.01	0.13	0.01	0.22	0.02	0.41	0.03
FXI policy shock	σ_{fx}	invgamma	1	2	1.35	0.12	3.19	0.36	5.61	0.49	5.86	1.09	8.60	1.68	26.91	6.10	1.96	0.21	6.62	0.60	3.52	0.39	1.83	0.19	3.40	0.30	3.17	0.34
Interest rate reaction to CPI inflation	γ_π	norm	0.5	0.34	0.93	0.24	0.61	0.28	0.92	0.19	0.74	0.28	0.37	0.21	0.70	0.21	0.59	0.19	0.57	0.22	0.40	0.16	0.68	0.21	0.35	0.21	0.54	0.25
Interest rate reaction to output gap	γ_y	beta	0.125	0.05	0.06	0.02	0.11	0.05	0.05	0.02	0.08	0.03	0.05	0.02	0.05	0.02	0.11	0.02	0.16	0.04	0.11	0.04	0.08	0.03	0.17	0.04	0.07	0.03
Interest rate smoothing	γ_i	beta	0.75	0.05	0.85	0.02	0.82	0.03	0.81	0.03	0.90	0.02	0.85	0.02	0.90	0.02	0.80	0.03	0.76	0.03	0.78	0.04	0.87	0.02	0.82	0.03	0.73	0.03
FXI response to change in exchange rate	$\gamma_{\Delta S}$	beta	0.5	0.125	0.17	0.05	0.17	0.07	0.69	0.04	0.86	0.03	0.83	0.03	0.93	0.02	0.21	0.07	0.37	0.06	0.33	0.08	0.24	0.10	0.26	0.08	0.33	0.06
FXI persistence	$\rho_{\Delta R}$	beta	0.5	0.15	0.59	0.09	0.39	0.12	0.42	0.07	0.53	0.08	0.38	0.08	0.40	0.08	0.50	0.12	0.23	0.08	0.31	0.09	0.73	0.12	0.50	0.10	0.45	0.08
FXI rule error correction	ρ_R	beta	0.05	0.025	0.00	0.00	0.04	0.02	0.00	0.00	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.00	0.03	0.01	0.01	0.00
LML - Laplace Approximation					-2241.50		-2106.02		-2540.95		-2464.01		-2299.98		-2565.05		-2001.86		-2785.91		-2077.55		-2093.65		-2607.77		-2920.11	
LML - Modified Harmonic Mean					-2241.21		-2106.46		-2541.52		-2461.10		-2300.37		-2565.04		-2001.87		-2786.25		-2076.38		-2093.22		-2609.22		-2920.16	

Appendix B. Table B.4: Country-Specific Posterior and Log Marginal Likelihoods with Exogenous FXI Rule in EMEs

Parameter		Prior distribution			Posterior distribution																							
		type	mean	std. dev.	EME1		EME2		EME3		EME4		EME5		EME6		EME7		EME8		EME9		EME10		EME11		EME12	
					mh mean	mh std	mh mean	mh std	mh mean	mh std	mh mean	mh std	mh mean	mh std	mh mean	mh std	mh mean	mh std	mh mean	mh std	mh mean	mh std	mh mean	mh std	mh mean	mh std	mh mean	mh std
Calvo parameter for import prices	ξ_m	beta	0.75	0.05	0.83	0.02	0.71	0.05	0.83	0.02	0.82	0.03	0.71	0.05	0.89	0.02	0.75	0.04	0.70	0.03	0.74	0.05	0.83	0.04	0.75	0.06	0.69	0.04
Calvo parameter for export prices	ξ_x	beta	0.75	0.05	0.88	0.02	0.75	0.05	0.79	0.05	0.93	0.01	0.87	0.02	0.93	0.01	0.77	0.04	0.84	0.05	0.91	0.02	0.80	0.04	0.91	0.01	0.72	0.04
Calvo parameter for domestic prices	ξ_p	beta	0.75	0.05	0.86	0.02	0.94	0.01	0.94	0.02	0.91	0.02	0.94	0.01	0.95	0.01	0.90	0.02	0.95	0.01	0.92	0.01	0.89	0.02	0.95	0.01	0.94	0.01
Calvo parameter for wages	ξ_w	beta	0.75	0.05	0.59	0.04	0.67	0.04	0.71	0.04	0.75	0.04	0.66	0.04	0.73	0.03	0.80	0.03	0.74	0.04	0.84	0.02	0.62	0.04	0.79	0.03	0.76	0.03
Imported goods price indexation	ι_m	beta	0.7	0.2	0.91	0.10	0.64	0.17	0.96	0.03	0.95	0.04	0.58	0.18	0.99	0.01	0.79	0.15	0.59	0.09	0.63	0.09	0.72	0.10	0.69	0.20	0.85	0.10
Domestic price indexation	ι_p	beta	0.7	0.2	0.82	0.08	0.53	0.13	0.21	0.10	0.18	0.08	0.86	0.07	0.20	0.07	0.66	0.16	0.19	0.09	0.19	0.09	0.77	0.08	0.56	0.13	0.58	0.11
Exported goods price indexation	ι_x	beta	0.7	0.2	0.53	0.17	0.50	0.18	0.56	0.17	0.80	0.05	0.79	0.07	0.64	0.11	0.60	0.17	0.62	0.18	0.90	0.07	0.67	0.13	0.89	0.04	0.42	0.16
Wage indexation	ι_w	beta	0.7	0.2	0.48	0.15	0.64	0.13	0.41	0.14	0.68	0.16	0.43	0.13	0.16	0.07	0.20	0.09	0.80	0.15	0.95	0.02	0.11	0.06	0.75	0.12	0.96	0.04
Wage sensitivity to exchange rate	ν	beta	0.1	0.05	0.02	0.01	0.07	0.03	0.06	0.05	0.06	0.04	0.03	0.01	0.08	0.02	0.00	0.00	0.13	0.07	0.03	0.02	0.01	0.00	0.01	0.01	0.06	0.03
Habit formation	$\varkappa_c$	norm	0.7	0.15	0.38	0.06	0.59	0.08	0.18	0.06	0.36	0.08	0.24	0.07	0.18	0.06	0.28	0.07	0.21	0.07	0.64	0.07	0.34	0.07	0.39	0.07	0.70	0.05
Discount factor	δ_c	beta	0.985	0.0075	0.98	0.01	0.97	0.01	0.97	0.01	0.97	0.01	0.97	0.01	0.97	0.01	0.98	0.01	0.97	0.01	0.97	0.01	0.97	0.01	0.97	0.01	0.97	0.01
FX market friction	Γ	beta	0.05	0.0125	0.03	0.01	0.02	0.01	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.03	0.01	0.01	0.00	0.02	0.00	0.01	0.00	0.02	0.00	0.02	0.01
Domestic riskpremium shock persistence	ρ_ψ	beta	0.75	0.1	0.68	0.06	0.77	0.06	0.70	0.07	0.87	0.02	0.75	0.06	0.72	0.08	0.67	0.06	0.79	0.07	0.66	0.07	0.79	0.05	0.89	0.03	0.65	0.06
Domestic demand shock persistence	ρ_υ	beta	0.85	0.05	0.91	0.03	0.93	0.03	0.89	0.02	0.95	0.02	0.85	0.04	0.88	0.03	0.89	0.02	0.90	0.03	0.90	0.04	0.94	0.02	0.88	0.03	0.94	0.02
Govt. expenditure shock persistence	ρ_g	beta	0.85	0.05	0.93	0.02	0.77	0.06	0.89	0.03	0.90	0.03	0.82	0.04	0.81	0.05	0.83	0.04	0.82	0.05	0.80	0.05	0.92	0.02	0.88	0.03	0.89	0.03
Import demand shock persistence	ρ_m	beta	0.85	0.05	0.78	0.04	0.77	0.05	0.86	0.03	0.76	0.06	0.76	0.05	0.88	0.03	0.75	0.06	0.82	0.05	0.81	0.04	0.94	0.02	0.82	0.05	0.83	0.04
Export demand shock persistence	ρ_{m^*}	beta	0.85	0.05	0.80	0.05	0.80	0.05	0.87	0.03	0.86	0.04	0.80	0.05	0.89	0.03	0.88	0.03	0.86	0.04	0.87	0.04	0.94	0.02	0.89	0.05	0.91	0.03
Exchange riskpremium shock persistence	ρ_{b_p}	beta	0.85	0.05	0.88	0.03	0.92	0.02	0.90	0.02	0.96	0.01	0.93	0.02	0.94	0.02	0.87	0.03	0.95	0.02	0.91	0.02	0.93	0.04	0.91	0.03	0.94	0.02
Consumption demand shock	σ_c	invgamma	0.5	200	1.96	0.26	3.28	0.60	4.55	0.47	3.74	0.48	4.59	0.55	3.89	0.37	3.41	0.36	6.18	0.78	1.49	0.21	3.29	0.52	3.29	0.45	2.20	0.44
Import markup shock	σ_{π_m}	invgamma	0.1	200	0.67	0.19	0.11	0.09	0.26	0.04	0.40	0.11	0.07	0.03	0.25	0.06	0.38	0.25	2.49	0.22	0.15	0.24	1.16	0.43	0.21	0.23	0.09	0.05
Domestic markup shock	σ_π	invgamma	0.1	200	0.63	0.07	1.25	0.13	0.40	0.05	0.66	0.06	0.21	0.02	0.65	0.06	0.22	0.08	0.09	0.05	0.61	0.06	0.14	0.12	0.78	0.07	0.55	0.05
Wage markup shock	σ_{π_w}	invgamma	0.1	200	2.08	0.21	2.17	0.24	2.98	0.30	1.36	0.20	2.75	0.27	2.43	0.22	0.55	0.05	3.52	0.36	0.56	0.07	1.64	0.18	0.44	0.05	1.63	0.21
Domestic riskpremium shock	σ_ψ	invgamma	0.1	200	1.20	0.20	1.93	0.47	1.10	0.23	0.79	0.12	1.25	0.23	0.70	0.17	1.13	0.20	1.61	0.35	1.39	0.31	1.27	0.36	0.71	0.12	2.84	0.49
Govt. expenditure shock	σ_g	invgamma	0.5	200	0.80	0.06	3.73	0.35	2.88	0.24	4.67	0.33	4.68	0.41	3.81	0.30	1.01	0.09	6.97	0.56	4.72	0.41	2.39	0.20	2.58	0.21	1.51	0.11
Import demand shock	σ_m	invgamma	1	200	5.66	0.49	5.85	0.53	4.89	0.44	3.98	0.34	6.68	0.59	3.74	0.30	3.98	0.34	5.83	0.46	3.26	0.29	5.94	0.56	4.30	0.34	5.40	0.42
Export demand shock	σ_{m^*}	invgamma	1	200	21.50	1.81	24.66	2.18	12.69	0.97	20.55	1.62	40.95	3.62	8.83	0.71	17.77	1.51	73.15	6.21	24.19	2.20	47.83	4.45	24.43	2.04	45.43	3.62
Exchange riskpremium shock	σ_{b_p}	invgamma	1	200	1.13	0.23	1.03	0.22	0.57	0.08	0.32	0.05	0.41	0.07	0.43	0.07	1.04	0.21	0.91	0.16	0.69	0.13	0.80	0.30	0.80	0.17	0.96	0.16
Interest rate policy shock	σ_i	invgamma	0.1	200	0.08	0.01	0.46	0.06	0.04	0.01	0.06	0.01	0.13	0.01	0.03	0.00	0.08	0.01	0.21	0.02	0.13	0.01	0.13	0.01	0.22	0.02	0.41	0.03
FXI policy shock	σ_{fx}	invgamma	1	2	1.28	0.10	2.78	0.25	6.73	0.57	5.00	0.40	6.22	0.54	12.47	0.99	1.72	0.15	6.95	0.57	3.17	0.28	1.63	0.15	3.11	0.25	3.14	0.24
Interest rate reaction to CPI inflation	γ_π	norm	0.5	0.34	0.91	0.23	0.62	0.27	0.99	0.19	1.20	0.26	0.50	0.21	0.88	0.23	0.60	0.18	0.59	0.23	0.41	0.17	0.82	0.22	0.32	0.21	0.40	0.22
Interest rate reaction to output gap	γ_y	beta	0.125	0.05	0.06	0.03	0.11	0.04	0.05	0.01	0.05	0.02	0.05	0.02	0.04	0.01	0.11	0.02	0.17	0.04	0.11	0.04	0.07	0.03	0.16	0.03	0.06	0.02
Interest rate smoothing	γ_i	beta	0.75	0.05	0.85	0.02	0.82	0.03	0.81	0.03	0.86	0.03	0.84	0.02	0.88	0.02	0.80	0.03	0.76	0.03	0.78	0.04	0.87	0.02	0.82	0.03	0.72	0.03
FXI response to change in exchange rate	$\gamma_{\Delta S}$	beta	0.5	0.125																								
FXI persistence	$\rho_{\Delta R}$	beta	0.5	0.15	0.46	0.08	0.27	0.09	0.39	0.08	0.43	0.09	0.41	0.09	0.31	0.08	0.35	0.09	0.25	0.08	0.26	0.08	0.47	0.11	0.39	0.08	0.34	0.08
FXI rule error correction	ρ_R	beta	0.05	0.025	0.00	0.00	0.05	0.02	0.01	0.00	0.01	0.01	0.02	0.01	0.03	0.01	0.01	0.00	0.03	0.01	0.02	0.01	0.01	0.00	0.04	0.02	0.02	0.01
LML - Laplace Approximation					-2236.57		-2096.76		-2573.78		-2511.58		-2330.68		-2576.77		-1996.57		-2789.97		-2081.77		-2085.41		-2605.65		-2933.78	
LML - Modified Harmonic Mean					-2236.23		-2097.06		-2565.02		-2512.96		-2330.63		-2579.08		-1995.90		-2791.23		-2078.84		-2086.01		-2604.50		-2934.15	

Appendix B. Table B.5: Country-Specific Posterior and Log Marginal Likelihoods for Endogenous and Exogenous FXI Rules in AEs

		Prior distribution			Posterior distribution																			
					Endogenous FXI rule										**Exogenous FXI rule**									
Parameter		type	mean	std. dev.	AE1		AE2		AE3		AE4		AE5		AE1		AE2		AE3		AE4		AE5	
					mh mean	mh std	mh mean	mh std	mh mean	mh std	mh mean	mh std	mh mean	mh std	mh mean	mh std	mh mean	mh std	mh mean	mh std	mh mean	mh std	mh mean	mh std
Calvo parameter for import prices	ξ_m	beta	0.75	0.05	0.96		0.89	0.02	0.81	0.03	0.77	0.03	0.83	0.02	0.96		0.89	0.02	0.83	0.03	0.76	0.03	0.83	0.02
Calvo parameter for export prices	ξ_x	beta	0.75	0.05	0.95	0.01	0.74	0.05	0.92	0.01	0.92	0.01	0.91	0.01	0.96	0.00	0.73	0.05	0.92	0.01	0.92	0.01	0.91	0.01
Calvo parameter for domestic prices	ξ_p	beta	0.75	0.05	0.88	0.02	0.86	0.03	0.84	0.02	0.82	0.03	0.78	0.05	0.88	0.02	0.85	0.03	0.83	0.03	0.82	0.03	0.79	0.04
Calvo parameter for wages	ξ_w	beta	0.75	0.05	0.81	0.03	0.72	0.03	0.70	0.04	0.85	0.02	0.87	0.01	0.83	0.02	0.72	0.03	0.69	0.04	0.85	0.02	0.87	0.01
Imported goods price indexation	ι_m	beta	0.7	0.2	0.83	0.08	0.98	0.02	0.43	0.16	0.53	0.14	0.87	0.08	0.97	0.02	0.98	0.02	0.61	0.13	0.50	0.11	0.87	0.08
Domestic price indexation	ι_p	beta	0.7	0.2	0.61	0.22	0.37	0.10	0.68	0.14	0.77	0.15	0.29	0.10	0.87	0.09	0.38	0.11	0.61	0.13	0.78	0.14	0.28	0.10
Exported goods price indexation	ι_x	beta	0.7	0.2	0.99		0.43	0.14	0.63	0.09	0.94	0.01	0.94	0.02	0.99		0.43	0.14	0.64	0.08	0.95	0.01	0.94	0.02
Wage indexation	ι_w	beta	0.7	0.2	0.47	0.19	0.09	0.05	0.16	0.09	0.13	0.07	0.97	0.01	0.30	0.11	0.09	0.05	0.17	0.09	0.13	0.06	0.96	0.02
Wage sensitivity to exchange rate	ν	beta	0.1	0.05	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Habit formation	$\varkappa_c$	norm	0.7	0.15	0.29	0.07	0.16	0.05	0.22	0.06	0.18	0.05	0.30	0.06	0.25	0.06	0.16	0.05	0.22	0.06	0.18	0.06	0.30	0.06
Discount factor	δ_c	beta	0.985	0.0075	0.97	0.01	0.98	0.01	0.97	0.01	0.97	0.01	0.96	0.01	0.96	0.01	0.98	0.01	0.97	0.01	0.97	0.01	0.96	0.01
FX market friction	Γ	beta	0.05	0.0125	0.03	0.01	0.01	0.00	0.02	0.01	0.02	0.01	0.02	0.01	0.02	0.00	0.01	0.00	0.02	0.01	0.02	0.01	0.02	0.01
Domestic riskpremium shock persistence	ρ_ψ	beta	0.75	0.1	0.90	0.03	0.89	0.02	0.77	0.05	0.86	0.03	0.75	0.05	0.87	0.03	0.89	0.02	0.77	0.05	0.86	0.03	0.75	0.05
Domestic demand shock persistence	ρ_υ	beta	0.85	0.05	0.95	0.02	0.91	0.02	0.95	0.02	0.95	0.01	0.96	0.01	0.97	0.01	0.91	0.02	0.95	0.01	0.95	0.01	0.96	0.01
Govt. expenditure shock persistence	ρ_g	beta	0.85	0.05	0.87	0.03	0.95	0.01	0.88	0.03	0.93	0.01	0.96	0.01	0.88	0.03	0.95	0.01	0.88	0.03	0.93	0.01	0.96	0.01
Import demand shock persistence	ρ_m	beta	0.85	0.05	0.84	0.04	0.81	0.04	0.74	0.07	0.81	0.03	0.83	0.03	0.84	0.04	0.82	0.04	0.74	0.06	0.81	0.04	0.84	0.03
Export demand shock persistence	ρ_{m^*}	beta	0.85	0.05	0.94	0.02	0.92	0.03	0.88	0.04	0.95	0.01	0.97	0.01	0.94	0.02	0.92	0.03	0.89	0.04	0.95	0.01	0.97	0.01
Exchange riskpremium shock persistence	ρ_{b_p}	beta	0.85	0.05	0.93	0.02	0.91	0.02	0.89	0.02	0.89	0.02	0.91	0.02	0.91	0.02	0.90	0.02	0.89	0.03	0.88	0.02	0.91	0.02
Consumption demand shock	σ_c	invgamma	0.5	200	2.57	0.33	3.28	0.36	2.13	0.31	2.63	0.28	1.88	0.19	2.02	0.22	3.28	0.36	2.11	0.30	2.63	0.27	1.89	0.21
Import markup shock	σ_{π_m}	invgamma	0.1	200	0.20	0.04	0.62	0.11	0.48	0.24	0.65	0.14	0.80	0.16	0.12	0.03	0.64	0.11	0.12	0.10	0.69	0.13	0.80	0.16
Domestic markup shock	σ_π	invgamma	0.1	200	0.07	0.04	0.85	0.08	0.20	0.16	0.20	0.13	0.76	0.07	0.15	0.02	0.85	0.07	0.44	0.06	0.16	0.11	0.76	0.07
Wage markup shock	σ_{π_w}	invgamma	0.1	200	0.45	0.05	0.74	0.06	1.25	0.14	0.95	0.08	0.17	0.01	0.41	0.03	0.73	0.06	1.27	0.14	0.94	0.08	0.17	0.01
Domestic riskpremium shock	σ_ψ	invgamma	0.1	200	0.36	0.07	0.44	0.08	0.64	0.12	0.42	0.06	0.55	0.10	0.40	0.08	0.43	0.07	0.63	0.13	0.41	0.06	0.54	0.11
Govt. expenditure shock	σ_g	invgamma	0.5	200	0.87	0.07	1.06	0.09	1.16	0.10	0.92	0.06	1.15	0.08	0.87	0.06	1.05	0.08	1.14	0.09	0.92	0.06	1.15	0.08
Import demand shock	σ_m	invgamma	1	200	2.10	0.19	4.43	0.34	3.78	0.36	2.16	0.15	3.65	0.26	1.99	0.15	4.45	0.36	3.75	0.33	2.18	0.16	3.64	0.26
Export demand shock	σ_{m^*}	invgamma	1	200	7.72	0.56	24.93	1.93	14.02	1.22	11.44	0.77	27.21	1.86	7.69	0.53	24.75	1.89	14.09	1.20	11.55	0.83	27.03	1.82
Exchange riskpremium shock	σ_{b_p}	invgamma	1	200	0.57	0.13	0.68	0.14	1.03	0.19	0.74	0.10	0.91	0.12	0.71	0.11	0.71	0.15	1.04	0.20	0.74	0.10	0.92	0.13
Interest rate policy shock	σ_i	invgamma	0.1	200	0.08	0.01	0.06	0.01	0.09	0.01	0.10	0.01	0.06	0.01	0.07	0.01	0.06	0.01	0.09	0.01	0.10	0.01	0.06	0.01
FXI policy shock	σ_{fx}	invgamma	1	2	3.30	0.48	2.32	0.19	2.47	0.25	0.56	0.05	1.40	0.12	2.84	0.22	2.39	0.19	2.16	0.20	0.52	0.04	1.35	0.11
Interest rate reaction to CPI inflation	γ_π	norm	0.5	0.34	0.91	0.38	1.22	0.22	0.80	0.27	1.46	0.25	1.14	0.24	1.37	0.24	1.21	0.23	0.79	0.25	1.46	0.26	1.13	0.24
Interest rate reaction to output gap	γ_y	beta	0.125	0.05	0.23	0.07	0.06	0.02	0.08	0.03	0.08	0.03	0.04	0.02	0.11	0.03	0.06	0.02	0.07	0.03	0.08	0.03	0.04	0.02
Interest rate smoothing	γ_i	beta	0.75	0.05	0.91	0.02	0.86	0.02	0.85	0.03	0.82	0.03	0.79	0.03	0.89	0.02	0.86	0.02	0.84	0.03	0.82	0.02	0.79	0.03
FXI response to change in exchange rate	$\gamma_{\Delta S}$	beta	0.5	0.125	0.20	0.11	0.18	0.03	0.13	0.05	0.04	0.01	0.11	0.03										
FXI persistence	$\rho_{\Delta R}$	beta	0.5	0.15	0.30	0.10	0.15	0.06	0.28	0.10	0.24	0.09	0.30	0.09	0.21	0.07	0.13	0.05	0.17	0.06	0.17	0.06	0.27	0.08
FXI rule error correction	ρ_R	beta	0.05	0.025	0.02	0.01	0.04	0.02	0.05	0.02	0.03	0.01	0.06	0.03	0.03	0.01	0.07	0.02	0.06	0.03	0.03	0.01	0.07	0.03
LML - Laplace Approximation					-2360.06		-2506.22		-2035.57		-2798.13		-2791.62		-2354.12		-2506.13		-2026.19		-2777.73		-2784.08	
LML - Modified Harmonic Mean					-2358.92		-2506.03		-2034.56		-2796.33		-2791.96		-2353.14		-2506.02		-2025.36		-2777.12		-2784.31	

PUBLICATIONS

An Estimated DSGE Model for Integrated Policy Analysis
Working Paper No. WP/2023/135