Financially Constrained Intermediaries and the International Pass-Through of Monetary Policy*

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Abstract

In this paper, we investigate the role of currency dealers in the global transmission of US (un)conventional monetary policy. We develop a two-country New Keynesian model with local banks and global currency dealers in a segmented international financial market, both of which are financially constrained. We calibrate the model by targeting estimates from a structural vector autoregression. Our quantitative analysis indicates that currency dealers' constraint is crucial for the transmission and effectiveness of quantitative easing in an open economy. The calibrated model also rationalizes the major exchange rate puzzles, particularly the downward term structure of currency carry trade risk premia.

Keywords: Currency dealers, Exchange rate disconnect, Financial constraints, Global portfolio flows, Home bias, Segmented markets, Risk premia, Monetary policy

JEL: E12, E52, F31, F32, G11, G21

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1 Introduction

A large empirical literature has documented the strong impact of US monetary policy on global financial markets (Bauer and Neely, 2014; Kalemli-Özcan, 2019; Miranda-Agrippino and Rey, 2020; Bhattarai and Neely, 2022; Maggiori, 2022). Yet the economic mechanism behind the global impact of asset purchases by the Federal Reserve (Fed), in particular, is not well understood. How does quantitative easing (QE) "work" in an open economy? How do exchange rates respond to the Fed's announcements?

In this paper, we provide a quantitative theory on international transmission of monetary policy that hinges on the limited risk-bearing capacity of financial intermediaries, in particular foreign exchange (FX) dealers. We build on the insights of Gabaix and Maggiori (2015) and Itskhoki and Mukhin (2021), who emphasize the role of FX dealers in determining exchange rates. We quantify the role of financially constrained intermediaries, especially FX dealers, in the international pass-through of (un)conventional monetary policy through investors' portfolio rebalancing channel. To this end, we develop a quantitative general equilibrium model that features financially constrained local banks and global FX dealers under a segmented global financial market, wherein FX dealers intermediate liquidity imbalances resulting from banks' portfolio rebalancing. We calibrate the model and conduct quantitative experiments based on our estimates from matching simulated and estimated impulse response functions (IRFs). Importantly, we demonstrate that FX dealers' constraint is crucial to explain the impact of QE on exchange rates and the effectiveness of QE policy's stimulation on domestic economy in an international setting. The calibrated model also closely matches a large set of target moments on exchange rate dynamics, international business cycles, and term structure of currency carry trade, which validates the model estimation, demonstrates the model's generality, and highlights a novel exchange rate disconnect mechanism.

We begin our analysis with an empirical case study of the "taper tantrum" period, during which global financial markets reacted sharply to the news of an impending slowdown of the Fed's asset purchases in 2013. Using high-frequency currency order flow data, we document strong and instant reactions of the US dollar exchange rates to the Federal Open Market Committee (FOMC) announcements, associated with sudden increase in FX dealers' dollar intermediation between nondealer banks and investors. This finding hints at a potentially important role played by FX dealers in global transmission of monetary shocks.

Motivated by this evidence, we build a two-country New Keynesian dynamic stochastic general equilibrium (DSGE) model that extends the framework of Gertler and Karadi (2011, 2013) to the international context with an imperfect currency market modeled as Gabaix and Maggiori (2015) and Itskhoki and Mukhin (2021). The model features two types of financial intermediaries, local banks and global FX dealers, both subject to binding financial constraints. In each country, banks hold and trade both domestic and foreign risky assets, including equity and long-term bonds. As in Gertler and Karadi (2011, 2013), equity premia and bond term premia arise from banks' binding constraints so that QE policy by a central bank is effective in the model. Banks bear exchange rate risk and holding cost arising from their investment in foreign assets. Global financial market is segmented wherein domestic agents are not able to directly borrow from or lend to foreign agents in short-term debt, while global FX dealers intermediate the currency imbalances resulting from banks' portfolio rebalancing and firms' import and export of goods. FX dealers do not hold or trade other risky assets; then banks' asset trading and FX dealers' currency exchange are separated. FX dealers have limited risk-bearing capacity due to the binding constraints. As a result, uncovered interest parity (UIP) fails and capital flows affect exchange rates, as in Gabaix and Maggiori (2015) and Itskhoki and Mukhin (2021). Compared to their models, a crucial distinction is the introducing portfolio rebalancing of financially constrained banks.

In our model, financially constrained intermediaries, especially FX dealers, play a critical role in the global pass-through of monetary shocks.[1] Specifically, lowering the domestic target rate (or a QE surprise) expands domestic banks' risky asset demand by lowering their funding cost (or by injecting liquidity). The resulting increased demand for risky assets then raises asset prices, lowers the respective expected returns, and boosts banks' net worth, amplified by banks' leverage. In order to intermediate the banks' extra demand for foreign assets, FX dealers have to (short-)sell foreign currency and buy domestic currency. Due to limited risk-bearing capacity, their ability to do so is imperfectly elastic, so that the home currency depreciates in order to compensate them with additional expected excess return, which endogenously impedes banks' portfolio adjustment. This feedback between FX dealers' limited risk-bearing capacity and banks' leverage implies that the impact of monetary policy is asymmetric across countries, since its pass-through to foreign economy is constrained by the exchange rate adjustment. The mutually reinforcing role of constraints faced by the two types of financial intermediaries is a novel channel for understanding global transmission of monetary policy.

[1] This is consistent with the empirical evidence in Roussanov and Wang (2022) that FX dealers' currency order flows explain much of the variation in the US dollar exchange rates at daily frequency, especially around monetary policy announcements.

We calibrate the model and estimate several key parameters, including the FX dealers' risk-bearing capacity, by matching the impulse responses to US conventional monetary shocks from model simulation and estimates from a Bayesian proxy structural vector autoregression (BP-SVAR). Based on the calibrated model, we conduct quantitative experiments introducing QE shocks. We document two important quantitative findings. First, FX dealers' constraint is crucial for explaining the strong impact of QE on exchange rates. Absent this constraint, there is no significant response of exchange rates to QE shocks, which is in sharp contrast to the empirical evidence. Second, the impact of QE on the domestic real economy is much weaker if FX dealers are unconstrained. Intuitively, in the absence of frictions in FX market, UIP holds and capital flows have no effect on exchange rates. Consequently, a large amount of liquidity injected by the QE spills over into the foreign country, diluting its impact on the domestic asset prices and real economy. Our quantitative analysis further indicates that the limited international transmission of QE policy is mainly attributed to FX dealers' financial constraint, rather than the unwillingness of foreign institutions to hold "home" assets due to the holding cost. Finally, we demonstrate that FX dealers' limited risk-bearing capacity is important for reconciling the apparent inconsistency between the instant overshooting of exchange rates to conventional monetary shocks and the failure of UIP.

Our quantitative model is able to rationalize the major exchange rate puzzles as considered in Itskhoki and Mukhin (2021) (including Meese and Rogoff (1983) disconnect puzzle, the UIP puzzle in Fama (1984), Backus and Smith (1993) puzzle, the Purchasing Power Parity (PPP) puzzle as in Rogoff (1996), and the terms-of-trade puzzle in Atkeson and Burstein (2008)), and also closely match the international business cycle moments. In addition, our model explains the otherwise puzzling downward-sloping term structure of currency carry trade risk premia as documented by Lustig, Stathopoulos, and Verdelhan (2019). Our quantitative experiments show that introducing financially constrained intermediaries operating in a segmented global financial market is sufficient to account for these puzzles. Intuitively, FX dealers' inelastic response to banks' portfolio rebalancing induced by financial shocks disconnects exchange rates from macroeconomic fundamentals and generates an offsetting effect between currency risk premium and bond term premia differential. Our quantitative analysis illustrates a novel mechanism for the "exchange rate disconnect" phenomenon that relies on investors' portfolio rebalancing.

Related Literature. Our paper relates to several strands of literature in international finance. Among these, the most closely related studies are Greenwood, Hanson, Stein, and

Sunderam (2023) and Gourinchas, Ray, and Vayanos (2022), who extend the preferred-habit model of term structure by Vayanos and Vila (2021) into an international setting. In their models, global bond and FX markets are integrated, and domestic and foreign bond term premia and FX premium are jointly determined by the risk-averse global arbitrager's optimal portfolio choice with hedging demand. Unlike their global arbitrager, FX dealers in our model only intermediate currency imbalances and do not hold or trade any other risky assets, as in Gabaix and Maggiori (2015) and Itskhoki and Mukhin (2021). This also aligns with the empirical findings of Roussanov and Wang (2022). Different from the hedging channel with integrated bond and FX trading, our model relies on intermediaries' binding financial constraints and segmented bond and FX trading, which allow us to directly quantify the importance of FX dealers' constraints in global monetary spillover. Compared to partial equilibrium models, the introducing production sectors and international goods trade in our model allow us to examine the impact of US monetary policy on the global economy. Different from other general equilibrium analysis as in Kekre and Lenel (2024), we mainly focus on the examination of FX dealers' role in the international monetary policy transmission. Additionally, recent studies on monetary spillover, such as Devereux, Engel, and Wu (2023), Bianchi, Bigio, and Engel (2023), Akinci and Queralto (2024), and Jiang, Krishnamurthy, Lustig, and Sun (2024), have not examined the role of FX dealers yet, which turns out to be our key contribution.

Our paper also addresses the issue of portfolio choice indeterminacy in a two-country DSGE model. To tackle this, we introduce banks' quadratic cost of foreign asset holding, covered by households. This approach differs from the local perturbation by Devereux and Sutherland (2010, 2011), the global method by Tille and Van Wincoop (2010) and Rabitsch, Stepanchuk, and Tsyrennikov (2015), the quadratic cost for households' portfolio adjustment as in Bacchetta and Van Wincoop (2021), and the quadratic collateral as in Devereux, Engel, and Wu (2023). Compared to these approaches, we obtain a simple and tractable solution for portfolio choice.

Finally, we contribute to the empirical studies of US monetary policy's impact on exchange rates and global economy. Using different identified methods, the vast number of studies on the global pass-through of conventional monetary policy include Eichenbaum and Evans (1995), Faust and Rogers (2003), Andersen, Bollerslev, Diebold, and Vega (2003, 2007), Faust, Rogers, Wang, and Wright (2007), and Scholl and Uhlig (2008), among others. For the transmission of unconventional monetary policy, the related studies include Bauer and Neely (2014), Neely (2015), Rogers, Scotti, and Wright (2014, 2018), Kalemli-

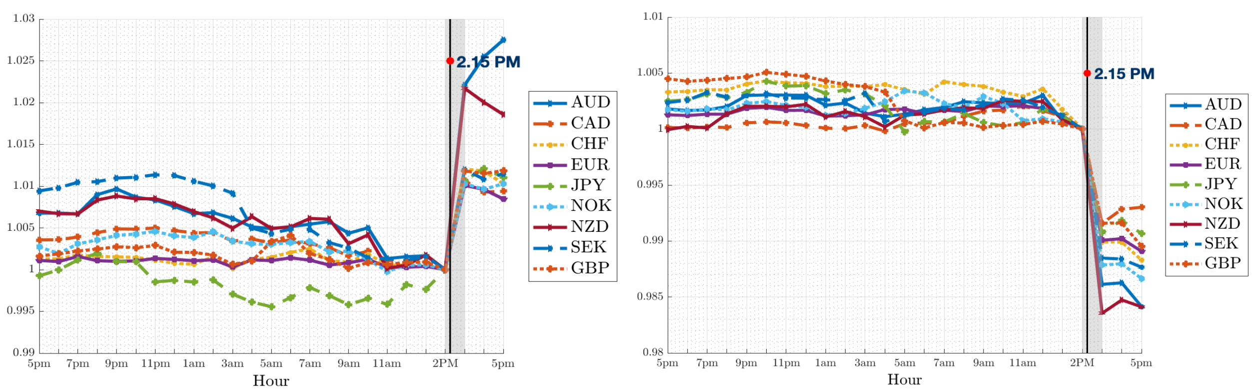
Özcan (2019), Stavrakeva and Tang (2023), Chari, Dilts Stedman, and Lundblad (2021), and Roussanov and Wang (2022), among others. Our empirical results reveal the potential role played by FX dealers in the transmission of monetary policy shocks to exchange rates and portfolio flows, which is absent among existing studies.

Layout. Our paper proceeds as follows. Section 2 presents the empirical case study during the "taper tantrum" period. Section 3 develops a two-country New Keynesian DSGE model with an imperfect currency market. Section 4 calibrates the model by matching empirical IRFs and reports quantitative results. Section 5 concludes.

2 Motivation: Taper Tantrum

We begin with a case study on two special FOMC announcements on June 19 and September 18, 2013. Using high-frequency data, we document the strong and instant reactions of exchange rates to monetary surprises and attribute this finding to FX dealers' surge in dollar intermediation around the narrow announcement windows.

Figure 1: Exchange rates of the US dollar against nine AE currencies (G10 currencies) around the FOMC announcements on June 19 and Sep 18, 2013

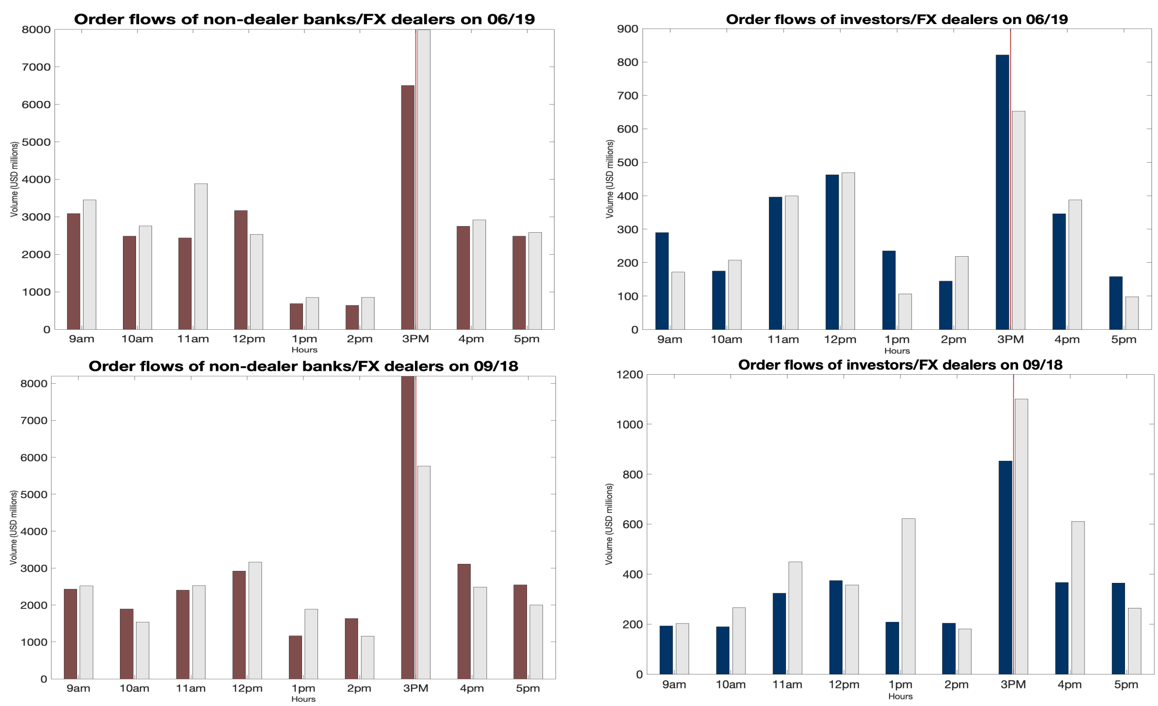


Note: The exchange rates are expressed in units of foreign currencies per US dollar; the values at 2:00 pm are normalized to unity. The left and right panels are for the announcements on June 19 and Sep 18, 2013, respectively.

Since mid-2013, the Fed has signaled a slowdown in its long-term bond purchases after several rounds of QE, initiating the "taper tantrum" period. Specifically, on June 19, 2013, the Fed unexpectedly announced to "anticipate to moderate the monthly pace of purchases later this year," surprising markets that had anticipated ongoing QE. On that day, US 10-year yields rose by 13 basis points (bps), the S&P 500 fell by 1.39%, and the US dollar appreciated by about 1% on average against advanced economy (AE) currencies. Expectations that the Fed would soon taper its purchases persisted. However, at the September 18, 2013 FOMC meeting, contrary to expectations, the Fed opted to "await more evidence" before adjusting its purchase pace, contracting the financial market with a 15 bps drop in US 10-year yields, 1.23% rise in S&P 500, and 1% averaged depreciation of the US dollar against AE currencies on that day. These events demonstrate the significant market impact of the Fed's large-scale asset purchases (LSAP) policy.

Using hourly frequency exchange rate and currency order flow data from CLS, we observe significant currency market reactions tightly clustered around these two announcements. In Figure 1, the US dollar appreciated (depreciated) against AE currencies strongly and immediately following a tightening (easing) surprise on the Fed's LSAP policy, occurring at 2:15 pm. The average appreciations and depreciations from 2:00 pm to 3:00 pm are 135 bps and -111 bps, which are 3.30 and -2.78 times the daily standard deviation, respectively.[2] In addition, the weekly path of exchange rates plotted in Appendix A.1 shows that the strong reactions are not tied to specific hours.

Figure 2: Currency order flows (million USD) between nondealer banks/investors and FX dealers for nine currency pairs around FOMC announcements on June 19 and Sep 18, 2013



Note: Red/blue bar is the side of nondealer banks'/investors' "buying the dollar from and selling foreign currencies to" FX dealers; gray bar vice versa. "3PM" represents the order flows from 2:00 pm to 3:00 pm.

To understand the driving force behind the exchange rates' strong fluctuations, we examine the trading behaviors of currency market makers, that is, FX dealers, around these announcements. Figure 2 shows that from 2:00 pm to 3:00 pm on June 19, 2013, FX dealers

[2] The daily standard deviation of average exchange rate changes for 9 currency pairs since 2000 is 41 bps.

significantly increased their dollar buying from nondealer banks and dollar selling to institutional investors. The opposite pattern is observed within the same window on September 18, 2013. These observations indicate that following monetary surprises, FX dealers balance surges in global investors' dollar demand or supply with funding liquidity from nondealer banks. FX dealers' rapidly large amounts of currency intermediation within the narrow windows explains the sharp and pronounced exchange rate fluctuations shown in Figure 1, which also aligns with the theoretical frameworks in Gabaix and Maggiori (2015) and Itskhoki and Mukhin (2021). This finding is further justified by the estimation based on BP-SVAR and the case study for emerging markets (EMs) with portfolio data from JP Morgan, reported in Appendix A. All of these highlight the role of FX dealers in the global transmission of monetary shocks, yet there are no related studies in the literature.

3 The Model

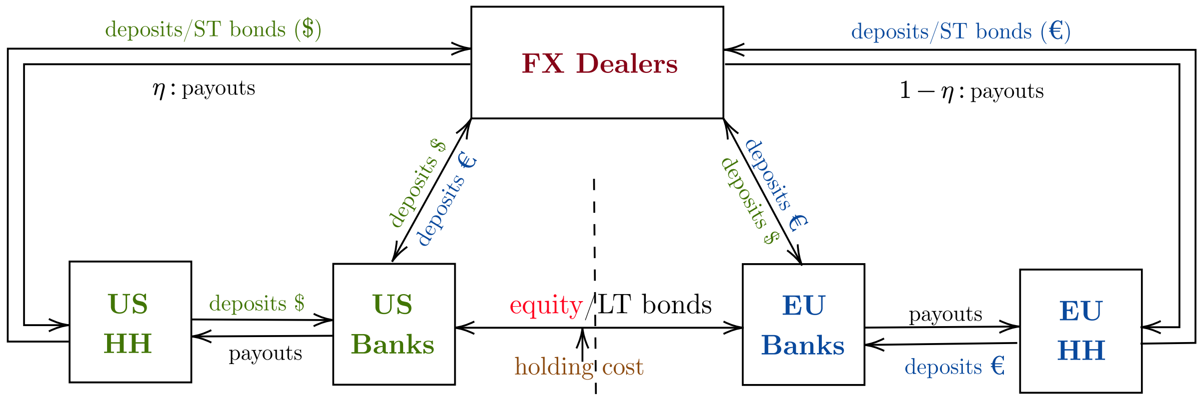
In this section, we develop a two-country New Keynesian DSGE model to study the role of currency dealers in the global transmission of monetary policy through the lens of banks' portfolio rebalancing. The model extends Gertler and Karadi (2011, 2013) to an international context with cross-border assets and goods trading. It also features an imperfect currency market as in Gabaix and Maggiori (2015) and Itskhoki and Mukhin (2021), whereas the major distinction is introducing financially constrained banks and their portfolio rebalancing.

The two countries are symmetric, denoted as home (the United States) and foreign (e.g, the European Union, labeled with an asterisk). Each country has its own nominal account in which local prices are quoted. The nominal exchange rate $\mathcal{E}_t$ represents the price of home currency (the US dollar) in terms of foreign currency. An increase in $\mathcal{E}_t$ means a nominal appreciation in home currency. We denote $e_t \equiv \mathcal{E}_t \frac{P_t}{P_t^*}$ as the spot real exchange rate in units of foreign currency per home currency, where P_t and P_t^* are the aggregate price levels of home and foreign countries, respectively.

The model consists of local households, banks, and goods producers in each country, as well as global FX dealers. Consolidated government in each country conducts monetary and fiscal policy. Figure 3 shows the key sectors in the model, and the whole economy structure is shown in Figure B1. We describe the setup for home country in the following sections; the setup for foreign country is analogous and presented in Appendix B.

A notable feature of Figure 3 is that global financial market is segmented, wherein FX dealers only hold and trade currencies of both countries to intermediate the global liquid-

Figure 3: The key ingredients of model structure



ity imbalances due to the inability of direct international borrowing and lending. Consequently, banks' equity and long-term bond trading and FX dealers' currency exchange are segmented. This is our key specification, which is different from the integrated bond and FX markets as in Greenwood et al. (2023) and Gourinchas, Ray, and Vayanos (2022). This specification is reasonable from several aspects. First, unlike major dealer banks and hedge funds, bond and FX trading for pension funds and insurance companies are likely separated. Roussanov and Wang (2022) provide the empirical evidence for the segmentation in FX market: FX dealers' daily net dollar transactions with nondealer banks and investors significantly explain daily exchange rate fluctuations of the dollar against AE currencies: 22.51% and 5.77% on FOMC days, and 2.04% and 0.22% on non-FOMC days. In addition, equity and FX trading might not be tightly linked, whereas equity flows have the strong impact on exchange rates as in Hau and Rey (2006). Finally, the different leverage or regulation requirements across sectors within a major bank might also separate asset trading from currency exchange.

3.1 Households

In each country, there is a unit continuum of identical households. They consume local final goods and save by making deposits in local banks or holding domestic short-term bonds. Each household comprises workers and bankers. Workers supply labor to local firms and return wages to households. Each banker runs a local bank owned by related households and retains earnings from asset investment. In each period, bankers stochastically exit and become workers with probability $1 - \sigma$ and are replaced with an equal number of workers such that the fraction of each occupation is fixed over time. Exiting bankers disburse retained earnings to their households, and new bankers receive a fixed start-up fund from their households.

Domestic households maximize lifetime utility over consumption and labor:

$$\mathbb{E}_t \sum_{i=0}^{\infty} \beta^i \left\{ \frac{C_{t+i}^{1-\sigma_c} - 1}{1-\sigma_c} - \frac{\chi}{1+\eta} L_{t+i}^{1+\eta} \right\},$$

where β is the discount factor, σ_c represents the relative risk aversion, $1/\eta$ is the Frisch elasticity of labor supply, and χ governs the importance of labor in utility.

Bank deposits and short-term bonds are perfectly substitutable one-period risk-less real bonds and pay a gross real return R_t from period t to $t+1$. Let D_{ht} be the total quantity of local short-term debt, w_t be the real wage, DIV_t be the net payouts from ownership of both non-financial firms and financial firms (local banks and FX dealers), X be the total start-up funds paid to new bankers, and T_t be the lump-sum transfers. We consider scenarios where households are either allowed or not allowed to hold domestic risky assets. In the case where households do not hold risky assets, their real budget constraint is

$$C_t + D_{ht} = w_t L_t + DIV_t - X + T_t + R_{t-1} D_{h,t-1}. \tag{1}$$

More details and extensions of the household's problem are given in Appendix B and C.

3.2 Banks

Within each country, a unit continuum of competitive banks owned by local households intermediate funds from households to non-financial firms and government. The local banks raise deposits from local households and invest in non-financial firms' equities and government long-term bonds of both countries.

Equities are state-contingent claims issued by intermediate goods firms to finance their capital. The claim has market value Q_t (Q_t^*) and net payout Z_t (Z_t^*) per period. Their capital depreciates at a constant rate δ with replacement price Q_{t+1} (Q_{t+1}^*). Notably, the claims can be treated as either equities or corporate loans, as demonstrated by Jarociński and Karadi (2020).[3] The real returns on domestic and foreign equities are

$$R_{k,t+1} = \frac{Z_{t+1} + (1-\delta) Q_{t+1}}{Q_t} \quad \text{and} \quad R_{k,t+1}^* = \frac{Z_{t+1}^* + (1-\delta) Q_{t+1}^*}{Q_t^*}.$$

Government long-term bonds are perpetuities with real income flows of 1, κ, κ^2, etc., as in Carlstrom, Fuerst, and Paustian (2017). The prices of domestic and foreign government

[3]Banks here can also be interpreted as levered investors.

long-term bonds are q_t and q_t^*; then the real bond returns are

$$R_{b,t+1} = \frac{1+\kappa q_{t+1}}{q_t} \quad \text{and} \quad R^*_{b,t+1} = \frac{1+\kappa q^*_{t+1}}{q^*_t}. \tag{2}$$

The associated real yields of long-term bonds are: $R_{yt} = q_t^{-1} + \kappa$ and $R_{y^*t} = q_t^{*-1} + \kappa$.

Bank's Optimization Problem. In each period, a domestic bank chooses s_{ht} (s_{ft}) shares of domestic (foreign) non-financial firm equity and b_{ht} (b_{ft}) shares of domestic (foreign) long-term bonds, and funds asset purchases with deposits d_t from local households and net worth n_t accumulated through retained earnings. Bank's real balance sheet in units of home currency is then given by

$$Q_t s_{ht} + q_t b_{ht} + \frac{Q_t^* s_{ft} + q_t^* b_{ft}}{e_t} = n_t + d_t, \tag{3}$$

where net worth is accumulated as gross earnings on risky assets in excess of funding cost:

$$n_t = R_{kt} Q_{t-1} s_{h,t-1} + R_{bt} q_{t-1} b_{h,t-1} + \frac{R^*_{kt} Q^*_{t-1} s_{f,t-1} + R^*_{bt} q^*_{t-1} b_{f,t-1}}{e_t} - R_{t-1} d_{t-1}. \tag{4}$$

Importantly, we assume that domestic banks experience a cost for foreign asset holdings,

$$\left[\frac{\kappa_1}{2} \left(\frac{Q_t^* s_{ft} - Q^*_{ss} \bar{s}_f}{e_t n_t} \right)^2 + \frac{\kappa_2}{2} \left(\frac{q_t^* b_{ft} - q^*_{ss} \bar{b}_f}{e_t n_t} \right)^2 \right] n_t, \tag{5}$$

where Q^*_{ss} and q^*_{ss} are the steady-state prices of foreign assets in real units of foreign currency, and $\bar{s}_f$ and $\bar{b}_f$ are the steady-state shares of foreign assets held by domestic banks. We set the values of $\bar{s}_f$ and $\bar{b}_f$ to match data directly, featuring home bias of asset holding at steady state. The quadratic holding cost captures home bias of asset holding deviated from steady-state values with sensitivity parameters κ_1 and κ_2. In this way, we introduce exogenous home bias of asset holding both at and away from steady state. This is not only consistent with the empirical fact on foreign asset holding cost, but is also the key part of our model that tackles portfolio choice indeterminacy as in Devereux and Sutherland (2011). We further assume this holding cost is covered by bankers as a lump-sum transfer to associated households, which yields a simple and tractable solution for portfolio choice.

Bankers maximize expected terminal net worth with the following Bellman equations:

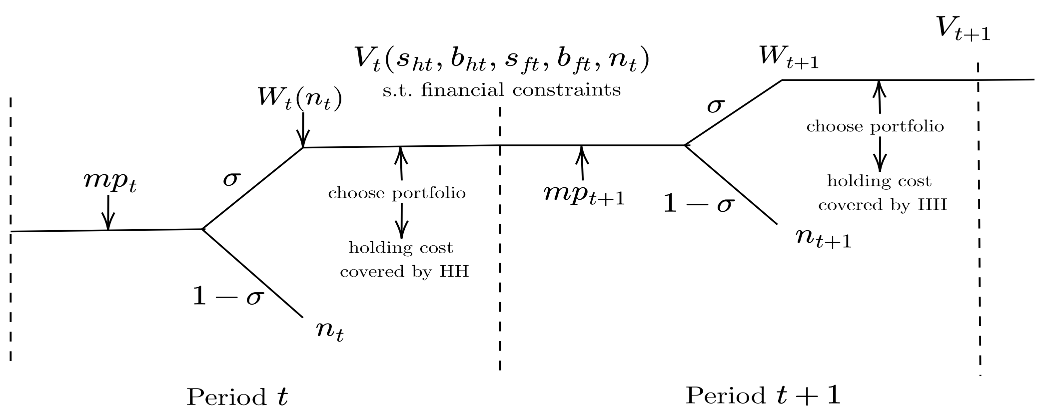
$$V_t(s_{ht}, b_{ht}, s_{ft}, b_{ft}, n_t) = \mathbb{E}_t \Lambda_{t,t+1} \left[(1-\sigma) n_{t+1} + \sigma W_{t+1}(n_{t+1}) \right],$$

and

$$W_t(n_t) = \max_{s_{ht}, b_{ht}, s_{ft}, b_{ft}} V_t(s_{ht}, b_{ht}, s_{ft}, b_{ft}, n_t) - \left[\frac{\kappa_1}{2} \left(\frac{Q_t^* s_{ft} - Q_{ss}^* \bar{s}_f}{e_t n_t} \right)^2 + \frac{\kappa_2}{2} \left(\frac{q_t^* b_{ft} - q_{ss}^* \bar{b}_f}{e_t n_t} \right)^2 \right] n_t,$$

where $\Lambda_{t,t+1}$ is the domestic household's stochastic discount factor between periods t and $t+1$, $V_t(s_{ht}, b_{ht}, s_{ft}, b_{ft}, n_t)$ is the end-of-period value function (after portfolio decisions), and $W_t(n_t)$ is the beginning-of-period value function (before portfolio decisions, but after occupation and other shocks). The holding cost is paid by bankers during the portfolio decision process. Figure 4 shows detailed timeline of bankers' decision making.

Figure 4: Timeline of events for each period



Similar to Gertler and Karadi (2013), bankers face a moral hazard problem that limits their ability to arbitrage. We assume that bankers are able to divert the fraction θ of equity and the fraction $\Delta\theta$ with $\Delta \in [0, 1)$ of government bonds under management at the end of each period. Upon diverting, depositors can force banks into bankruptcy and recover the remaining portion of assets. We also assume that the divertible fractions for domestic and foreign assets of the same type are equal. Overall, bankers are subject to the following financial constraint:

$$V_t(s_{ht}, b_{ht}, s_{ft}, b_{ft}, n_t) \geq \theta \left(Q_t s_{ht} + \Delta q_t b_{ht} + \frac{Q_t^* s_{ft} + \Delta q_t^* b_{ft}}{e_t} \right), \tag{6}$$

where the left-hand side is bankers' continuation value and the right-hand side is the gain from diverting funds.[4]

Solution with Aggregation. Because individual banks are identical, we solve the model at the aggregate level. We denote $\{S_{Ht}, B_{Ht}, S_{Ft}, B_{Ft}\}$ as domestic banks' aggregate holdings

[4]It is straightforward to extend the model to allow time-varying θ_t and Δ_t; and the solutions are the same.

of domestic and foreign assets, and N_t as their aggregate net worth. Given the evolution of individual bank's net worth in (4), the aggregate net worth dynamics is

$$N_t = \sigma \left[\left(R_{kt} - R_{t-1}\right) Q_{t-1} S_{H,t-1} + \left(R_{bt} - R_{t-1}\right) q_{t-1} B_{H,t-1} + \left(\frac{R^*_{kt}}{e_t} - \frac{R_{t-1}}{e_{t-1}} \right) Q^*_{t-1} S_{F,t-1} \right.$$
$$\left. + \left(\frac{R^*_{bt}}{e_t} - \frac{R_{t-1}}{e_{t-1}} \right) q^*_{t-1} B_{F,t-1} + R_{t-1} N_{t-1} \right] + X,$$

where σ is the fraction of surviving banks, and X is the total start-up funds to new banks.

From the optimal conditions for domestic asset holdings, the expected excess returns on domestic assets are

$$\mathbb{E}_t \left[\tilde{\Lambda}_{t,t+1} \left(R_{k,t+1} - R_t\right) \right] = \frac{\lambda_t}{1+\lambda_t} \theta \;\; \text{and} \;\; \mathbb{E}_t \left[\tilde{\Lambda}_{t,t+1} \left(R_{b,t+1} - R_t\right) \right] = \Delta \cdot \frac{\lambda_t}{1+\lambda_t} \theta, \tag{7}$$

where λ_t is the Lagrange multiplier associated with financial constraint in (6), and $\widetilde{\Lambda}_{t,t+1}$ is bankers' "augmented" stochastic discount factor:

$$\widetilde{\Lambda}_{t,t+1} \equiv \Lambda_{t,t+1} \cdot \left[1 - \sigma + \sigma \frac{\partial W_{t+1}(n_{t+1})}{\partial n_{t+1}} \right].$$

The expected excess returns of domestic assets increase with the tightness of financial constraint, measured by λ_t. Nonbinding constraint implies zero expected excess returns on risky assets. Because limits to arbitrage is weaker for long-term government bonds compared to equity ($\Delta < 1$), then the expected excess return of long-term bonds is also lower.

Domestic banks' optimal foreign asset holdings are given by

$$Q^*_t S_{Ft} = Q^*_{ss} \bar{S}_F + (1+\lambda_t)\, \mathbb{E}_t \left[\tilde{\Lambda}_{t,t+1} \left(\frac{R^*_{k,t+1} e_t}{e_{t+1}} - R_{k,t+1} \right) \right] \frac{N_t}{\kappa_1} e_t, \tag{8}$$

$$q^*_t B_{Ft} = q^*_{ss} \bar{B}_F + (1+\lambda_t)\, \mathbb{E}_t \left[\tilde{\Lambda}_{t,t+1} \left(\frac{R^*_{b,t+1} e_t}{e_{t+1}} - R_{b,t+1} \right) \right] \frac{N_t}{\kappa_2} e_t. \tag{9}$$

From (8) and (9), banks are exposed to exchange rate risk, and their optimal foreign asset holdings increase with dollar return differentials of the same asset type. Notably, we relate banks' foreign bond holding in (9) to the excess return of long-term bond carry trade in Lustig, Stathopoulos, and Verdelhan (2019). A larger shadow value of net worth λ_t enhances bankers' willingness to substitute towards assets with relatively higher returns. Banks' foreign asset holdings also increase with their net worth n_t, and decrease in parameters κ_1 and κ_2, as banks are less restricted to adjust foreign asset positions with higher net worth or lower holding cost. Overall, the model yields a solution that exhibits home bias in asset holding arising from both exogenous holding cost and endogenous exchange rate risk.

In equilibrium, the binding financial constraint in (6) imposes an endogenous leverage requirement on banks' aggregate holdings of risk-adjusted domestic assets:

$$Q_t S_{Ht} + \Delta q_t B_{Ht} \leq \phi_t N_t + \psi_t \text{ with equality if } \lambda_t > 0, \tag{10}$$

where ϕ_t and ψ_t are independent of individual banks and given by (B9) and (B10) in Appendix B.2, respectively. If the constraint is binding, leverage ratio ϕ_t amplifies the shocks to banks' net worth, and generates a reinforcing feedback loop between net worth and asset prices, that is, the financial accelerator mechanism as in Bernanke and Gertler (1989).

3.3 Currency Dealers

The international financial market is segmented, wherein FX dealers with limited risk-bearing capacity intermediate the currency imbalances arising from assets and goods trade. As in Gabaix and Maggiori (2015) and Itskhoki and Mukhin (2021), FX dealers trade only short-term bonds in both currencies, and are not able to hold risky assets or retain capital. At the end of each period, FX dealers distribute η fraction of net profits to domestic households and the rest to foreign households.

At period t, FX dealers maximize the expected real return from liquidity intermediation by choosing a position of foreign and domestic short-term bonds $\{d_{st}e_t, -d_{st}\}$:

$$V_t^d = \max_{d_{st}} \mathbb{E}_t \left[\left(\eta \Lambda_{t,t+1} + (1-\eta) \Lambda^*_{t,t+1} \frac{e_{t+1}}{e_t} \right) \left(\frac{R_t^* e_t}{e_{t+1}} - R_t \right) \right] d_{st},$$

subject to the financial constraint:

$$V_t^d \geq \Gamma_t d_{st}^2 e_t, \tag{11}$$

where Γ_t measures FX dealers' risk-bearing capacity. Because individual FX dealers are identical, FX dealers' aggregate supply of dollar liquidity D_{st} is given by

$$D_{st} = \frac{1}{\Gamma_t} \mathbb{E}_t \left[\left(\eta \Lambda_{t,t+1} + (1-\eta) \Lambda^*_{t,t+1} \frac{e_{t+1}}{e_t} \right) \left(\frac{R_t^*}{e_{t+1}} - \frac{R_t}{e_t} \right) \right]. \tag{12}$$

If $\Gamma_t = 0$, FX dealers earn zero net profit because of the infinite ability of liquidity intermediation, the risk-adjusted UIP holds, capital flows have no effect on exchange rates, and the international financial market is effectively integrated. If $\Gamma_t > 0$, the financial constraint in (11) is binding and FX dealers are effectively risk averse, leading to an upward-sloping supply curve for the dollar, the failure of UIP, and the segmentation of global financial market. FX dealers are unable to intermediate any imbalances if $\Gamma_t \to \infty$, corresponding to financial autarky (FA) case with $D_{st} = 0$. In equilibrium, real exchange rate e_t adjusts to clear currency market; that is, FX dealers' dollar supply equates to net dollar demand (D_{dt}) arising from assets and goods trading:[5]

$$
\begin{aligned}
D_{dt} = & \underbrace{(Q_t S^*_{Ht} - Q_{t-1} S^*_{H,t-1} R_{kt}) - (Q^*_t S_{Ft} - Q^*_{t-1} S_{F,t-1} R^*_{kt})/e_t}_{\text{net equity inflows to the US}} \\
& + \underbrace{(q_t B^*_{Ht} - q_{t-1} B^*_{H,t-1} R_{bt}) - (q^*_t B_{Ft} - q^*_{t-1} B_{F,t-1} R^*_{bt})/e_t}_{\text{net bond inflows to the US}} \\
& + \underbrace{\left[\gamma_y \frac{(p^*_{Ht} e_t)^{1-\eta_y}}{e_t} Y^*_t - \gamma_y \left(\frac{p_{Ft}}{e_t} \right)^{1-\eta_y} Y_t \right]}_{\text{net exports of the US}} + \underbrace{R_{t-1} D_{s,t-1}}_{\text{dollar debt payoff}} + \underbrace{\eta \left(\frac{R^*_{t-1} e_{t-1}}{e_t} - R_{t-1} \right) D_{s,t-1}}_{\text{profits rebated to US households}} .
\end{aligned}
$$

When US banks have extra demand for foreign assets with higher returns, FX dealers long the dollar and short foreign currency ($D_{st} < 0$). Then the dollar depreciates at the current period and is expected to appreciate subsequently such that FX dealers are compensated with positive expected profits. According to the optimal foreign asset holdings in (8) and (9), the dollar's depreciation and expected appreciation impede banks' substitution toward foreign assets, which endogenously generates home bias of asset holding.

Importantly, we demonstrate that FX dealers' limited risk-bearing capacity is crucial to explain the puzzling downward term structure of currency carry trade risk premia uncovered in Lustig, Stathopoulos, and Verdelhan (2019). In this section, we first provide some heuristic qualitative analysis.

In the model, a negative shock in Δ_t relaxes domestic banks' constraints, expands their demand for domestic long-term bonds, and lowers the expected excess return:

$$
\mathbb{E}_t \left[\log \left(\frac{R^*_{b,t+1}}{R^*_t} \right) \right] > \mathbb{E}_t \left[\log \left(\frac{R_{b,t+1}}{R_t} \right) \right] . \tag{13}
$$

Based on the optimal condition in (9), domestic banks substitute towards foreign long-term bonds, raising the aggregate demand for domestic deposits such that $R^*_t < R_t$. The currency market clearing condition implies the current depreciation and expected appreciation of home currency, and

$$
\mathbb{E}_t \left[\log \left(\frac{R^*_t e_t}{R_t e_{t+1}} \right) \right] \approx \mathbb{E}_t \left[\frac{R^*_t e_t}{R_t e_{t+1}} - 1 \right] < 0. \tag{14}
$$

[5]The definition of net portfolio flows aligns with the flow data in Bertaut and Tryon (2007) and Bertaut and Judson (2014), which is used in our SVAR estimation. Net exports of the US and the modified D_{dt} with noise traders of Itskhoki and Mukhin (2021) are defined in Appendix B.3.

Hence, our model with shocks in Δ_t rationalizes the forward premium puzzle in Fama (1984). We further decompose the long-term bond carry trade risk premia into:

$$\underbrace{\mathbb{E}_t\left[\log\left(\frac{R^*_{b,t+1}e_t}{R_{b,t+1}e_{t+1}}\right)\right]}_{\text{LT bond carry trade risk premia}} = \underbrace{\mathbb{E}_t\left[\log\left(\frac{R^*_t e_t}{R_t e_{t+1}}\right)\right]}_{\text{currency risk premium}} + \underbrace{\mathbb{E}_t\left[\log\left(\frac{R^*_{b,t+1}}{R^*_t}\right) - \log\left(\frac{R_{b,t+1}}{R_t}\right)\right]}_{\text{bond local currency term premia differential}}. \tag{15}$$

The model with shocks in Δ_t also generates a negative correlation between foreign-minus-US bond term premia differential and foreign currency risk premium in (15), which rationalizes the decline in long-term bond carry trade risk premia. The steeper foreign yield curve slope and lower foreign short-term rate in this case further explain the exactly opposite signs of predictive regression coefficients conditional on the respective variables in table 1 of Lustig, Stathopoulos, and Verdelhan (2019). Different from Greenwood et al. (2023) and Gourinchas, Ray, and Vayanos (2022), our general equilibrium model rationalizes this puzzle based on the separation of banks' asset trading and FX dealers' currency intermediation. The key insight is: FX dealers seize profits through currency exchange resulting from banks' portfolio rebalancing. Detailed quantitative analysis is provided in Section 4.

3.4 Producers

There are three types of non-financial firms in the production sector within each country: intermediate goods producers, capital producers, and retail firms. Following Gertler and Karadi (2011, 2013), we introduce nominal price rigidities in the retail firm sector.

3.4.1 Intermediate Goods Producers

Intermediate goods producers are competitive and sell homogeneous intermediate goods to local retail firms. They use labor and capital as inputs and produce output according to a Cobb–Douglas technology:

$$Y_{mt} = A_t K_t^{\alpha} L_t^{1-\alpha},$$

where Y_{mt} is intermediate goods output, A_t is total factor productivity, K_t is capital input, and L_t is labor input. Capital stock depreciates at constant rate δ, and intermediate goods producers buy I_t units of new capital from local capital producers at the end of each period. Their aggregate capital evolves as:

$$K_{t+1} = I_t + (1-\delta)K_t.$$

Intermediate goods firms finance new capital by raising funds from domestic banks. The firms issue a unit of state-contingent claim for each unit of capital at real price Q_t, and pay a dividend of Z_t per claim each period. The total number of claims S_t is equal to the units of capital acquired K_{t+1}, implying both prices are Q_t. Because of perfect competition, they earn zero profits such that optimal labor demand L_t and capital demand K_t are given by

$$L_t = p_{mt}(1-\alpha)\frac{Y_{mt}}{w_t} \quad \text{and} \quad K_t = p_{mt}\alpha\frac{Y_{mt}}{Z_t},$$

with the real price of home intermediate goods p_{mt}.

3.4.2 Capital Producers

Within each country, a unit continuum of competitive capital producers makes new capital using local final goods as input and sells it to local intermediate goods producers. We assume that local households own capital producers and receive their profits as lump-sum transfers. Capital producers' objective is to maximize discounted real profits by choosing the amount of investment I_t:

$$\max_{I_t} \mathbb{E}_t \sum_{k=0}^{\infty} \Lambda_{t,t+k} \left\{ Q_{t+k} I_{t+k} - \left[1 + f\left(\frac{I_{t+k}}{I_{ss}}\right)\right] I_{t+k} \right\},$$

where $f\left(I_t/I_{ss}\right)$ is the adjustment cost per unit of investment. We assume that the cost is quadratic in the net growth rate of new capital relative to steady-state value: $f\left(I_t/I_{ss}\right) = \frac{\kappa_I}{2}\left(I_t/I_{ss} - 1\right)^2$. The price of capital Q_t is determined by the optimal condition for investment, given in Appendix B.5.

3.4.3 Retail Firms

Retail firms in each country costlessly repackage a unit of local intermediate goods into a unit of differentiated retail good $i \in [0,1]$, and sell it to local and foreign final goods producers, which is associated with cross-border goods trade. Local and imported retail goods are then aggregated to goods baskets by competitive final goods producers:

$$Y_{jt} = \left[\int_0^1 Y_{jt}(i)^{\frac{\theta_y - 1}{\theta_y}} di\right]^{\frac{\theta_y}{\theta_y - 1}}, \text{ for } j \in \{H, F\}, \tag{16}$$

and domestic final goods are produced by:

$$Y_t = \left[(1-\gamma_y)^{\frac{1}{\eta_y}} Y_{Ht}^{\frac{\eta_y - 1}{\eta_y}} + \gamma_y^{\frac{1}{\eta_y}} Y_{Ft}^{\frac{\eta_y - 1}{\eta_y}}\right]^{\frac{\eta_y}{\eta_y - 1}}, \tag{17}$$

where $Y_{jt}(i)$ is retail good i from country $j \in \{H, F\}$, Y_{Ht} (Y_{Ft}) is the domestic (foreign) goods basket, and Y_t is domestic final goods. The parameter θ_y measures the elasticity of substitution among retail goods within a basket, η_y is the elasticity of substitution between domestic and foreign goods baskets, and $\gamma_y \in \left[0, \frac{1}{2}\right)$ captures the degree of home bias.

Retail goods pricing is subject to nominal rigidities as in Calvo (1983). Each firm is able to freely adjust its prices with probability $1 - \phi_p$ each period. Accordingly, the firm resets prices $\hat{P}_{Ht}(i)$ and $\hat{P}^*_{Ht}(i)$ to maximize expected discounted real profits subject to the restriction on adjustment frequency. We consider the schemes of producer currency pricing (PCP) and local currency pricing (LCP). Further details on retail firms are given in Appendix B.6.

3.5 Government Policy

In each country, a consolidated government consists of a central bank and a fiscal authority. The government has a fixed consumption G, supplies long-term bonds B_t at price q_t, and makes lump-sum transfers T_t to domestic households. The central bank finances the domestic long-term government bond purchases B_{gt} by issuing domestic short-term debt D_{gt} with balance sheet $q_t B_{gt} = D_{gt}$, where the associated profits are transferred to the domestic fiscal authority. The budget constraint of consolidated government is:

$$G + R_{bt}q_{t-1}B_{t-1} - q_t B_t + R_{t-1}D_{g,t-1} - D_{gt} + T_t = R_{bt}q_{t-1}B_{g,t-1} - q_t B_{gt}, \tag{18}$$

where $R_{bt}q_{t-1}B_{t-1} - q_t B_t$ is net repayment for long-term bonds, $R_{t-1}D_{g,t-1} - D_{gt}$ is net repayment for short-term debt, and $R_{bt}q_{t-1}B_{g,t-1} - q_t B_{gt}$ is net revenue from domestic central bank's long-term bond holdings.

Conventional Monetary Policy. Let i_t be the nominal interest rate with steady-state value i_{ss}. We assume that conventional monetary policy is characterized by a Taylor rule:

$$i_t = (1 - \rho_r)\left[i_{ss} + \phi_\pi (\ln \Pi_t - \ln \Pi_{ss}) + \phi_y (\ln Y_t - \ln Y_{ss})\right] + \rho_r i_{t-1} + \sigma_r \varepsilon_{it}, \tag{19}$$

where $\rho_r \in (0, 1)$ is the smoothing parameter, Π_{ss} and Y_{ss} are the steady-state gross inflation target and gross output, and ε_{it} is the interest rate shock with standard deviation σ_r. We restrict attention to parameter values giving rise to a determinate equilibrium, i.e. $\phi_\pi > 1$.

QE or LSAP Policy. We model the Fed's QE or LSAP policy as its domestic long-term bond purchases (B_{gt}) in the ZLB environment. Different from Carlstrom, Fuerst, and Paustian (2017) and Karadi and Nakov (2021) modeling QE shock as an AR(2) process, we calibrate QE shocks (B_{gt}) by matching the Fed's actual holding proportion of US long-term government bonds in two rounds of QE: "QE1" and "QE2", plotted in Figure D1.

3.6 Equilibrium

We focus on the equilibrium in which the financial constraints of both banks and FX dealers are always binding. The final output of each country is divided among consumption, investment, government expenditure, and foreign asset holding cost. The market clearing condition of home final goods is:

$$Y_t = C_t + \left[1 + f\left(\frac{I_t}{I_{ss}}\right)\right] I_t + G + \left\{\frac{\kappa_1}{2}\left[\frac{Q_t^*\left(S_{Ft} - \bar{S}_F\right)}{e_t N_t}\right]^2 + \frac{\kappa_2}{2}\left[\frac{q_t^*\left(B_{Ft} - \bar{B}_F\right)}{e_t N_t}\right]^2\right\} N_t.$$

For the market of international goods trade, the total home intermediate goods output is equal to the aggregate retail goods used for domestic and foreign final goods production, that is, $Y_{mt} = \int_0^1 \left[Y_{Ht}(i) + Y_{Ht}^*(i)\right] di$ with $Y_{Ht}(i)$ and $Y_{Ht}^*(i)$ defined in (B24).

To close the model section, we need clearing conditions for the markets of equity, long-term government bonds, and short-term debt in each country, as well as the currency market. Equity market clearing requires that $K_{t+1} = S_{Ht} + S_{Ht}^*$; that is, capital stock is equal to total equity holdings of domestic and foreign banks. The supply of long-term government bonds is fixed at $\bar{B}$, and the market clearing condition is $\bar{B} = B_{gt} + B_{Ht} + B_{Ht}^*$. Real wage adjusts to clear the labor market in each country. The currency market clearing condition is $D_{dt} = D_{st}$. We verify the consistency of two countries' budget constraints with the currency market clearing condition in Appendix B.7. Walras's Law implies the clearing of the short-term debt markets. The formal definition of equilibrium is given in Appendix B.8.

4 Quantitative Analysis

In this section, we design several sets of experiments to quantitatively examine the role of FX dealers in the global transmission of (un)conventional monetary policy. We solve the model around the steady state with intermediaries' binding constraints. We calibrate some of the parameters and estimate the remaining ones from the IRF matching. We conduct the quantitative analysis for QE shocks under the baseline ($\Gamma_t > 0$) and UIP ($\Gamma_t \to 0$) models with ZLB constraints. In the following sections, we present the quantitative results under the PCP scheme wherein households do not hold risky assets. The results for PCP and LCP schemes with households holding assets are provided in Appendix D as robustness check.

Table 1: Monthly calibrated parameter values

Parameter	Value	Description	Target or source
θ	0.944	Fraction of divertible equity	Targeted equity excess returns
Δ	0.270	Scale factor of divertible bond	Targeted bond excess returns
σ	0.980	Survival probability of banks	Gertler and Kiyotaki (2015)
X	0.045	Transfer to the entering bankers	Steady-state leverage: 4
κ	0.992	Bond income flow rate	Sims and Wu (2021)
$(S^h_{h,ss} + S_{H,ss})/K_{ss}$	0.700	Domestic equity holding share	Atkeson, Heathcote, and Perri (2022)
$(B^h_{h,ss} + B_{H,ss})/\bar{B}$	0.600	Domestic bond holding share	Foreign share of public debt: 40%
$S^h_{h,ss}/(S^h_{h,ss} + S_{H,ss})$	0.370	HH equity holding share	Federal Reserve's financial accounts
$B^h_{h,ss}/(B^h_{h,ss} + B_{H,ss})$	0.200	HH bond holding share	Federal Reserve's financial accounts
η	0.500	US share of FX dealers	Gabaix and Maggiori (2015)

4.1 Calibration

Table 1 lists the key calibrated parameters for financial intermediaries. We set the bond coupon decay rate κ in (2) to be $1 - 120^{-1}$, such that the maturity of long-term bonds is 10 years. We set the monthly survival probability of banks (σ) to be 0.98, implying an expected horizon of 50 months. We target annualized excess returns of 500 bps on equity and 135 bps on long-term bonds at steady state, implying $\theta = 0.944$ and $\Delta = 0.27$. Following Gertler and Karadi (2011), a steady-state leverage of four implies $X = 0.045$. We assume that domestic (foreign) banks hold 70% of domestic (foreign) equity and 60% of domestic (foreign) long-term bonds in the steady state. For the cases allowing households to hold risky assets, we assume that local households hold 26% of local equity and 12% of local long-term bonds in the steady state, calculated based on the Fed's US financial accounts. Finally, we let $e_{ss} = 1$ and $\eta = 1/2$. Other parameters are drawn from the standard literature shown in Table D1. We provide more details on calibration in Appendix D.

4.2 Estimation

We adopt the approach in Christiano, Trabandt, and Walentin (2010, 2021) to estimate the remaining parameters described in Table 2 by matching model's impulse responses to a US target surprise to those from BP-SVAR estimation with the monetary instruments of Swanson (2021). Because FX dealers' currency intermediation and investors' portfolio rebalancing are remarkably strong around the FOMC announcement windows as documented in Roussanov and Wang (2022), the IRFs of financial variables to monetary shocks would be particularly informative for the estimation of Γ_t, κ_1 and κ_2. The sample period of monthly BP-SVAR estimation is from January 1995 to June 2019. In this section, we consider the case of the US against nine developed countries with equal weights. We provide more details on variable construction, empirical analysis, and the estimation for the US against the EU in Appendix D. We consider the specifications of constant Γ, endogenous $\Gamma_t = \gamma \text{var}_t(\Delta \ln e_{t+1})$, and exogenous Γ_t as $\ln \Gamma_t = (1-\rho_\Gamma) \ln \bar{\Gamma} + \rho_\Gamma \ln \Gamma_{t-1} + \epsilon_{\Gamma t}$ following a target surprise. θ and Δ are time-invariant in the exercise of IRF matching.

Table 2: Priors and posteriors of estimated parameters

Parameter	Description	Prior (mean, std)	Posterior mode [2.5%, 97.5%]		
		[Bounds]	Const. Γ_t	Endo. Γ_t	Exog. Γ_t
κ_1	Equity holding cost	Gamma(1, 0.5)	0.361	0.223	0.208
		[0.01, 10]	[0.185, 1.076]	[0.082, 0.593]	[0.082, 0.640]
κ_2	Bond holding cost	Gamma(1, 0.5)	1.502	1.512	1.571
		[0.01, 10]	[1.145, 2.577]	[1.068, 2.386]	[1.160, 2.478]
Γ_{ss}	Steady state of Γ_t	Gamma(0.1, 0.02)	0.086	0.114	0.109
		[0.01, 10]	[0.060, 0.116]	[0.078, 0.157]	[0.080, 0.157]
ϕ_p	Price rigidity	Beta(0.8, 0.15)	0.978	0.967	0.965
		[0.001, 0.999]	[0.960, 0.988]	[0.946, 0.983]	[0.948, 0.982]
κ_I	Investment adjust cost	Gamma(1, 0.5)	0.623	0.598	0.389
		[0.01, 10]	[0.357, 1.980]	[0.274, 1.740]	[0.207, 1.901]
ρ_r	Taylor rule smoothing	Beta(0.8, 0.15)	0.939	0.901	0.920
		[0.001, 0.999]	[0.877, 0.967]	[0.859, 0.996]	[0.851, 0.996]
σ_r	Target surprise vol	Uniform	0.0011	0.0016	0.0016
		[0, 0.01]	[0.0006, 0.0019]	[0.0001, 0.0022]	[0.0001, 0.0024]

Let Θ be the vector of estimated parameters, $\mathbf{\Psi}(\Theta)$ denote the mapping from Θ to the model's IRFs, and $\hat{\mathbf{\Psi}}$ denote the corresponding empirical estimates. With the assumption $\hat{\mathbf{\Psi}} \sim_a N(\mathbf{\Psi}(\Theta), \mathbf{V})$ and a prior distribution $p(\Theta)$ for Θ, the posterior density of Θ is

$$p(\Theta|\hat{\mathbf{\Psi}}, \mathbf{V}) \propto p(\Theta) \cdot |\mathbf{V}|^{-1/2} \exp\left[-\frac{1}{2}(\hat{\mathbf{\Psi}} - \mathbf{\Psi}(\Theta))' \mathbf{V}^{-1} (\hat{\mathbf{\Psi}} - \mathbf{\Psi}(\Theta))\right],$$

where detailed derivations and implementation procedures are shown in the Appendix D.

Table 2 reports the priors $p(\Theta)$ and posterior mode of estimated parameters under different specifications of FX dealers' risk-bearing capacity Γ_t. The closely estimated values of parameters under three cases justify the robustness of model estimation. In particular, our estimated Γ or Γ_{ss} is around 0.1, which is in line with the back-of-the-envelope calculation in Gabaix and Maggiori (2015). Figure 5 shows the associated IRF matching results for seven variables over the first 24 months. Overall, the model's simulation results closely match the empirical IRFs for all three cases. The last panel in Figure 5 displays the estimated paths of Γ_t under different scenarios as described. Upon a tightening conventional monetary shock, we find that Γ_t rises immediately, implying that FX dealers are more financially constrained or risk averse. This is potentially explained by the impact of increased exchange rate volatility on FX dealers' risk-bearing capacity. We further report the IRF matching results under the UIP ($\Gamma_t \to 0$) and FA ($\Gamma_t \to \infty$) cases in Appendix D. We show that the model simulation is not able to match BP-SVAR estimates under the UIP case, indicating that FX dealers' binding constraints ($\Gamma_t > 0$) are crucial to match the empirical patterns. We also find that the IRF matching results under the baseline and FA cases are close, implying that FX dealers' limited risk-bearing capacity Γ_t is sufficiently large.

Figure 5 displays the instant overshooting of exchange rates from both BP-SVAR estimation and model simulation; that is, home currency appreciates immediately following a tightening target surprise and is expected to depreciate thereafter. This finding is consistent with Kim, Moon, and Velasco (2017), who show that delayed overshooting is primarily a phenomenon of the 1980s and attribute the instant overshooting since then to that UIP is close to hold. However, this argument contradicts the significant currency carry trade risk premium shown in Lustig, Roussanov, and Verdelhan (2011) over the same sample period. Our framework rationalizes the instant overshooting of exchange rates in Figure 5 but with the failure of UIP because $\Gamma_t > 0$ in all cases.

4.3 Quantitative Results

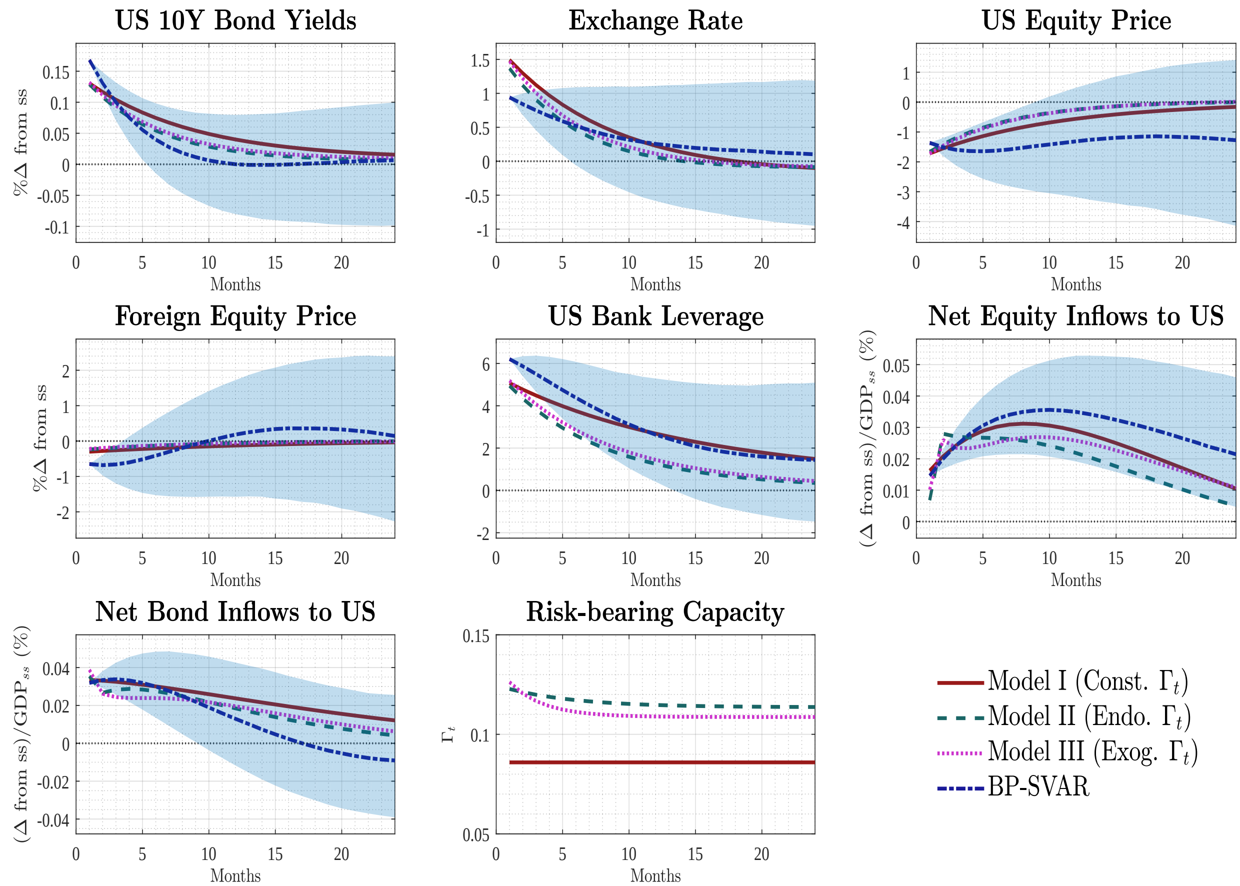
In this section, we first report the impulse responses of additional variables to a conventional monetary policy shock in Figure 6, which are associated with the IRF matching in Figure 5. The results of QE experiments are reported in Figure 7 and 8. We further simulate the model with different types of shocks to match a large set of target moments on exchange rate puzzles in Itskhoki and Mukhin (2021), the regression coefficients on bond term premia and currency risk premium in Lustig, Stathopoulos, and Verdelhan (2019), and the international business cycle moments. We introduce the time-varying θ_t and Δ_t in the moment matching, and keep them constant in the analysis of monetary policy.[6]

Conventional Monetary Policy. Figures 5 and 6 plot the impulse responses of key variables to a domestic tightening target surprise under the baseline cases with constant, endogenous, and exogenous specifications of Γ_t.

Figures 5 and 6 show that a tightening target surprise generates an exaggerated contraction on the domestic financial market and real economy. Because of nominal rigidities, a

[6]We assume that monetary policy's impact on θ_t and Δ_t is negligible.

Figure 5: Impulse responses to a target surprise: BP-SVAR estimation and model simulation



Note: The blue dashed line depicts the median IRFs of related variables to a normalized US target surprise such that US 3-month yields increases by 25 bps, and blue shaded bands are 90% credible sets. The simulated impulse responses are based on the posterior mode of parameters in Table 2. Model I specifies Γ to be fixed over time (red solid line); Model II specifies $\Gamma_t \equiv \gamma \text{var}_t(\Delta \ln e_{t+1})$ (green dashed line); Model III specifies $\ln \Gamma_t = (1 - \rho_\Gamma) \ln \bar{\Gamma} + \rho_\Gamma \ln \Gamma_{t-1} + \epsilon_{\Gamma t}$ (pink dashed line). The estimated paths are reported in the last panel. Nominal variables are normalized by inflation, and are translated to real ones. Portfolio flows are normalized by steady-state GDP value, calculated as the average of US GDP value and nine AE countries' GDP values with equal weights.

domestic tightening target shock raises domestic banks' funding cost, depresses their asset demand, decreases asset prices, and contracts their net worth. Banks' leverage amplifies this negative shock to their net worth through the financial accelerator mechanism, which is justified by the remarkable contraction of asset prices and banks' net worth in Figures 5 and 6. The rise of banks' leverage is also consistent with the equity constraint framework as in Bernanke and Gertler (1989). The magnified drop in banks' capital investment further worsens consumption, employment, and final output as shown in Figure 6.

Figures 5 and 6 also show that a tightening target surprise triggers net portfolio inflows to home country, resulting from domestic banks' reduction in asset holdings. FX dealers intermediate these imbalances, and the home currency appreciates because of FX dealers' limited risk-bearing capacity. The weaker foreign currency promotes foreign exports, inducing capital outflows from home to foreign country. In equilibrium, portfolio flows from assets trading outweigh capital flows from goods trading, as depicted in Figure 6.

As shown in Figures 5 and 6, a tightening domestic target surprise also contracts the foreign financial market and real economy through banks' portfolio rebalancing. Since domestic banks reduce the foreign asset positions, the prices decline and foreign banks expand asset holdings such that the foreign real interest rate rises. In equilibrium, foreign banks' balance sheet deteriorates because of the drop in asset prices, which then weakens foreign investment and real economy. Notably, Figures 5 and 6 exhibit largely asymmetric responses of domestic and foreign variables. This is because the holding cost of (5) and exchange rate risk in (8) and (9) impede domestic banks' reduction in foreign assets, leading to a moderate decline in foreign asset prices. Because of the larger drop in domestic asset prices and the home bias of asset holding at and away from steady state, domestic banks' balance sheets deteriorate much more than foreign banks. Banks' leverage amplifies these discrepancies in asset prices and banks' net worth across countries, intensifying global capital flows and exchange rate fluctuations. The asymmetric impact on the financial market is then transmitted to investment, production, consumption, and employment, as shown in Figure 6. Overall, the home bias effect and leverage effect reinforce each other such that a tightening domestic target surprise generates a significantly asymmetric impact on financial markets and the real economy of the two countries. This is a novel mechanism for the international monetary policy pass-through.

Finally, we compare the IRFs to a conventional monetary policy shock under the baseline, UIP and FA cases in Appendix D. We find that the IRFs under the baseline case are close to those under the FA case, which reflects that Γ under the baseline case is sufficiently large. Similar to the IRF matching results, the responses of variables under the baseline case are distant from those under the UIP case.

Quantitative Easing. In Figures 7 and 8, we compare the IRFs to the "QE2" shock in Figure D1 under the baseline and UIP-related cases, corresponding to segmented and integrated global financial markets. We specify the UIP-1 case with $(\Gamma, \kappa_1, \kappa_2) \to 0$ and the UIP-2 case with $\Gamma \to 0$ and $(\kappa_1, \kappa_2) > 0$, where the rest of parameters including (κ_1, κ_2) are the same as the baseline case. We re-estimate the model by letting $\Gamma \to 0$ and specify this as the UIP-3 case. The experiments are conducted in an environment with a constant Γ and ZLB constraints. To drive the economy to ZLB, we first simulate the model with a sequence of negative nominal interest rate shocks in Taylor rule of (19) such that ZLB constraints bind until the end of the "QE2" shock.

For the baseline case, Figures 7 and 8 show that a domestic QE shock raises asset prices, expands capital investment, and stimulates the real economy of both countries, but at largely asymmetric scales. To elaborate, the injected liquidity by QE relaxes banks' financial constraints, expands their aggregate demand for both domestic and foreign assets, and pushes up the asset prices. Because of exchange rate risk and holding cost faced by foreign banks, domestic central bank purchases more domestic long-term bonds from and inject more liquidity into local banks. Domestic banks then allocate more injected funds to local assets, generating a significantly asymmetric impact on asset prices and banks' net worth across countries. Similarly, banks' leverage further amplifies these asymmetric impacts. Home currency depreciates associated with the net capital outflows from home to foreign country, as asset trade flows outweigh goods trade flows. Figure 8 displays that the largely asymmetric impacts on financial markets are then propagated to real economic activities in the two countries, indicating that domestic QE effectively stimulates home economy, but its benefit to foreign economy is limited under the baseline case.

However, Figure 7 shows that the real exchange rate stays almost constant in response to QE shocks under the UIP cases, despite being associated with enormous net capital flows. This is in sharp contrast to the responses under the baseline case and the empirical findings of the case study and BP-SVAR estimation. Intuitively, under the UIP cases, the real exchange rate is irrelevant to capital flows and is solely determined by the real risk-free rate differential, which is moderately affected by QE shocks. Meanwhile, FX dealers are able to absorb any imbalances if UIP holds, and a large amount of the injected liquidity instantly spills over to foreign country through banks' portfolio adjustment in a frictionless currency market. When the global financial market is effectively integrated, we observe nearly identical responses of net capital flows under the UIP-1 case ($(\kappa_1, \kappa_2) \to 0$) without exogenous foreign asset holding cost and the UIP-2 case ($(\kappa_1, \kappa_2) > 0$) with the cost, which are around 4.5 times larger than those in the baseline case with $\Gamma > 0$. This indicates that FX dealers' constraints play a major role in preventing the injected liquidity's spillover to foreign country instead of the exogenous holding cost. Then we conclude that Γ is critical to explain QE shocks' strong impact on exchange rates and global portfolio flows.

Figure 8 displays another key finding: FX dealers' limited risk-bearing capacity plays a crucial role for the effectiveness of domestic QE. In Figure 8, we observe nearly identical responses of domestic and foreign real economic variables under the UIP cases; however, their responses are significantly different in the baseline case. Over the first 12 months, on average, the increase in domestic output under the UIP-1 and UIP-2 cases is around 73% and 79% of the increase under the baseline case, respectively. In contrast, the increase of foreign output under the UIP-1 and UIP-2 cases is around 1.58 and 1.44 times larger than the increase under the baseline case. Hence, if the global financial market is effectively integrated, domestic QE policy's stimulation effect on local real economy is much less effective, whereas the stimulation on foreign economy is notably strong. This is consistent with the enormous capital outflows to foreign country in Figure 7. Large-scale liquidity spillover in a perfect currency market dilutes QE policy's stimulation effect on the domestic economy and benefits the foreign economy much more than the baseline case with a segmented global financial market. Overall, we conclude the effectiveness of domestic QE is mainly attributed to FX dealers' limited risk-bearing capacity instead of exogenous holding cost.

We also re-estimate the model by setting $\Gamma \to 0$, and conduct the experiments based on the new estimates, labeled as UIP-3. In Figure 8, we find that the IRFs under the UIP-3 case are close to those under the UIP-1 and UIP-2 cases, which further justifies the important role of FX dealers' constraints in the transmission and effectiveness of QE.

Finally, the quantitative results under the baseline case are close to those under the FA case as shown in Appendix D, which indicates that estimated Γ in the baseline case is sufficiently large to guarantee the effectiveness of domestic QE policy.

Model Simulation. The calibrated model with estimates from IRF matching is able to match a large set of target moments, which validates the calibration, estimation, and generality of the model. In details, we simulate the model in monthly frequency with the calibrated parameters in Table D1 and the estimates in the case of constant Γ in Table 2, and specify domestic banks' financial shocks as:

$$\ln \theta_t = \ln \theta + \rho \left(\ln \theta_{t-1} - \ln \theta\right) + \sigma_\theta \varepsilon_{\theta t},\ \ln \Delta_t = \ln \Delta + \rho \left(\ln \Delta_{t-1} - \ln \Delta\right) + \sigma_\Delta \varepsilon_{\Delta t}.$$

We also specify the noise trader shocks of Itskhoki and Mukhin (2021) as $D_{nt} = \rho D_{n,t-1} + \sigma_n \varepsilon_{nt}$, domestic productivity shocks as $\ln A_t = \rho \ln A_{t-1} + \sigma_A \varepsilon_{At}$, and domestic interest rate shocks as ε_{it} in the Taylor rule of (19), respectively. Following Itskhoki and Mukhin (2021), we set $\rho^3 = 0.97$ for all shocks in monthly frequency. We assume $(\varepsilon_{\theta t}, \varepsilon_{\Delta t}, \varepsilon_{nt}, \varepsilon_{At}, \varepsilon_{it}) \sim_{i.i.d} N(\mathbf{0}, \mathbf{I})$, which are also independently distributed across time. Foreign shocks $(\varepsilon^*_{\theta t}, \varepsilon^*_{\Delta t}, \varepsilon^*_{At}, \varepsilon^*_{it})$ are defined symmetrically. We also consider the correlated shocks of the same type by introducing global shocks. For instance, we specify Δ_t and Δ^*_t as $\ln \Delta_t = \ln \Delta + \rho \left(\ln \Delta_{t-1} - \ln \Delta\right) + \sigma_\Delta \varepsilon_{\Delta t} + \sigma^g_\Delta \varepsilon^g_{\Delta t}$ and $\ln \Delta^*_t = \ln \Delta + \rho \left(\ln \Delta^*_{t-1} - \ln \Delta\right) + \sigma_\Delta \varepsilon^*_{\Delta t} + \sigma^g_\Delta \varepsilon^g_{\Delta t}$, where $\varepsilon^g_{\Delta t}$ is a global shock and $(\varepsilon_{\Delta t}, \varepsilon^*_{\Delta t}, \varepsilon^g_{\Delta t}) \sim_{i.i.d} N(\mathbf{0}, \mathbf{I})$. Other correlated shocks are defined similarly.

Table 3: Model moments

Moments	Data	Single-Type Shocks			Multiple Shocks		
		D_{nt}	Δ_t	θ_t	Domestic	Global-1	Global-2
A. Exchange rate disconnect (quarterly):							
$\rho\left(\Delta\hat{\mathcal{E}}\right)$	≈ 0	−0.12	−0.12	−0.11	−0.11	−0.11	−0.11
		(0.09)	(0.09)	(0.09)	(0.09)	(0.08)	(0.08)
$\sigma\left(\Delta\hat{\mathcal{E}}\right)/\sigma\left(\Delta\hat{Y}\right)$	5.20	7.12	3.30	2.31	4.23	3.82	3.73
$\sigma\left(\Delta\hat{\mathcal{E}}\right)/\sigma\left(\Delta\hat{C}\right)$	6.30	44.79	15.21	6.83	5.28	4.46	4.26
B. Real exchange rate and the PPP (quarterly):							
$\rho\left(\hat{e}\right)$	0.94	0.73	0.73	0.79	0.82	0.82	0.83
		(0.06)	(0.06)	(0.07)	(0.07)	(0.07)	(0.07)
$\sigma\left(\Delta\hat{e}\right)/\sigma\left(\Delta\hat{\mathcal{E}}\right)$	0.99	1.00	1.00	0.99	0.99	0.99	0.99
$\mathrm{corr}\left(\Delta\hat{e}, \Delta\hat{\mathcal{E}}\right)$	0.99	1.00	1.00	1.00	0.99	0.99	0.99
C. Backus-Smith (quarterly):							
$\mathrm{corr}\left(\Delta\hat{e}, \Delta\hat{C} - \Delta\hat{C}^*\right)$	−0.40	−0.55	−0.53	−0.58	−0.41	−0.48	−0.49
		(0.04)	(0.04)	(0.04)	(0.07)	(0.06)	(0.06)
$\sigma\left(\hat{i} - \hat{i}^*\right)/\sigma\left(\Delta\hat{\mathcal{E}}\right)$	0.06	0.06	0.07	0.09	0.15	0.15	0.15
$\rho\left(\hat{i} - \hat{i}^*\right)$	0.90	0.96	0.96	0.97	0.96	0.97	0.97
$\rho\left(\hat{i}\right)$	0.97	0.96	0.96	0.97	0.97	0.95	0.95
D. Forward premium (monthly):							
Fama β	−0.81	−4.39	−4.26	−3.42	−0.52	−0.73	−0.69
		(2.43)	(2.25)	(1.87)	(0.92)	(1.16)	(1.09)
Fama R^2	0.01	0.03	0.04	0.05	0.01	0.02	0.02
		(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)
Carry trade SR	0.35	0.45	0.47	0.48	0.23	0.24	0.24
		(0.16)	(0.16)	(0.20)	(0.14)	(0.15)	(0.15)
E. International business cycle moments (quarterly):							
$\sigma\left(\Delta\hat{C}\right)/\sigma\left(\Delta\hat{Y}\right)$	0.81	0.16	0.22	0.34	0.80	0.86	0.88
$\mathrm{corr}\left(\Delta\hat{C}, \Delta\hat{Y}\right)$	0.64	−0.93	−0.96	−0.98	−0.04	0.44	0.45
$\mathrm{corr}\left(\Delta\hat{I}, \Delta\hat{Y}\right)$	0.76	0.94	1.00	1.00	0.92	0.82	0.82
$\mathrm{corr}\left(\Delta\hat{Y}, \Delta\hat{Y}^*\right)$	0.50	−1.00	−0.45	0.90	−0.22	0.42	0.44
$\mathrm{corr}\left(\Delta\hat{C}, \Delta\hat{C}^*\right)$	0.54	−1.00	0.95	0.96	0.79	0.72	0.73
$\mathrm{corr}\left(\Delta\hat{I}, \Delta\hat{I}^*\right)$	0.45	−1.00	0.99	1.00	0.67	0.69	0.69
F. Terms of trade and net exports (quarterly):							
$\sigma\left(\Delta\hat{s}\right)/\sigma\left(\Delta\hat{\mathcal{E}}\right)$	0.25	0.97	0.97	0.98	0.98	0.98	0.98
$\mathrm{corr}\left(\Delta\hat{c}, \Delta\hat{\mathcal{E}}\right)$	0.20	−0.99	−0.99	−0.99	−0.99	−0.99	−0.99
$\sigma\left(\Delta\widehat{NX}\right)/\sigma\left(\Delta\hat{e}\right)$	0.09	0.12	0.11	0.10	0.11	0.11	0.11
$\mathrm{corr}\left(\Delta\widehat{NX}, \hat{e}\right)$	0.35	0.65	0.64	0.61	0.68	0.68	0.68

Note: The moments in Column "Data" are from Itskhoki and Mukhin (2021) except that the moments on forward premium puzzle are from Lustig, Stathopoulos, and Verdelhan (2019) as Table 4. Column "Δ_t" reports the simulated moments with a single "$\varepsilon_{\Delta t}$" shock, similar for Columns "θ_t" and "D_{nt}". Column "Domestic" reports the simulated moments with shocks $(\varepsilon_{\theta t}, \varepsilon_{\Delta t}, \varepsilon_{nt}, \varepsilon_{At}, \varepsilon_{it})$ by matching six moments in Panel D and regression coefficients in Column "Data" of Table 4, and the estimates are: $\sigma_\theta = 0.018$, $\sigma_n = 0.14$, $\sigma_A = 0.020$, $\sigma_r = 0.0004$; Column "Global-1" matches the same moments as "Domestic" with all specified shocks excluding $\varepsilon_{\Gamma t}$; the estimates are: $\sigma^g_\Delta = 0.076$, $\sigma_\theta = 0.048$, $\sigma^g_\theta = 0.0001$, $\sigma_n = 0.32$, $\sigma_A = 0.027$, $\sigma^g_A = 0.028$, $\sigma_r = 0.0001$, $\sigma^g_r = 0.0015$; Column "Global-2" matches the same moments as "Domestic" based on all shocks with estimates: $\sigma^g_\Delta = 0.018$, $\sigma_\theta = 0.049$, $\sigma^g_\theta = 0.0026$, $\sigma_n = 0.28$, $\sigma_A = 0.026$, $\sigma^g_A = 0.029$, $\sigma_r = 0.0001$, $\sigma^g_r = 0.0015$, $\sigma_\Gamma = 0.51$. Monthly variables are translated into quarterly values in Panels A, B, C, E, F.

We report the model simulated moments on exchange rate puzzles (including the Meese-

Rogoff disconnect puzzle, the UIP puzzle, the Backus-Smith puzzle, the PPP puzzle, and the terms-of-trade puzzle) and international business cycles in Table 3. Our model simulations with single-type shocks in Δ_t, θ_t, or D_{nt} are able to rationalize the major exchange rate puzzles as a single noise trader shock in Itskhoki and Mukhin (2021), although noise trader shocks in our model generate much larger volatility of nominal exchange rates relative to aggregate output or consumption growth. With multiple global shocks ("Global-1 and 2"), our model simulations closely match the related target moments. The estimated volatilities of banks' financial shocks in Δ_t, noise trader shocks, and FX dealers' financial shocks in Γ_t are substantially greater than those of macroeconomic shocks, aligning with the traditional opinion that financial variables are more volatile than macroeconomic fundamentals. The estimated volatility of noise trader shocks is around 30% of the volatility of shocks in Δ_t, indicating that banks' financial shock is an important driving force in the fluctuations of currency market and global economy. Overall, we identify a novel exchange rate disconnect mechanism based on banks' portfolio rebalancing under a segmented international financial market.

Table 4: Regressions coefficients matching on term structure of currency carry trade

		Single-Type Shocks			Multiple Shocks		
Moments	Data	Δ_t	θ_t	D_{nt}	Domestic	Global-1	Global-2
A. Short-term interest rate diff. (foreign-minus-home):							
Bond local currency return diff.	−0.78	−4.84	−0.89	−0.42	−0.62	−0.49	−0.48
	(0.32)	(4.88)	(0.38)	(0.06)	(1.31)	(1.07)	(1.09)
Currency excess return	1.81	5.26	4.42	5.39	1.52	1.73	1.69
	(1.47)	(2.25)	(1.87)	(2.43)	(0.92)	(1.16)	(1.09)
Bond dollar return diff.	1.03	0.41	3.54	4.97	0.90	1.26	1.19
	(1.51)	(2.67)	(1.51)	(2.39)	(1.18)	(1.21)	(1.19)
B. Yield curve slope diff. (foreign-minus-home):							
Bond local currency return diff.	2.18	2.97	1.05	−0.51	2.35	2.27	2.29
	(0.50)	(1.61)	(0.20)	(0.22)	(1.07)	(1.02)	(1.04)
Currency excess return	−1.23	−1.79	−4.46	0.94	−1.20	−1.22	−1.24
	(1.99)	(0.98)	(1.43)	(3.39)	(0.64)	(0.73)	(0.71)
Bond dollar return diff.	0.95	1.22	−3.41	0.49	1.16	1.03	1.02
	(2.00)	(0.73)	(1.24)	(3.30)	(0.83)	(0.96)	(0.95)

Note: Variables of the first column are defined in (15). Column "Data" is the panel regression results of the US dollar against AE currencies from Table 1 in Lustig, Stathopoulos, and Verdelhan (2019) with the sample period "Jan 1995-Dec 2015". Similar to Table 3, Columns "Δ_t", "θ_t", "D_{nt}", "Domestic", "Global-1" and "Global-2" report the regression results based on simulated data. Standard deviations are reported in bracket.

We run the regressions in table 1 of Lustig, Stathopoulos, and Verdelhan (2019) with model simulated data and report the results in Table 4. We find that the puzzling downward term structure of currency carry trade risk premia is mainly accounted for by banks' financial shocks in Δ_t. The analysis in Section 3.3 is justified by the positive (negative) predictive coefficient of foreign-minus-domestic long-term bond excess return and the negative (positive) predictive coefficient of currency excess return in (15) conditional on the foreign-minus-domestic yield curve slope differential (foreign-minus-domestic short-rate differential). In contrast, a single shock in θ_t or a noise trader shock in the model is not able to fully explain the puzzling facts. Model simulations with multiple shocks further improve the moment matching of regression coefficients.

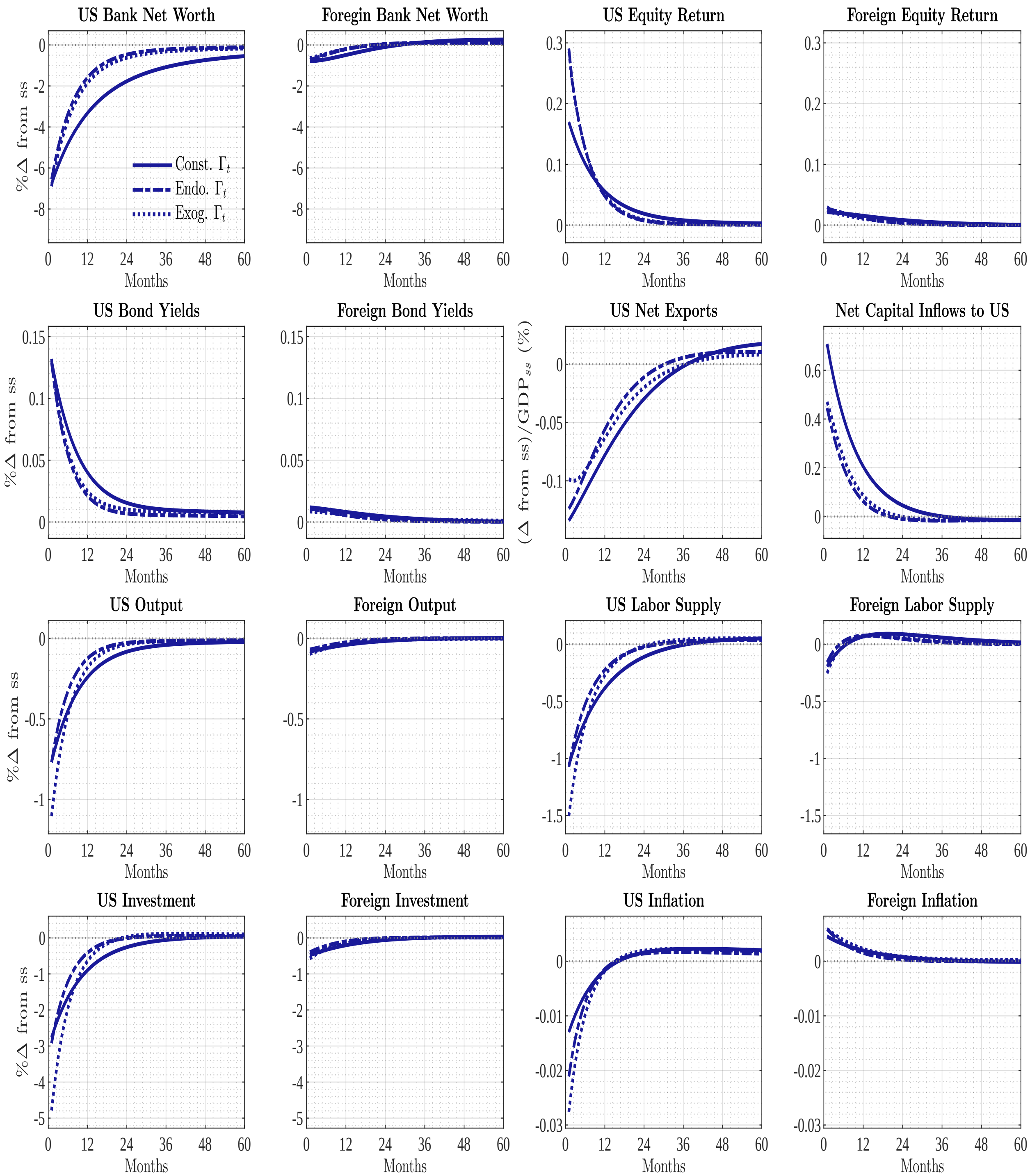
Tables 3 and 4 show that high-interest-rate currency tends to appreciate based on model simulations, which rationalizes the forward premium puzzle in Fama (1984). However, we also observe the instant overshooting of exchange rates following a tightening target surprise in Figure 5; that is, domestic currency appreciates immediately and is then expected to depreciate. Intuitively, portfolio flows or currency imbalances triggered by target monetary surprises dominate those induced by other shocks around the windows of monetary surprise. Outside these windows, currency imbalances induced by banks' financial shocks mainly account for the forward premium puzzle. Hence, our model reconciles the seeming inconsistency between the forward premium puzzle in Fama (1984) and instant exchange rate overshooting in Kim, Moon, and Velasco (2017) and Figure 5.

5 Conclusion

This paper highlights the critical role of FX dealers' financial constraints in the international transmission of US (un)conventional monetary policy. We examine the monetary policy transmission through the lens of global investors' portfolio rebalancing with a two-country New Keynesian DSGE model. Our quantitative results reveal that FX dealers' binding constraint is crucial for the explanation of QE's large impact on exchange rates and the effectiveness of central bank's QE policy. Beyond the analysis on monetary spillover, our quantitative analysis with banks' financial constraint shocks rationalizes the major exchange rate puzzles in the classical literature, as well as the puzzling downward term structure of currency carry trade risk premia. Overall, we quantify a novel exchange rate disconnect mechanism based on investors' portfolio rebalancing.

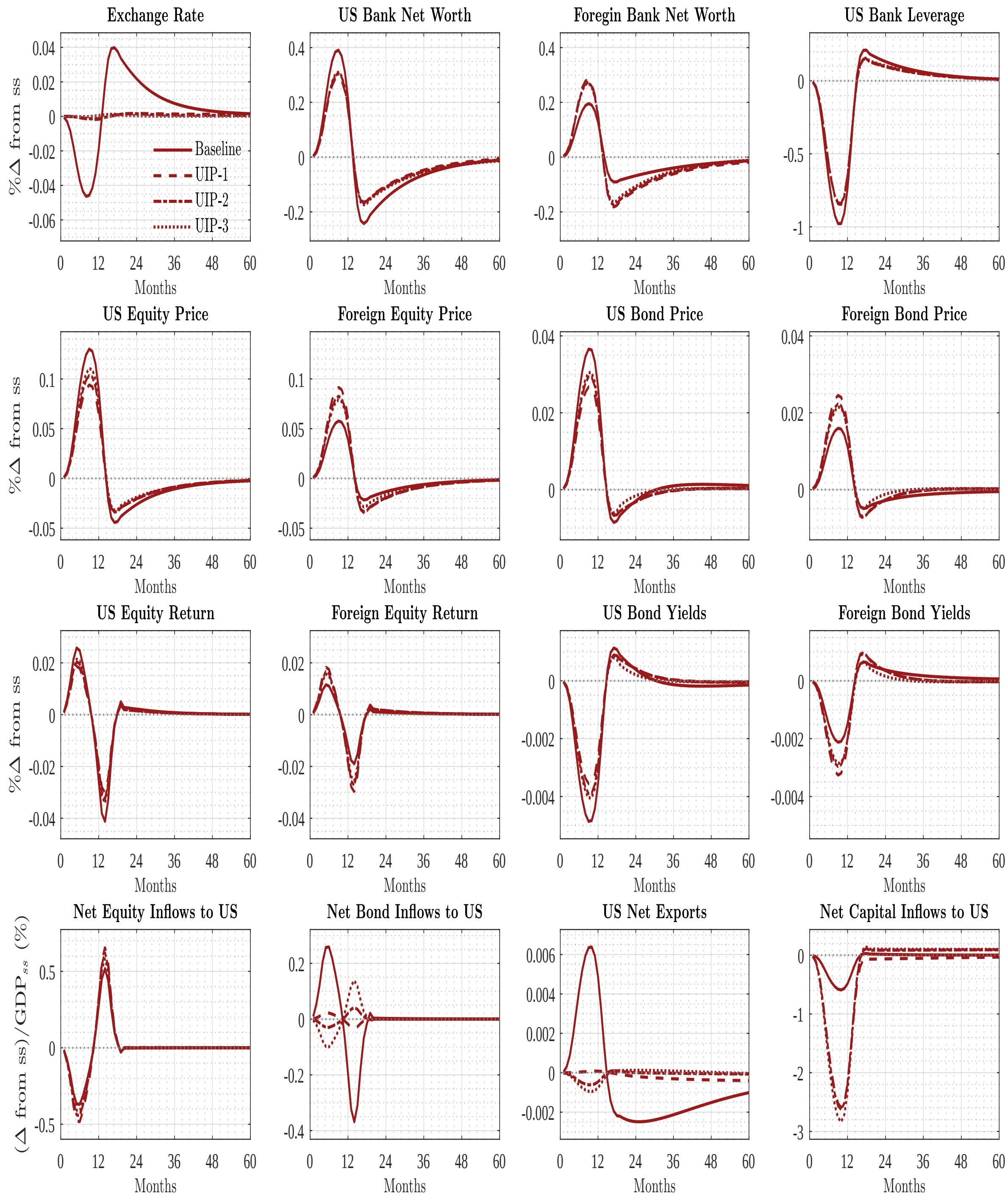
However, the current model is not able to account for the failure of covered interest parity after the global financial crisis shown in Du, Tepper, and Verdelhan (2018) or the presence of convenience yields described in Jiang, Krishnamurthy, and Lustig (2021). Additionally, our framework can also be used to quantitatively study the FX intervention policy as in Fanelli and Straub (2021). All of these are interesting directions for future work.

Figure 6: IRFs to a conventional monetary policy shock with different specifications of Γ_t



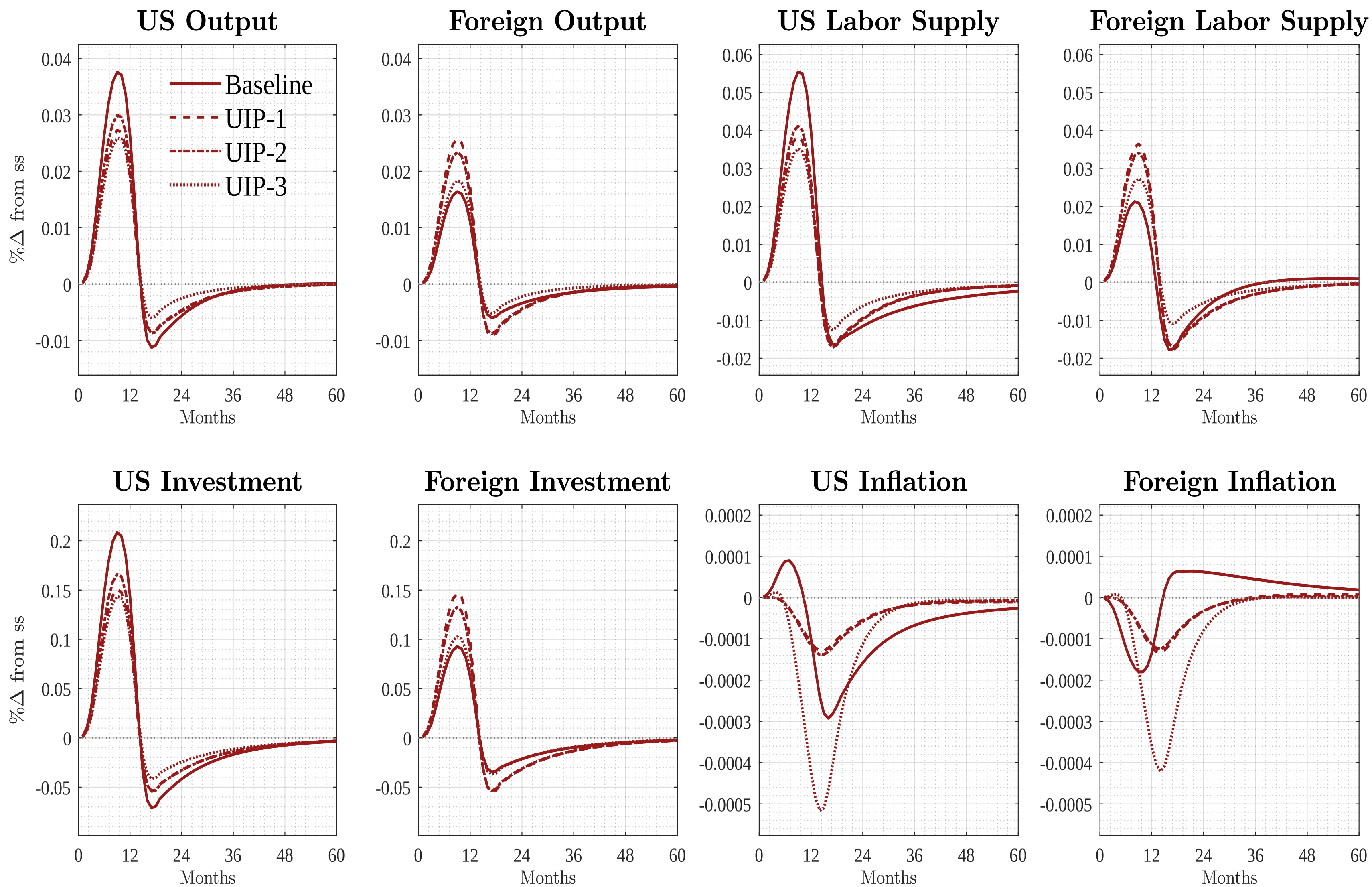
Note: The simulation results are based on the posterior mode of parameters in Table 2. In Panels "US Net Exports" and "Net Capital Inflows to US", the IRFs are reported as % of deviations from steady-state values relative to steady-state GDP. In the other panels, the IRFs are reported as % deviations from steady-state values.

Figure 7: IRFs of financial variables to "QE2" shocks under the baseline and UIP cases with ZLB constraints



Note: The simulation results for the baseline, UIP-1 and UIP-2 cases are based on the posterior mode of parameters from Column "Const. Γ_t" in Table 2. For the UIP-3 case, the results are based the posterior mode of parameters from Column "UIP" in Table D2. In the last row, the IRFs are reported as % of deviations from steady-state values relative to steady-state GDP. In the other rows, the IRFs are reported as % deviations from steady-state values.

Figure 8: IRFs of real economic variables to "QE2" shocks under the baseline and UIP cases with ZLB constraints



Note: The simulation results for the baseline, UIP-1 and UIP-2 cases are based on the posterior mode of parameters from Column "Const. Γ_t" in Table 2. For the UIP-3 case, the results are based the posterior mode of parameters from Column "UIP" in Table D2. The IRFs are reported as % deviations from steady-state values.

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Online Appendix for "Financially Constrained Intermediaries and the International Pass-Through of Monetary Policy"

List of appendices

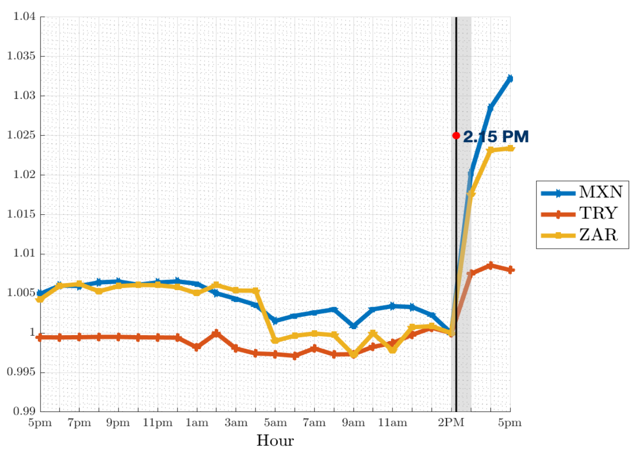
Appendix A Data, Method and Additional Empirical Results

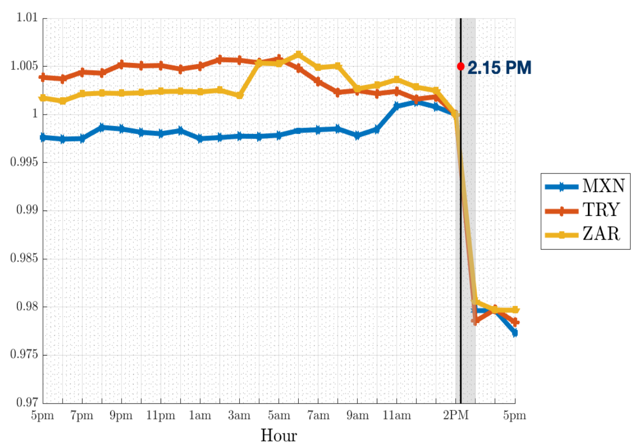
We provide additional empirical results for the event studies in Section 2. In Figure A1, we show that exchange rates of the dollar against several EM currencies reacted strongly around the narrow windows of associated FOMC announcements. Figure A2 shows the weekly path of exchange rates in the related FOMC announcement weeks. Figure A7 plots the portfolio flows and exchange rates between the US and seven EMs during the "taper tantrum" period. Figure A3 to A6 show the currency order flows for individual G10 currency pairs.

A.1 Additional Results in Event Studies

Around the announcements on June 19, 2013 and Sep 18, 2013, we show that the US dollar appreciated or depreciated sharply by around 2% against EM currencies on average in Figure A1. Compared to AE currencies, EM currencies have much stronger responses to the announcements, which is consistent with the traditional wisdom.

Figure A1: Exchange rates of the US dollar against several EM currencies around FOMC announcements on June 19, 2013 and Sep 18, 2013

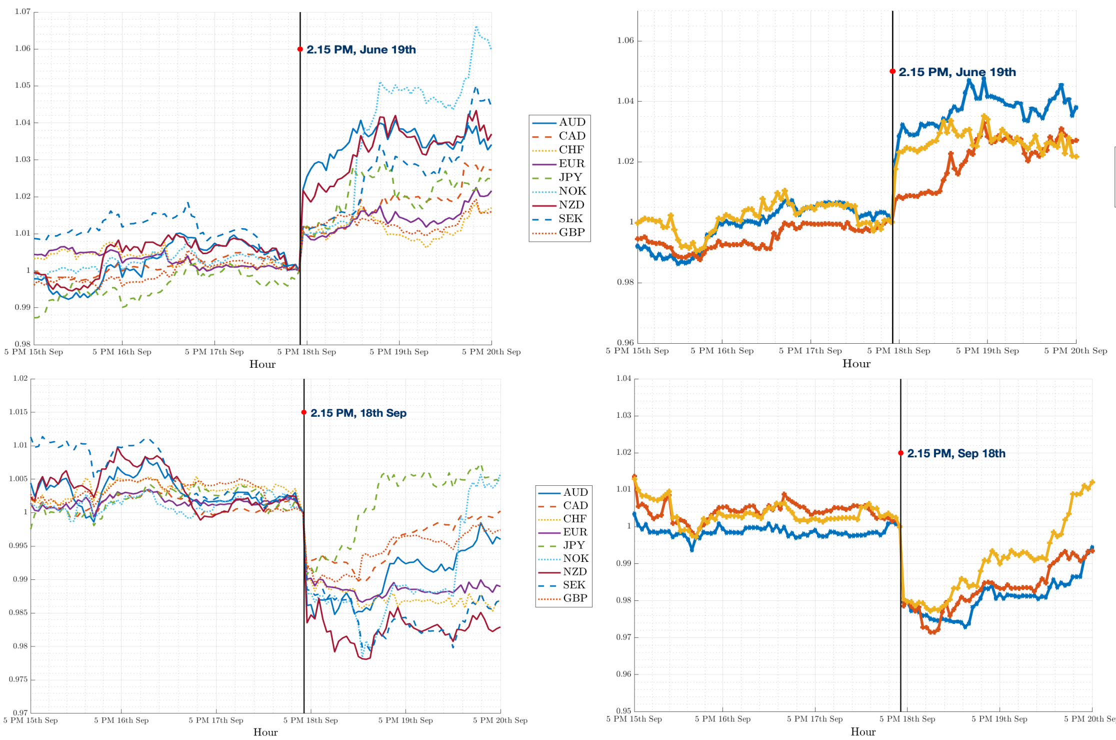




Note: The exchange rates are expressed in units of foreign currencies per US dollar; the values at 2:00 pm are normalized to unity. The left and right panels are for the announcements on June 19 and Sep 18, 2013, respectively.

In Figure A2, we plot the variations of exchange rates for the whole week to account for the hourly fixed effect. We find that there are no significant reactions of exchange rates from 2:00 pm to 3:00 pm on other non-announcement days within the announcement weeks, which indicates that the strong reactions of exchange rates are independent of specific hours (2:00 pm to 3:00 pm). We also report the currency order flows between FX dealers and nondealer banks or global investors for individual G10 currencies in Figure A3 to A6 around these two special announcements. Overall, the findings for individual currencies are consistent with the aggregate evidence, although the findings based on order flows of some currencies between investors and FX dealers show slight inconsistencies with the aggregate results. This is due to the fact that CLS only covers a part of global investors' order flows compared to nondealer banks' order flows. Hence, the results might be sensitive to idiosyncratic noise trading.

Figure A2: Exchange rates of the US dollar against AE and several EM currencies in the FOMC announcement weeks of June 19, 2013 and September 18, 2013



Note: The exchange rates are expressed in units of foreign currencies per US dollar; the values at 2:00 pm on June 19, 2013 and September 18, 2013 are normalized to unity. The top and bottom panels are for the announcement weeks of June 19, 2013 and Sep 18, 2013, respectively.

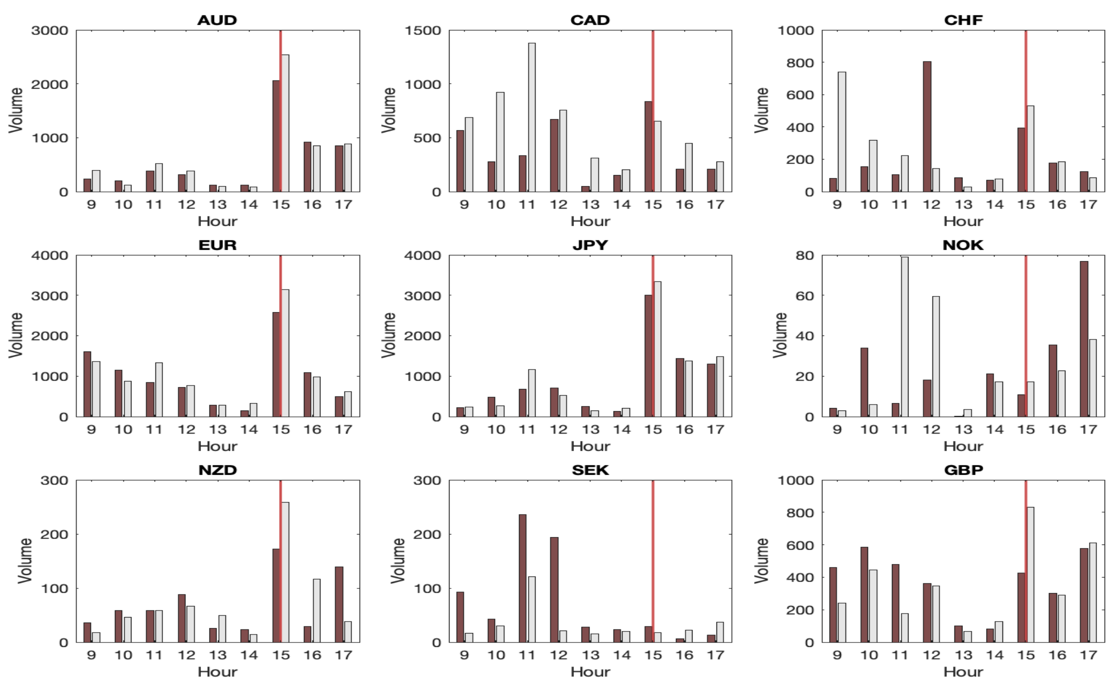
Moreover, we examine US monetary policy's impact on global investors' portfolio flows between EMs and the US with the data from JP Morgan Chase & Co. Institute. In the left panel of Figure A7, we plot the investors' cumulative net portfolio inflows to the US from seven EMs with associated currencies: BRL, MXN, IDR, INR, THB, TRY, and ZAR.[7] Importantly, we observe a striking reversal in global investors' portfolio inflows to the US since

[7] Farrell, Eckerd, Zhao, and O'Brien (2020) show the similar graph, their copyright should be noticed. We thank George Eckerd for sharing JP Morgan's portfolio flows data with us.

May 2013, which corresponds exactly to the beginning of the "taper tantrum". Specifically, there was a growing portfolio outflow from the US to EMs up to 7.68 billion USD by May 2013, but it quickly reverted to the trend by mid-June. In particular, on June 19, 2013, the cumulative portfolio flows flipped sign from -0.74 to 0.81 billion USD. Since then, the portfolio inflows to the US from EMs grew rapidly to 20.03 billion USD by the end of 2013. However, in sharp contrast to 2013, there was a constant investors' portfolio outflow from the US to EMs in other years.

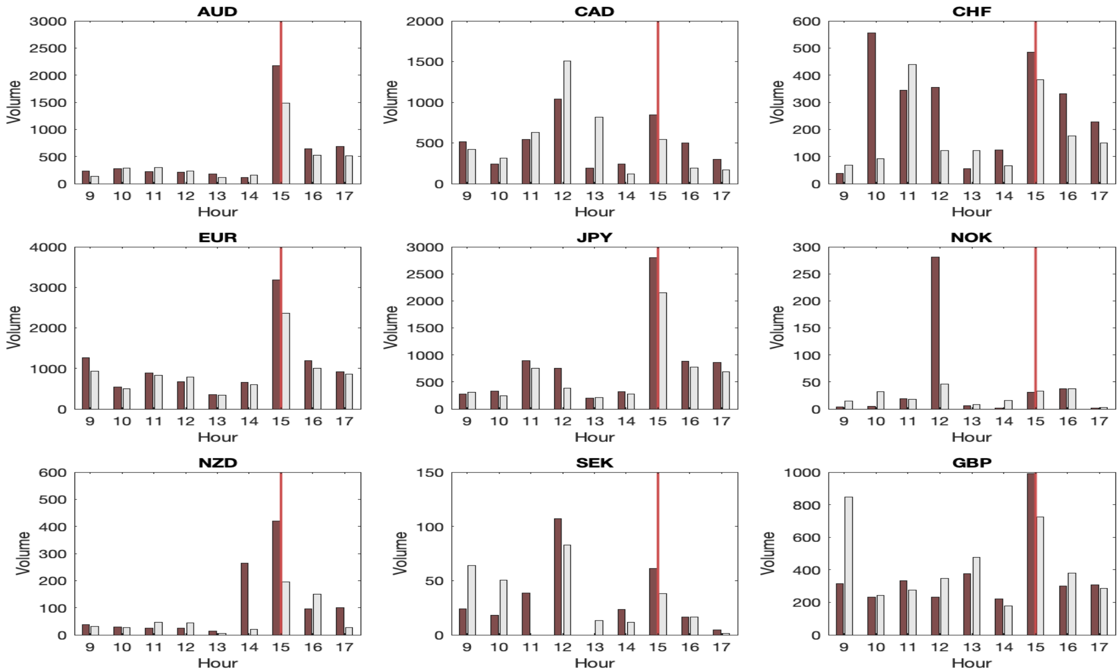
We further zoom in the analysis by just focusing on the "taper tantrum" period from May 2013 to Sep 2013. The right panel of Figure A7 graphs investors' aggregate portfolio inflows to the US from EMs and the average exchange rates of the US dollar vis-à-vis the related EM currencies during this period. It shows that the growing portfolio inflows to the US are associated with a constant appreciation of the dollar. Notably, the slopes of both portfolio inflows and appreciation of the dollar are the steepest on June 19, 2013, which further justifies the strong impact of the Fed's asset tapering on exchange rates by inducing global investors' portfolio rebalancing.

Figure A3: Currency order flows (million USD) for G10 currency pairs between nondealer banks and FX dealers around FOMC announcement on June 19, 2013



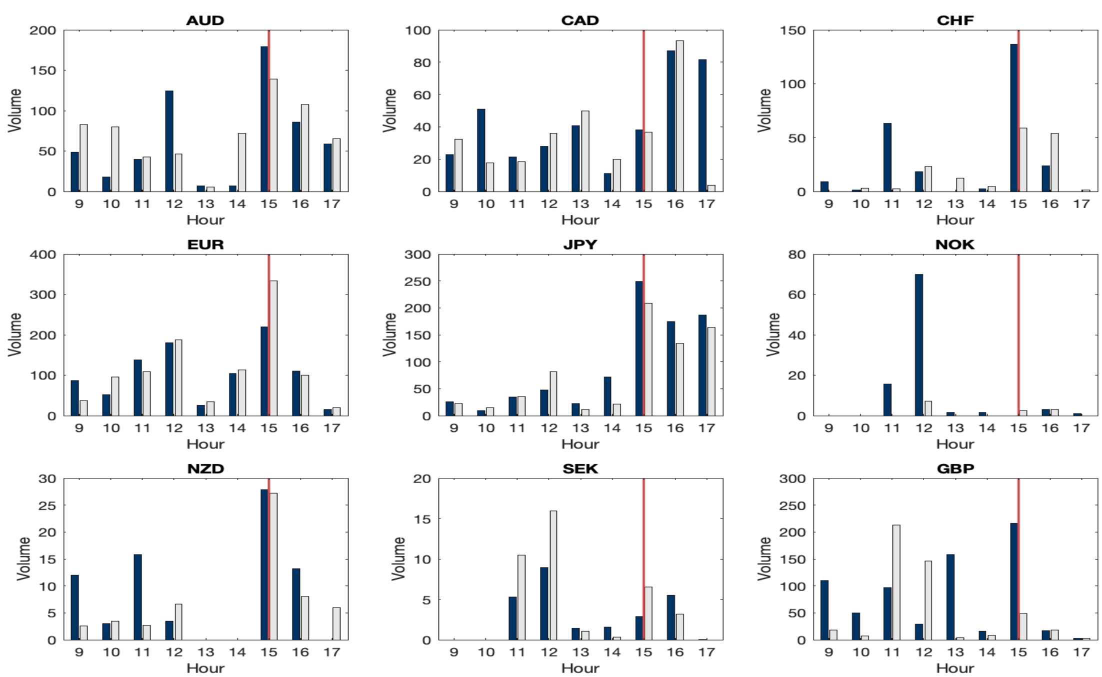
Note: The dark red bar is the side of nondealer banks' "buying the dollar from and selling foreign currencies to" FX dealers; the white bar vice versa. The order flows are in units of million USD.

Figure A4: Currency order flows (million USD) for G10 currency pairs between nondealer banks and FX dealers around FOMC announcement on Sep 18, 2013



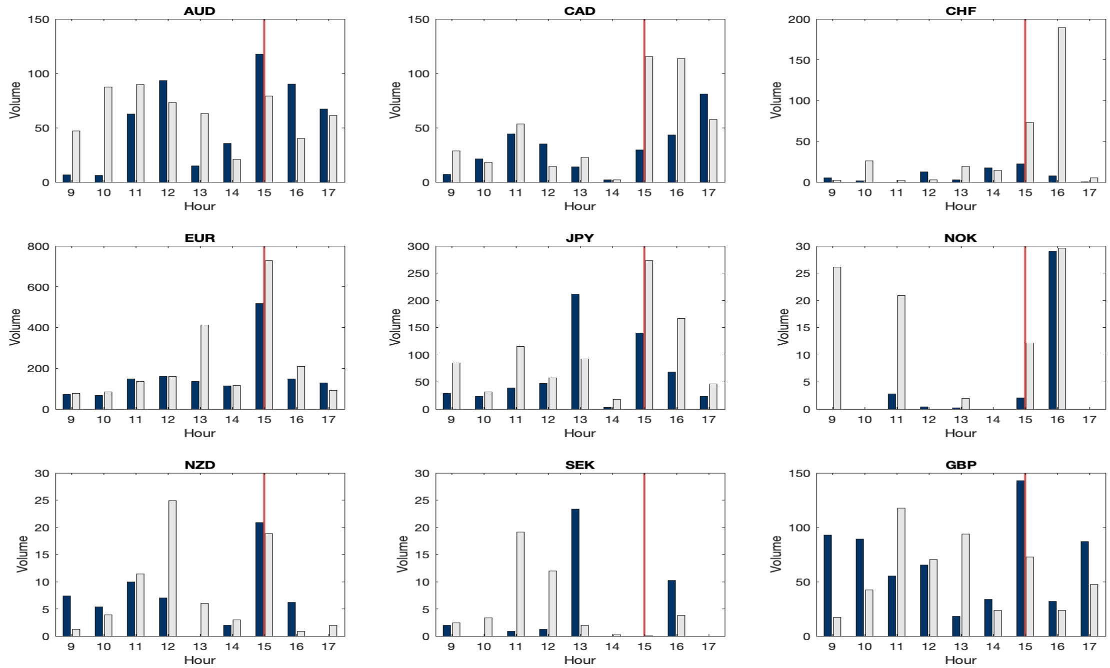
Note: The dark red bar is the side of nondealer banks' "buying the dollar from and selling foreign currencies to" FX dealers; the white bar vice versa. The order flows are in units of million USD.

Figure A5: Currency order flows (million USD) for G10 currency pairs between global investors and FX dealers around FOMC announcement on June 19, 2013



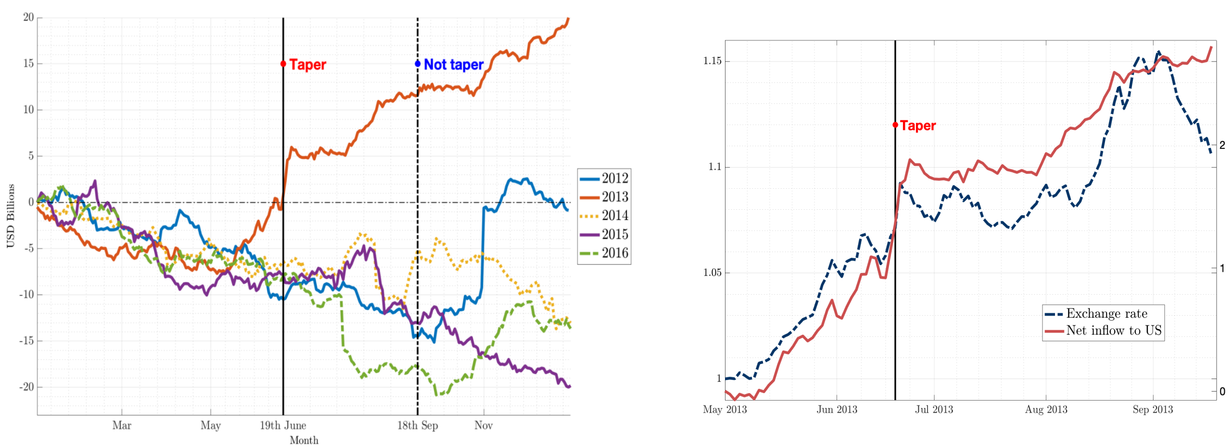
Note: The dark blue bar is the side of investors' "buying the dollar from and selling foreign currencies to" FX dealers; the white bar vice versa. The order flows are in units of million USD.

Figure A6: Currency order flows (million USD) for G10 currency pairs between global investors and FX dealers around FOMC announcement on Sep 18, 2013



Note: The dark blue bar is the side of investors' "buying the dollar from and selling foreign currencies to" FX dealers; the white bar vice versa. The order flows are in units of million USD.

Figure A7: Investors' cumulative portfolio inflows from EMs to the US



Note: The solid and dashed vertical lines correspond to June 19, 2013 and Sep 18, 2013. The cumulative flows are in units of billion USD. The exchange rate is expressed in units of foreign currency per US dollar with the initial value normalized to one.

A.2 BP-SVAR Estimation

A.2.1 Data Descriptions and Variable Constructions

We obtain daily frequency US treasury yields data, Thomson Reuters exchange rate data (collected at 5:00 pm EST in the US), and MSCI equity indices for different countries from Datastream for the period from 01/03/1994 to 06/28/2019. We choose the data of the last business day in each month to get the monthly data. For the group of developed countries, we focus on the G10 currency pairs (AUD, CAD, CHF, EUR, JPY, NOK, NZD, SEK, GBP) quoted against the US dollar. For the group of EMs, we select India, Indonesia, Mexico, South Africa, Thailand, and Turkey based on data availability.

The monthly CPI data is from FRED at the St. Louis Fed with the index level = 100 in 2015. For countries with only quarterly data available, such as Australia and New Zealand, we interpolate the quarterly data into monthly data smoothly. Moreover, the time series for unemployment rate and industrial production of the US are also from FRED.

We get the monetary policy shock instruments ("target", "forward guidance", and "LSAP" factors) and the associated FOMC announcement dates from Swanson (2021), where each factor has unit sample variance and a positive effect on yield changes. We include a total of 213 FOMC announcements from 01/03/1994 to 06/28/2019. For the month with more than one FOMC announcement, we aggregate the monetary policy shocks within that month as the monthly instruments.

The US cross-border monthly portfolio flow data is from Bertaut and Tryon (2007) and Bertaut and Judson (2014). Here, we provide only the essential information of the dataset, and more details can be found in the original papers. The monthly cross-border portfolio positions and net flows are summarized by the following accounting identity:

$$S_{i,j,t} = S_{i,j,t-1}\left(1 + R_{i,j,t}\right) + F_{i,j,t} + A_{i,j,t}. \tag{A1}$$

From the claim side, $S_{i,j,t}$ is the US holdings of asset type j from country i at time t, $R_{i,j,t}$ is the total return on country i's return index for asset type j, $F_{i,j,t}$ is the associated net flow, $A_{i,j,t}$ is the adjustment term; and the other way around for the liability side.

We analyze the portfolio inflow data on foreign holdings of US equity and long-term bonds, and outflow data on US holdings of foreign equity and long-term bonds. As in Brennan and Cao (1997) and Hau and Rey (2006), we smooth the net portfolio flows by averaging them over the previous 12 months. The value of flows is in billions of USD.

A.2.2 Method

To identify the dynamic effects of monetary surprises on exchange rates and global portfolio flows, we consider the following structural VAR model:

$$\mathbf{A}_0\mathbf{y}_t = \sum_{\ell=1}^{p} \mathbf{A}_\ell \mathbf{y}_{t-\ell} + \mathbf{c} + \mathbf{e}_t, \quad \text{for} \quad 1 \leq t \leq T, \tag{A2}$$

where the structural matrix $\mathbf{A}_0$ is invertible, $\mathbf{y}_t$ is an $n \times 1$ vector of endogenous variables and $\mathbf{e}_t$ is an $n \times 1$ vector of structural shocks with unit variance. We further assume that the policy indicator y_t^p is the first element of $\mathbf{y}_t$ and $e_t^p \in \mathbf{e}_t$ is the associated policy shock.

Following the literature, we choose 3-month, 1-year, and 10-year US TIPS yields as the policy indicators for "target rate" surprise, "forward guidance" surprise, and "QE" surprise, respectively. The associated external instruments or monetary proxies are from Swanson (2021). For the choice of other endogenous variables in VAR estimation, we include the average real exchange rates of the dollar against AE or EM currencies, the leverage ratio from He, Kelly, and Manela (2017), and the net equity and long-term bond inflows to the US. The monthly US claim and liability portfolio flow data are from Bertaut and Tryon (2007) and Bertaut and Judson (2014). We smooth the flows by averaging them over the previous 12 months as in Brennan and Cao (1997) and Hau and Rey (2006). Since the long-term bond portfolio flow data is only available after 1995, we analyze the effect of "target rate" surprises since then until June 2019, which corresponds to the available sample period of monetary proxies in Swanson (2021). For "QE" shocks, we focus on the ZLB period from June 2008 to the end of 2015, when the Fed's announcements had a much larger effect on long-term yields. Importantly, we normalize all nominal variables with CPI and translate them into the respective real ones. As a robustness check, we further include the log of CPI, the log of industrial production, and the unemployment rate of the US in VAR estimation as Gertler and Karadi (2015) and Ramey (2016), which are potentially useful for forecasting other variables. More details about data construction can be found in the section above.

Turning to the SVAR in (A2), it is equivalent to consider the following reduced-form VAR:

$$\mathbf{y}_t - \boldsymbol{B}'\mathbf{x}_t = \varepsilon_t,$$

where $\mathbf{x}_t = \left[\mathbf{y}'_{t-1}, \ldots, \mathbf{y}'_{t-p}, 1\right]'$, $\boldsymbol{B} = \left[\mathbf{A}_0^{-1}\mathbf{A}_1, \ldots, \mathbf{A}_0^{-1}\mathbf{A}_p, \mathbf{c}\right]'$ and $\varepsilon_t|\mathcal{F}_t = \mathbf{A}_0^{-1}\mathbf{e}_t|\mathcal{F}_t \sim N(\mathbf{0}, \Omega_{\varepsilon,\varepsilon})$ with $\Omega_{\varepsilon,\varepsilon} = (\mathbf{A}'_0\mathbf{A}_0)^{-1}$.

The key identification condition of monetary shocks is

$$\mathbf{z}_t e_t^p \neq 0, \quad \text{and} \quad \mathbf{z}_t \mathbf{e}_{(-p),t} = \mathbf{0},$$

where $\mathbf{z}_t$ denotes the associated proxy for monetary surprises and $\mathbf{e}_{(-p),t}$ denotes the structural shocks except policy indicator shock e_t^p at time t, so as for the reduced-form shocks $\varepsilon_{(-p),t}$ and $\varepsilon_{p,t}$. The coefficients are estimated by

$$\varepsilon_{(-p),t} = \frac{\mathbf{A}_{0,[(-p),1]}^{-1}}{A_{0,[p,1]}^{-1}} \widehat{\varepsilon}_t^p + \boldsymbol{\epsilon}_{(-p),t},$$

where $\widehat{\varepsilon}_t^p = \widehat{A}_{0,[p,1]}^{-1} \mathbf{z}_t$ is the fitted value by regressing ε_t^p on $\mathbf{z}_t$, $A_{0,[p,1]}^{-1}$ is the p-th element of the first column of $\mathbf{A}_0^{-1}$, and $\mathbf{A}_{0,[(-p),1]}^{-1}$ includes the left elements in the first column of $\mathbf{A}_0^{-1}$ except $A_{0,[p,1]}^{-1}$.

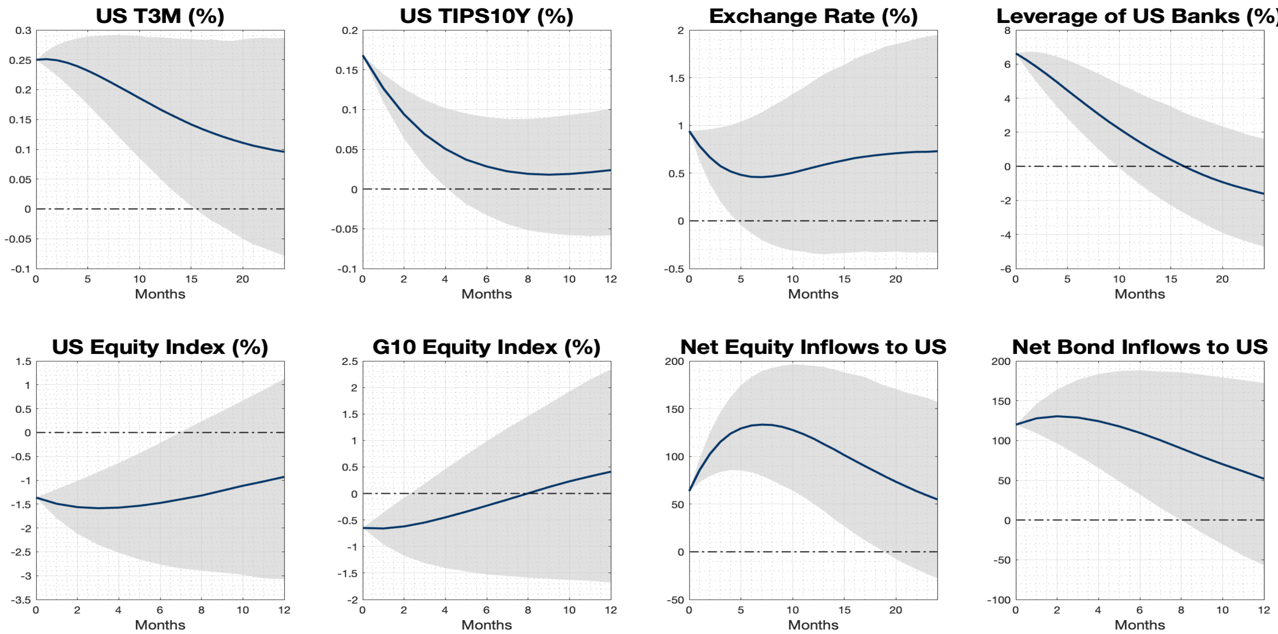
To generate the credible sets, we adopt the Bayes estimation procedure developed in Caldara and Herbst (2019), which is also used in Miranda-Agrippino and Rey (2020) and Rogers, Scotti, and Wright (2018). Bayes methods enjoy the advantages to handle the estimation with short sample period and avoid the potential misleading inference based on bootstrap procedure. We choose the diffuse priors as in Rogers, Scotti, and Wright (2018).[8] The detailed MCMC algorithm is shown in Appendix A.2.4.

A.2.3 Empirical Results

We first report the impulse responses of endogenous variables to conventional monetary policy shocks in Figure A8. The magnitudes of all coefficients are normalized such that one unit of conventional monetary policy shock increases US 3-month bond yields by 25 bps. Under this normalization, US 10-year TIPS yields increase by roughly 17 bps and then decline quickly. A unit of "target" surprise raises the average exchange rates of the US dollar against G10 currencies by around 1% instantaneously. The leverage ratio increases by 6.62% on impact and remains significantly positive for the following year. The increase in leverage following a monetary tightening is consistent with the equity constraint framework as in Bernanke and Gertler (1989), He and Krishnamurthy (2013) and Brunnermeier and Sannikov (2014), implying that an adverse shock leading to a decline in net worth increases the bank's leverage. Moreover, consistent with the findings in Bernanke and Kuttner (2005),

[8]Unlike Caldara and Herbst (2019) and Miranda-Agrippino and Rey (2020) with 12 month lags and Minnesota priors, we pin down one period lag based on BIC.

Figure A8: IRFs (with 90% CI) of variables for the average of AEs to US conventional monetary policy shocks since 1995

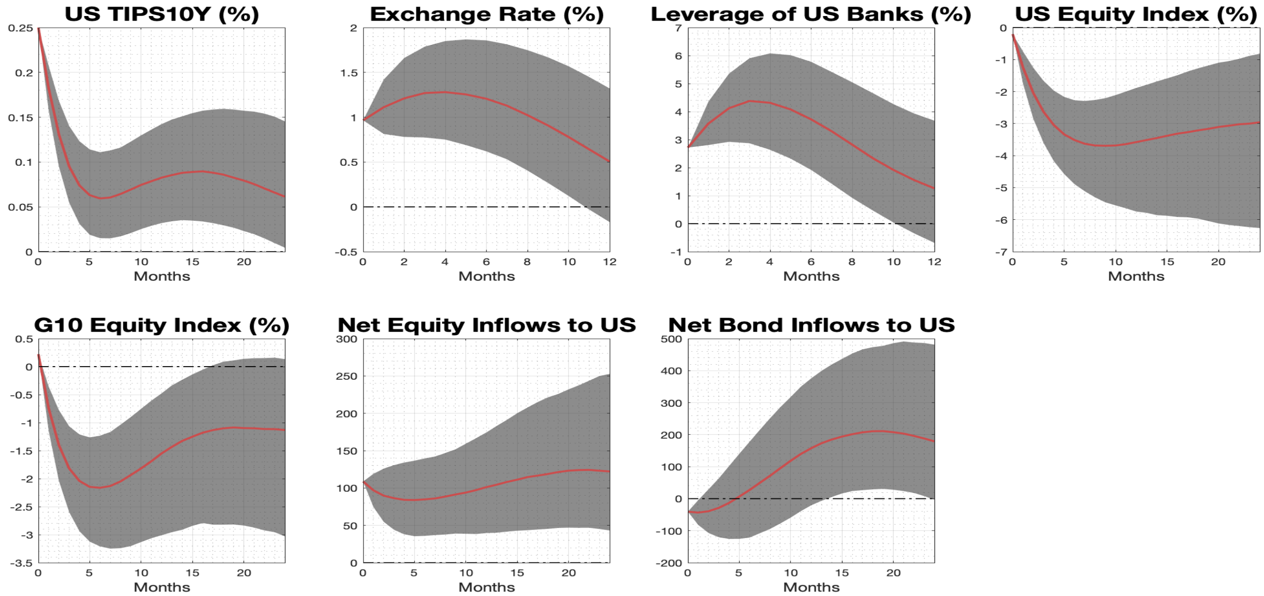


Note: IRFs are reported as % deviation from the sample means. Portfolio flows are in units of million USD.

a tightening US conventional monetary surprise lowers domestic MSCI equity index by 1.36% with a significant negative effect lasting for four months. The average of MSCI equity indices for nine developed countries also decreases by 0.65% with the effect lasting for two months, where both the magnitude and duration of the response are approximately half of those of US equity index. Importantly, we find that a unit of tightening target surprise induces net equity inflows of 63.72 million USD from the other AEs to the US on average. The respective response reaches a peak of 103.73 million USD after six months, then falls to zero around 15 months later. Meanwhile, the initial response of average net bond inflows to the US rises sharply by 119.92 million USD, then declines to zero gradually. Taken together, the responses of equity and bond inflows provide direct evidence of the transmission of US conventional monetary policy through investors' portfolio rebalancing.

The IRFs of endogenous variables to negative QE ("-QE") surprises are reported in Figure A9. Here, the sample period is from 08/2008 to 12/2015, corresponding to the ZLB period. Since the sample period is relatively short, we report the 68% confidence sets in the figure. We use 10-year TIPS rate as policy indicator for "-QE" policy shock and normalize its coefficient of response to be 0.25% at the initial period. It is not surprising that a unit of "-QE" surprise causes a long-lasting increase in the 10-year rate. The US dollar appreciates by 0.87% and then keeps increasing over the following four months. The leverage of US banks

Figure A9: IRFs (with 68% CI) of variables for the average of AEs to negative QE monetary surprises during the ZLB period (2008-2015)

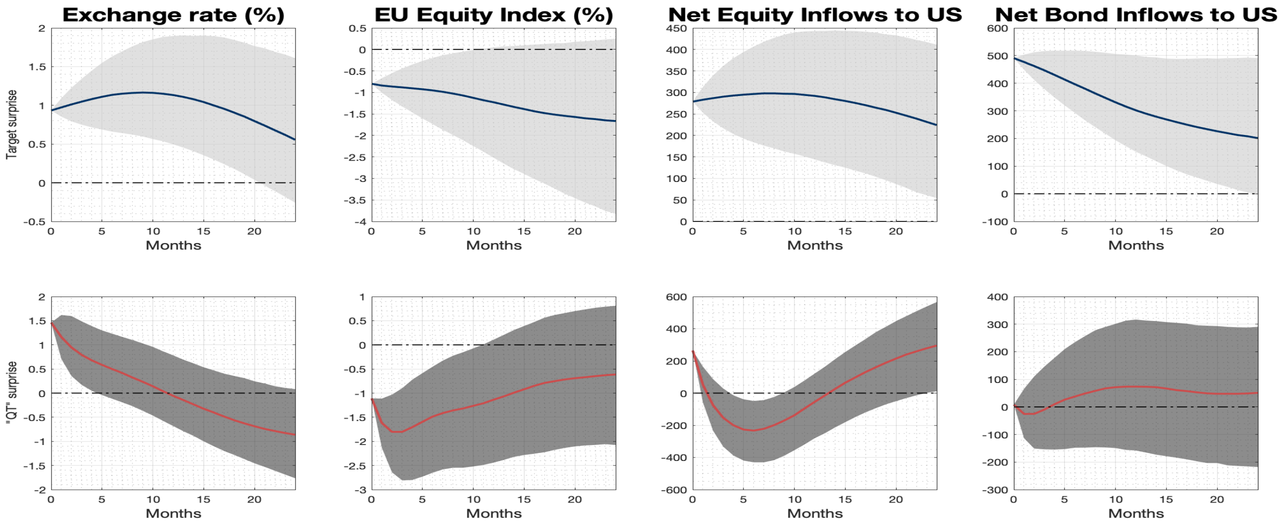


Note: IRFs are reported as % deviation from the sample means. Portfolio flows are in units of million USD.

rises from 2.12% to 3.62% and then returns to the trend. "-QE" shocks also lower the average of MSCI equity indices for AEs significantly, but both magnitude and horizon on impact are modest compared to US equity index. It is also associated with a relatively constant equity inflows to the US (around 100 million USD), which lasts for more than two years. A puzzling observation is that there is a relatively small amount of bond outflows from the US to foreign countries. There are several potential explanations for this puzzling observation during ZLB period. First, since our analysis includes the financial crisis period, a possible explanation can be the "flight to safety" effect as in Stavrakeva and Tang (2023) and Kekre and Lenel (2024): foreign investors still prefer to hold US long-term bonds as safe assets, even though the yields are lower. Second, given the data construction method for portfolio flows in (A1), since the Fed's QE raises the price of US long-term bonds significantly, there might be positive net bond inflows to the US associated with the Fed's purchase of long-term bonds due to this large price effect. However, upon a QE shock, there is a significantly large amount of bond outflows to foreign countries in 14 months. Our quantitative results in Section 4 further verify this point.

Finally, we report the BP-SVAR estimation results for the EU against the US in Figure A10, where we only focus on the IRFs of several important variables. A unit of tightening target surprise normalized as before is initially associated with 0.94% appreciation of the dollar

Figure A10: IRFs (with 90% or 68% CIs) of EU variables to US monetary shocks



Note: The sample period is since 1999. Sample period for responses (68% CI) to QE shocks is same as before.

vis-à-vis the euro, 0.80% decline in EU equity index, around 280 million USD net equity inflows and 500 million USD net bond inflows from the EU to the US. We also find that a normalized "-QE" shock induces 1.38% appreciation of the dollar against the euro, 1.08% decrease in EU equity index, around 250 million USD equity and a small amount of bond inflows from the EU to the US at the initial period. The subsequent impact on bond flows remains ambiguous due to the price effects of the Fed's long-term bond purchases. Overall, the financial variables of the EU have much larger responses to US monetary policy than the average across nine developed countries.

A.2.4 Bayesian Implementation

In the empirical analysis part, we employ the Bayes Proxy-SVAR developed in Caldara and Herbst (2019) and Rogers, Scotti, and Wright (2018) to identify the effect of monetary policy shocks with the following SVAR(p) model:

$$A(\boldsymbol{L})\mathbf{y}_t = \mathbf{c} + \mathbf{e}_t,$$

with $A(\boldsymbol{L}) = A_0 - A_1\boldsymbol{L} - A_2\boldsymbol{L}^2 - \cdots - A_p\boldsymbol{L}^p$. We can rewrite the SVAR(p) into the following equation form:

$$\mathbf{A}_0\mathbf{y}_t = \sum_{\ell=1}^{p} \mathbf{A}_\ell \mathbf{y}_{t-\ell} + \mathbf{c} + \mathbf{e}_t, \quad \text{for} \quad 1 \leq t \leq T, \tag{A3}$$

where $\mathbf{y}_t$ is an $n \times 1$ vector of endogenous variables, $\mathbf{e}_t$ is an $n \times 1$ vector of structural shocks, $\mathbf{A}_\ell$ is an $n \times n$ matrix of structural parameters for $0 \leq \ell \leq p$ where $\mathbf{A}_0$ is invertible, $\mathbf{c}$ is an $n \times 1$ vector of intercepts, p is the lag length, and T is the sample size. $\mathbf{e}_t$ is normally distributed with mean zero and identity covariance matrix $\mathbf{I}_n$, conditional on the information set $\mathcal{F}_t$ that consists of past information and initial conditions $\mathbf{y}_0, \ldots, \mathbf{y}_{1-p}$.

Equivalently, we can translate the structural VAR model in (A3) into the following reduced-form VAR:

$$\mathbf{y}_t - \boldsymbol{B}'\mathbf{x}_t = \varepsilon_t, \tag{A4}$$

where $\mathbf{x}_t = \left[\mathbf{y}'_{t-1}, \ldots, \mathbf{y}'_{t-p}, 1\right]'$, $\boldsymbol{B} = \left[\mathbf{A}_0^{-1}\mathbf{A}_1, \ldots, \mathbf{A}_0^{-1}\mathbf{A}_p, \mathbf{c}\right]'$ and $\varepsilon_t|\mathcal{F}_t = \mathbf{A}_0^{-1}\mathbf{e}_t|\mathcal{F}_t \sim N(\mathbf{0}, \Omega_{\varepsilon,\varepsilon})$ with $\Omega_{\varepsilon,\varepsilon} = (\mathbf{A}'_0\mathbf{A}_0)^{-1}$.

We further denote the instruments of monetary policy shocks in Swanson (2021) as $\mathbf{M}_{1:T} = (m_1, ..., m_T)'$ and the associated structural monetary policy shocks in (A3) as e_t^{MP}. First, we assume that $m_t|\mathcal{F}_t \sim N(0, \sigma_m^2)$ and $\Delta\mathbf{z}_t|\mathcal{F}_t \sim N(\mathbf{0}, \Omega_{\Delta\mathbf{z},\Delta\mathbf{z}})$. Second, to identify the monetary policy shocks, we impose the standard identification condition that m_t is correlated with e_t^{MP} with covariance $\sigma_{m,MP}$, but is orthogonal to all other structural shocks e_t^{NMP}, i.e., $Cov[m_t, e_t^{MP}|\mathcal{F}_t] = \sigma_{m,MP}$ and $Cov[m_t, e_t^{NMP}|\mathcal{F}_t] = \mathbf{0}$. Finally, to achieve the shape identification, we assume that monetary policy shocks on FOMC days cannot predict change of any endogenous variables for the following days after the corresponding FOMC announcements. We denote the endogenous variables with daily frequency data available in $\mathbf{y}_t$ as $\mathbf{z}_t$, the last assumption implies that $Cov[\Delta\mathbf{z}_t, m_t|\mathcal{F}_t] = Cov[S\varepsilon_t, m_t|\mathcal{F}_t] \neq \mathbf{0}$ and $Cov[m_t, \Delta\mathbf{z}_{t-j}|\mathcal{F}_t] = \mathbf{0}$ for any $j \neq 0$, where S is the selection matrix such that $\mathbf{z}_t = S\mathbf{y}_t$. Here, as Rogers, Scotti, and Wright (2018), we assume that market is efficient which implies that the information conveyed by monetary policy shocks can be quickly absorbed by the market participants within the corresponding FOMC announcement days.

Given the fact that $[\varepsilon'_t,\ \Delta\mathbf{z}'_t,\ m_t]'$ is conditional Gaussian, we can derive the joint conditional likelihood function of the observed monthly data and daily change of endogenous variables $\mathbf{z}_t$ on FOMC announcement days, and also the instruments of monetary policy shocks as follows:

$$\begin{bmatrix} \mathbf{y}_t - \boldsymbol{B}'\mathbf{x}_t \\ \Delta\mathbf{z}_t \\ m_t \end{bmatrix} \Bigg| \mathcal{F}_t = \begin{bmatrix} \varepsilon_t \\ \Delta\mathbf{z}_t \\ m_t \end{bmatrix} \Bigg| \mathcal{F}_t \sim N\left(\begin{bmatrix} \mathbf{0} \\ \mathbf{0} \\ 0 \end{bmatrix}, \begin{bmatrix} \Omega_{\varepsilon,\varepsilon} & \Omega_{\varepsilon,\Delta\mathbf{z}} & \gamma \\ \Omega_{\Delta\mathbf{z},\varepsilon} & \Omega_{\Delta\mathbf{z},\Delta\mathbf{z}} & S\gamma \\ \gamma' & \gamma' S' & \sigma_m^2 \end{bmatrix} \right),$$

where $\boldsymbol{\gamma} = Cov[\varepsilon_t, m_t|\mathcal{F}_t] = \sigma_{m,MP}\mathbf{A}_{0,(:,1)}^{-1}$ and $\mathbf{A}_{0,(:,1)}^{-1}$ is the first column of $\mathbf{A}_0^{-1}$, and S is the selection matrix such that $\mathbf{z}_t = S\mathbf{y}_t$.

By recalling the property of conditional multivariate normal distribution, it follows

$$m_t|\mathbf{y}_t, \Delta\mathbf{z}_t, \boldsymbol{B}, \boldsymbol{\Omega}, \gamma, \sigma_m \sim N(\mu_{m_t|\mathbf{y}_t,\Delta\mathbf{z}_t}, V_{m_t|\mathbf{y}_t,\Delta\mathbf{z}_t}) \tag{A5}$$

with conditional mean

$$\mu_{m_t|\mathbf{y}_t,\Delta\mathbf{z}_t} = \begin{bmatrix}\gamma' & \gamma' S'\end{bmatrix} \boldsymbol{\Omega}^{-1} \begin{bmatrix}\varepsilon_t \\ \Delta\mathbf{z}_t\end{bmatrix},$$

and conditional variance matrix

$$V_{m_t|\mathbf{y}_t,\Delta\mathbf{z}_t} = \sigma_m^2 - \begin{bmatrix}\gamma' & \gamma' S'\end{bmatrix} \boldsymbol{\Omega}^{-1} \begin{bmatrix}\gamma \\ S\gamma\end{bmatrix},$$

where $\boldsymbol{\Omega} = \begin{bmatrix}\Omega_{\varepsilon,\varepsilon} & \Omega_{\varepsilon,\Delta\mathbf{z}} \\ \Omega_{\Delta\mathbf{z},\varepsilon} & \Omega_{\Delta\mathbf{z},\Delta\mathbf{z}}\end{bmatrix}$.

Based on Bayes Theorem, we can decompose the likelihood function of all the observed data into the likelihood function of endogenous variables which only depends on $\boldsymbol{B}$ and $\boldsymbol{\Omega}$, and the conditional likelihood function of $\mathbf{M_{1:T}}$:

$$p(\mathbf{Y_{1:T}}, \mathbf{\Delta Z_{1:T}}, \mathbf{M_{1:T}}|\boldsymbol{B}, \boldsymbol{\Omega}, \gamma, \sigma_m) = p(\mathbf{Y_{1:T}}, \mathbf{\Delta Z_{1:T}}|\boldsymbol{B}, \boldsymbol{\Omega})p(\mathbf{M_{1:T}}|\mathbf{Y_{1:T}}, \mathbf{\Delta Z_{1:T}}, \boldsymbol{B}, \boldsymbol{\Omega}, \gamma, \sigma_m).$$

With the the conditional normal distribution in (A5), we can derive the conditional likelihood function of $\mathbf{M_{1:T}}$ as

$$\mathbf{M_{1:T}}|\mathbf{Y_{1:T}}, \mathbf{\Delta Z_{1:T}}, \boldsymbol{B}, \boldsymbol{\Omega}, \gamma, \sigma_m \sim N\left(\mu_{M|Y,\Delta Z}, V_{M|Y,\Delta Z}\right)$$

Finally, we can obtain the posterior distribution of the parameters of interest $(\boldsymbol{B}, \boldsymbol{\Omega}, \gamma, \sigma_m)$ via Bayes rule with a diffuse prior $|\Omega|^{-(l+1)}$ as follows.[9]

$$\begin{aligned}
p(B, \Omega, \gamma, \tilde{\psi} \mid Y, W, Z) &\propto p(\mathbf{Y_{1:T}}, \mathbf{\Delta Z_{1:T}}, \mathbf{M_{1:T}}|\boldsymbol{B}, \boldsymbol{\Omega}, \gamma, \sigma_m)|\boldsymbol{\Omega}|^{-(l+1)/2} \\
&= p(\mathbf{Y_{1:T}}, \mathbf{\Delta Z_{1:T}}|\boldsymbol{B}, \boldsymbol{\Omega})p(\mathbf{M_{1:T}}|\mathbf{Y_{1:T}}, \mathbf{\Delta Z_{1:T}}, \boldsymbol{B}, \boldsymbol{\Omega}, \gamma, \sigma_m)|\boldsymbol{\Omega}|^{-(l+1)/2} \\
&\propto |\boldsymbol{\Omega}|^{-(l+1)/2} \exp\left(-\frac{1}{2}\operatorname{tr}\left(\boldsymbol{\Omega}^{-1}\boldsymbol{\Lambda}(\boldsymbol{B})'\boldsymbol{\Lambda}(\boldsymbol{B})\right)\right) \\
&\times \frac{1}{V_{M|Y,\Delta Z}} \exp\left(-\frac{1}{2V^2_{M|Y,\Delta Z}}\left(\mathbf{M_{1:T}} - \mu_{M|Y,\Delta Z}\right)'\left(\mathbf{M_{1:T}} - \mu_{M|Y,\Delta Z}\right)\right)
\end{aligned}$$

where $\boldsymbol{\Lambda}(\boldsymbol{B}) = [\mathbf{Y_{1:T}} - \mathbf{X_{1:T}}\boldsymbol{B} \;\; \mathbf{\Delta Z_{1:T}}]$.

[9] For simplicity, we choose the diffuse prior for parameters as Rogers, Scotti, and Wright (2018), instead of Minnesota priors in Caldara and Herbst (2019). We leave the choice of priors as a robustness check for the empirical results.

Algorithm : (Metropolis-within-Gibbs Algorithm) For $i = 1, \ldots, N$, at i-th iteration step,

(0): Obtain the OLS estimator of $\boldsymbol{B}$ and associated covariance matrix denoted as $\hat{\boldsymbol{B}}$ and $\hat{\boldsymbol{\Sigma}}$. Pin down the lag of VAR based on BIC.

(1): For parameter block $(\boldsymbol{B}, \boldsymbol{\Omega})$, we get the posterior draws from independence chain Metropolis-Hastings. Let $q(\boldsymbol{B}, \boldsymbol{\Omega})$ denote the proposal density (normal-Wishart distribution) and $(\boldsymbol{B}^i, \boldsymbol{\Omega}^i)$ denote the realizations of the draws. The algorithm of independence chain Metropolis-Hastings is given by

- Draw $\boldsymbol{\Omega}^i$ from $\mathcal{IW}(\cdot; \boldsymbol{\Lambda}'(\hat{\boldsymbol{B}})\boldsymbol{\Lambda}(\hat{\boldsymbol{B}}), T - l - 1)$.
- Draw $vec(\boldsymbol{B}^i)$ from $N(vec(\hat{\boldsymbol{B}}), \hat{\boldsymbol{\Sigma}} \otimes [\mathbf{X}'_{\mathbf{1:T}}\mathbf{X}_{\mathbf{1:T}}]^{-1})$.
- Accept the new proposal $(\boldsymbol{B}^i, \boldsymbol{\Omega}^i)$ with probability:

$$\alpha = \min\left(\frac{p\left(\boldsymbol{B}^i, \boldsymbol{\Omega}^i, \gamma, \tilde{\psi} \mid \mathbf{Y}_{\mathbf{1:T}}, \boldsymbol{\Delta}\mathbf{Z}_{\mathbf{1:T}}, \mathbf{M}_{\mathbf{1:T}}\right)}{p\left(\boldsymbol{B}, \boldsymbol{\Omega}, \gamma, \tilde{\psi} \mid \mathbf{Y}_{\mathbf{1:T}}, \boldsymbol{\Delta}\mathbf{Z}_{\mathbf{1:T}}, \mathbf{M}_{\mathbf{1:T}}\right)} \frac{q(\boldsymbol{B}, \boldsymbol{\Omega})}{q(\boldsymbol{B}^i, \boldsymbol{\Omega}^i)}, 1\right).$$

(2): For parameter block $(\gamma, \tilde{\psi})$, we get the posterior draws from a random walk Metropolis-Hastings $\left(\gamma^i, \tilde{\psi}^i\right)$; that is, let the proposed value for each of these parameters be the existing value plus a Gaussian shock. Acceptance probability α is:

- Draw γ^i from $N(\gamma^{i-1}, c^2)$.
- Draw $\tilde{\psi}^i$ from $N(\tilde{\psi}^{i-1}, c^2)$.
- Accept the new proposal $\left(\gamma^i, \tilde{\psi}^i\right)$ with probability:

$$\alpha = \min\left(\frac{p\left(\mathbf{M}_{\mathbf{1:T}} | \mathbf{Y}_{\mathbf{1:T}}, \boldsymbol{\Delta}\mathbf{Z}_{\mathbf{1:T}}, \boldsymbol{B}^i, \boldsymbol{\Omega}^i, \gamma^i, \tilde{\psi}^i\right)}{p\left(\mathbf{M}_{\mathbf{1:T}} | \mathbf{Y}_{\mathbf{1:T}}, \boldsymbol{\Delta}\mathbf{Z}_{\mathbf{1:T}}, \boldsymbol{B}^i, \boldsymbol{\Omega}^i \gamma, \tilde{\psi}\right)}, 1\right)$$

The variance of increment random variable (c^2) is chosen to target an acceptance rate of around 20%.

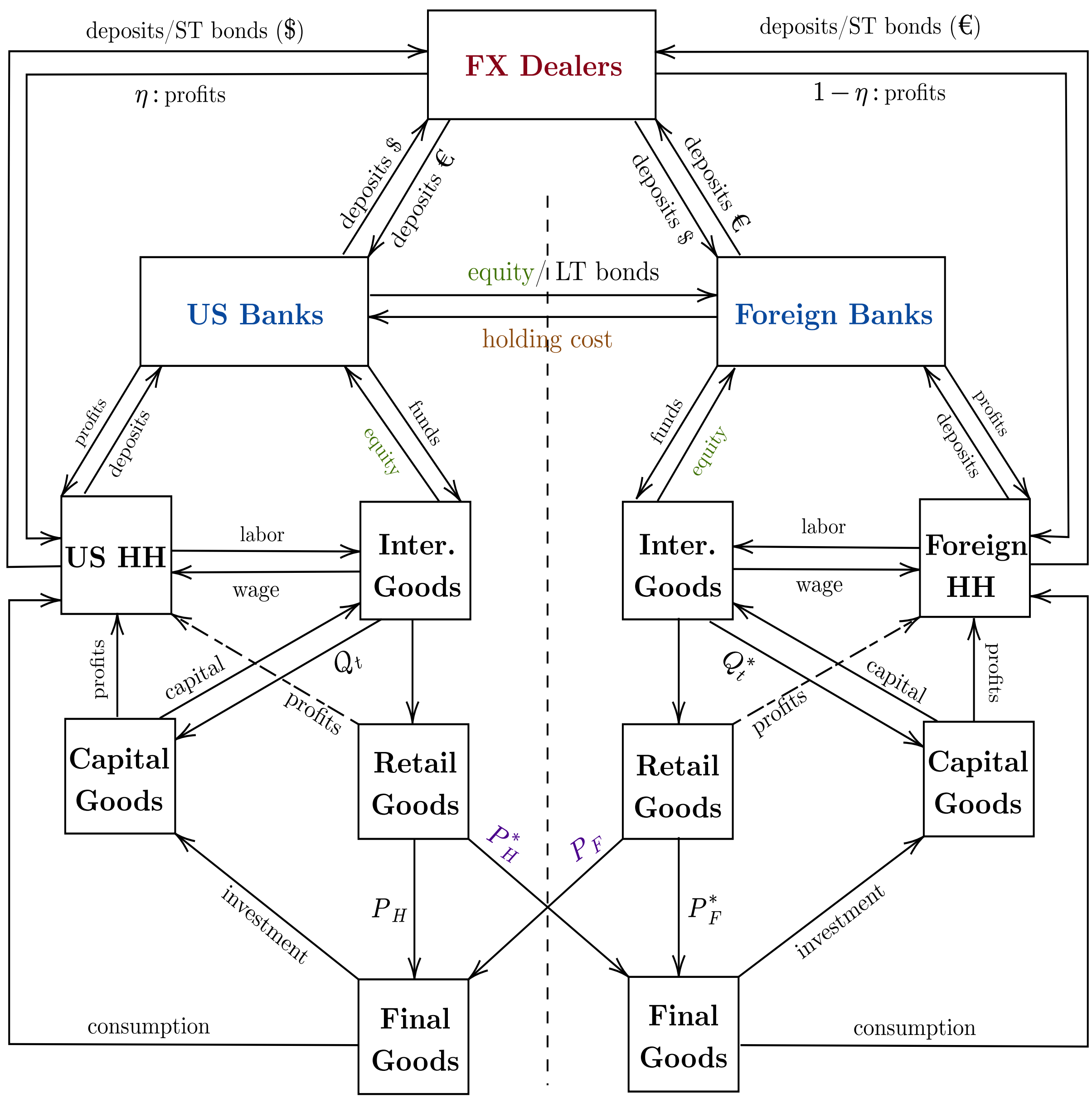
(3): Repeat steps (1)–(2) to get the posterior distribution with 5000 times, discarding an initial burn-in sample (1000 times).

(4): Normalize magnitude of a positive monetary policy shock to increase monthly yields by 25 bps. The "target", "path", and "LSAP" factors are used as instruments for US 3-month, 1-year, and 10-year bond yields, respectively. Based on the posterior draws, calculate the impulse responses and credible sets for the parameters of interest.

Appendix B Full Model Setup and Derivations

This appendix provides additional details on the setup and derivations of the model in Section 3. The entire model structure is presented in Figure B1. Given the symmetry of the model, we focus on the detailed derivations for home agents' problem and list essential results for the solution to foreign agents' problem.

Figure B1: The model structure



B.1 Households

A representative home household maximizes lifetime utility over consumption and labor:

$$\mathbb{E}_t \sum_{i=0}^{\infty} \beta^i \left\{ \frac{C_{t+i}^{1-\sigma_c} - 1}{1 - \sigma_c} - \frac{\chi}{1+\eta} L_{t+i}^{1+\eta} \right\},$$

subject to the budget constraint:

$$\begin{aligned} & C_t + D_{ht} + Q_t S_{ht}^h + \frac{1}{2}\kappa_{h1} \left(Q_t S_{ht}^h - Q_{ss} \bar{S}_h^h \right)^2 + q_t B_{ht}^h + \frac{1}{2}\kappa_{h2} \left(q_t B_{ht}^h - q_{ss} \bar{B}_h^h \right)^2 \\ & = w_t L_t + DIV_t - X + T_t + R_{t-1} D_{h,t-1} + R_{kt} Q_{t-1} S_{h,t-1}^h + R_{bt} q_{t-1} B_{h,t-1}^h, \end{aligned} \tag{B1}$$

where S_{ht}^h and B_{ht}^h are the household's domestic firm equity and long-term government bond holdings, respectively. We assume that the household experiences a holding cost for domestic risky assets, $\frac{\kappa_{h1}}{2} \left(Q_t S_{ht}^h - Q_{ss} \bar{S}_h^h \right)^2$ and $\frac{\kappa_{h2}}{2} \left(q_t B_{ht}^h - q_{ss} \bar{B}_h^h \right)^2$, where $\bar{S}_h^h$ and $\bar{B}_h^h$ are the amounts of risky assets that the household can hold costlessly, and κ_{h1} and κ_{h2} measure the sensitivity of holding cost with respect to the deviation of asset holdings from the costless amounts. In the quantitative analysis, we consider two specifications: an imperfect domestic market where households are not allowed to hold risky assets ($\kappa_{h1}, \kappa_{h2} \to \infty$), and a partially imperfect market where households incur non-zero holding cost for domestic risky assets ($\kappa_{h1}, \kappa_{h2} > 0$).

The first-order conditions for the domestic household's utility maximization are

$$\begin{aligned} \chi L_t^\eta &= \mu_t w_t, \\ 1 &= \mathbb{E}_t \left[\Lambda_{t,t+1} R_t \right], \\ Q_t S_{ht}^h &= Q_{ss} \bar{S}_h^h + \frac{1}{\kappa_{h1}} \mathbb{E}_t \left[\Lambda_{t,t+1} \left(R_{k,t+1} - R_t \right) \right], \\ q_t B_{ht}^h &= q_{ss} \bar{B}_h^h + \frac{1}{\kappa_{h2}} \mathbb{E}_t \left[\Lambda_{t,t+1} \left(R_{b,t+1} - R_t \right) \right], \end{aligned}$$

The associated variables are defined as

$$\Lambda_{t,t+1} = \frac{\beta \mu_{t+1}}{\mu_t}, \quad \mu_t = C_t^{-\sigma_c},$$

where $\Lambda_{t,t+1}$ is the stochastic discount factor between period t and $t+1$, and μ_t is the marginal utility of consumption.

Symmetrically, the first-order conditions for a foreign household's utility maximization are given by

$$\chi\left(L_t^*\right)^\eta = \mu_t^* w_t^*,$$
$$1 = \mathbb{E}_t\left[\Lambda_{t,t+1}^* R_t^*\right],$$
$$Q_t^* S_{ft}^{h*} = Q_{ss}^* \bar{S}_f^{h*} + \frac{1}{\kappa_{h1}}\mathbb{E}_t\left[\Lambda_{t,t+1}\left(R_{k,t+1}^* - R_t^*\right)\right],$$
$$q_t^* B_{ft}^{h*} = q_{ss}^* \bar{B}_f^{h*} + \frac{1}{\kappa_{h2}}\mathbb{E}_t\left[\Lambda_{t,t+1}\left(R_{b,t+1}^* - R_t^*\right)\right],$$

with the associated variables defined as

$$\Lambda_{t,t+1}^* = \frac{\beta\mu_{t+1}^*}{\mu_t^*}, \quad \mu_t^* = \left(C_t^*\right)^{-\sigma_c}.$$

B.2 Banks

This part provides the solution to a domestic banker's value functions $W_t(n_t)$ (before the portfolio decision, but after occupation shocks) and $V_t(s_{ht}, b_{ht}, s_{ft}, b_{ft}, n_t)$ (after the portfolio decision). The domestic banker's value function $W_t(n_t)$ is defined as

$$W_t(n_t) = \max_{s_{ht}, b_{ht}, s_{ft}, b_{ft}} V_t(s_{ht}, b_{ht}, s_{ft}, b_{ft}, n_t) - \left[\frac{\kappa_1}{2}\left(\frac{Q_t^* s_{ft} - Q_{ss}^* \bar{s}_f}{e_t n_t}\right)^2 + \frac{\kappa_2}{2}\left(\frac{q_t^* b_{ft} - q_{ss}^* \bar{b}_f}{e_t n_t}\right)^2\right] n_t, \tag{B2}$$

subject to the incentive constraint

$$V_t(s_{ht}, b_{ht}, s_{ft}, b_{ft}, n_t) \geq \theta\left(Q_t s_{ht} + \Delta q_t b_{ht} + \frac{Q_t^* s_{ft} + \Delta q_t^* b_{ft}}{e_t}\right). \tag{B3}$$

The domestic banker's value function $V_t(s_{ht}, b_{ht}, s_{ft}, b_{ft}, n_t)$ is given by

$$V_t(s_{ht}, b_{ht}, s_{ft}, b_{ft}, n_t) = \mathbb{E}_t \Lambda_{t,t+1}\left[(1-\sigma)n_{t+1} + \sigma W_{t+1}(n_{t+1})\right], \tag{B4}$$

with the law of motion for net worth

$$\begin{aligned} n_{t+1} = \; & (R_{k,t+1} - R_t) Q_t s_{ht} + (R_{b,t+1} - R_t) q_t b_{ht} + R_t n_t \\ & + \left(\frac{R_{k,t+1}^*}{e_{t+1}} - \frac{R_t}{e_t}\right) Q_t^* s_{ft} + \left(\frac{R_{b,t+1}^*}{e_{t+1}} - \frac{R_t}{e_t}\right) q_t^* b_{ft}. \end{aligned} \tag{B5}$$

We obtain the solution to value functions by guess and verify. First, we conjecture that V_t is linear in all arguments:

$$V_t\left(s_{ht}, b_{ht}, s_{ft}, b_{ft}, n_t\right) = \mu_{st} Q_t s_{ht} + \mu_{bt} q_t b_{ht} + \mu_{s^*t} Q_t^* s_{ft} + \mu_{b^*t} q_t^* b_{ft} + \nu_t n_t + \vartheta_t. \tag{B6}$$

Similarly, we conjecture that W_t is a linear function of net worth:

$$W_t\left(n_t\right) = \phi_{wt} n_t + v_{wt}. \tag{B7}$$

Let $\widetilde{\Lambda}_{t,t+1} \equiv \Lambda_{t,t+1} \cdot \left(1-\sigma+\sigma\phi_{w,t+1}\right)$ be the banker's "augmented" stochastic discount factor. By plugging (B7) and net worth equation (B5) into value function (B4), we obtain the following expression of V_t:

$$\begin{aligned}
V_t\left(s_{ht}, b_{ht}, s_{ft}, b_{ft}, n_t\right) &= \mathbb{E}_t\left[\Lambda_{t,t+1}\left(1-\sigma+\sigma\phi_{w,t+1}\right) n_{t+1}\right] + \sigma\mathbb{E}_t\left[\Lambda_{t,t+1} v_{w,t+1}\right] \\
= \; & \mathbb{E}_t\left\{\tilde{\Lambda}_{t,t+1}\left[\left(R_{k,t+1}-R_t\right) Q_t s_{ht} + \left(R_{b,t+1}-R_t\right) q_t b_{ht} + \left(\frac{R^*_{k,t+1}}{e_{t+1}} - \frac{R_t}{e_t}\right) Q^*_t s_{ft}\right]\right\} \\
& + \mathbb{E}_t\left\{\tilde{\Lambda}_{t,t+1}\left[\left(\frac{R^*_{b,t+1}}{e_{t+1}} - \frac{R_t}{e_t}\right) q^*_t b_{ft} + R_t n_t\right]\right\} + \sigma\mathbb{E}_t\left[\Lambda_{t,t+1} v_{w,t+1}\right].
\end{aligned}$$

By matching the coefficients of the above equation with the linear conjecture of V_t in (B6), we obtain the corresponding coefficients as follows:

$$\begin{aligned}
\mu_{st} &= \mathbb{E}_t\left[\tilde{\Lambda}_{t,t+1}\left(R_{k,t+1}-R_t\right)\right], \\
\mu_{bt} &= \mathbb{E}_t\left[\tilde{\Lambda}_{t,t+1}\left(R_{b,t+1}-R_t\right)\right], \\
\mu_{s^*t} &= \mathbb{E}_t\left[\tilde{\Lambda}_{t,t+1}\left(\frac{R^*_{k,t+1}}{e_{t+1}} - \frac{R_t}{e_t}\right)\right], \\
\mu_{b^*t} &= \mathbb{E}_t\left[\tilde{\Lambda}_{t,t+1}\left(\frac{R^*_{b,t+1}}{e_{t+1}} - \frac{R_t}{e_t}\right)\right], \\
\nu_t &= \mathbb{E}_t\left[\tilde{\Lambda}_{t,t+1} R_t\right], \\
\vartheta_t &= \sigma\mathbb{E}_t\left[\Lambda_{t,t+1} v_{w,t+1}\right].
\end{aligned}$$

Next, let λ_t be the Lagrange multiplier associated with incentive constraint (B3), and define the Lagrangian for maximization problem in (B2) as follows:

$$\begin{aligned}
\mathcal{L}_t = \; & V_t\left(s_{ht}, b_{ht}, s_{ft}, b_{ft}, n_t\right) - \frac{\kappa_1}{2}\left(\frac{Q^*_t s_{ft} - Q^*_{ss}\bar{s}_f}{e_t n_t}\right)^2 n_t - \frac{\kappa_2}{2}\left(\frac{q^*_t b_{ft} - q^*_{ss}\bar{b}_f}{e_t n_t}\right)^2 n_t \\
& + \lambda_t\left[V_t\left(s_{ht}, b_{ht}, s_{ft}, b_{ft}, n_t\right) - \theta\left(Q_t s_{ht} + \Delta q_t b_{ht} + \frac{Q^*_t s_{ft} + \Delta q^*_t b_{ft}}{e_t}\right)\right].
\end{aligned}$$

The first-order conditions with respect to asset positions are given by:

$$\frac{\partial \mathcal{L}_t}{\partial s_{ht}} = \left(1+\lambda_t\right)\mu_{st} Q_t - \lambda_t \theta Q_t = 0,$$

$$\frac{\partial \mathcal{L}_t}{\partial b_{ht}} = (1+\lambda_t)\,\mu_{bt} q_t - \lambda_t \theta \Delta q_t = 0,$$

$$\frac{\partial \mathcal{L}_t}{\partial s_{ft}} = (1+\lambda_t)\,\mu_{s^*t} Q_t^* - \kappa_1 \frac{Q_t^* s_{ft} - Q_{ss}^* \bar{s}_f}{e_t n_t}\left(\frac{Q_t^*}{e_t}\right) - \lambda_t \theta \frac{Q_t^*}{e_t} = 0,$$

$$\frac{\partial \mathcal{L}_t}{\partial b_{ft}} = (1+\lambda_t)\,\mu_{b^*t} q_t^* - \kappa_2 \frac{q_t^* b_{ft} - q_{ss}^* \bar{b}_f}{e_t n_t}\left(\frac{q_t^*}{e_t}\right) - \lambda_t \theta \frac{\Delta q_t^*}{e_t} = 0.$$

By substituting the expressions for coefficients from the conjectured solution V_t in (B6) into the first-order conditions, we obtain the solutions for the expected excess returns on domestic risky assets and the optimal positions of foreign risky assets as follows:

$$\mathbb{E}_t\left[\tilde{\Lambda}_{t,t+1}\left(R_{k,t+1} - R_t\right)\right] = \frac{\lambda_t}{1+\lambda_t}\theta,$$

$$\mathbb{E}_t\left[\tilde{\Lambda}_{t,t+1}\left(R_{b,t+1} - R_t\right)\right] = \Delta \cdot \frac{\lambda_t}{1+\lambda_t}\theta,$$

$$Q_t^* s_{ft} = Q_{ss}^* \bar{s}_f + \left\{(1+\lambda_t)\,\mathbb{E}_t\left[\tilde{\Lambda}_{t,t+1}\left(\frac{R_{k,t+1}^* e_t}{e_{t+1}} - R_t\right)\right] - \lambda_t \theta\right\}\frac{n_t}{\kappa_1} e_t,$$

$$q_t^* b_{ft} = q_{ss}^* \bar{b}_f + \left\{(1+\lambda_t)\,\mathbb{E}_t\left[\tilde{\Lambda}_{t,t+1}\left(\frac{R_{b,t+1}^* e_t}{e_{t+1}} - R_t\right)\right] - \lambda_t \theta \Delta\right\}\frac{n_t}{\kappa_2} e_t.$$

Note that when the incentive constraint (B3) is nonbinding, i.e., $\lambda_t = 0$, the expected excess returns on domestic risky assets are zero, and the deviations in optimal foreign asset holdings from steady-state values increase with the expected excess returns on foreign assets relative to domestic deposit rate in terms of home currency.

To solve the value functions, we first solve the risk-weighted holdings of domestic assets, $Q_t s_{ht} + \Delta q_t b_{ht}$, by substituting the first-order conditions into the incentive constraint. By plugging the guessed solution (B6) into the incentive constraint (B3), using the condition $\mu_{bt} = \Delta \mu_{st}$, and rearranging the terms, we obtain

$$(\theta - \mu_{st})\left(Q_t s_{ht} + \Delta q_t b_{ht}\right) \le \left(\mu_{s^*t} - \frac{\theta}{e_t}\right) Q_t^* s_{ft} + \left(\mu_{b^*t} - \frac{\theta \Delta}{e_t}\right) q_t^* b_{ft} + \nu_t n_t + \vartheta_t.$$

By moving the terms of $Q_t^* s_{ft}$ and $q_t^* b_{ft}$ to the left-hand side and dividing both sides by $\theta - \mu_{st}$, we get the following inequality:

$$\frac{\nu_t n_t + \vartheta_t}{\theta - \mu_{st}} \ge Q_t s_{ht} + \Delta q_t b_{ht} + \frac{\theta - e_t \mu_{s^*t}}{\theta - \mu_{st}} \cdot \frac{Q_t^* s_{ft}}{e_t} + \frac{\theta - \mu_{b^*,t} e_t / \Delta}{\theta - \mu_{st}} \cdot \frac{\Delta q_t^* b_{ft}}{e_t}.$$

Moreover, by substituting the expressions for $Q_t^* s_{ft}$ and $q_t^* b_{ft}$, the above inequality yields the following solution

$$Q_t s_{ht} + \Delta q_t b_{ht} \leq \phi_t n_t + \psi_t, \tag{B8}$$

with the slope coefficient ϕ_t given by:

$$\phi_t = \frac{\kappa_1^{-1}\left(\mu_{s^*t}e_t - \theta\right)\left[\left(1+\lambda_t\right)\mu_{s^*t}e_t - \lambda_t\theta\right] + \kappa_2^{-1}\left(\mu_{b^*t}e_t - \theta\Delta\right)\left[\left(1+\lambda_t\right)\mu_{b^*t}e_t - \lambda_t\theta\Delta\right] + \mathbb{E}_t\left[\tilde{\Lambda}_{t,t+1}R_t\right]}{\theta - \mu_{st}}, \tag{B9}$$

and the intercept ψ_t given by:

$$\psi_t = \frac{\left(\mu_{s^*t} - \frac{\theta}{e_t}\right)Q_{ss}^*\bar{s}_f + \left(\mu_{b^*t} - \frac{\theta\Delta}{e_t}\right)q_{ss}^*\bar{b}_f + \sigma\mathbb{E}_t\left[\Lambda_{t,t+1}v_{w,t+1}\right]}{\theta - \mu_{st}}. \tag{B10}$$

Similarly, by substituting the first-order conditions into the maximization problem in (B2), we obtain the expression for the slope coefficient ϕ_{wt} as

$$\begin{aligned}\phi_{wt} = & \frac{\left[(1-\lambda_t)\mu_{s^*t}e_t + \lambda_t\theta\right]\left[\left(1+\lambda_t\right)\mu_{s^*t}e_t - \lambda_t\theta\right]}{2\kappa_1} \\ & + \frac{\left[(1-\lambda_t)\mu_{b^*t}e_t + \lambda_t\Delta\theta\right]\left[\left(1+\lambda_t\right)\mu_{b^*t}e_t - \lambda_t\theta\Delta\right]}{2\kappa_2} + \mathbb{E}_t\left[\tilde{\Lambda}_{t,t+1}R_t\right] + \phi_t\mu_{st},\end{aligned} \tag{B11}$$

and the expression for the intercept v_{wt} as

$$v_{wt} = \mu_{st}\psi_t + \mu_{s^*t}Q_{ss}^*\bar{s}_f + \mu_{b^*t}q_{ss}^*\bar{b}_f + \sigma\mathbb{E}_t\left[\Lambda_{t,t+1}v_{w,t+1}\right]. \tag{B12}$$

In addition, by substituting the first-order conditions and (B8) into (B6), we can express the value function V_t as a linear function of n_t as follows:

$$V_t = \phi_{vt}n_t + v_{vt},$$

where the slope coefficient ϕ_{vt} is

$$\begin{aligned}\phi_{vt} = & \frac{\mu_{s^*t}e_t}{\kappa_1}\left[\left(1+\lambda_t\right)\mu_{s^*t}e_t - \lambda_t\theta\right] + \frac{\mu_{b^*t}e_t}{\kappa_2}\left[\left(1+\lambda_t\right)\mu_{b^*t}e_t - \lambda_t\theta\Delta\right] \\ & + \mathbb{E}_t\left[\tilde{\Lambda}_{t,t+1}R_t\right] + \phi_t\mu_{st},\end{aligned}$$

and the intercept v_{vt} is

$$v_{vt} = \mu_{st}\psi_t + \mu_{s^*t}Q_{ss}^*\bar{s}_f + \mu_{b^*t}q_{ss}^*\bar{b}_f + \sigma\mathbb{E}_t\left[\Lambda_{t,t+1}v_{w,t+1}\right].$$

For the foreign country, a banker's value function $W_t^*(n_t^*)$ (before the portfolio decision, but after occupation shocks) is defined as follows:

$$W_t^*(n_t^*) = \max_{s_{ht}^*, b_{ht}^*, s_{ft}^*, b_{ft}^*} V_t^*(s_{ht}^*, b_{ht}^*, s_{ft}^*, b_{ft}^*, n_t^*) - \left\{ \frac{\kappa_1}{2} \left[\frac{e_t(Q_t s_{ht}^* - Q_{ss}\bar{s}_h^*)}{n_t^*} \right]^2 + \frac{\kappa_2}{2} \left[\frac{e_t(q_t b_{ht}^* - q_{ss}\bar{b}_h^*)}{n_t^*} \right]^2 \right\} n_t^*, \tag{B13}$$

subject to the incentive constraint:

$$V_t^*(s_{ht}^*, b_{ht}^*, s_{ft}^*, b_{ft}^*, n_t^*) \geq \theta \left[Q_t^* s_{ft}^* + \Delta q_t^* b_{ft}^* + (Q_t s_{ht}^* + \Delta q_t b_{ht}^*) e_t \right]. \tag{B14}$$

The foreign banker's value function $V_t^*(s_{ht}^*, b_{ht}^*, s_{ft}^*, b_{ft}^*, n_t^*)$ (after the portfolio decision) is

$$V_t^*(s_{ht}^*, b_{ht}^*, s_{ft}^*, b_{ft}^*, n_t^*) = \mathbb{E}_t \Lambda_{t,t+1}^* \left[(1-\sigma) n_{t+1}^* + \sigma W_{t+1}^*(n_{t+1}^*) \right], \tag{B15}$$

with the law of motion for net worth:

$$\begin{aligned} n_{t+1}^* = \quad & (R_{k,t+1}^* - R_t^*) Q_t^* s_{ft}^* + (R_{b,t+1}^* - R_t^*) q_t^* b_{ft}^* + R_t^* n_t^* \\ & + \left(R_{k,t+1} e_{t+1} - R_t^* e_t \right) Q_t s_{ht}^* + \left(R_{b,t+1} e_{t+1} - R_t^* e_t \right) q_t b_{ht}^*. \end{aligned} \tag{B16}$$

We conjecture a linear solution to V_t^* as follows:

$$\begin{aligned} & V_t^* \left(s_{ht}^*, b_{ht}^*, s_{ft}^*, b_{ft}^*, n_t^* \right) \\ = \; & \mu_{st}^* Q_t s_{ht}^* + \mu_{bt}^* q_t b_{ht}^* + \mu_{s^*t}^* Q_t^* s_{ft}^* + \mu_{b^*t}^* q_t^* b_{ft}^* + \nu_t^* n_t^* + \vartheta_t^*. \end{aligned} \tag{B17}$$

For W_t^*, we conjecture that it is linear in net worth:

$$W_t^* \left(n_t^* \right) = \phi_{wt}^* n_t^* + v_{wt}^*. \tag{B18}$$

Substituting (B16) and (B18) into (B15) and matching the coefficients with the conjectured form of V_t^* in (B17) yields the following expressions for the coefficients:

$$\mu_{s^*t}^* = \mathbb{E}_t \left[\tilde{\Lambda}_{t,t+1}^* \left(R_{k,t+1}^* - R_t^* \right) \right],$$

$$\mu_{b^*t}^* = \mathbb{E}_t \left[\tilde{\Lambda}_{t,t+1}^* \left(R_{b,t+1}^* - R_t^* \right) \right],$$

$$\mu_{st}^* = \mathbb{E}_t \left[\tilde{\Lambda}_{t,t+1}^* \left(R_{k,t+1} e_{t+1} - R_t^* e_t \right) \right],$$

$$\mu_{bt}^* = \mathbb{E}_t \left[\tilde{\Lambda}_{t,t+1}^* \left(R_{b,t+1} e_{t+1} - R_t^* e_t \right) \right],$$

$$\nu_t^* = \mathbb{E}_t \left[\tilde{\Lambda}_{t,t+1}^* R_t^* \right],$$

$$\vartheta_t^* = \sigma \mathbb{E}_t \left[\Lambda_{t,t+1}^* v_{t+1}^* \right].$$

Next, let λ_t^* be the Lagrange multiplier associated with incentive constraint (B14). The maximization problem in (B13) yields the following first-order conditions.

$$\mathbb{E}_t\left[\tilde{\Lambda}_{t,t+1}^*\left(R_{k,t+1}^* - R_t^*\right)\right] = \frac{\lambda_t^*\theta}{1+\lambda_t^*},$$

$$\mathbb{E}_t\left[\tilde{\Lambda}_{t,t+1}^*\left(R_{b,t+1}^* - R_t^*\right)\right] = \frac{\lambda_t^*\theta\Delta}{1+\lambda_t^*},$$

$$Q_t s_{ht}^* = Q_{ss}\bar{s}_h^* + \left\{(1+\lambda_t^*)\,\mathbb{E}_t\left[\tilde{\Lambda}_{t,t+1}^*\left(\frac{R_{k,t+1}e_{t+1}}{e_t} - R_t^*\right)\right] - \lambda_t^*\theta\right\}\frac{n_t^*}{\kappa_1}\frac{1}{e_t},$$

$$q_t b_{ht}^* = q_{ss}\bar{b}_h^* + \left\{(1+\lambda_t^*)\,\mathbb{E}_t\left[\tilde{\Lambda}_{t,t+1}^*\left(\frac{R_{b,t+1}e_{t+1}}{e_t} - R_t^*\right)\right] - \lambda_t^*\theta\Delta\right\}\frac{n_t^*}{\kappa_2}\frac{1}{e_t}.$$

When the incentive constraint (B14) is nonbinding, i.e., $\lambda_t^* = 0$, the expected excess returns on foreign risky assets are zero, and the deviations in optimal domestic asset holdings from steady-state values increase with the expected excess returns on domestic assets relative to foreign deposit rate in terms of foreign currency.

For foreign banks, the risk-weighted holdings of foreign assets, $Q_t^* s_{ft}^* + \Delta q_t^* b_{ft}^*$, can be derived by plugging the first-order conditions into the incentive constraint. The solution is

$$Q_t^* s_{ft}^* + \Delta q_t^* b_{ft}^* \leq \phi_t^* n_t^* + \psi_t^*,$$

where the equality holds if $\lambda_t^* > 0$. The associated slope coefficient ϕ_t^* is given by

$$\phi_t^* = \frac{\kappa_1^{-1}\left(\mu_{st}^* e_t^{-1} - \theta\right)\left[(1+\lambda_t^*)\,\mu_{st}^* e_t^{-1} - \lambda_t^*\theta\right] + \kappa_2^{-1}\left(\mu_{bt}^* e_t^{-1} - \theta\Delta\right)\left[(1+\lambda_t^*)\,\mu_{bt}^* e_t^{-1} - \lambda_t^*\theta\Delta\right] + \mathbb{E}_t\left[\tilde{\Lambda}_{t,t+1}^* R_t^*\right]}{\theta - \mu_{s^*t}^*}, \tag{B19}$$

and the intercept ψ_t^* is given by

$$\psi_t^* = \frac{\left(\mu_{st}^* - \theta e_t\right) Q_{ss}\bar{s}_h + \left(\mu_{bt}^* - \theta\Delta e_t\right) q_{ss}\bar{b}_h + \sigma\mathbb{E}_t\left[\Lambda_{t,t+1}^* v_{w,t+1}^*\right]}{\theta - \mu_{s^*t}^*}. \tag{B20}$$

In the linear conjecture (B18) of $W_t^*(n_t^*)$, the expression for the slope coefficient ϕ_{wt}^* is

$$\phi_{wt}^* = \frac{\left[(1-\lambda_t^*)\mu_{st}^* e_t^{-1} + \lambda_t^*\theta\right]\left[(1+\lambda_t^*)\,\mu_{st}^* e_t^{-1} - \lambda_t^*\theta\right]}{2\kappa_1} + \frac{\left[(1-\lambda_t^*)\mu_{bt}^* e_t^{-1} + \lambda_t^*\Delta\theta\right]\left[(1+\lambda_t^*)\,\mu_{bt}^* e_t^{-1} - \lambda_t^*\theta\Delta\right]}{2\kappa_2} + \mathbb{E}_t\left[\tilde{\Lambda}_{t,t+1}^* R_t^*\right] + \phi_t^*\mu_{s^*t}^*,$$

and the expression for the intercept v^*_{wt} is given by

$$v^*_{wt} = \mu^*_{s^*t}\psi^*_t + \mu^*_{st}Q_{ss}\bar{s}_h + \mu^*_{bt}q_{ss}\bar{b}_h + \sigma\mathbb{E}_t\left[\Lambda^*_{t,t+1}v^*_{w,t+1}\right].$$

Finally, the value function V^*_t in equilibrium is also a linear function of n^*_t:

$$V^*_t = \phi^*_{vt}n^*_t + v^*_{vt},$$

with the slope coefficient ϕ^*_{vt} given by

$$\begin{aligned}\phi^*_{vt} = &\frac{\mu^*_{st}}{\kappa_1 e_t}\left[(1+\lambda^*_t)\,\mu^*_{st}e_t^{-1} - \lambda^*_t\theta\right] + \frac{\mu^*_{bt}}{\kappa_2 e_t}\left[(1+\lambda^*_t)\,\mu^*_{bt}e_t^{-1} - \lambda^*_t\theta\Delta\right]\\ &+\mathbb{E}_t\left[\tilde{\Lambda}^*_{t,t+1}R^*_t\right] + \phi^*_t\mu^*_{s^*t},\end{aligned}$$

and the intercept v^*_{vt} given by

$$v^*_{vt} = \mu^*_{s^*t}\psi^*_t + \mu^*_{st}Q_{ss}\bar{s}_h + \mu^*_{bt}q_{ss}\bar{b}_h + \sigma\mathbb{E}_t\left[\Lambda^*_{t,t+1}v^*_{w,t+1}\right].$$

Solution with Aggregation. We denote $\{S_{Ht}, B_{Ht}, S_{Ft}, B_{Ft}\}$ as the domestic banks' aggregate holdings of domestic and foreign assets, and N_t as their aggregate net worth. Given the evolution of individual bank's net worth in (4), the aggregate net worth N_t evolves as

$$\begin{aligned}N_t = \sigma\Bigg[&(R_{kt} - R_{t-1})\,Q_{t-1}S_{H,t-1} + (R_{bt} - R_{t-1})\,q_{t-1}B_{H,t-1} + \left(\frac{R^*_{kt}}{e_t} - \frac{R_{t-1}}{e_{t-1}}\right)Q^*_{t-1}S_{F,t-1}\\ &+\left(\frac{R^*_{bt}}{e_t} - \frac{R_{t-1}}{e_{t-1}}\right)q^*_{t-1}B_{F,t-1} + R_{t-1}N_{t-1}\Bigg] + X,\end{aligned}$$

where σ is the fraction of surviving banks, and X is the aggregate startup funds to new bankers. Symmetrically, the aggregate net worth for foreign banks evolves according to

$$\begin{aligned}N^*_t = \sigma\big[&\left(R^*_{kt} - R^*_{t-1}\right)Q^*_{t-1}S^*_{F,t-1} + \left(R^*_{bt} - R^*_{t-1}\right)q^*_{t-1}B^*_{F,t-1} + \left(R_{kt}e_t - R^*_{t-1}e_{t-1}\right)Q_{t-1}S^*_{H,t-1}\\ &+\left(R_{bt}e_t - R^*_{t-1}e_{t-1}\right)q_{t-1}B^*_{H,t-1} + R^*_{t-1}N^*_{t-1}\big] + X.\end{aligned}$$

Furthermore, domestic banks' aggregate foreign asset holdings are

$$\begin{aligned}Q^*_tS_{Ft} &= Q^*_{ss}\bar{S}_F + (1+\lambda_t)\,\mathbb{E}_t\left[\tilde{\Lambda}_{t,t+1}\left(\frac{R^*_{k,t+1}e_t}{e_{t+1}} - R_{k,t+1}\right)\right]\frac{N_t}{\kappa_1}e_t,\\ q^*_tB_{Ft} &= q^*_{ss}\bar{B}_F + (1+\lambda_t)\,\mathbb{E}_t\left[\tilde{\Lambda}_{t,t+1}\left(\frac{R^*_{b,t+1}e_t}{e_{t+1}} - R_{b,t+1}\right)\right]\frac{N_t}{\kappa_2}e_t.\end{aligned}$$

Foreign banks' aggregate domestic asset holdings are

$$Q_t S^*_{Ht} = Q_{ss}\bar{S}^*_H + (1+\lambda^*_t)\,\mathbb{E}_t\left[\tilde{\Lambda}^*_{t,t+1}\left(\frac{R_{k,t+1}e_{t+1}}{e_t} - R^*_{k,t+1}\right)\right]\frac{N^*_t}{\kappa_1 e_t},$$
$$q_t B^*_{Ht} = q_{ss}\bar{B}^*_H + (1+\lambda^*_t)\,\mathbb{E}_t\left[\tilde{\Lambda}^*_{t,t+1}\left(\frac{R_{b,t+1}e_{t+1}}{e_t} - R^*_{b,t+1}\right)\right]\frac{N^*_t}{\kappa_2 e_t}.$$

Given the optimal foreign asset positions, the incentive constraint (B3) places an endogenous capital requirement on domestic banks' aggregate domestic asset holdings:

$$Q_t S_{Ht} + \Delta q_t B_{Ht} \leq \phi_t N_t + \psi_t \text{ with equality if } \lambda_t > 0, \tag{B21}$$

where ϕ_t and ψ_t are independent of bank-specific characteristics and given by (B9) and (B10), respectively. Similarly, the endogenous capital requirement on foreign banks' aggregate foreign asset holdings is

$$Q^*_t S^*_{Ft} + \Delta q^*_t B^*_{Ft} \leq \phi^*_t N^*_t + \psi^*_t \text{ with equality if } \lambda^*_t > 0,$$

where ϕ^*_t and ψ^*_t are defined in (B19) and (B20).

B.3 International Financial Market and Currency Dealers

FX dealers maximize the expected real return from a position of domestic short-term debt ($-d_{st}$) and a position of foreign short-term debt ($d_{st}e_t$) at period t:

$$V^d_t = \max_{d_{st}} \mathbb{E}_t\left[\left(\eta\Lambda_{t,t+1} + (1-\eta)\Lambda^*_{t,t+1}\frac{e_{t+1}}{e_t}\right)\left(\frac{R^*_t e_t}{e_{t+1}} - R_t\right)\right] d_{st},$$

subject to the financial constraint:

$$V^d_t \geq \Gamma_t d^2_{st} e_t.$$

We follow Gabaix and Maggiori (2015) and assume that FX dealers' risk-bearing capacity is limited by $\Gamma_t d^2_{st} e_t$. This is consistent with Itskhoki and Mukhin (2021) if $\Gamma_t = \gamma \text{var}_{ss}(\Delta \ln e_{t+1})$ as a constant, where $\text{var}_{ss}(\Delta \ln e_{t+1})$ is the steady-state variance of logarithmic change of real exchange rate. In the quantitative analysis, we also consider an endogenous or exogenous time-varying Γ_t.

By substituting the value function into the constraint and rearranging terms, we obtain FX dealer's optimal position on domestic short-term debt as follows:

$$d_{st} = \frac{1}{\Gamma_t}\mathbb{E}_t\left[\left(\eta\Lambda_{t,t+1} + (1-\eta)\Lambda^*_{t,t+1}\frac{e_{t+1}}{e_t}\right)\left(\frac{R^*_t}{e_{t+1}} - \frac{R_t}{e_t}\right)\right].$$

Similar to Itskhoki and Mukhin (2021), our model incorporates liquidity demand for currency by noise traders in the international financial market. These traders engage in a zero-capital strategy, taking long positions in home currency and short positions in foreign currency, or vice versa, depending on their excess demand for foreign currency. We denote the noise traders' total position of domestic short-term debt as D_{nt} with their total position of foreign short-term debt given by $D^*_{nt} = -D_{nt}e_t$. We model the noise traders' demand for domestic short-term debt as an exogenous AR(1) process:

$$D_{nt} = \rho_n D_{n,t-1} + \sigma_n \varepsilon_{nt}.$$

where $\rho_n \in (0,1)$ and σ_n parameterize its persistence and volatility, respectively. At the end of each period, noise traders distribute $\tilde{\eta}$ fraction of net profits to domestic households and the rest to foreign households.

In equilibrium, the currency market clearing condition is

$$D_{dt} = D_{st},$$

where D_{st} is FX dealers' aggregate dollar supply, and D_{dt} is the net dollar demand as the sum of net US exports, net buying volume of US risky assets, dollar debt repaid by FX dealers from the previous period, noise traders' net dollar demand, as well as FX dealers' and noise traders' profits rebated to US households:

$$\begin{aligned}
D_{dt} = {} & \underbrace{(Q_t S^*_{Ht} - Q_{t-1}S^*_{H,t-1}R_{kt}) - (Q^*_t S_{Ft} - Q^*_{t-1}S_{F,t-1}R^*_{kt})/e_t}_{\text{net equity inflows to the US}} \\
& + \underbrace{(q_t B^*_{Ht} - q_{t-1}B^*_{H,t-1}R_{bt}) - (q^*_t B_{Ft} - q^*_{t-1}B_{F,t-1}R^*_{bt})/e_t}_{\text{net bond inflows to the US}} \\
& + \underbrace{\gamma_y \frac{(p^*_{Ht}e_t)^{1-\eta_y}}{e_t}Y^*_t - \gamma_y\left(\frac{p_{Ft}}{e_t}\right)^{1-\eta_y}Y_t}_{\text{net exports of the US}} + \underbrace{R_{t-1}D_{s,t-1}}_{\text{dollar debt payoff}} + \underbrace{\eta\left(\frac{R^*_{t-1}e_{t-1}}{e_t} - R_{t-1}\right)D_{s,t-1}}_{\text{dealers' profits to US households}} \\
& + \underbrace{D_{nt} - R_{t-1}D_{n,t-1}}_{\text{net dollar demand of noise traders}} + \underbrace{\tilde{\eta}\left(R_{t-1} - \frac{R^*_{t-1}e_{t-1}}{e_t}\right)D_{n,t-1}}_{\text{noise traders' profits to US households}}.
\end{aligned} \tag{B22}$$

Here, it is worth mentioning that the definition of net portfolio flows is consistent with the data construction in Bertaut and Tryon (2007) and Bertaut and Judson (2014). As modeled in Appendix B.6, final goods producers import varieties of retail goods from both domestic and foreign countries. The real value of net US exports is then defined as

$$
\begin{aligned}
&\int_0^1 \frac{P^*_{Ht}(i)}{P_t\mathcal{E}_t} Y^*_{Ht}(i)di - \int_0^1 \frac{P_{Ft}(i)}{P_t} Y_{Ft}(i)di \\
=&\gamma_y \left(\frac{P^*_{Ht}}{P^*_t}\right)^{\theta_y-\eta_y} \frac{1}{P_t\mathcal{E}_t}\int_0^1 \frac{(P^*_{Ht}(i))^{1-\theta_y}}{(P^*_t)^{-\theta_y}} Y^*_t di - \gamma_y \left(\frac{P_{Ft}}{P_t}\right)^{\theta_y-\eta_y} \int_0^1 \frac{(P_{Ft}(i))^{1-\theta_y}}{P_t^{1-\theta_y}} Y_t di \\
=&\gamma_y \frac{P^*_t}{P_t\mathcal{E}_t}\left(\frac{P^*_{Ht}}{P^*_t}\right)^{1-\eta_y} Y^*_t - \gamma_y \left(\frac{P_{Ft}}{P_t}\right)^{1-\eta_y} Y_t \\
=&\gamma_y \frac{(p^*_{Ht}\cdot e_t)^{1-\eta_y}}{e_t} Y^*_t - \gamma_y \left(\frac{p_{Ft}}{e_t}\right)^{1-\eta_y} Y_t.
\end{aligned}
$$

Moreover, FX dealers repay their dollar debt with accrued interest $R_{t-1}D_{s,t-1}$ from the previous period and rebate net profits $\eta\left(\frac{R^*_{t-1}e_{t-1}}{e_t} - R_{t-1}\right)D_{s,t-1}$ to US households, and noise traders have a net dollar demand $D_{nt} - R_{t-1}D_{n,t-1}$ and rebate net profits $\tilde{\eta}\left(R_{t-1} - \frac{R^*_{t-1}e_{t-1}}{e_t}\right)D_{n,t-1}$ to US households.

B.4 Intermediate Goods Producers

Intermediate goods producers are competitive and sell homogeneous intermediate goods to local retail firms. They produce the intermediate goods using a Cobb-Douglas technology:

$$Y_{mt} = A_t K_t^{\alpha} L_{pt}^{1-\alpha},$$

where K_t and L_{pt} are the capital and labor input, respectively. The capital stock K_t depreciates at a constant rate δ. Then the aggregate capital accumulates according to

$$K_{t+1} = I_t + (1-\delta)K_t.$$

Since intermediate goods producers are competitive and the production function is constant returns to scale in capital and labor, the intermediate goods price is equal to the marginal cost of production:

$$p_{mt} = \min_{K_t, L_{pt}} \left\{Z_t K_t + w_t L_{pt}; \text{s.t. } A_t K_t^{\alpha} L_{pt}^{1-\alpha} = 1.\right\} = \frac{1}{A_t}\left(\frac{Z_t}{\alpha}\right)^{\alpha}\left(\frac{w_t}{1-\alpha}\right)^{1-\alpha}.$$

The corresponding labor and capital demand are given by

$$L_{pt} = \frac{(1-\alpha)p_{mt}Y_{mt}}{w_t} \quad \text{and} \quad K_t = \frac{\alpha p_{mt} Y_{mt}}{Z_t}.$$

Symmetrically, the foreign intermediate goods price is

$$p_{mt}^* = \frac{1}{A_t^*} \left(\frac{Z_t^*}{\alpha} \right)^{\alpha} \left(\frac{w_t^*}{1-\alpha} \right)^{1-\alpha},$$

and the associated labor and capital demand are given by

$$L_{pt}^* = \frac{(1-\alpha) p_{mt}^* Y_{mt}^*}{w_t^*} \quad \text{and} \quad K_t^* = \frac{\alpha p_{mt}^* Y_{mt}^*}{Z_t^*}.$$

B.5 Capital Producers

Capital producers make new capital using local final goods as input. They are competitive and sell new capital to local intermediate goods producers at price Q_t. We assume that local households own capital producers and receive their profits as lump-sum transfers. The capital producers maximize the discounted real profits by choosing the amount of investment I_t:

$$\max_{\{I_{t+k}\}_{k=0}^{\infty}} \mathbb{E}_t \sum_{k=0}^{\infty} \Lambda_{t,t+k} \left\{ Q_{t+k} I_{t+k} - \left[1 + f\left(\frac{I_{t+k}}{I_{ss}} \right) \right] I_{t+k} \right\},$$

where $f(I_t/I_{ss})$ is the adjustment cost per unit of investment. We assume that the cost is quadratic in the net growth rate of new capital relative to steady-state value: $f(I_t/I_{ss}) = \frac{\kappa_I}{2}(I_t/I_{ss} - 1)^2$. The first-order condition for domestic investment I_t is

$$Q_t = 1 + f\left(\frac{I_t}{I_{ss}} \right) + \frac{I_t}{I_{ss}} f'\left(\frac{I_t}{I_{ss}} \right). \tag{B23}$$

Symmetrically, the first-order condition for foreign investment I_t^* is

$$Q_t^* = 1 + f\left(\frac{I_t^*}{I_{ss}^*} \right) + \frac{I_t^*}{I_{ss}^*} f'\left(\frac{I_t^*}{I_{ss}^*} \right).$$

B.6 Retail Firms

Given the CES technology of Y_t in (16) and (17), the domestic final goods producers minimize within-period cost of production:

$$P_t Y_t = \int_0^1 \left[P_{Ht}(i) Y_{Ht}(i) + P_{Ft}(i) Y_{Ft}(i) \right] di,$$

where $P_{Ht}(i)$ and $P_{Ft}(i)$ are the nominal home-currency prices of home and foreign retail good i in the home market.

The cost minimization implies isoelastic demand functions:

$$Y_{Ht}(i) = (1-\gamma_y)\left(\frac{P_{Ht}}{P_t}\right)^{-\eta_y}\left(\frac{P_{Ht}(i)}{P_{Ht}}\right)^{-\theta_y} Y_t \text{ and } Y_{Ft}(i) = \gamma_y\left(\frac{P_{Ft}}{P_t}\right)^{-\eta_y}\left(\frac{P_{Ft}(i)}{P_{Ft}}\right)^{-\theta_y} Y_t, \tag{B24}$$

where P_{Ht} and P_{Ft} are the aggregate price indices of retail goods baskets:

$$P_{Ht} = \left[\int_0^1 P_{Ht}(i)^{1-\theta_y} di\right]^{\frac{1}{1-\theta_y}} \quad \text{and} \quad P_{Ft} = \left[\int_0^1 P_{Ft}(i)^{1-\theta_y} di\right]^{\frac{1}{1-\theta_y}}.$$

The retail goods input by foreign final goods producers is characterized by a symmetric demand system:

$$Y^*_{Ht}(i) = \gamma_y\left(\frac{P^*_{Ht}}{P^*_t}\right)^{-\eta_y}\left(\frac{P^*_{Ht}(i)}{P^*_{Ht}}\right)^{-\theta_y} Y^*_t \text{ and } Y^*_{Ft}(j) = (1-\gamma_y)\left(\frac{P^*_{Ft}}{P^*_t}\right)^{-\eta_y}\left(\frac{P^*_{Ft}(j)}{P^*_{Ft}}\right)^{-\theta_y} Y^*_t, \tag{B25}$$

where $P^*_{Ht}(i)$ and $P^*_{Ft}(i)$ are the nominal foreign-currency prices of home and foreign retail good i in the foreign market, and P^*_{Ht} and P^*_{Ft} are the associated aggregate price indices of retail goods baskets:

$$P^*_{Ht} = \left[\int_0^1 P^*_{Ht}(i)^{1-\theta_y} di\right]^{\frac{1}{1-\theta_y}} \quad \text{and} \quad P^*_{Ft} = \left[\int_0^1 P^*_{Ft}(i)^{1-\theta_y} di\right]^{\frac{1}{1-\theta_y}}.$$

The retail firms are monopolistically competitive and set the optimal goods prices subject to nominal rigidities as in Calvo (1983). They choose the retail goods prices $P_{Ht}(i)$ and $P^*_{Ht}(i)$ to maximize the discounted sum of future real profits:

$$\mathbb{E}_t \sum_{k=0}^{\infty} \phi_p^k \Lambda_{t,t+k}\left\{\left[\frac{P_{Ht}(i)}{P_{t+k}} - p_{m,t+k}\right] Y_{H,t+k}(i) + \left[\frac{P^*_{Ht}(i)}{(\iota\mathcal{E}_t + (1-\iota)\,\mathcal{E}_{t+k})\,P_{t+k}} - p_{m,t+k}\right] Y^*_{H,t+k}(i)\right\},$$

where $\iota \in \{0,1\}$ with $\iota = 1$ corresponding to the scheme of PCP and $\iota = 0$ to the scheme of LCP. From (B24) and (B25), the domestic and foreign demand for home good i is given by

$$Y_{H,t+k}(i) = (1-\gamma_y)\left(\frac{P_{H,t+k}}{P_{t+k}}\right)^{-\eta_y}\left(\frac{P_{Ht}(i)}{P_{H,t+k}}\right)^{-\theta_y} Y_{t+k},$$
$$Y^*_{H,t+k}(i) = \gamma_y\left(\frac{P^*_{H,t+k}}{P^*_{t+k}}\right)^{-\eta_y}\left(\frac{\mathcal{E}_{t+k}P^*_{Ht}(i)}{(\iota\mathcal{E}_t + (1-\iota)\,\mathcal{E}_{t+k})\,P^*_{H,t+k}}\right)^{-\theta_y} Y^*_{t+k},$$

where Y_{t+k} and Y^*_{t+k} are the aggregate demand in home and foreign country at period $t+k$, respectively.

Denote the optimal reset prices of home retailer i as $\hat{P}_{Ht}(i)$ and $\hat{P}^*_{Ht}(i)$. The first-order conditions for the retailer's profit maximization problem are given by

$$\sum_{k=0}^{\infty}\phi_p^k\Lambda_{t,t+k}\left[\frac{\hat{P}_{Ht}(i)}{P_{t+k}}-\frac{\theta_y}{\theta_y-1}\cdot p_{m,t+k}\right]Y_{H,t+k}(i)=0, \tag{B26}$$

and

$$\sum_{k=0}^{\infty}\phi_p^k\Lambda_{t,t+k}\left[\frac{\hat{P}^*_{Ht}(i)}{\left(\iota\mathcal{E}_t+(1-\iota)\,\mathcal{E}_{t+k}\right)P_{t+k}}-\frac{\theta_y}{\theta_y-1}\cdot p_{m,t+k}\right]Y^*_{H,t+k}(i)=0. \tag{B27}$$

Due to the identical marginal production cost $p_{m,t+k}$ and symmetric demand functions $Y_{H,t+k}(i)$ and $Y^*_{H,t+k}(i)$, the optimal reset prices are identical across retailers in the same country. Thus we omit the goods index i of optimal reset prices as long as it does not cause any confusion. The optimal reset prices do not have a closed-form solution, but can be expressed in a recursive form as follows. We first define the following variables:

$$\begin{aligned}
X_{1,Ht}&=\sum_{k=0}^{\infty}\phi_p^k\Lambda_{t,t+k}p_{m,t+k}\left(P_{t+k}\right)^{\eta_y}\left(P_{H,t+k}\right)^{\theta_y-\eta_y}Y_{t+k},\\
X_{2,Ht}&=\sum_{k=0}^{\infty}\phi_p^k\Lambda_{t,t+k}\left(P_{t+k}\right)^{\eta_y-1}\left(P_{H,t+k}\right)^{\theta_y-\eta_y}Y_{t+k},\\
X^*_{1,Ht}&=\sum_{k=0}^{\infty}\phi_p^k\Lambda_{t,t+k}p_{m,t+k}\left(\frac{P^*_{H,t+k}}{P^*_{t+k}}\right)^{-\eta_y}\left(\frac{\mathcal{E}_{t+k}}{\left(\iota\mathcal{E}_t+(1-\iota)\,\mathcal{E}_{t+k}\right)P^*_{H,t+k}}\right)^{-\theta_y}Y^*_{t+k},\\
X^*_{2,Ht}&=\sum_{k=0}^{\infty}\phi_p^k\Lambda_{t,t+k}\frac{\left(P^*_{H,t+k}/P^*_{t+k}\right)^{-\eta_y}}{\left(\iota\mathcal{E}_t+(1-\iota)\,\mathcal{E}_{t+k}\right)P_{t+k}}\left(\frac{\mathcal{E}_{t+k}}{\left(\iota\mathcal{E}_t+(1-\iota)\,\mathcal{E}_{t+k}\right)P^*_{H,t+k}}\right)^{-\theta_y}Y^*_{t+k}.
\end{aligned}$$

These variables can be written recursively as

$$\begin{aligned}
X_{1,Ht}&=p_{mt}(P_t)^{\eta_y}(P_{Ht})^{\theta_y-\eta_y}Y_t+\phi_p\Lambda_{t,t+1}X_{1,H,t+1},\\
X_{2,Ht}&=(P_t)^{\eta_y-1}(P_{Ht})^{\theta_y-\eta_y}Y_t+\phi_p\Lambda_{t,t+1}X_{2,H,t+1},\\
X^*_{1,Ht}&=p_{mt}(P^*_t)^{\eta_y}\left(P^*_{Ht}\right)^{\theta_y-\eta_y}Y^*_t+\phi_p\Lambda_{t,t+1}\left(\frac{\mathcal{E}_t}{\mathcal{E}_{t+1}}\right)^{\theta_y\cdot\iota}X^*_{1,H,t+1},\\
X^*_{2,Ht}&=\frac{1}{P_t\mathcal{E}_t}(P^*_t)^{\eta_y}\left(P^*_{Ht}\right)^{\theta_y-\eta_y}Y^*_t+\phi_p\Lambda_{t,t+1}\left(\frac{\mathcal{E}_t}{\mathcal{E}_{t+1}}\right)^{(\theta_y-1)\cdot\iota}X^*_{2,H,t+1}.
\end{aligned}$$

Hence, by rearranging terms in (B26) and (B27) and replacing the terms with the above notations, the optimal nominal reset prices of home retailers are given by

$$\hat{P}_{Ht}=\frac{\theta_y}{\theta_y-1}\frac{X_{1,Ht}}{X_{2,Ht}},\quad \hat{P}^*_{Ht}=\frac{\theta_y}{\theta_y-1}\frac{X^*_{1,Ht}}{X^*_{2,Ht}}.$$

Moreover, define $x_{1,Ht}=X_{1,Ht}/(P_t)^{\theta_y}$, $x_{2,Ht}=X_{2,Ht}/(P_t)^{\theta_y-1}$, $\hat{p}_{Ht}=\hat{P}_{Ht}/P_t$, and $p_{Ht}=$

P_{Ht}/P_t. The optimal real reset price for home-produced home goods is given by

$$\hat{p}_{Ht} = \frac{\theta_y}{\theta_y - 1}\frac{x_{1,Ht}}{x_{2,Ht}},$$
$$x_{1,Ht} = p_{mt}p_{Ht}^{\theta_y-\eta_y}Y_t + \phi_p\Lambda_{t,t+1}x_{1,H,t+1}(\Pi_{t+1})^{\theta_y},$$
$$x_{2,Ht} = p_{Ht}^{\theta_y-\eta_y}Y_t + \phi_p\Lambda_{t,t+1}x_{2,H,t+1}(\Pi_{t+1})^{\theta_y-1}.$$

Note that p_{Ht} and $\hat{p}_{Ht}$ are, respectively, the aggregate price index and optimal reset price in real home currency of home retail goods in home market. Similarly, define $x^*_{1,Ht} = X^*_{1,Ht}/(P^*_t)^{\theta_y}$, $x^*_{2,Ht} = X^*_{2,Ht}P_t\mathcal{E}_t/(P^*_t)^{\theta_y}$, $\hat{p}^*_{Ht} = \hat{P}^*_{Ht}/(P_t\mathcal{E}_t)$, $p^*_{Ht} = P^*_{Ht}/(P_t\mathcal{E}_t)$, the real reset price for home-produced foreign goods is given by

$$\hat{p}^*_{Ht} = \frac{\theta_y}{\theta_y - 1}\frac{x^*_{1,Ht}}{x^*_{2,Ht}},$$
$$x^*_{1,Ht} = p_{mt}(p^*_{Ht}\cdot e_t)^{\theta_y-\eta_y}Y^*_t + \phi_p\Lambda_{t,t+1}\left(\frac{\mathcal{E}_t}{\mathcal{E}_{t+1}}\right)^{\theta_y\cdot\iota}x^*_{1,H,t+1}(\Pi^*_{t+1})^{\theta_y},$$
$$x^*_{2,Ht} = (p^*_{Ht}\cdot e_t)^{\theta_y-\eta_y}Y^*_t + \phi_p\Lambda_{t,t+1}\left(\frac{\mathcal{E}_t}{\mathcal{E}_{t+1}}\right)^{1+(\theta_y-1)\cdot\iota}x^*_{2,H,t+1}\frac{(\Pi^*_{t+1})^{\theta_y}}{\Pi_{t+1}}.$$

Note that p^*_{Ht} and $\hat{p}^*_{Ht}$ are, respectively, the aggregate price index and optimal reset price in real home currency of home retail goods in foreign market.

For foreign retailers, the optimal reset prices in real terms are derived in a similar way. The first-order conditions for their profit maximization are given by

$$\sum_{k=0}^{\infty}\phi_p^k\Lambda^*_{t,t+k}\left[\frac{\hat{P}^*_{Ft}(i)}{P^*_{t+k}} - \frac{\theta_y}{\theta_y-1}\cdot p^*_{m,t+k}\right]Y^*_{F,t+k}(i) = 0,$$

and
$$\sum_{k=0}^{\infty}\phi_p^k\Lambda^*_{t,t+k}\left[\frac{(\iota\mathcal{E}_t + (1-\iota)\,\mathcal{E}_{t+k})\,\hat{P}_{Ft}(i)}{P^*_{t+k}} - \frac{\theta_y}{\theta_y-1}\cdot p^*_{m,t+k}\right]Y_{F,t+k}(i) = 0,$$

where $\hat{P}^*_{Ft}(i)$ and $\hat{P}_{Ft}(i)$ are the optimal nominal reset prices of foreign retail good i in foreign and domestic markets, and they are also identical across foreign retailers. To obtain the real value of these reset prices, let us denote $\hat{p}^*_{Ft} = \hat{P}^*_{Ft}/P^*_t$, $p^*_{Ft} = P^*_{Ft}/P^*_t$, $\hat{p}_{Ft} = \hat{P}_{Ft}\mathcal{E}_t/P^*_t$, $p_{Ft} = P_{Ft}\mathcal{E}_t/P^*_t$. Note that p^*_{Ft} and $\hat{p}^*_{Ft}$ are the aggregate price index and optimal reset price in real foreign currency of foreign retail goods sold in the foreign market, and p_{Ft} and $\hat{p}_{Ft}$ are the aggregate price index and optimal reset price in real foreign currency of foreign retail goods sold in the home market. The optimal reset prices in real terms can be written in the following recursive form:

$$
\begin{aligned}
\hat{p}^*_{Ft} &= \frac{\theta_y}{\theta_y - 1}\frac{x^*_{1,F,t}}{x^*_{2,F,t}}, \\
x^*_{1,Ft} &= p^*_{mt}(p^*_{Ft})^{\theta_y-\eta_y}Y^*_t + \phi_p\Lambda^*_{t,t+1}x^*_{1,F,t+1}(\Pi^*_{t+1})^{\theta_y}, \\
x^*_{2,Ft} &= (p^*_{Ft})^{\theta_y-\eta_y}Y^*_t + \phi_p\Lambda^*_{t,t+1}x^*_{2,F,t+1}(\Pi^*_{t+1})^{\theta_y-1},
\end{aligned}
$$

and

$$
\begin{aligned}
\hat{p}_{Ft} &= \frac{\theta_y}{\theta_y - 1}\frac{x_{1,F,t}}{x_{2,F,t}}, \\
x_{1,Ft} &= p^*_{mt}\left(\frac{p_{Ft}}{e_t}\right)^{\theta_y-\eta_y} Y_t + \phi_p\Lambda^*_{t,t+1}\left(\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}\right)^{\theta_y\cdot\iota} x_{1,F,t+1}(\Pi_{t+1})^{\theta_y}, \\
x_{2,Ft} &= \left(\frac{p_{Ft}}{e_t}\right)^{\theta_y-\eta_y} Y_t + \phi_p\Lambda^*_{t,t+1}\left(\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}\right)^{1+(\theta_y-1)\cdot\iota} x_{2,F,t+1}\frac{(\Pi_{t+1})^{\theta_y}}{\Pi^*_{t+1}}.
\end{aligned}
$$

B.7 Aggregation

This section characterizes the dynamics of aggregate price indices of retail goods baskets, aggregate demand, and budget constraint of each country.

Price Aggregation. In principle, we need a market clearing condition for each retail good, since the prices can be heterogeneous. Thanks to the homothetic preference and i.i.d. opportunity of resetting prices, the laws of motion for the nominal price indices of home retail goods baskets sold in each country have the following recursive form:

$$
\begin{aligned}
P_{Ht} &= \left[\int_0^1 P_{Ht}(i)^{1-\theta_y}di\right]^{\frac{1}{1-\theta_y}} = \left[(1-\phi_p)\left(\hat{P}_{Ht}\right)^{1-\theta_y} + \phi_p\left(P_{H,t-1}\right)^{1-\theta_y}\right]^{\frac{1}{1-\theta_y}}, \\
P^*_{Ht} &= \left[\int_0^1 P^*_{Ht}(i)^{1-\theta_y}di\right]^{\frac{1}{1-\theta_y}} = \left[(1-\phi_p)\left(\hat{P}^*_{Ht}\right)^{1-\theta_y} + \phi_p\left(P^*_{H,t-1}\right)^{1-\theta_y}\right]^{\frac{1}{1-\theta_y}}.
\end{aligned}
$$

Denote the real price indices of home baskets in home currency as $p_{Ht} = P_{Ht}/P_t$ and $p^*_{Ht} = \frac{P^*_{Ht}}{P_t\mathcal{E}_t}$, the above equations imply

$$
p_{Ht} = \left[(1-\phi_p)\left(\hat{p}_{Ht}\right)^{1-\theta_y} + \phi_p\left(\frac{p_{H,t-1}}{\Pi_t}\right)^{1-\theta_y}\right]^{\frac{1}{1-\theta_y}}, \tag{B28}
$$

$$
p^*_{Ht} = \left[(1-\phi_p)\left(\hat{p}^*_{Ht}\right)^{1-\theta_y} + \phi_p\left(\frac{p^*_{H,t-1}}{\Pi_t}\cdot\frac{\mathcal{E}_{t-1}}{\mathcal{E}_t}\right)^{1-\theta_y}\right]^{\frac{1}{1-\theta_y}}. \tag{B29}
$$

Note that the nominal exchange rate is $\mathcal{E}_t = \frac{e_t P_t^*}{P_t}$, it follows that

$$\frac{\mathcal{E}_t}{\mathcal{E}_{t-1}} = \frac{\Pi_t^*}{\Pi_t} \cdot \frac{e_t}{e_{t-1}}.$$

For foreign producers, denote the real price indices of foreign retail goods baskets in foreign currency as $p_{Ft}^* = P_{Ft}^*/P_t^*$ and $p_{Ft} = \frac{P_{Ft}\mathcal{E}_t}{P_t^*}$. The laws of motion for these price indices are similar to those of the home goods baskets:

$$p_{Ft}^* = \left[(1-\phi_p) \left(\hat{p}_{Ft}^*\right)^{1-\theta_y} + \phi_p \left(\frac{p_{F,t-1}^*}{\Pi_t^*} \right)^{1-\theta_y} \right]^{\frac{1}{1-\theta_y}}, \tag{B30}$$

$$p_{Ft} = \left[(1-\phi_p) \left(\hat{p}_{Ft}\right)^{1-\theta_y} + \phi_p \left(\frac{p_{F,t-1}}{\Pi_t^*} \cdot \frac{\mathcal{E}_t}{\mathcal{E}_{t-1}} \right)^{1-\theta_y} \right]^{\frac{1}{1-\theta_y}}. \tag{B31}$$

At the country level, the price index of aggregate home demand satisfies:

$$1 = \left[(1-\gamma_y) \left(\frac{P_{Ht}}{P_t} \right)^{1-\eta_y} + \gamma_y \left(\frac{P_{Ft}}{P_t} \right)^{1-\eta_y} \right]^{\frac{1}{1-\eta_y}} = (1-\gamma_y) \left(p_{Ht}\right)^{1-\eta_y} + \gamma_y \left(\frac{p_{Ft}}{e_t} \right)^{1-\eta_y},$$

where in the second equality, we apply the definitions of p_{Ht}, p_{Ft} and e_t given above. Similarly, the real price index of aggregate foreign demand satisfies

$$1 = (1-\gamma_y) \left(p_{Ft}^*\right)^{1-\eta_y} + \gamma_y \left(p_{Ht}^* \cdot e_t\right)^{1-\eta_y}.$$

Combining the above relations with the aggregate prices in (B28), (B29), (B30), and (B31), the domestic inflation rate is given by

$$\begin{aligned} 1 = (1-\gamma_y) &\left[(1-\phi_p) \left(\hat{p}_{Ht}\right)^{1-\theta_y} + \phi_p \left(\frac{p_{H,t-1}}{\Pi_t} \right)^{1-\theta_y} \right]^{\frac{1-\eta_y}{1-\theta_y}} \\ &+ \gamma_y \left[(1-\phi_p) \left(\frac{\hat{p}_{Ft}}{e_t} \right)^{1-\theta_y} + \phi_p \left(\frac{p_{F,t-1}}{\Pi_t \cdot e_{t-1}} \right)^{1-\theta_y} \right]^{\frac{1-\eta_y}{1-\theta_y}}, \end{aligned}$$

and the foreign inflation rate is given by

$$\begin{aligned} 1 = (1-\gamma_y) &\left[(1-\phi_p) \left(\hat{p}_{Ft}^*\right)^{1-\theta_y} + \phi_p \left(\frac{p_{F,t-1}^*}{\Pi_t^*} \right)^{1-\theta_y} \right]^{\frac{1-\eta_y}{1-\theta_y}} \\ &+ \gamma_y \left[(1-\phi_p) \left(\hat{p}_{Ht}^* \cdot e_t\right)^{1-\theta_y} + \phi_p \left(\frac{p_{H,t-1}^* \cdot e_{t-1}}{\Pi_t^*} \right)^{1-\theta_y} \right]^{\frac{1-\eta_y}{1-\theta_y}}. \end{aligned}$$

Demand Aggregation. For a home retail good i, the total output $Y_t(i)$ is given by $Y_t(i) = Y_{Ht}(i) + Y_{Ht}^*(i)$, where $Y_{Ht}(i)$ and $Y_{Ht}^*(i)$ are the demand of domestic and foreign markets:

$$Y_{Ht}(i) = (1-\gamma_y)\left(\frac{P_{Ht}}{P_t}\right)^{-\eta_y}\left(\frac{P_{Ht}(i)}{P_{Ht}}\right)^{-\theta_y} Y_t, \quad Y_{Ht}^*(i) = \gamma_y\left(\frac{P_{Ht}^*}{P_t^*}\right)^{-\eta_y}\left(\frac{P_{Ht}^*(i)}{P_{Ht}^*}\right)^{-\theta_y} Y_t^*,$$

and Y_t and Y_t^* are country-level aggregate demand:

$$\begin{aligned} Y_t = C_t + \left[1 + f\left(\frac{I_t}{I_{ss}}\right)\right] I_t + G + \left\{\frac{\kappa_1}{2}\left[\frac{Q_t^*\left(S_{Ft} - \bar{S}_F\right)}{e_t N_t}\right]^2 + \frac{\kappa_2}{2}\left[\frac{q_t^*\left(B_{Ft} - \bar{B}_F\right)}{e_t N_t}\right]^2\right\} N_t \\ + \frac{1}{2}\kappa_{h1}\left(Q_t S_{ht}^h - Q_{ss}\bar{S}_h^h\right)^2 + \frac{1}{2}\kappa_{h2}\left(q_t B_{ht}^h - q_{ss}\bar{B}_h^h\right)^2, \end{aligned} \tag{B32}$$

and

$$\begin{aligned} Y_t^* = C_t^* + \left[1 + f\left(\frac{I_t^*}{I_{ss}^*}\right)\right] I_t^* + G^* + \left\{\frac{\kappa_1}{2}\left[\frac{Q_t e_t\left(S_{Ht}^* - \bar{S}_H^*\right)}{N_t^*}\right]^2 + \frac{\kappa_2}{2}\left[\frac{q_t e_t\left(B_{Ht}^* - \bar{B}_H^*\right)}{N_t^*}\right]^2\right\} N_t^* \\ + \frac{1}{2}\kappa_{h1}\left(Q_t^* S_{ft}^{h*} - Q_{ss}^*\bar{S}_f^{h*}\right)^2 + \frac{1}{2}\kappa_{h2}\left(q_t^* B_{ft}^{h*} - q_{ss}^*\bar{B}_f^{h*}\right)^2. \end{aligned}$$

Let $Y_{mt} = \int_0^1 Y_t(i)di$ and $Y_{mt}^* = \int_0^1 Y_t^*(i)di$ be the aggregate output of home and foreign intermediate goods. By plugging in the expression of $Y_t(i)$ given above, we obtain

$$Y_{mt} = \int_0^1 Y_t(i)di = (1-\gamma_y)p_{Ht}^{\theta_y - \eta_y}\zeta_{Ht}Y_t + \gamma_y(p_{Ht}^* \cdot e_t)^{\theta_y - \eta_y}\zeta_{Ht}^* Y_t^*,$$

where ζ_{Ht} and ζ_{Ht}^* are price dispersion of home retail goods in home and foreign markets:

$$\zeta_{Ht} = \int_0^1 \left(\frac{P_{Ht}(i)}{P_t}\right)^{-\theta_y} di, \qquad \zeta_{Ht}^* = \int_0^1 \left(\frac{P_{Ht}^*(i)}{P_t^*}\right)^{-\theta_y} di.$$

Since the price resetting opportunity is i.i.d. across retailers, we can derive the law of motion for the price dispersion measure ζ_{Ht} as follows:

$$\begin{aligned} \zeta_{Ht} &= (1-\phi_p)\left(\hat{p}_{Ht}\right)^{-\theta_y} + \int_{1-\phi_p}^1 \left(\frac{P_{H,t-1}(i)}{P_t}\right)^{-\theta_y} di \\ &= (1-\phi_p)\left(\hat{p}_{Ht}\right)^{-\theta_y} + \phi_p \Pi_t^{\theta_y}\zeta_{H,t-1}, \end{aligned}$$

where the second equality applies the law of large numbers. Similarly, the law of motion for the price dispersion measure ζ_{Ht}^* can be written as

$$\zeta_{Ht}^* = (1-\phi_p)\left(\hat{p}_{Ht}^* \cdot e_t\right)^{-\theta_y} + \phi_p\left(\Pi_t^*\right)^{\theta_y}\zeta_{H,t-1}^*.$$

For the foreign country, the aggregate output of intermediate goods is given by

$$Y_{mt}^* = (1-\gamma_y)(p_{Ft}^*)^{\theta_y-\eta_y}\zeta_{Ft}^* Y_t^* + \gamma_y \left(\frac{p_{Ft}}{e_t}\right)^{\theta_y-\eta_y} \zeta_{Ft} Y_t,$$

where the price dispersion measures evolve according to

$$\begin{aligned}\zeta_{Ft}^* &= (1-\phi_p)\left(\hat{p}_{Ft}^*\right)^{-\theta_y} + \phi_p \left(\Pi_t^*\right)^{\theta_y} \zeta_{F,t-1}^*,\\ \zeta_{Ft} &= (1-\phi_p)\left(\frac{\hat{p}_{Ft}}{e_t}\right)^{-\theta_y} + \phi_p \left(\Pi_t\right)^{\theta_y} \zeta_{F,t-1}.\end{aligned}$$

Country Budget Constraint. As in Itskhoki and Mukhin (2021), the model equilibrium requires a budget constraint for the home country, which is derived as follows.

First, the aggregate profits of domestic retail firms are given by

$$\begin{aligned}&\int_0^1 \left(\frac{P_{Ht}(i)}{P_t} - p_{mt}\right) Y_{Ht}(i)di + \int_0^1 \left(\frac{P_{Ht}^*(i)}{\mathcal{E}_t P_t} - p_{mt}\right) Y_{Ht}^*(i)di\\ &= \int_0^1 \left[\frac{P_{Ht}(i)}{P_t} Y_{Ht}(i) + \frac{P_{Ft}(i)}{P_t} Y_{Ft}(i)\right] di + \int_0^1 \frac{P_{Ht}^*(i)}{\mathcal{E}_t P_t} Y_{Ht}^*(i)di - \int_0^1 \frac{P_{Ft}(i)}{P_t} Y_{Ft}(i)di - p_{mt}Y_{mt}\\ &= Y_t + NX_t - p_{mt}Y_{mt},\end{aligned}$$

where NX_t represents the net exports of the US. In the second line we use the domestic intermediate goods market clearing condition $Y_{mt} = \int_0^1 \left[Y_{Ht}(i) + Y_{Ht}^*(i)\right] di$, and in the third line we use the domestic final goods producers' zero-profit condition $P_tY_t = \int_0^1 [P_{Ht}(i)Y_{Ht}(i) + P_{Ft}(i)Y_{Ft}(i)]di$ and the definition of the US net exports.

Given the expression for retailers' profits, we can express the aggregate payouts from non-financial and financial firms to domestic households, DIV_t, as follows:

$$\begin{aligned}DIV_t = &\underbrace{(1-\sigma)N_{et}}_{\text{Net worth of home exit banks}} \underbrace{- \left\{\frac{\kappa_1}{2}\left[\frac{Q_t^*(S_{Ft}-\bar{S}_F)}{e_t N_t}\right]^2 + \frac{\kappa_2}{2}\left[\frac{q_t^*(B_{Ft}-\bar{B}_F)}{e_t N_t}\right]^2\right\} N_t}_{\text{Home banks' holding cost}}\\ &\underbrace{+\eta\left(\frac{R_{t-1}^* e_{t-1}}{e_t} - R_{t-1}\right) D_{s,t-1}}_{\text{Dealers' profits to home HH}} + \underbrace{Q_t I_t - \left[1 + f\left(\frac{I_t}{I_{ss}}\right)\right] I_t}_{\text{Home capital producers' profits}}\\ &+\underbrace{Y_t + NX_t - p_{mt}Y_{mt}}_{\text{Home retailers' profits}} \underbrace{+\tilde{\eta}\left(R_{t-1} - \frac{R_{t-1}^* e_{t-1}}{e_t}\right) D_{n,t-1}}_{\text{Noise traders' profits to home HH}},\end{aligned} \tag{B33}$$

where N_{et} represents the aggregate net worth of existing banks at the beginning of period t

before occupation shocks. From (4), the expression of N_{et} is given by

$$\begin{aligned} N_{et} &= R_{kt}Q_{t-1}S_{H,t-1} + R_{bt}q_{t-1}B_{H,t-1} + \frac{R^*_{kt}}{e_t}Q^*_{t-1}S_{F,t-1} + \frac{R^*_{bt}}{e_t}q^*_{t-1}B_{F,t-1} - R_{t-1}D_{t-1} \\ &= \left[Z_t + (1-\delta)Q_t\right]K_t - R_{kt}Q_{t-1}S^*_{H,t-1} + R_{bt}q_{t-1}(B_{t-1} - B^*_{H,t-1} - B_{g,t-1}) \\ &\quad + \frac{R^*_{kt}}{e_t}Q^*_{t-1}S_{F,t-1} + \frac{R^*_{bt}}{e_t}q^*_{t-1}B_{F,t-1} - R_{t-1}D_{t-1}, \end{aligned} \tag{B34}$$

where the first line is the definition of N_{et}, and in the second line we use the definition of R_{kt} and the clearing conditions for equity and long-term bond markets. In addition, combining (B34) with the law of motion for aggregate bank net worth N_t, we obtain

$$N_t = \sigma N_{et} + X. \tag{B35}$$

Next, by aggregating individual bank balance sheet (3) and replacing N_t with (B35), we obtain the following equation for domestic banks' aggregate balance sheet:

$$Q_t S_{Ht} + q_t B_{Ht} + \frac{Q^*_t S_{Ft} + q^*_t B_{Ft}}{e_t} = \sigma N_{et} + X + D_t. \tag{B36}$$

Finally, by adding up domestic households' budget constraint (1), domestic banks' aggregate balance sheet (B36), and domestic government budget constraint (18), we obtain

$$\begin{aligned} & C_t + G + \left[1 + f\left(\frac{I_t}{I_{ss}}\right)\right] I_t + \left\{\frac{\kappa_1}{2}\left[\frac{Q^*_t(S_{Ft} - \bar{S}_F)}{e_t N_t}\right]^2 + \frac{\kappa_2}{2}\left[\frac{q^*_t(B_{Ft} - \bar{B}_F)}{e_t N_t}\right]^2\right\} N_t \\ & + \frac{1}{2}\kappa_{h1}\left(Q_t S^h_{ht} - Q_{ss}\bar{S}^h_h\right)^2 + \frac{1}{2}\kappa_{h2}\left(q_t B^h_{ht} - q_{ss}\bar{B}^h_h\right)^2 - Y_t \\ = & \left(Q_t S^*_{Ht} - R_{kt}Q_{t-1}S^*_{H,t-1}\right) - \left(Q^*_t S_{Ft} - R^*_{kt}Q^*_{t-1}S_{F,t-1}\right)/e_t \\ & + \left(q_t B^*_{Ht} - R_{bt}q_{t-1}B^*_{H,t-1}\right) - \left(q^*_t B_{Ft} - R^*_{bt}q^*_{t-1}B_{F,t-1}\right)/e_t \\ & + \eta\left(\frac{R^*_{t-1}e_{t-1}}{e_t} - R_{t-1}\right) D_{s,t-1} + \tilde{\eta}\left(R_{t-1} - \frac{R^*_{t-1}e_{t-1}}{e_t}\right) D_{n,t-1} \\ & + NX_t + R_{t-1}\tilde{D}_{s,t-1} - \tilde{D}_{st}, \end{aligned} \tag{B37}$$

where $\tilde{D}_{st} \equiv D_{ht} - D_t - D_{gt}$ is the home country's holdings of home short-term debt issued by FX dealers in the international financial market. In the derivation, we substitute the expressions for DIV_t and N_{et}, and employ the intermediate goods producers' zero-profit condition $p_{mt}Y_{mt} = w_t L_t + Z_t K_t$, the equity market clearing condition and the long-term bond market clearing condition.

The first and second lines of (B37) represent the net demand for home final goods, which is zero due to the home final goods market clearing condition (B32). Then the home country budget constraint is

$$\begin{aligned}
&\tilde{D}_{st} - R_{t-1}\tilde{D}_{s,t-1} \\
= &\left(Q_t S^*_{Ht} - R_{kt} Q_{t-1} S^*_{H,t-1}\right) - \left(Q^*_t S_{Ft} - R^*_{kt} Q^*_{t-1} S_{F,t-1}\right)/e_t \\
&+ \left(q_t B^*_{Ht} - R_{bt} q_{t-1} B^*_{H,t-1}\right) - \left(q^*_t B_{Ft} - R^*_{bt} q^*_{t-1} B_{F,t-1}\right)/e_t \\
&+\eta\left(\frac{R^*_{t-1}e_{t-1}}{e_t} - R_{t-1}\right) D_{s,t-1} + \tilde{\eta}\left(R_{t-1} - \frac{R^*_{t-1}e_{t-1}}{e_t}\right) D_{n,t-1} + NX_t, \qquad \text{(B38)}
\end{aligned}$$

Combine (B38) with the home short-term debt market clearing condition $D_{st} = \tilde{D}_{st} + D_{nt}$, we obtain

$$\begin{aligned}
D_{st} = &\left(Q_t S^*_{Ht} - R_{kt} Q_{t-1} S^*_{H,t-1}\right) - \left(Q^*_t S_{Ft} - R^*_{kt} Q^*_{t-1} S_{F,t-1}\right)/e_t \\
&+ \left(q_t B^*_{Ht} - R_{bt} q_{t-1} B^*_{H,t-1}\right) - \left(q^*_t B_{Ft} - R^*_{bt} q^*_{t-1} B_{F,t-1}\right)/e_t \\
&+\eta\left(\frac{R^*_{t-1}e_{t-1}}{e_t} - R_{t-1}\right) D_{s,t-1} + \tilde{\eta}\left(R_{t-1} - \frac{R^*_{t-1}e_{t-1}}{e_t}\right) D_{n,t-1} + NX_t \\
&+R_{t-1}D_{s,t-1} + D_{nt} - R_{t-1}D_{n,t-1}, \qquad \text{(B39)}
\end{aligned}$$

Note that (B39) aligns with the currency market clearing condition $D_{st} = D_{dt}$. This is because (B39) achieves the market clearing of home short-term debt in the international financial market, with the right-hand side being the aggregate demand from home country and noise traders, and the left-hand side representing FX dealers' supply. Through FX dealers' zero-capital balance sheet, (B39) inherently implies the clearing of the currency market.

A paralell equation to (B37) for foreign country is

$$\begin{aligned}
&C^*_t + G^* + \left[1 + f\left(\frac{I^*_t}{I^*_{ss}}\right)\right] I^*_t + \left\{\frac{\kappa_1}{2}\left[\frac{e_t Q_t (S^*_{Ht} - \bar{S}^*_H)}{N^*_t}\right]^2 + \frac{\kappa_2}{2}\left[\frac{e_t q_t (B^*_{Ht} - \bar{B}^*_H)}{N^*_t}\right]^2\right\} N^*_t \\
&+\frac{1}{2}\kappa_{h1}\left(Q^*_t S^{h*}_{ft} - Q^*_{ss}\bar{S}^{h*}_f\right)^2 + \frac{1}{2}\kappa_{h2}\left(q^*_t B^{h*}_{ft} - q^*_{ss}\bar{B}^{h*}_f\right)^2 - Y^*_t \\
= &\left(Q^*_t S_{Ft} - R^*_{kt} Q^*_{t-1} S_{F,t-1}\right) - \left(Q_t S^*_{Ht} - R_{kt} Q_{t-1} S^*_{H,t-1}\right)\cdot e_t \\
&+ \left(q^*_t B_{Ft} - R^*_{bt} q^*_{t-1} B_{F,t-1}\right) - \left(q_t B^*_{Ht} - R_{bt} q_{t-1} B^*_{H,t-1}\right)\cdot e_t \\
&+\left(\frac{R^*_{t-1}e_{t-1}}{e_t} - R_{t-1}\right)\left[(1-\eta)D_{s,t-1} - (1-\tilde{\eta})D_{n,t-1}\right] e_t + NX^*_t + \tilde{D}_{st}e_t - R^*_{t-1}\tilde{D}_{s,t-1}e_{t-1} \\
= &-e_t \cdot \left(D_{dt} - D_{st}\right),
\end{aligned}$$

where NX^*_t is the net exports of the foreign country. In the first equality, we apply FX dealers' zero-capital balance sheet. In the second equality, we use $NX^*_t = -NX_t \cdot e_t$. The foreign final goods market clearing condition implies that the foreign country budget constraint is also consistent with $D_{dt} = D_{st}$. As stated in Itskhoki and Mukhin (2021), this is a version of *Walras Law* in our economy with FX dealers, making the foreign country budget constraint a redundant equation in the equilibrium system.

B.8 Definition of Equilibrium

In the model equilibrium, the agents solve their own maximization problems, and all markets clear. Therefore, we define the model equilibrium as follows.

Definition. Given the path of shocks $\{\varepsilon_{it}, \varepsilon^*_{it}, B_{gt}, B^*_{gt}, \varepsilon_{nt}\}$, a *competitive equilibrium* is a path of home household decisions $\{C_t, L_t, D_{ht}, S^h_{ht}, B^h_{ht}\}$, foreign household decisions $\{C^*_t, L^*_t, D^*_{ht}, S^{h*}_{ft}, B^{h*}_{ft}\}$, home producer decisions $\{K_t, L_{pt}, I_t, Y_t, Y_{Ht}, Y_{Ft}, Y_{Ht}(i), Y_{Ft}(i), Y_{mt}\}$, foreign producer decisions $\{K^*_t, L^*_{pt}, I^*_t, Y^*_t, Y^*_{Ht}, Y^*_{Ft}, Y^*_{Ht}(i), Y^*_{Ft}(i), Y^*_{mt}\}$, home bank decisions $\{s_{ht}, b_{ht}, s_{ft}, b_{ft}, n_t\}$, foreign bank decisions $\{s^*_{ht}, b^*_{ht}, s^*_{ft}, b^*_{ft}, n^*_t\}$, aggregate quantities $\{S_{Ht}, S^*_{Ht}, B_{Ht}, B^*_{Ht}, S_{Ft}, S^*_{Ft}, B_{Ft}, B^*_{Ft}, N_t, N^*_t\}$, FX dealer decisions $\{D_{st}\}$, noise trader decisions $\{D_{nt}\}$, prices $\{e_t, w_t, w^*_t, Z_t, Z^*_t, Q_t, Q^*_t, q_t, q^*_t, p_{Ht}, p^*_{Ht}, p_{Ft}, p^*_{Ft}\}$, asset returns $\{R_{kt}, R_{bt}, R_t, R^*_{kt}, R^*_{bt}, R^*_t\}$, inflation rates $\{\Pi_t, \Pi^*_t\}$, fiscal and monetary variables $\{G, B_t, D_{gt}, T_t, i_t, G^*, B^*_t, D^*_{gt}, T^*_t, i^*_t\}$, such that in each period: (1) households, producers, banks and FX dealers maximize their objective functions taking as given equilibrium prices, asset returns, inflation rates, and fiscal and monetary variables; (2) the government budget constraint and monetary policy rules hold; (3) all markets clear: intermediate goods markets, retail goods markets, final goods markets, capital markets, labor markets, short-term debt (deposits and short-term bonds) markets, currency market, firm equity markets, and long-term government bond markets.

B.9 Steady State

In this section, we provide the solutions for the steady state. Our goal is to express endogenous variables and model-specific parameters in terms of observable empirical moments and parameters calibrated outside of the model. In the steady state, we consider the symmetric case with $e_{ss} = 1$.

Households. The steady-state values of the stochastic discount factors $\{\Lambda_{ss}, \Lambda^*_{ss}\}$ and the marginal utility of consumption $\{\mu_{ss}, \mu^*_{ss}\}$ are given by

$$\Lambda_{ss} = \Lambda^*_{ss} = \beta \quad \text{and} \quad \mu_{ss} = \mu^*_{ss} = C_{ss}^{-\sigma_c}. \tag{B40}$$

The Euler equation and the first-order condition for labor supply imply that the steady-state risk-free rate and labor supply are given by

$$R_{ss} = R^*_{ss} = \frac{1}{\Lambda_{ss}} = \frac{1}{\bar{\beta}}, \qquad \frac{\chi L^{\eta}_{ss}}{\mu_{ss}} = \frac{\chi (L^*_{ss})^{\eta}}{\mu^*_{ss}} = w_{ss} = w^*_{ss}. \tag{B41}$$

Here we calibrate χ by matching the moment $L_{ss} = L^*_{ss} = 1/3$.

Finally, the first-order conditions for risky asset holdings imply

$$S^h_{h,ss} = S^{h*}_{f,ss} = \bar{S}^h_h + \frac{1}{\kappa_{h1} Q_{ss}} \Lambda_{ss} \left(R_{k,ss} - R_{ss}\right), \quad B^h_{h,ss} = B^{h*}_{f,ss} = \bar{B}^h_h + \frac{1}{\kappa_{h2} q_{ss}} \Lambda_{ss} \left(R_{b,ss} - R_{ss}\right).$$

Here we calibrate $\bar{S}^h_h$ and $\bar{B}^h_h$ by matching households' steady-state holding share of domestic equity and long-term government bonds.

Banks. First, the banks' steady-state holdings of risky assets are calibrated from the literature or data, with the calibration details provided in Appendix D.

From (2), the steady-state values of long-term bond prices are

$$q_{ss} = q^*_{ss} = \frac{1}{R_{b,ss} - \kappa}.$$

From banks' first-order conditions, the steady-state excess returns are given by

$$\tilde{\Lambda}_{ss} \left(R_{k,ss} - R_{ss}\right) = \frac{\lambda_{ss}\theta}{1 + \lambda_{ss}} \text{ and } \tilde{\Lambda}_{ss} \left(R_{b,ss} - R_{ss}\right) = \frac{\lambda_{ss}\theta\Delta}{1 + \lambda_{ss}}, \tag{B42}$$

$$\tilde{\Lambda}^*_{ss} \left(R^*_{k,ss} - R^*_{ss}\right) = \frac{\lambda^*_{ss}\theta}{1 + \lambda^*_{ss}} \text{ and } \tilde{\Lambda}^*_{ss} \left(R^*_{b,ss} - R^*_{ss}\right) = \frac{\lambda^*_{ss}\theta\Delta}{1 + \lambda^*_{ss}}.$$

Therefore, we can pin down the value of Δ by using the following equation:

$$\Delta = \frac{R_{b,ss} - R_{ss}}{R_{k,ss} - R_{ss}}.$$

It follows that the steady-state values of ϕ_t, ϕ^*_t, ψ_t and ψ^*_t are given by

$$\phi_{ss} = \phi^*_{ss} = \frac{\tilde{\Lambda}_{ss} R_{ss}}{\theta - \tilde{\Lambda}_{ss} \left(R_{k,ss} - R_{ss}\right)} = \frac{\tilde{\Lambda}_{ss} R_{ss}}{\theta - \frac{\lambda_{ss}\theta}{1+\lambda_{ss}}} = \frac{1 + \lambda_{ss}}{\theta} \tilde{\Lambda}_{ss} R_{ss},$$

$$\begin{aligned} \psi_{ss} = \psi^*_{ss} &= \frac{\left(\tilde{\Lambda}_{ss} \left(R^*_{k,ss} - R_{ss}\right) - \theta\right) Q^*_{ss} \bar{s}_f + \left(\tilde{\Lambda}_{ss} \left(R^*_{b,ss} - R_{ss}\right) - \theta\Delta\right) q^*_{ss} \bar{b}_f + \sigma \Lambda_{ss} v_{w,ss}}{\theta - \tilde{\Lambda}_{ss} \left(R_{k,ss} - R_{ss}\right)} \\ &= -Q^*_{ss} \bar{s}_f - \Delta q^*_{ss} \bar{b}_f + \frac{(1 + \lambda_{ss})}{\theta} \sigma \Lambda_{ss} v_{w,ss}, \end{aligned}$$

where the auxiliary intercept term $v_{w,ss}$ is

$$\begin{aligned} v_{w,ss} &= \tilde{\Lambda}_{ss}\left(R_{k,ss}-R_{ss}\right)\psi_{ss}+\tilde{\Lambda}_{ss}\left(R^*_{k,ss}-R_{ss}\right)Q^*_{ss}\bar{s}_f+\tilde{\Lambda}_{ss}\left(R^*_{b,ss}-R_{ss}\right)q^*_{ss}\bar{b}_f+\sigma\Lambda_{ss}v_{w,ss} \\ &= \left(1+\lambda_{ss}\right)\sigma\beta v_{w,ss}. \end{aligned}$$

Our calibration implies that $(1+\lambda_{ss})\,\sigma\beta \neq 1$, then we get $v_{w,ss}=0$. Then the expressions of ψ_{ss} and ψ^*_{ss} simplify to

$$\psi_{ss}=\psi^*_{ss}=-Q^*_{ss}\bar{s}_f-\Delta q^*_{ss}\bar{b}_f.$$

Therefore, we can pin down the value of ϕ_{ss} from the data by plugging the expression of ψ_{ss} into the binding incentive constraint, that is,

$$\phi_{ss}=\frac{Q_{ss}s_{h,ss}+\Delta q_{ss}b_{h,ss}}{n_{ss}}-\frac{\psi_{ss}}{n_{ss}}=\frac{Q_{ss}S_{H,ss}+\Delta q_{ss}B_{H,ss}+Q^*_{ss}\bar{S}_F+\Delta q^*_{ss}\bar{B}_F}{N_{ss}}.$$

Next, we derive the steady-state values of value function coefficients ϕ_{wt}, ϕ^*_{wt}, ϕ_{vt}, ϕ^*_{vt}, Lagrange multipliers λ_t, λ^*_t, and the parameter θ of the incentive constraint, in terms of ϕ_{ss}, $R_{k,ss}$ and R_{ss}. First, the steady-state values of slopes ϕ_{wt} and ϕ^*_{wt} are given by

$$\phi_{w,ss}=\phi^*_{w,ss}=\tilde{\Lambda}_{ss}R_{ss}+\phi_{ss}\tilde{\Lambda}_{ss}\left(R_{k,ss}-R_{ss}\right)=\left(1+\lambda_{ss}\right)\tilde{\Lambda}_{ss}R_{ss}. \tag{B43}$$

By comparing the expressions of ϕ_{ss} and $\phi_{w,ss}$, we can express the value of $\phi_{w,ss}$ as

$$\phi_{w,ss}=\theta\phi_{ss}. \tag{B44}$$

Note that in the steady state, the banks do not pay holding cost. Therefore, the value function $V_t(n_t)$ must be equal to $W_t(n_t)$ in the steady state, which implies

$$\phi_{v,ss}=\phi^*_{v,ss}=\phi_{w,ss}.$$

We use (B42), (B43), and (B44) to derive the values of λ_{ss} and λ^*_{ss}; that is,

$$\frac{\lambda_{ss}\theta}{1+\lambda_{ss}}=\tilde{\Lambda}_{ss}\left(R_{k,ss}-R_{ss}\right)=\tilde{\Lambda}_{ss}R_{ss}\frac{R_{k,ss}-R_{ss}}{R_{ss}}=\frac{\theta\phi_{ss}}{1+\lambda_{ss}}\frac{R_{k,ss}-R_{ss}}{R_{ss}},$$

which implies $\lambda_{ss}=\phi_{ss}\frac{R_{k,ss}-R_{ss}}{R_{ss}}$. Symmetrically we have $\lambda^*_{ss}=\lambda_{ss}$.

From (B43) and (B44), the parameter θ in the incentive constraint is given by

$$\theta\phi_{ss}=\left(1+\lambda_{ss}\right)\tilde{\Lambda}_{ss}R_{ss}=\left(1+\lambda_{ss}\right)\beta\left(1-\sigma+\sigma\theta\phi_{ss}\right)R_{ss},$$

which further implies

$$\theta\phi_{ss} = \frac{(1+\lambda_{ss})\,\beta\,(1-\sigma)\,R_{ss}}{1-(1+\lambda_{ss})\,\beta\sigma R_{ss}}.$$

Therefore, the parameter θ can be expressed in the observable moments and parameters calibrated outside of the model as follows:

$$\theta = \frac{1}{\phi_{ss}}\frac{(1+\lambda_{ss})\,\beta\,(1-\sigma)\,R_{ss}}{1-(1+\lambda_{ss})\,\beta\sigma R_{ss}} = \frac{1}{\phi_{ss}}\frac{[R_{ss}+\phi_{ss}\,(R_{k,ss}-R_{ss})]\,\beta\,(1-\sigma)}{1-[R_{ss}+\phi_{ss}\,(R_{k,ss}-R_{ss})]\,\beta\sigma}.$$

Given the values of θ and ϕ_{ss}, we can obtain the value of $\phi_{w,ss}$. Moreover, the law of motion for aggregate bank net worth implies

$$\begin{aligned} X = X^* &= N_{ss} - \sigma\left[(R_{k,ss}-R_{ss})\left(Q_{ss}S_{H,ss} + \Delta q_{ss}B_{H,ss} + Q^*_{ss}\bar{S}_F + \Delta q^*_{ss}\bar{B}_F\right) + R_{ss}N_{ss}\right] \\ &= N_{ss}\left\{1-\sigma\left[(R_{k,ss}-R_{ss})\,\phi_{ss} + R_{ss}\right]\right\}. \end{aligned}$$

Producers. For capital producers, the steady-state adjustment cost is zero. According to the first-order condition (B23) for investment, the steady-state capital goods prices are

$$Q_{ss} = Q^*_{ss} = 1.$$

Then the definition of equity return implies that the steady-state values of net payouts Z_t and Z^*_t are given by

$$Z_{ss} = Z^*_{ss} = R_{k,ss} - 1 + \delta.$$

Since the steady-state aggregate productivity A_{ss} and A^*_{ss} are normalized to 1, the real prices of intermediate goods are given by

$$p_{m,ss} = p^*_{m,ss} = \left(\frac{Z_{ss}}{\alpha}\right)^{\alpha}\left(\frac{w_{ss}}{1-\alpha}\right)^{1-\alpha}.$$

From the capital accumulation equation, the capital stock and investment in the steady state are given by

$$K_{ss} = K^*_{ss} = \frac{\alpha w_{ss} L_{ss}}{(1-\alpha)Z_{ss}}, \quad \text{and} \quad I_{ss} = I^*_{ss} = \delta K_{ss}.$$

The aggregate output of intermediate goods producers is $Y_{m,ss} = Y^*_{m,ss} = K^{1-\alpha}_{ss}L^{\alpha}_{ss}$.

For the prices of retail goods, we consider the steady state with $\Pi_{ss} = \Pi^*_{ss} = 1$. Hence the real reset price of home-produced home goods is given by

$$x_{1,H,ss} = \frac{p_{m,ss}\,p_{H,ss}^{\theta_y-\eta_y}Y_{ss}}{1-\phi_p\bar{\beta}},\ x_{2,H,ss} = \frac{p_{H,ss}^{\theta_y-\eta_y}Y_{ss}}{1-\phi_p\bar{\beta}},\ \hat{p}_{H,ss} = \frac{\theta_y}{\theta_y-1}p_{m,ss}.$$

Symmetrically, the steady-state values of the other reset prices are given by

$$\hat{p}^*_{H,ss} = \hat{p}^*_{F,ss} = \hat{p}_{F,ss} = \frac{\theta_y}{\theta_y - 1} p_{m,ss}.$$

Aggregation. According to the definition, the aggregate price indices for home and foreign goods baskets are given by

$$p_{H,ss} = \hat{p}_{H,ss},\ p^*_{H,ss} = \hat{p}^*_{H,ss},\ p_{F,ss} = \hat{p}_{F,ss},\ p^*_{F,ss} = \hat{p}^*_{F,ss}.$$

Since the real exchange rate is one, the price indices of aggregate demand in two countries imply $\hat{p}_{H,ss} = \hat{p}^*_{H,ss} = \hat{p}_{F,ss} = \hat{p}^*_{F,ss} = 1$. Then we obtain $p_{m,ss} = \frac{\theta_y - 1}{\theta_y}$. Therefore, the steady-state values of real wages are given by

$$w_{ss} = w^*_{ss} = (1-\alpha)\left(\frac{\alpha}{Z_{ss}}\right)^{\frac{\alpha}{1-\alpha}} p_{m,ss}^{\frac{1}{1-\alpha}}. \tag{B45}$$

Moreover, the final goods market clearing condition implies

$$C_{ss} = C^*_{ss} = Y_{ss} - G - I_{ss} - \frac{1}{2\kappa_{h1}}\left[\Lambda_{ss}\left(R_{k,ss} - R_{ss}\right)\right]^2 - \frac{1}{2\kappa_{h2}}\left[\Lambda_{ss}\left(R_{b,ss} - R_{ss}\right)\right]^2.$$

FX Dealers. In the steady state, the net flows of risky assets are given by

$$\begin{aligned}
&\text{Net equity inflows to the US} = Q_{ss} S^*_{H,ss}\left(1 - R_{k,ss}\right) - Q^*_{ss} S_{F,ss}\left(1 - R^*_{k,ss}\right) = 0,\\
&\text{Net bond inflows to the US} = q_{ss} B^*_{H,ss}\left(1 - R_{b,ss}\right) - q^*_{ss} B_{F,ss}\left(1 - R^*_{b,ss}\right) = 0,
\end{aligned}$$

where we apply the symmetry $Q_{ss} = Q^*_{ss}$, $S^*_{H,ss} = S_{F,ss}$, $R_{k,ss} = R^*_{k,ss}$, $q_{ss} = q^*_{ss}$, $B^*_{H,ss} = B_{F,ss}$ and $R_{b,ss} = R^*_{b,ss}$.

The steady-state value of US net exports is

$$\text{Net exports of the US} = \gamma_y\left[\left(p^*_{H,ss}\right)^{1-\eta_y} Y^*_{ss} - \left(p_{F,ss}\right)^{1-\eta_y} Y_{ss}\right] = 0,$$

where the last equality is derived from the symmetry $p^*_{H,ss} = p_{F,ss}$ and $Y_{ss} = Y^*_{ss}$.

Moreover, the symmetry $R_{ss} = R^*_{ss}$ implies that FX dealers' aggregate holdings of US short-term debt are

$$D_{s,ss} = \frac{1}{\Gamma}\left[\left(\eta\Lambda_{ss} + (1-\eta)\Lambda^*_{ss}\right)\left(R^*_{ss} - R_{ss}\right)\right] = 0.$$

Therefore, the currency market clearing condition implies that the steady-state net dollar demand is $D_{d,ss} = D_{s,ss} = 0$.

Appendix C Alternative Models

C.1 Habit Formation and Endogenous Discount Factor

This section introduces habit formation and endogenous discount factor into households' problem. The representative domestic household's utility function is

$$\mathbb{E}_t \sum_{i=0}^{\infty} \beta_{t+i} \left\{ \frac{\left(C_{t+i} - hC_{t+i-1}\right)^{1-\sigma_c} - 1}{1-\sigma_c} - \frac{\chi}{1+\eta} L_{t+i}^{1+\eta} \right\}.$$

The parameter h represents the degree of habit persistence, and β_t is an endogenous discount factor given by

$$\beta_{t+1} = \beta_t \cdot \bar{\beta} \left[\frac{C_t - hC_{t-1}}{(1-h)C_{ss}} \right]^{-\epsilon_c}, \quad \beta_0 = 1,$$

where $\epsilon_c \in (0, \sigma_c)$, $\bar{\beta} \in (0,1)$, and C_{ss} is the household's steady-state consumption.

Denote $\tilde{\beta}_t \equiv \bar{\beta} \left[\frac{C_t - hC_{t-1}}{(1-h)C_{ss}} \right]^{-\epsilon_c}$ as the per period discount factor and $\tilde{\beta}_{c,t} \equiv -\epsilon_c \bar{\beta} \frac{(C_t - hC_{t-1})^{-\epsilon_c - 1}}{[(1-h)C_{ss}]^{-\epsilon_c}}$ as the derivative of $\tilde{\beta}_t$ with respect to C_t. Combine with the budget constraint (B1), the first-order conditions for the household's utility maximization are given by

$$\begin{aligned}
\chi L_t^{\eta} &= \mu_t w_t, \\
1 &= \mathbb{E}_t \left[\Lambda_{t,t+1} R_t \right], \\
Q_t S_{ht}^h &= Q_{ss} \bar{S}_h^h + \frac{1}{\kappa_{h1}} \mathbb{E}_t \left[\Lambda_{t,t+1} \left(R_{k,t+1} - R_t \right) \right], \\
q_t B_{ht}^h &= q_{ss} \bar{B}_h^h + \frac{1}{\kappa_{h2}} \mathbb{E}_t \left[\Lambda_{t,t+1} \left(R_{b,t+1} - R_t \right) \right],
\end{aligned}$$

with the associated variables defined as

$$\begin{aligned}
\Lambda_{t,t+1} &= \frac{\tilde{\beta}_t \mu_{t+1}}{\mu_t}, \\
\mu_t &= (C_t - hC_{t-1})^{-\sigma_c} - h\tilde{\beta}_t \mathbb{E}_t (C_{t+1} - hC_t)^{-\sigma_c} - \tilde{\beta}_{ct} \psi_{ct} + h\tilde{\beta}_t \mathbb{E}_t \left[\tilde{\beta}_{c,t+1} \psi_{c,t+1} \right], \\
\psi_{ct} &= -\mathbb{E}_t \left[\frac{\left(C_{t+1} - hC_t\right)^{1-\sigma_c} - 1}{1-\sigma_c} - \frac{\chi}{1+\eta} L_{t+1}^{1+\eta} \right] + \mathbb{E}_t \left[\psi_{c,t+1} \tilde{\beta}_{t+1} \right],
\end{aligned}$$

where $\Lambda_{t,t+1}$ is the stochastic discount factor between period t and $t+1$ and μ_t is the marginal utility of consumption C_t.

Symmetrically, foreign households' first-order conditions for utility maximization are

$$
\begin{aligned}
\chi\left(L_t^*\right)^\eta &= \mu_t^* w_t^*, \\
1 &= \mathbb{E}_t\left[\Lambda_{t,t+1}^* R_t^*\right], \\
Q_t^* S_{ht}^{h*} &= Q_{ss}^* \bar{S}_h^{h*} + \frac{1}{\kappa_{h1}} \mathbb{E}_t\left[\Lambda_{t,t+1}\left(R_{k,t+1}^* - R_t^*\right)\right], \\
q_t^* B_{ht}^{h*} &= q_{ss}^* \bar{B}_h^{h*} + \frac{1}{\kappa_{h2}} \mathbb{E}_t\left[\Lambda_{t,t+1}\left(R_{b,t+1}^* - R_t^*\right)\right],
\end{aligned}
$$

with the associated variables defined as

$$
\begin{aligned}
\Lambda_{t,t+1}^* &= \frac{\tilde{\beta}_t^* \mu_{t+1}^*}{\mu_t^*}, \\
\mu_t^* &= (C_t^* - hC_{t-1}^*)^{-\sigma_c} - h\tilde{\beta}_t^* \mathbb{E}_t (C_{t+1}^* - hC_t^*)^{-\sigma_c} - \tilde{\beta}_{ct}^* \psi_{ct}^* + h\tilde{\beta}_t^* \mathbb{E}_t\left[\tilde{\beta}_{c,t+1}^* \psi_{c,t+1}^*\right], \\
\psi_{ct}^* &= -\mathbb{E}_t\left[\frac{\left(C_{t+1}^* - hC_t^*\right)^{1-\sigma_c} - 1}{1-\sigma_c} - \frac{\chi}{1+\eta}\left(L_{t+1}^*\right)^{1+\eta}\right] + \mathbb{E}_t\left[\psi_{c,t+1}^* \tilde{\beta}_{t+1}^*\right],
\end{aligned}
$$

where $\tilde{\beta}_t^* \equiv \bar{\beta}\left[\frac{C_t^* - hC_{t-1}^*}{(1-h)C_{ss}^*}\right]^{-\epsilon_c}$ and $\tilde{\beta}_{c,t}^* \equiv -\epsilon_c \bar{\beta} \frac{\left(C_t^* - hC_{t-1}^*\right)^{-\epsilon_c - 1}}{\left[(1-h)C_{ss}^*\right]^{-\epsilon_c}}$.

C.2 Sticky Wage

This section introduces sticky nominal wages into labor market. In each country, a unit continuum of labor unions, indexed by $h \in [0,1]$, purchase labor competitively from local households at rate MRS_t (MRS_t^*) and repackage it into differentiated labor variety L_{ht}. These labor varieties are sold to a local representative labor packer, who combines them into final labor for production L_{dt} via a CES aggregator with elasticity of substitution θ_w:

$$
L_{dt} = \left(\int_0^1 L_{ht}^{\frac{\theta_w - 1}{\theta_w}} dh\right)^{\frac{\theta_w}{\theta_w - 1}}.
$$

Denote W_{ht} as the nominal wage of labor variety h. Then the labor demand is

$$
L_{ht} = \left(\frac{W_{ht}}{W_t}\right)^{-\theta_w} L_{dt}, \quad \text{where} \quad W_t = \left(\int_0^1 W_{ht}^{1-\theta_w} dh\right)^{\frac{1}{1-\theta_w}}. \tag{C1}
$$

For households, mrs_t (mrs_t^*) is the wage rate of supplying labor to local labor unions. Thus the first-order conditions for their labor supply are

$$
\chi L_t^\eta = \mu_t mrs_t \quad \text{and} \quad \chi\left(L_t^*\right)^\eta = \mu_t^* mrs_t^*. \tag{C2}
$$

Wage Setting. Labor unions set wages as in Calvo (1983). The probability of resetting wage each period is $1-\phi_w$. A home labor union maximizes discounted sum of real profits:

$$\max_{W_{h,t}} \mathbb{E}_t \sum_{s=0}^{\infty} \phi_w^s \Lambda_{t,t+s} \left[W_{h,t}^{1-\theta_w} P_{t+s}^{\theta_w-1} w_{t+s}^{\theta_w} L_{d,t+s} - mrs_{t+s} W_{i,t}^{-\theta_w} P_{t+s}^{\theta_w} w_{t+s}^{\theta_w} L_{d,t+s} \right].$$

The first-order condition for the labor union's profit maximization problem is

$$\mathbb{E}_t \sum_{s=0}^{\infty} \phi_w^s \Lambda_{t,t+s} \left[P_{t+s}^{\theta_w-1} w_{t+s}^{\theta_w} L_{d,t+s} W_{h,t} - \frac{\theta_w}{\theta_w - 1} mrs_{t+s} P_{t+s}^{\theta_w} w_{t+s}^{\theta_w} L_{d,t+s} \right] = 0.$$

Due to the identical marginal cost mrs_t, the optimal reset wages are identical across labor unions within a country. Hence, we drop the index h without causing any confusion, and the optimal reset wage $\hat{W}_t$ is given by

$$\begin{aligned}
\hat{W}_t &= \frac{\theta_w}{\theta_w - 1} \frac{F_{1,t}}{F_{2,t}}, \\
F_{1,t} &= mrs_t P_t^{\theta_w} w_t^{\theta_w} L_{dt} + \phi_w \Lambda_{t,t+1} F_{1,t+1}, \\
F_{2,t} &= P_t^{\theta_w-1} w_t^{\theta_w} L_{dt} + \phi_w \Lambda_{t,t+1} F_{2,t+1}.
\end{aligned}$$

Denote the optimal reset wage in real terms as $\hat{w}_t = \hat{W}_t / P_t$, and its solution is given by

$$\begin{aligned}
\hat{w}_t &= \frac{\theta_w}{\theta_w - 1} \frac{f_{1,t}}{f_{2,t}}, \\
f_{1,t} &= mrs_t w_t^{\theta_w} L_{dt} + \phi_w \Lambda_{t,t+1} \Pi_{t+1}^{\theta_w} f_{1,t+1}, \\
f_{2,t} &= w_t^{\theta_w} L_{dt} + \phi_w \Lambda_{t,t+1} \Pi_{t+1}^{\theta_w-1} f_{2,t+1},
\end{aligned}$$

where $w_t = W_t / P_t$ is the domestic aggregate real wage, $f_{1,t} = F_{1,t} / P_t^{\theta_w}$, and $f_{2,t} = F_{2,t} / P_t^{\theta_w - 1}$.

Symmetrically, the optimal reset wages in real terms for foreign labor unions are

$$\begin{aligned}
\hat{w}_t^* &= \frac{\theta_w}{\theta_w - 1} \frac{f_{1,t}^*}{f_{2,t}^*}, \\
f_{1,t}^* &= mrs_t^* \left(w_t^*\right)^{\theta_w} L_{dt}^* + \phi_w \Lambda_{t,t+1}^* \left(\Pi_{t+1}^*\right)^{\theta_w} f_{1,t+1}^*, \\
f_{2,t}^* &= \left(w_t^*\right)^{\theta_w} L_{dt}^* + \phi_w \Lambda_{t,t+1}^* \left(\Pi_{t+1}^*\right)^{\theta_w-1} f_{2,t+1}^*.
\end{aligned}$$

Labor Aggregation. Integrating (C1) across h and using $\int_0^1 L_{ht} dh = L_t$ yields

$$L_t = L_{dt} \xi_t, \tag{C3}$$

where ξ_t is the wage dispersion in home country:

$$\xi_t = \int_0^1 \left(\frac{w_{ht}}{w_t}\right)^{-\theta_w} dh.$$

Since the wage resetting opportunity is i.i.d. across labor unions, we can derive the law of motion for the wage dispersion measure ξ_t as follows:

$$\begin{aligned}\xi_t &= (1-\phi_w)\left(\frac{\hat{w}_t}{w_t}\right)^{-\theta_w} + \int_{1-\phi_w}^1 \left(\frac{W_{h,t-1}}{W_t}\right)^{-\theta_w} dh \\ &= (1-\phi_w)\left(\frac{\hat{w}_t}{w_t}\right)^{-\theta_w} + \phi_w \Pi_t^{\theta_w}\left(\frac{w_t}{w_{t-1}}\right)^{\theta_w}\xi_{t-1}. \end{aligned} \tag{C4}$$

Moreover, the domestic aggregate nominal wage evolves according to

$$W_t^{1-\theta_w} = (1-\phi_w)\left(\hat{W}_t\right)^{1-\theta_w} + \phi_w W_{t-1}^{1-\theta_w}.$$

Dividing both sides by $P_t^{1-\theta_w}$ gives the law of motion for the domestic aggregate real wage:

$$w_t^{1-\theta_w} = (1-\phi_w)\left(\hat{w}_t\right)^{1-\theta_w} + \phi_w \Pi_t^{\theta_w-1} w_{t-1}^{1-\theta_w}. \tag{C5}$$

Symmetrically, the foreign aggregate labor supply is given by

$$L_t^* = L_{dt}^* \xi_t^*,$$

where the wage dispersion measure ξ_t^* follows

$$\xi_t^* = (1-\phi_w)\left(\frac{\hat{w}_t^*}{w_t^*}\right)^{-\theta_w} + \phi_w \left(\Pi_t^*\right)^{\theta_w}\left(\frac{w_t^*}{w_{t-1}^*}\right)^{\theta_w}\xi_{t-1}^*.$$

Moreover, the aggregate real wage evolves according to

$$\left(w_t^*\right)^{1-\theta_w} = (1-\phi_w)\left(\hat{w}_t^*\right)^{1-\theta_w} + \phi_w \left(\Pi_t^*\right)^{\theta_w-1}\left(w_{t-1}^*\right)^{1-\theta_w}.$$

Steady State. Given the steady-state inflation $\Pi_{ss} = \Pi_{ss}^* = 1$, the steady-state real reset wage of differentiated labor variety is given by

$$f_{1,ss} = f_{1,ss}^* = \frac{mrs_{ss} w_{ss}^{\theta_w} L_{d,ss}}{1-\phi_w\beta}, \quad f_{2,ss} = f_{2,ss}^* = \frac{w_{ss}^{\theta_w} L_{d,ss}}{1-\phi_w\beta}, \quad \hat{w}_{ss} = \hat{w}_{ss}^* = \frac{\theta_w}{\theta_w - 1} mrs_{ss}.$$

Combining the above equations with (C3), (C4) and (C5), we obtain

$$\xi_{ss} = \xi_{ss}^* = 1, \quad \hat{w}_{ss} = \hat{w}_{ss}^* = w_{ss}, \quad mrs_{ss} = mrs_{ss}^* = \frac{\theta_w - 1}{\theta_w} w_{ss}, \quad L_{d,ss} = L_{d,ss}^* = L_{ss},$$

where the steady-state aggregate real wages w_{ss} and w^*_{ss} are given by (B45), and the steady-state aggregate labor supply is $L_{ss} = L^*_{ss} = 1/3$. Additionally, from households' labor supply (C2), we calibrate χ using

$$\chi = \frac{\theta_w - 1}{\theta_w} \cdot \frac{\mu_{ss} w_{ss}}{L^\eta_{ss}}, \tag{C6}$$

with μ_{ss} given by (B40).

C.3 An Alternative Model without Final Goods Producers

In this section, we develop an alternative model without final goods producers as in Itskhoki and Mukhin (2021). We assume that the intermediate goods producers and retail firms in the baseline model are integrated into a continuum of goods producers, who produce a variety of differentiated goods. These goods are consumed by domestic and foreign households, and are used as inputs for capital producers, government expenditure, and the holding cost of risky assets, using the same aggregator as household consumption. More details on the setup of households and goods producers are as follows.

Households. The domestic households allocate their within-period consumption expenditure $P_t C_t$ between home and foreign varieties of goods $C_{jt}(i)$, for $j \in \{H, F\}$ and $i \in [0, 1]$ via a two-layer CES aggregator:

$$C_t = \left[(1-\gamma_c)^{\frac{1}{\eta_c}} C_{Ht}^{\frac{\eta_c - 1}{\eta_c}} + \gamma_c^{\frac{1}{\eta_c}} C_{Ft}^{\frac{\eta_c - 1}{\eta_c}} \right]^{\frac{\eta_c}{\eta_c - 1}}, \tag{C7}$$

and

$$C_{jt} = \left[\int_0^1 C_{jt}(i)^{\frac{\theta_c - 1}{\theta_c}} di \right]^{\frac{\theta_c}{\theta_c - 1}} \quad \text{for } j \in \{H, F\}, \tag{C8}$$

where C_{Ht} and C_{Ft} are baskets of home and foreign produced goods, $\eta_c > 1$ measures the elasticity of substitution between home and foreign goods, $\gamma_c \in \left[0, \frac{1}{2}\right)$ measures the home bias, $\theta_c > 1$ measures the elasticity of substitution between goods within baskets.

The households minimize expenditure $P_t C_t = \int_0^1 \left[P_{Ht}(i) C_{Ht}(i) + P_{Ft}(i) C_{Ft}(i) \right] di$ subject to (C7) and (C8), where $P_{Ht}(i)$ and $P_{Ft}(i)$ are the nominal home-currency prices of home and foreign variety i in home market. This implies the following demand functions:

$$C_{Ht}(i) = (1-\gamma_c) \left(\frac{P_{Ht}}{P_t} \right)^{-\eta_c} \left(\frac{P_{Ht}(i)}{P_{Ht}} \right)^{-\theta_c} C_t \text{ and } C_{Ft}(i) = \gamma_c \left(\frac{P_{Ft}}{P_t} \right)^{-\eta_c} \left(\frac{P_{Ft}(i)}{P_{Ft}} \right)^{-\theta_c} C_t,$$

where P_{Ht} and P_{Ft} are the aggregate price indices of goods baskets:

$$P_{Ht} = \left[\int_0^1 P_{Ht}(i)^{1-\theta_c} di \right]^{\frac{1}{1-\theta_c}} \quad \text{and} \quad P_{Ft} = \left[\int_0^1 P_{Ft}(i)^{1-\theta_c} di \right]^{\frac{1}{1-\theta_c}}.$$

The consumption demand of foreign households is symmetric:

$$C^*_{Ht}(i) = \gamma_c \left(\frac{P^*_{Ht}}{P^*_t} \right)^{-\eta_c} \left(\frac{P^*_{Ht}(i)}{P^*_{Ht}} \right)^{-\theta_c} C^*_t \text{ and } C^*_{Ft}(i) = (1-\gamma_c) \left(\frac{P^*_{Ft}}{P^*_t} \right)^{-\eta_c} \left(\frac{P^*_{Ft}(i)}{P^*_{Ft}} \right)^{-\theta_c} C^*_t,$$

where $P^*_{Ht}(i)$ and $P^*_{Ft}(i)$ are the nominal foreign-currency prices of home and foreign variety i in foreign market, and P^*_{Ht} and P^*_{Ft} are the aggregate price indices of baskets:

$$P^*_{Ht} = \left[\int_0^1 P^*_{Ht}(i)^{1-\theta_c} di \right]^{\frac{1}{1-\theta_c}} \quad \text{and} \quad P^*_{Ft} = \left[\int_0^1 P^*_{Ft}(i)^{1-\theta_c} di \right]^{\frac{1}{1-\theta_c}}.$$

Goods Producers. The goods producers in each country produce a variety of differentiated good $i \in [0, 1]$ and sell it in local and foreign markets. The production function of domestic goods producers is

$$Y_t(i) = A_t K^\alpha_t(i) L^{1-\alpha}_{pt}(i),$$

where A_t is total factor productivity, $K_t(i)$ is capital input, and $L_{pt}(i)$ is labor input. Given the wage rate w_t and equity payout Z_t, the producers' marginal production cost is

$$MC_t = \min_{K_t, L_t} \left\{ Z_t K_t + w_t L_{pt}; \text{s.t. } A_t K^{1-\alpha}_t L^\alpha_{pt} = 1. \right\} = \frac{1}{A_t} \left(\frac{Z_t}{\alpha} \right)^\alpha \left(\frac{w_t}{1-\alpha} \right)^{1-\alpha}.$$

The corresponding labor demand and capital demand are given by

$$L_{pt}(i) = \frac{(1-\alpha) MC_t Y_t(i)}{w_t}, \quad K_t(i) = \frac{\alpha MC_t Y_t(i)}{Z_t}.$$

The setup for foreign goods producers is symmetric with the following solution:

$$MC^*_t = \frac{1}{A^*_t} \left(\frac{Z^*_t}{\alpha} \right)^\alpha \left(\frac{w^*_t}{1-\alpha} \right)^{1-\alpha}, \quad L^*_{pt}(i) = \frac{(1-\alpha) MC^*_t Y^*_t(i)}{w^*_t}, \quad K^*_t(i) = \frac{\alpha MC^*_t Y^*_t(i)}{Z^*_t}.$$

The producers set goods prices subject to nominal rigidities as in Calvo (1983), which is the same as retail goods pricing problem in the baseline model, except that the aggregate demand Y_t (Y^*_t) is relabeled as $\mathcal{Y}_t$ ($\mathcal{Y}^*_t$), the intermediate goods price p_{mt} (p^*_{mt}) is relabeled as MC_t (MC^*_t), the intermediate goods output Y_{mt} (Y^*_{mt}) is relabeled as Y_t (Y^*_t), and the parameters $\{\gamma_y, \eta_y, \theta_y\}$ are relabeled as $\{\gamma_c, \eta_c, \theta_c\}$, respectively. Thus we omit the derivations of optimal reset prices in this section.

Appendix D Additional Results of Quantitative Analysis

This section elaborates on the procedures for model simulation, calibration, and estimation, and provides additional quantitative results.

Simulation Method. We solve the model around the steady state with intermediaries' binding financial constraints. The UIP-related models are solved with $\Gamma = 10^{-5}$. Additionally, the UIP-1 models are solved with $\kappa_1 = \kappa_2 = 1.4 \times 10^{-3}$, while the UIP-2 models use the same values of (κ_1, κ_2) as the baseline models. The rest of the parameters are the same for the UIP-1, UIP-2, and baseline models. The financial autarky models are solved based on $D_{st} = 0$, corresponding to $\Gamma \to \infty$. Models with a constant Γ are solved by linear approximation around the non-stochastic steady state via Dynare, while models with time-varying Γ_t are solved by quadratic approximation, as the first-order approximation of FX dealers' dollar liquidity supply D_{st} with respect to Γ_t around the steady state is zero. For the quantitative analysis of QE shocks with ZLB constraints, we solve a piecewise linear version of the model using OccBin from Guerrieri and Iacoviello (2015).

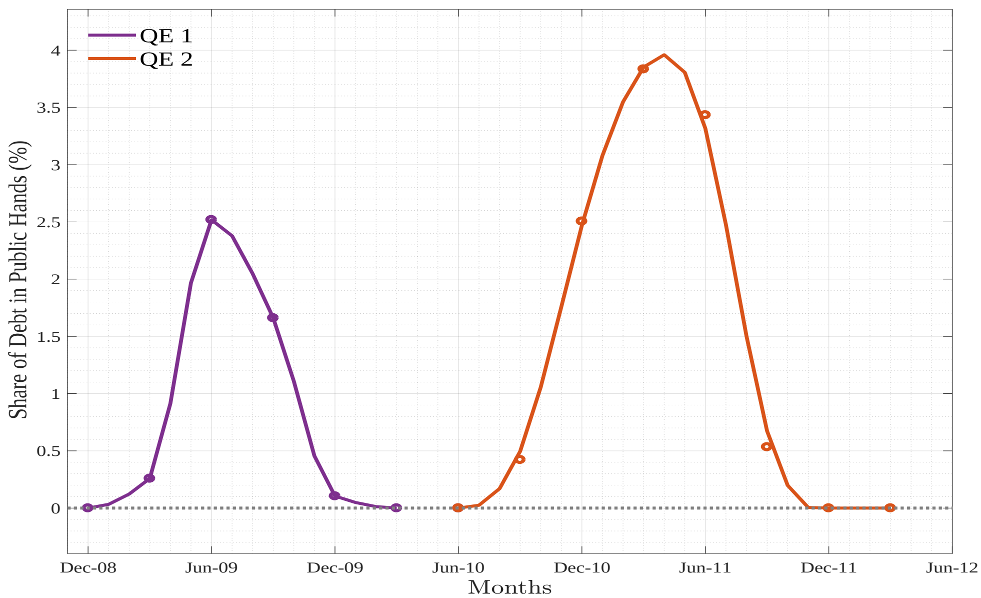
The analysis of conventional monetary policy shocks simulates the models with a one-unit unexpected shock to the domestic nominal interest rate in the first period, which means $\varepsilon_{i1} = 1$ and $\varepsilon_{it} = 0$ for $t \geq 2$ in (19). In the analysis of QE shocks, we first introduce unexpected negative nominal interest rate shocks in the domestic country with $\varepsilon_{it} = -5$ for the first four periods, driving the economy to the ZLB thereafter. Starting from the fifth period, we simulate the models with a sequence of unexpected shocks B_{gt} that matches the Fed's holding proportion of US long-term government bonds in "QE2", as shown in Figure D1.

Calibration. The model is calibrated at a monthly frequency with the calibrated parameters reported in Table D1. Parameters related to households, producers, and monetary and fiscal policies are drawn from the standard literature. We set the households' monthly discount rate β to 0.998, the relative risk aversion σ_c to 2, and the inverse of the Frisch elasticity η to 1. The importance of labor in utility χ is calibrated to 9.449 to match a steady-state labor supply $L_{ss} = 1/3$ according to (B41). In the model with sticky nominal wages, we calibrate χ to 8.590 based on (C6). For the production sector, we set the capital share in production function to 0.33 and the monthly capital depreciation rate to 0.008, following Gertler and Karadi (2011, 2013). The elasticity of substitution θ_y within a retail goods basket is set to 11, targeting a 10% markup in the steady state. We choose the elasticity of substitution η_y between home and foreign goods baskets to be 3.8, as in Bajzik et al. (2020). Moreover, the

Table D1: Calibrated parameter values

Parameter	Value	Description	Target or source
A. Households			
β	0.998	Discount rate	Sims and Wu (2021)
χ	9.449	Importance of leisure	$L_{ss} = 1/3$
	[8.590]	[Under sticky nominal wages]	$L_{ss} = 1/3$
η	1.000	Inverse of Frisch elasticity	Itskhoki and Mukhin (2021)
σ_c	2.000	Relative risk aversion	Itskhoki and Mukhin (2021)
$S^h_{h,ss}/(S^h_{h,ss} + S_{H,ss})$	0.370	HH equity holding share	Federal Reserve's financial accounts
$B^h_{h,ss}/(B^h_{h,ss} + B_{H,ss})$	0.200	HH bond holding share	Federal Reserve's financial accounts
B. Banks			
θ	0.944	Fraction of divertible equity	Targeted equity excess returns
	[0.919]	[Under HH holding risky assets]	Targeted equity excess returns
Δ	0.270	Scale factor of divertible bond	Targeted bond excess returns
σ	0.980	Survival probability of banks	Gertler and Kiyotaki (2015)
X	0.045	Transfer to the entering bankers	Steady-state leverage: 4
	[0.037]	[Under HH holding risky assets]	Steady-state leverage: 4
κ	0.992	Bond income flow rate	Sims and Wu (2021)
$(S^h_{H,ss} + S_{H,ss})/K_{ss}$	0.700	Domestic equity holding share	Atkeson, Heathcote, and Perri (2022)
$(B^h_{h,ss} + B_{H,ss})/\bar{B}$	0.600	Domestic bond holding share	Foreign share of public debt: 40%
C. Producers			
α	0.330	Capital share	Gertler and Karadi (2011, 2013)
δ	0.008	Capital depreciation rate	Gertler and Karadi (2011, 2013)
η_y	3.800	Foreign elasticity of substitution	Bajzik et al. (2020)
θ_y	11.00	Home elasticity of substitution	10% markup
θ_w	11.00	Labor elasticity of substitution	Sims and Wu (2021)
γ_y	0.130	Trade openness	US trade-to-GDP ratio = 0.26
D. FX dealers			
η	0.500	US share of FX dealers	Gabaix and Maggiori (2015)
$\tilde{\eta}$	0.500	US share of noise traders	For symmetry
E. Government policy			
ϕ_Π	2.150	Taylor rule inflation	Clarida, Gali, and Gertler (2000)
ϕ_Y	0.083	Taylor rule output deviation	Clarida, Gali, and Gertler (2000)
G/Y	0.200	Steady-state government spending	Gertler and Karadi (2011, 2013)
$\bar{B}/(12Y)$	0.410	Steady-state bond supply	Sims and Wu (2021)

Figure D1: QE1 and QE2 shock sizes in the data



trade openness parameter γ_y is set to 0.13, consistent with a 0.26 trade-to-GDP ratio for the US. For monetary and fiscal policies, we adopt Taylor rule parameters $\phi_\Pi = 2.15$ and $\phi_Y = 0.083$, as in Clarida, Gali, and Gertler (2000). The steady-state government spending and long-term government bond supply are chosen to match a government spending share of output of 0.2 and an annualized debt-to-GDP ratio of 0.41, following Sims and Wu (2021).

For the parameters in the sectors of banks and FX dealers, we set the bond coupon decay rate κ in (2) to $1 - 120^{-1}$ such that the maturity of long-term bonds is 10 years. We choose the monthly survival probability of banks (σ) to be 0.98, implying an expected horizon of 50 months, which is close to Gertler and Kiyotaki (2015) and Sims and Wu (2021). We target the steady-state annualized excess return on equity at 500 bps, which is the average of the excess returns on equity (636 bps) and BBB corporate bonds (358 bps) among developed economies including the US. The equity excess return is calculated using data from Fama and French (2023) over January 1995 to June 2019. The corporate bond excess return is from Bekaert and De Santis (2021) over February 1998 to August 2018. We target the steady-state long-term bond excess return at 135 bps, which is the average of the 10-year minus 3-month government bond yield spreads for the US (148 bps) and other G10 countries (122 bps) over January 1995 to June 2019, using data from Bloomberg. This implies $\Delta = 0.27$ according to (7). Following Gertler and Karadi (2011), we target a steady-state leverage of 4. In scenarios where households are not allowed to hold domestic risky assets, the steady-state excess return on equity and leverage ratio imply $\theta = 0.944$ and $X = 0.045$, respectively.

For models where households hold domestic risky assets, we calibrate θ to 0.919 and X to 0.037. We set the share of domestic banks' and households' total holdings of domestic equity $(S^h_{h,ss} + S_{H,ss})/K_{ss} = 0.70$ in the steady state, and symmetrically, $(S^{h*}_{f,ss} + S^*_{F,ss})/K^*_{ss} = 0.70$, with $S^h_{h,ss} = S^{h*}_{f,ss} = 0$ if households are not allowed to hold domestic equity. The share of domestic equity held by domestic agents in the steady state is from Atkeson, Heathcote, and Perri (2022). In scenarios where households hold domestic risky assets, we set the share of domestic households' equity holdings at $S^h_{h,ss}/(S^h_{h,ss} + S_{H,ss}) = 0.37$, based on the Federal Reserve's US financial accounts. For long-term bond holdings, we set $(B^h_{h,ss} + B_{H,ss})/\bar{B} = 0.6$, and symmetrically $(B^{h*}_{f,ss} + B^*_{F,ss})/\bar{B}^* = 0.6$ to match the foreign share of US Federal debt held by the public over 1995 to 2007 from FRED, which is also close to the value in Tabova and Warnock (2021). If households are not allowed to hold domestic long-term bonds, then $B^h_{h,ss} = B^{h*}_{f,ss} = 0$. Otherwise, the share of domestic households' long-term bond holdings is $B^h_{h,ss}/(B^h_{h,ss} + B_{H,ss}) = 0.20$, which is also from the Federal Reserve's US financial accounts. Finally, we let $e_{ss} = 1$ in the steady state and assume symmetric ownership of FX dealers and noise traders, that is, $\eta = 1/2$ and $\tilde{\eta} = 1/2$, respectively.

Parameter Estimation. We estimate the remaining parameters by matching the model's impulse responses to a US conventional monetary policy shock with those from BP-SVAR estimation for the first 24 months. We match the impulse responses of seven variables: US 10Y bond yields, exchange rate, US equity price, foreign equity price, US bank leverage, net equity inflows to the US, and net bond inflows to the US. The sample size for BP-SVAR estimation spans from January 1995 to June 2019. Our estimation includes the case of the US against nine AEs, equally weighted, and the case of the US against the EU.

We normalize the IRFs of net equity and bond inflows from BP-SVAR estimation by the annual average of detrended real GDP of the US and foreign economy. For the case of the US against nine AEs, we collect nominal GDP data in US dollars from the IMF World Economic Outlook Database and US annual CPI data from FRED over 1995 to 2019. We deflate the annual nominal GDP of all countries by US CPI index with the base year 1995, and remove the long-run growth rate of the deflated GDP for each country. The impulse responses and associated confidence intervals of net equity and bond inflows from BP-SVAR estimation are then normalized by the average detrended GDP of all countries, which approximates the steady-state GDP. Finally, we match the IRFs based on these normalized estimates. The same procedure applies in the case of the US against the EU.

In Section 4.2 of the main text, we report the model estimations with constant Γ, endogenous $\Gamma_t \equiv \gamma \mathrm{var}_t(\Delta \ln e_{t+1})$, and exogenous Γ_t, under the PCP scheme without households holding domestic risky assets or sticky nominal wages. Here, we provide more details on the model solution and estimation. The first-order approximation of the model solution for the case with endogenous Γ_t implies that $\ln \Gamma_t = \ln \bar{\Gamma} + \tilde{\gamma}\,(\Delta \ln e_{t+1})$, and we estimate the steady-state value $\bar{\Gamma} > 0$ and the parameter $\tilde{\gamma}$. For the case with exogenous Γ_t, we model $\varepsilon_{\Gamma t} = \sigma_\Gamma \varepsilon_{it}$ with the conventional monetary policy shock ε_{it} defined in the Taylor rule (19). Then $\ln \Gamma_t = (1-\rho_\Gamma)\ln \bar{\Gamma} + \rho_\Gamma \ln \Gamma_{t-1} + \sigma_\Gamma \varepsilon_{it}$, where we assume that FX dealers' risk-bearing capacity (Γ_t) responds instantly to a US conventional monetary policy shock and the logarithm of Γ_t evolves according to an AR(1) process after the shock. In this case, we estimate the parameters: $\bar{\Gamma}$, $\rho_\Gamma \in (0,1)$, and σ_Γ.

In this appendix, we consider model estimations for the following alternative specifications: the PCP scheme without households holding domestic risky assets, the PCP scheme with households holding domestic risky assets, the LCP scheme with households holding domestic risky assets, and the PCP scheme with sticky nominal wages and without households holding domestic risky assets. Additionally, we estimate the model under the PCP scheme without households holding domestic risky assets for the case of the US against the EU.

In the specifications without households holding risky assets, the estimated parameters include banks' foreign asset holding cost (κ_1, κ_2), FX dealers' risk-bearing capacity (Γ_t), nominal price rigidity (ϕ_p), investment adjustment cost (κ_I), and the persistence and volatility of target surprise (ρ_r, σ_r). If households are allowed to hold risky assets, we additionally estimate households' asset holding cost (κ_{h1}, κ_{h2}). For the model with sticky nominal wages, we also estimate nominal wage rigidity (ϕ_w). For all specifications, we estimate the models with a constant Γ for the baseline ($\Gamma > 0$), financial autarky ($\Gamma \to \infty$), and UIP ($\Gamma \to 0$) cases. θ and Δ are time-invariant in all exercises of IRF matching and model estimations.

We employ the Bayesian impulse response matching method developed by Christiano, Trabandt, and Walentin (2010, 2021). Let Θ be the vector of estimated parameters, $\mathbf{\Psi}(\Theta)$ the mapping from Θ to the model's IRFs, and $\hat{\mathbf{\Psi}}$ the empirical estimates. Assuming $\hat{\mathbf{\Psi}} \sim_a N(\mathbf{\Psi}(\Theta), \mathbf{V})$ with a prior distribution $p(\Theta)$ for Θ, the posterior density of Θ is given by

$$p(\Theta|\hat{\mathbf{\Psi}}, \mathbf{V}) \propto p(\Theta) \cdot |\mathbf{V}|^{-1/2} \exp\left[-\frac{1}{2}(\hat{\mathbf{\Psi}} - \mathbf{\Psi}(\Theta))'\mathbf{V}^{-1}(\hat{\mathbf{\Psi}} - \mathbf{\Psi}(\Theta))\right]. \tag{D1}$$

For the baseline and financial autarky cases, the variance matrix $\mathbf{V}$ is diagonal, with entries representing the squared widths of the 90% confidence intervals derived from each variable's empirical IRFs. For the UIP cases, we set the variance matrix $\mathbf{V}$ to the identity matrix to better match the empirical IRFs.

Tables D2 to D6 report the priors and posteriors for the estimated parameters under the baseline, financial autarky and UIP cases with a constant Γ across alternative specifications, respectively. Following Christiano, Trabandt, and Walentin (2010, 2021), the posterior mode and marginal distributions of Θ are computed via a standard MCMC algorithm with a total of 2.5 million draws based on 10 chains. We use the first 20% of draws for burn-in. The acceptance rates are around 25% in each chain.

We have several important findings based on the estimation results. First, the estimates of Γ indicate that FX dealers have limited risk-bearing capacity in the baseline cases. As reported in Tables D2 to D6, the estimated values of Γ are consistently around 0.1 and statistically significant across different specifications. Furthermore, the estimates of κ_1 and κ_2 suggest that banks face considerable holding cost on foreign risky assets, implying a non-negligible exogenous home bias in asset holding away from the steady state.

Turning to the other parameters, the estimates of the nominal price rigidity parameter ϕ_p imply average durations of price stickiness ranging from 9 to 22 quarters, which are higher than the traditional estimate of 4 quarters in the literature (e.g., Galí and Gertler, 1999; Nakamura and Steinsson, 2008). This is because our model does not include real rigidities (e.g., Kimball demand) that would typically lower the estimated stickiness of prices, as discussed in Gagliardone and Gertler (2023). Our estimates of the investment adjustment cost parameter κ_I range between 0.2 and 1.3 across different specifications, which are lower than the values of 2.5 in Christiano, Eichenbaum, and Evans (2005) and 1.728 in Gertler and Karadi (2013). This is due to a different specification for the investment adjustment cost. In particular, our model assumes an adjustment cost of $f(I_t/I_{ss}) = \frac{\kappa_I}{2}(I_t/I_{ss} - 1)^2$, implying the following log-linearized first-order condition for investment:

$$\hat{I}_t = \frac{1}{\kappa_I}\hat{Q}_t.$$

In contrast, Christiano, Eichenbaum, and Evans (2005) and Gertler and Karadi (2013) assume an adjustment cost of $f(I_t/I_{t-1}) = \frac{\kappa_I}{2}(I_t/I_{t-1} - 1)^2$ with the following log-linearized first-order condition for investment:

$$\hat{I}_t = \hat{I}_{t-1} + \frac{1}{\kappa_I}\sum_{j=0}^{\infty}\beta^j \mathbb{E}_{t-1}\hat{Q}_{t+j}.$$

Given the same path of capital price responses, the former specification requires a lower κ_I to match the observed investment responses. Our estimates of κ_I align with this analysis. In addition, the estimates of the Taylor rule smoothing parameter ρ_r yield quarterly values around 0.8, consistent with estimates in the literature, such as Clarida, Gali, and Gertler (2000). For the models with households holding risky assets, our estimates of households' asset holding cost parameters, κ_{h1} and κ_{h2}, are approximately 0.8 and 0.9 under the PCP scheme, and around 0.5 and 1.5 under the LCP scheme. Prior research, such as Gertler and Karadi (2013), has usually assigned values to these parameters without rigorous quantification. We contribute to the literature by providing a benchmark estimation for these parameters. Lastly, for the models with sticky nominal wages, the estimates of the nominal wage rigidity parameter ϕ_w imply average durations of wage stickiness between 1.5 and 2.3 quarters, consistent with the estimates in Christiano, Eichenbaum, and Evans (2005).

Comparing the baseline and financial autarky cases, the estimated parameters are similar across all specifications. The associated IRF matching, plotted in Figures D2 to D6, also shows that the simulated impulse responses in both cases closely resemble each other and match the empirical IRFs. These results suggest that FX dealers' limited risk-bearing capacity Γ is sufficiently large under the baseline case such that the IRF matching results are close to those under the financial autarky case. Across different specifications, the main differences in estimation are that under the financial autarky cases, the estimates of the investment adjustment cost parameter (κ_I) are consistently lower than those under the baseline cases, and the banks' foreign asset holding cost parameters (κ_1, κ_2) are also lower in some specifications. These differences stem from the significantly stronger endogenous home bias under the financial autarky case with $\Gamma \to \infty$, which prevents the spillover of domestic conventional monetary policy shocks to the foreign economy. To match the same empirical IRFs of equity prices and net portfolio inflows, either a lower foreign asset holding cost (κ_1 and κ_2) or a higher price elasticity of investment ($1/\kappa_I$) is required to align with the completely endogenous home bias with $\Gamma \to \infty$.

In contrast, the estimated parameters in the UIP cases are significantly different from those in the baseline cases, where the estimated values in the UIP cases are very close to their prior modes for most of the parameters. Figures D2 to D6 show that the simulated impulse responses under the UIP cases fail to match the empirical IRFs for net equity and bond inflows. In contrast to the significant amounts of portfolio inflows to the home country from BP-SVAR estimation, there are significant portfolio outflows from the home country in response to a tightening domestic conventional monetary policy shock under the UIP cases. These results display significant quantitative discrepancies between the baseline and UIP cases, highlighting the crucial role of FX dealers' limited risk-bearing capacity Γ in the IRF matching.

Table D2: Priors and posteriors of estimated parameters under PCP scheme without households holding risky assets

Parameter	Description	Prior (mean, std)	Posterior Mode [2.5%, 97.5%]		
		[Bounds]	Baseline	FA	UIP
κ_1	Bank equity holding cost	Gamma (1,0.5)	0.361	0.202	0.682
		[0.01,10]	[0.185, 1.076]	[0.073, 0.528]	[0.173, 1.984]
κ_2	Bank bond holding cost	Gamma (1,0.5)	1.502	1.297	0.721
		[0.01,10]	[1.145, 2.577]	[0.985, 1.989]	[0.170, 1.988]
Γ_{ss}	Steady state of Γ_t	Gamma (0.1,0.02)	0.086	-	-
		[0.01,10]	[0.060, 0.116]	-	-
ϕ_p	Price rigidity	Beta (0.8,0.15)	0.978	0.981	0.936
		[0.001,0.999]	[0.960, 0.988]	[0.950, 0.992]	[0.498, 0.999]
κ_I	Investment adjust cost	Gamma (1,0.5)	0.623	0.253	0.769
		[0.01,10]	[0.357, 1.980]	[0.167, 0.304]	[0.182, 1.976]
ρ_r	Taylor rule smoothing	Beta (0.8,0.15)	0.939	0.944	0.940
		[0.001,0.999]	[0.877, 0.967]	[0.906, 0.979]	[0.497, 0.995]
σ_r	Target surprise vol	Uniform	0.0011	0.0011	0.0013
		[0,0.01]	[0.0006, 0.0019]	[0.0005, 0.0019]	[0.0000, 0.0095]

Note: Column "Prior" reports the type of prior distribution with mean and standard deviation in parentheses, and parameter bounds in brackets. Column "Posterior Mode" reports the posterior mode under the baseline, financial autarky and UIP cases with 95% confidence interval in brackets.

Table D3: Priors and posteriors of estimated parameters under PCP scheme with households holding risky assets

Parameter	Description	Prior (mean, std)	Posterior Mode [2.5%, 97.5%]		
		[Bounds]	Baseline	FA	UIP
κ_1	Bank equity holding cost	Gamma (1,0.4)	0.620	0.357	0.832
		[0.01,10]	[0.360, 1.764]	[0.178, 0.768]	[0.301, 1.792]
κ_2	Bank bond holding cost	Gamma (1,0.4)	1.077	0.842	0.917
		[0.01,10]	[0.845, 1.846]	[0.617, 1.350]	[0.305, 1.797]
κ_{h1}	HH equity holding cost	Gamma (1,0.4)	0.717	0.828	0.855
		[0.01,10]	[0.302, 1.764]	[0.298, 1.775]	[0.301, 1.793]
κ_{h2}	HH bond holding cost	Gamma (1,0.4)	0.839	0.813	0.954
		[0.01,10]	[0.307, 1.794]	[0.300, 1.784]	[0.303, 1.804]
Γ_{ss}	Steady state of Γ_t	Gamma (0.1,0.02)	0.083	-	-
		[0.01,10]	[0.050, 0.108]	-	-
ϕ_p	Price rigidity	Beta (0.8,0.15)	0.977	0.983	0.957
		[0.001,0.999]	[0.961, 0.990]	[0.949, 0.994]	[0.501, 0.999]
κ_I	Investment adjust cost	Gamma (0.7,0.4)	0.337	0.202	0.437
		[0.01,10]	[0.202, 1.212]	[0.126, 0.255]	[0.073, 1.471]
ρ_r	Taylor rule smoothing	Beta (0.8,0.15)	0.945	0.948	0.951
		[0.001,0.999]	[0.895, 0.969]	[0.923, 0.985]	[0.496, 0.995]
σ_r	Target surprise vol	Uniform	0.0012	0.0012	0.0018
		[0,0.01]	[0.0007, 0.0019]	[0.0005, 0.0017]	[0.0000, 0.0095]

Note: Column "Prior" reports the type of prior distribution with mean and standard deviation in parentheses, and parameter bounds in brackets. Column "Posterior Mode" reports the posterior mode under the baseline, financial autarky and UIP cases with 95% confidence interval in brackets.

Table D4: Priors and posteriors of estimated parameters under LCP scheme with households holding risky assets

Parameter	Description	Prior (mean, std)	Posterior Mode [2.5%, 97.5%]		
		[Bounds]	Baseline	FA	UIP
κ_1	Bank equity holding cost	Gamma (0.03,0.01)	0.026	0.024	0.029
		[0.01,10]	[0.012, 0.048]	[0.012, 0.046]	[0.012, 0.050]
κ_2	Bank bond holding cost	Gamma (0.5,0.1)	0.521	0.526	0.469
		[0.01,10]	[0.403, 0.656]	[0.411, 0.655]	[0.312, 0.698]
κ_{h1}	HH equity holding cost	Gamma (0.5,0.07)	0.488	0.487	0.501
		[0.01,10]	[0.368, 0.640]	[0.365, 0.638]	[0.366, 0.639]
κ_{h2}	HH bond holding cost	Gamma (1.5,0.07)	1.492	1.501	1.491
		[0.01,10]	[1.363, 1.638]	[1.365, 1.639]	[1.367, 1.639]
Γ_{ss}	Steady state of Γ_t	Gamma (0.1,0.02)	0.095	-	-
		[0.01,10]	[0.062, 0.137]	-	-
ϕ_p	Price rigidity	Beta (0.85,0.05)	0.985	0.984	0.861
		[0.001,0.999]	[0.975, 0.993]	[0.974, 0.993]	[0.750, 0.941]
κ_I	Investment adjust cost	Gamma (0.5,0.1)	0.467	0.364	0.491
		[0.01,10]	[0.371, 0.613]	[0.296, 0.466]	[0.311, 0.697]
ρ_r	Taylor rule smoothing	Beta (0.85,0.1)	0.989	0.988	0.925
		[0.001,0.999]	[0.981, 0.997]	[0.980, 0.996]	[0.649, 0.990]
σ_r	Target surprise vol	Uniform	0.0003	0.0003	0.0050
		[0,0.01]	[0.0001, 0.0005]	[0.0001, 0.0005]	[0.0000, 0.0095]

Note: Column "Prior" reports the type of prior distribution with mean and standard deviation in parentheses, and parameter bounds in brackets. Column "Posterior Mode" reports the posterior mode under the baseline, financial autarky and UIP cases with 95% confidence interval in brackets.

Table D5: Priors and posteriors of estimated parameters under PCP scheme with sticky wage and without households holding risky assets

Parameter	Description	Prior (mean, std)	Posterior Mode [2.5%, 97.5%]		
		[Bounds]	Baseline	FA	UIP
κ_1	Bank equity holding cost	Gamma (1,0.5)	0.280	0.233	0.762
		[0.01,10]	[0.144, 0.857]	[0.088, 0.619]	[0.185, 1.982]
κ_2	Bank bond holding cost	Gamma (1,0.5)	1.417	1.585	0.888
		[0.01,10]	[1.119, 2.479]	[1.199, 2.396]	[0.182, 2.001]
Γ_{ss}	Steady state of Γ_t	Gamma (0.1,0.02)	0.098	-	-
		[0.01,10]	[0.075, 0.133]	-	-
ϕ_p	Price rigidity	Beta (0.8,0.15)	0.979	0.981	0.936
		[0.001,0.999]	[0.964, 0.990]	[0.966, 0.991]	[0.501, 0.999]
ϕ_w	Wage rigidity	Beta (0.75,0.1)	0.853	0.847	0.773
		[0.001,0.999]	[0.674, 0.961]	[0.734, 0.958]	[0.552, 0.929]
κ_I	Investment adjust cost	Gamma (1,0.5)	0.959	0.249	0.740
		[0.01,10]	[0.539, 2.323]	[0.171, 0.308]	[0.180, 1.992]
ρ_r	Taylor rule smoothing	Beta (0.8,0.15)	0.904	0.902	0.927
		[0.001,0.999]	[0.848, 0.944]	[0.849, 0.937]	[0.497, 0.993]
σ_r	Target surprise vol	Uniform	0.0016	0.0020	0.0012
		[0,0.01]	[0.0009, 0.0024]	[0.0012, 0.0032]	[0.0000, 0.0095]

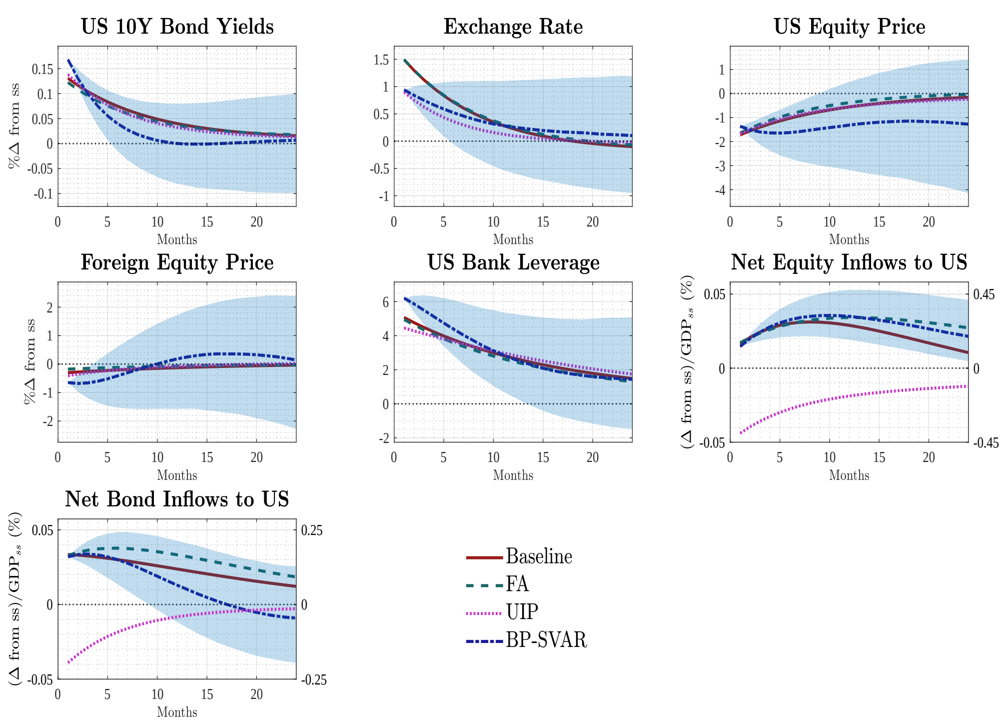
Note: Column "Prior" reports the type of prior distribution with mean and standard deviation in parentheses, and parameter bounds in brackets. Column "Posterior Mode" reports the posterior mode under the baseline, financial autarky and UIP cases with 95% confidence interval in brackets.

Table D6: Priors and posteriors of estimated parameters under PCP scheme without households holding risky assets for the US against the EU

Parameter	Description	Prior (mean, std) [Bounds]	Posterior Mode [2.5%, 97.5%] Baseline	FA	UIP
κ_1	Bank equity holding cost	Gamma (1,0.25)	0.489	0.444	0.931
		[0.01,10]	[0.320, 0.791]	[0.301, 0.747]	[0.543, 1.498]
κ_2	Bank bond holding cost	Gamma (1,0.25)	1.478	1.381	0.938
		[0.01,10]	[1.155, 1.943]	[1.124, 1.832]	[0.544, 1.500]
Γ_{ss}	Steady state of Γ_t	Gamma (0.1,0.02)	0.138	-	-
		[0.01,10]	[0.111, 0.181]	-	-
ϕ_p	Price rigidity	Beta (0.8,0.1)	0.964	0.972	0.842
		[0.001,0.999]	[0.942, 0.977]	[0.952, 0.986]	[0.605, 0.969]
κ_I	Investment adjust cost	Gamma (1,0.25)	1.279	0.852	0.943
		[0.01,10]	[0.883, 1.849]	[0.502, 1.401]	[0.540, 1.494]
ρ_r	Taylor rule smoothing	Beta (0.8,0.1)	0.929	0.908	0.839
		[0.001,0.999]	[0.883, 0.965]	[0.843, 0.951]	[0.603, 0.966]
σ_r	Target surprise vol	Uniform	0.0013	0.0014	0.0064
		[0,0.01]	[0.0007, 0.0021]	[0.0008, 0.0022]	[0.0000, 0.0095]

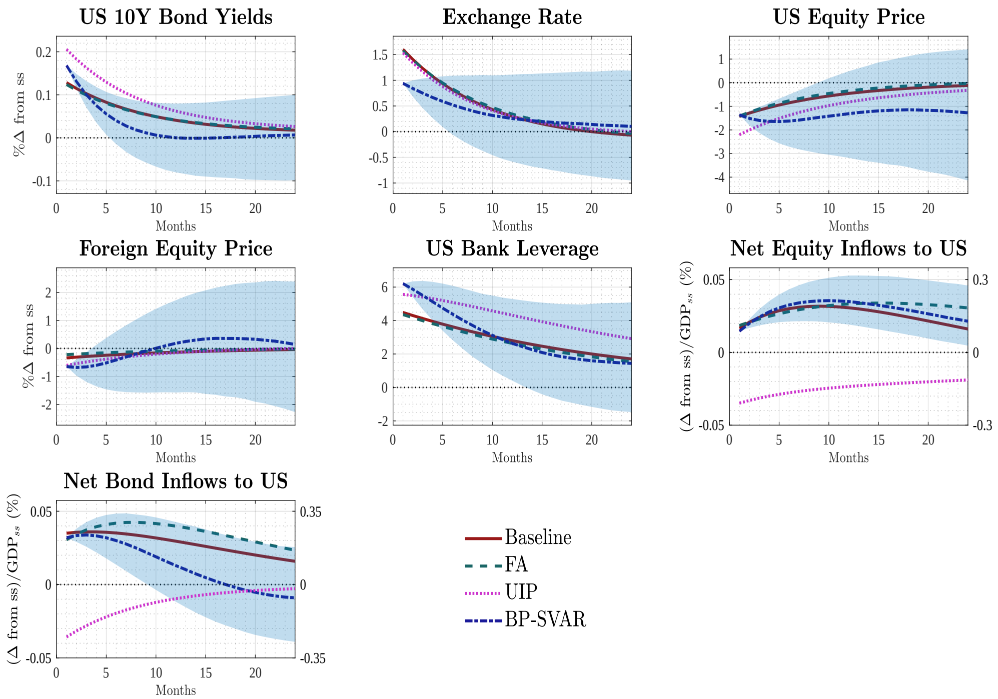
Note: Column "Prior" reports the type of prior distribution with mean and standard deviation in parentheses, and parameter bounds in brackets. Column "Posterior Mode" reports the posterior mode under the baseline, financial autarky and UIP cases with 95% confidence interval in brackets.

Figure D2: BP-SVAR estimation and model simulation under PCP scheme without households holding risky assets



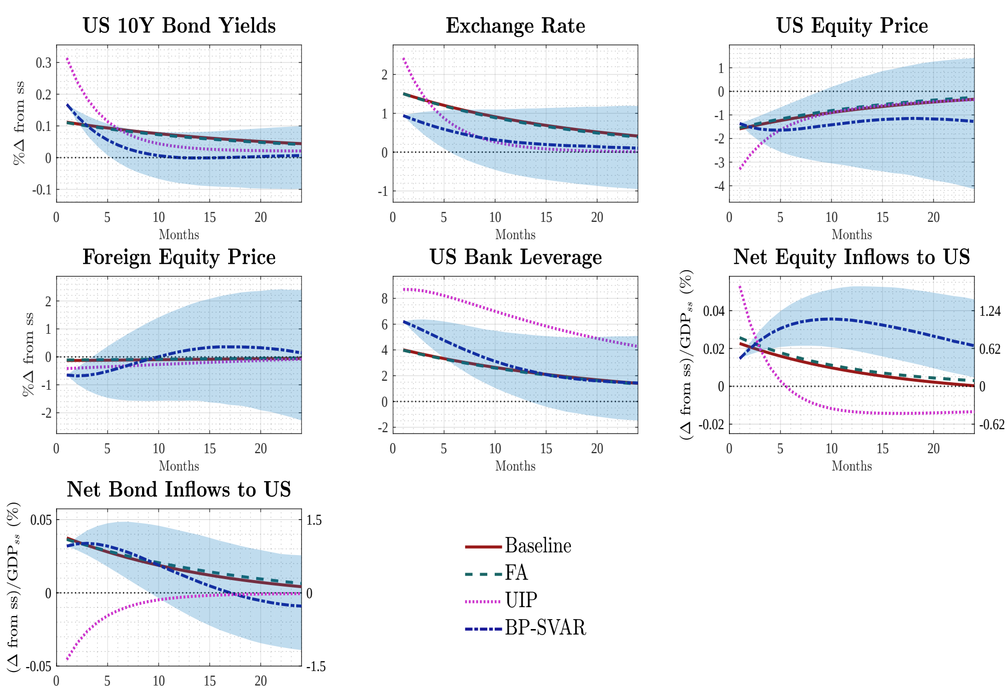
Note: The simulation results are based on the posterior mode of parameters from Table D2. In the last two panels, the right axis is for the pink dotted line (UIP), and the left axis is for the other lines.

Figure D3: BP-SVAR estimation and model simulation under PCP scheme with households holding risky assets



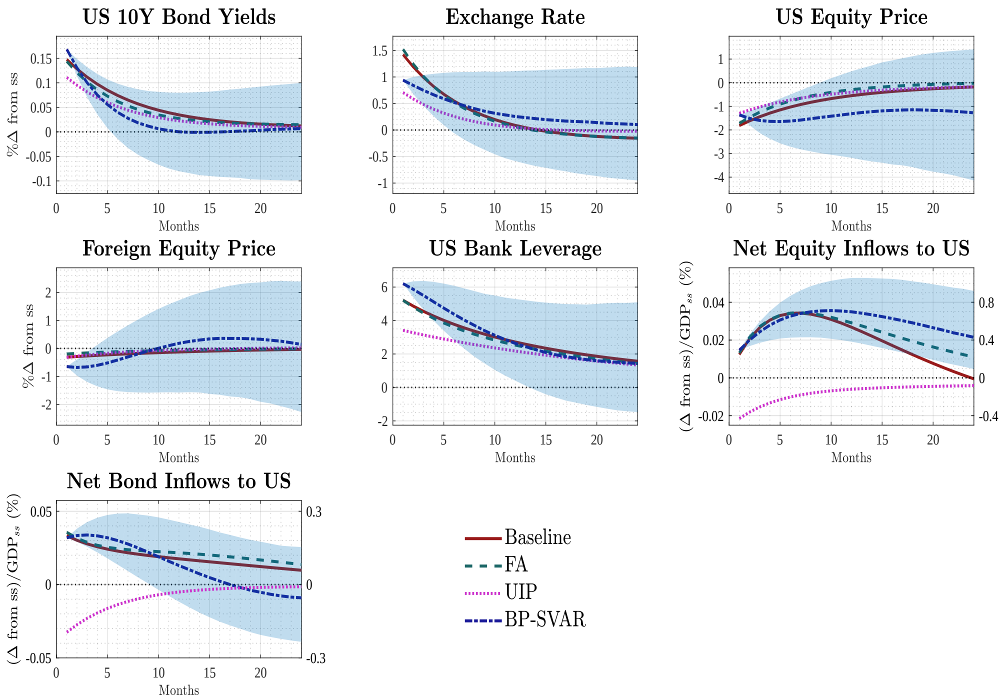
Note: The simulation results are based on the posterior mode of parameters from Table D3. In the last two panels, the right axis is for the pink dotted line (UIP), and the left axis is for the other lines.

Figure D4: BP-SVAR estimation and model simulation under LCP scheme with households holding risky assets



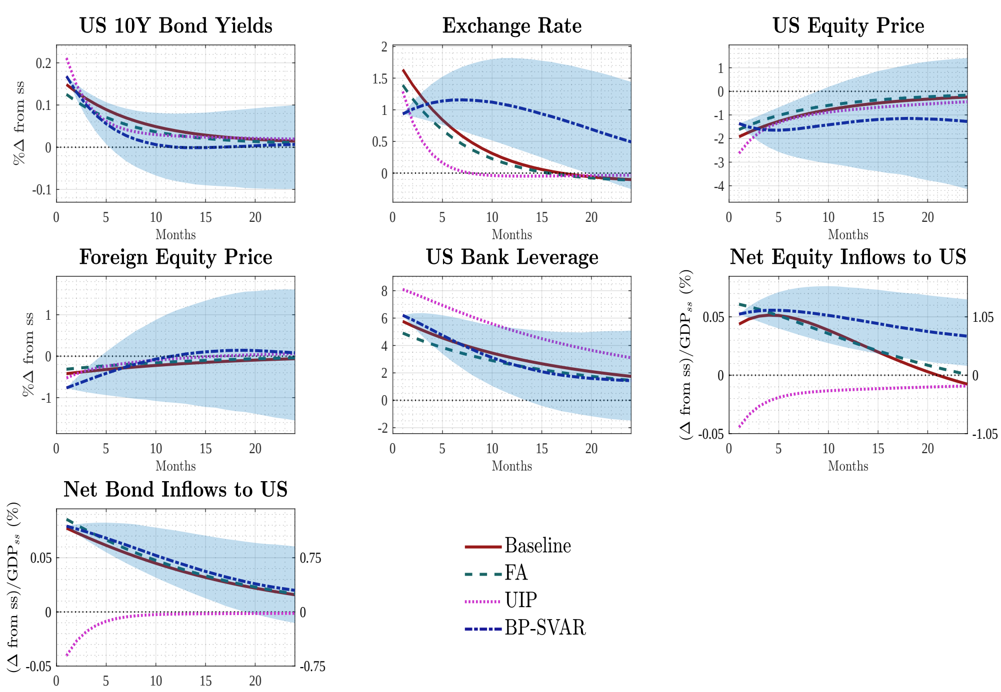
Note: The simulation results are based on the posterior mode of parameters from Table D4. In the last two panels, the right axis is for the pink dotted line (UIP), and the left axis is for the other lines.

Figure D5: BP-SVAR estimation and model simulation under PCP scheme with sticky wage and without households holding risky assets



Note: The simulation results are based on the posterior mode of parameters from Table D5. In the last two panels, the right axis is for the pink dotted line (UIP), and the left axis is for the other lines.

Figure D6: BP-SVAR estimation and model simulation under PCP scheme without households holding risky assets for the US against the EU



Note: The simulation results are based on the posterior mode of parameters from Table D6. In the last two panels, the right axis is for the pink dotted line (UIP), and the left axis is for the other lines.

Additional Quantitative Analysis of Conventional Monetary Policy. Figures D2 to D11 plot the impulse responses to a tightening US conventional monetary policy shock under the baseline, financial autarky, and UIP cases across different specifications.

Figures D2 to D11 show that the quantitative results of the baseline cases on the transmission of conventional monetary policy in Figures 5 and 6 are robust to different model specifications. A tightening domestic conventional monetary policy shock generates largely and significantly asymmetric contractions in the financial and real economic variables of both countries. The shock also leads to a significant appreciation of the home currency, net portfolio inflows to the home country, and a decline in home net exports. However, foreign inflation rates increase under the PCP scheme but decrease under the LCP scheme, as shown in the figures. This is because, under the PCP scheme, the appreciated home currency increases the export prices of home retail goods, encouraging foreign final goods producers to substitute foreign retail goods for home retail goods. The increased demand for foreign retail goods raises foreign labor demand and the price index of the foreign retail goods basket, driving up foreign inflation. In contrast, this effect is relatively weaker under the LCP scheme due to significant nominal price stickiness.

Although the impulse responses under the baseline cases are roughly close across different specifications, there are notable differences in magnitude. Under the PCP scheme for the US against G10 or the EU, the baseline models' IRFs closely match the empirical IRFs across different model specifications, as shown in Figures D2, D3, D5, and D6. Under the LCP scheme in Figure D4, the baseline model's impulse responses also match the empirical ones well. However, in contrast to the hump-shaped empirical IRFs of net equity inflows, the simulated impulse responses of net equity inflows decline monotonically over time. In addition, Figures D7 to D11 show that the baseline models' IRFs of other financial variables are similar in magnitude across different specifications under the PCP scheme. In contrast, Figure D9 shows relatively weaker responses of these financial variables under the LCP scheme, especially the foreign ones, which are almost constant in response to the conventional monetary policy shock.

For the real economic variables, Figures D7 to D11 show that the decline in domestic output, investment, and labor supply is generally more pronounced in specifications with a lower investment adjustment cost parameter κ_I. This is because the responses of real economic variables are driven by the responses of investment to equity price, which are related to the investment price elasticity $1/\kappa_I$. This pattern is also observed in the foreign real economic variables, except for foreign output under the LCP scheme, where the decrease in foreign output is the smallest among all specifications. We also observe larger asymmetry in the responses between domestic and foreign output under the LCP scheme compared to the PCP scheme. However, this asymmetry is relatively similar in magnitude across the specifications under the PCP scheme. Furthermore, both domestic and foreign inflation rates are lower in specifications with a lower nominal price rigidity parameter ϕ_p, as retail firms can adjust prices more quickly in response to tightening monetary policy shocks. Finally, the decrease in home net exports is the smallest in the specification under the LCP scheme and the largest in the specification under the PCP scheme for the US against the EU. Among the specifications under the PCP scheme for the US against G10, the decreases in home net exports are similar in magnitude.

Next, we report the quantitative results under the financial autarky cases. A key observation is that the impulse responses under the financial autarky cases are very close to those under the baseline cases. Figures D2 to D6 show that across all specifications, the impulse responses in the IRF matching under the financial autarky cases are very similar to those under the baseline cases and closely match the empirical IRFs. Figures D7 to D11 further show that the impulse responses of other financial variables are comparable in magnitude between both cases. However, unlike the baseline cases, net capital flows are always zero under the financial autarky cases, as net portfolio inflows are offset by a decline in home net exports. These results indicate that FX dealers' risk-bearing capacity Γ under the baseline case is sufficiently large such that the associated impulse responses are close to those under the financial autarky case. This finding also justifies the crucial role of FX dealers' limited risk-bearing capacity in the global transmission of conventional monetary policy.

The main differences between the baseline and financial autarky cases lie in the responses of real economic variables. Figures D7 to D11 show that output, investment, and labor supply exhibit stronger reactions under the financial autarky cases. The asymmetries in the responses between domestic and foreign economies are even larger under the financial autarky cases. This is mainly due to the higher FX dealers' risk-bearing capacity (Γ) and lower investment adjustment cost (κ_I) under the financial autarky cases. A higher Γ amplifies the endogenous home bias that limits portfolio flows, while a lower κ_I results in a larger contraction in investment in response to a tightening conventional monetary policy shock.

However, the simulated impulse responses under the UIP cases differ significantly from those under the baseline and financial autarky cases. Figures D2 to D6 show that a tightening domestic conventional monetary policy shock under the UIP case generates significant net portfolio outflows from home to foreign country, which sharply contradicts the portfolio inflows in the empirical IRFs, indicating that the UIP case fails to match the empirical IRFs. For other variables, the impulse responses under the UIP cases generally align with the empirical IRFs, though there are differences in magnitude across different specifications. Specifically, the impulse responses in the specification under the PCP scheme without households holding risky assets closely match the empirical IRFs shown in Figure D2. However, the specification under the PCP scheme with households holding risky assets overestimates the impulse responses of US 10Y bond yields in Figure D3. In the specification under the LCP scheme with households holding risky assets in Figure D4, most variables are overestimated. The specification under the PCP scheme with sticky nominal wages and without households holding risky assets in Figure D5 underestimates the impulse responses of US bank leverage. Lastly, the specification under the PCP scheme without households holding risky assets for the US against the EU in Figure D6 fails to capture the hump-shaped impulse responses of the exchange rate and overestimates those of US bank leverage. All these findings highlight the crucial role of FX dealers' limited risk-bearing capacity in explaining the impact of conventional monetary policy shocks on global financial market.

Figures D7 to D11 further show that the simulated impulse responses of other variables under the UIP cases differ significantly from those under the baseline and financial autarky cases. Notably, the net capital inflows are exceptionally larger under the UIP cases compared to the baseline and financial autarky cases, as FX dealers can absorb any imbalances when UIP holds. Across different specifications, the maximum increases in net capital inflows under the UIP cases range from 6% to 24% relative to steady-state GDP, while they range between 0.3% and 0.6% under the baseline cases.

In conclusion, the additional quantitative analysis of conventional monetary policy shows that the impulse responses under the baseline case are close to those under the financial autarky case but significantly different from those under the UIP case. This implies a sufficiently large risk-bearing capacity Γ of FX dealers under the baseline case, wherein the quantitative results are much closer to those under the financial autarky case instead of those under the UIP case. Our quantitative results in this section provide robust quantitative evidence for the failure of UIP condition and the crucial role of financially constrained FX dealers in the international transmission of US conventional monetary policy. This further supports the conclusion drawn in the main text.

Additional Quantitative Analysis of QE. We conduct the additional quantitative experiments of QE under three specifications: the PCP scheme without households holding risky assets, the PCP scheme with households holding risky assets, and the LCP scheme with households holding risky assets. Figures D12 to D15, along with Figures 7 and 8 in Section 4.3, plot the IRFs to the "QE2" shocks under the baseline and UIP-related cases. Figures D16 to D21 report the associated IRFs under the baseline and financial autarky cases. The experiments are conducted in an environment with a constant Γ and ZLB constraints.

Figures D16 to D21 show that the quantitative findings of the baseline cases on the transmission of unconventional monetary policy based on Figures 7 and 8 are robust to different model specifications. A domestic QE shock raises asset prices, increases capital investment, and stimulates the real economy with largely asymmetric effects on the two countries. The QE shock also leads to a significant depreciation of home currency, net portfolio outflows from home to foreign country, and an increase in home net exports. We also observe positive net bond inflows to home country in all specifications, as the domestic central bank's QE implementation reduces foreign banks' domestic bond holdings and also significantly increases the price of domestic long-term bonds. Because the price effect quantitatively dominates in the model, there are substantial bond inflows to home country according to the definition of net bond inflows in (B22). In addition, foreign inflation rates decrease in response to the domestic QE shock. This is because the depreciation of home currency lowers the export prices of home retail goods, leading to deflation in foreign country.

The impulse responses in the baseline cases vary in magnitude across different specifications. Figures D16 to D18 show that under the LCP scheme, net bond inflows are about 1.6 times larger, and net capital outflows are roughly 60% of those observed under the PCP scheme. This is due to the larger estimated value of Γ under the LCP scheme according to Tables D2 to D4. A larger Γ strengthens the endogenous home bias, which impedes foreign banks from selling domestic long-term bonds to the domestic central bank. This reduces net capital outflows and further enhances the price effect of the domestic central bank's bond purchases. Despite these differences, the impulse responses of other financial variables are roughly similar across different specifications.

However, there are notable differences in the IRFs of real economic variables across specifications in the baseline case, as shown in Figures D19 to D21. First, the stimulation effects of QE shocks on the real economy are more pronounced in specifications with a higher investment price elasticity $1/\kappa_I$. Given the similar impulse responses of equity prices across specifications in the baseline case, a higher investment price elasticity amplifies the responses of investment to QE shocks. Second, the asymmetric effects of QE on domestic and foreign economies vary across different specifications. Over the first 12 months, the average increase in foreign output is 44% of that in domestic output under the PCP scheme without households holding risky assets, while it is 36% under the PCP scheme with households holding risky assets or 63% under the LCP scheme with households holding risky assets. These differences are primarily driven by the values of κ_1 and κ_2, which are significantly lower under the LCP scheme than under the PCP scheme. Lower values of κ_1 and κ_2 weaken the exogenous home bias of asset holding such that larger amounts of injected liquidity spill over into the foreign country through banks' portfolio rebalancing. Consequently, the stimulation effects of QE shocks on domestic and foreign economies are relatively symmetric under the LCP scheme compared to the PCP scheme.

Next, we examine the effects of QE shocks under financial autarky with ZLB constraints in Figures D16 to D21. We specify the FA-1 case with $\Gamma \to \infty$ and the remaining parameters the same as the baseline case. For the financial autarky model with re-estimated parameters under $\Gamma \to \infty$, we specify it as the FA-2 case. For the baseline and FA-related cases, Figures D16 to D18 show that the impulse responses of financial variables are roughly close. However, there are two notable differences. First, net capital flows are always zero under the FA-1 and FA-2 cases, as portfolio outflows are offset by an increase in home exports. Second, there is a slightly larger depreciation of home currency associated with moderately larger amounts of net bond inflows under the FA-1 and FA-2 cases compared to the baseline case. This stems from a stronger endogenous home bias under the FA-1 and FA-2 cases, which leads to larger depreciation of home currency and amplifies the price effect of domestic central bank's bond purchases. These findings also indicate that FX dealers' limited risk-bearing capacity Γ is sufficiently large under the baseline case such that the impacts of QE shocks on financial markets are close between two cases.

For the real economic variables, there are several important quantitative findings by comparing the baseline and FA-related cases: although the absolute magnitudes of impulse responses for the same variables are significantly different, the relative stimulation effects between two countries are roughly close. Across different specifications shown in Figures D19 to D21, the average increase in domestic output over the first 12 months under the FA-2 cases is about 2.4, 1.6, and 1.3 times larger than that under the baseline cases. Additionally, the average increase in foreign output under the FA-2 cases is around 2.2, 1.6, and 1.2 times larger than that under the baseline cases. Moreover, the average increase in foreign output relative to domestic output over the first 12 months is 39%, 35%, and 57% under the FA-2 cases, compared to 44%, 36%, and 63% under the baseline cases, respectively. However, the impulse responses under the FA-1 cases closely resemble those under the baseline cases.

The difference in the absolute magnitudes of output responses between the baseline and FA-2 cases is mainly related to the lower investment adjustment cost (κ_I) under the FA-2 cases, as reported in Tables D2 to D4. On the other hand, the comparable relative stimulation effects between two countries, as well as the similar impulse responses between the baseline and FA-1 cases, suggest that FX dealers' limited risk-bearing capacity Γ is sufficiently large under the baseline case such that the effectiveness of QE on the domestic real economy is close to that under the financial autarky case.

Finally, we compare the quantitative effects of QE shocks under the baseline and UIP-related cases with ZLB constraints. Overall, our findings from the main text continue to hold across different specifications. First, Figures D12 and D13 show that the real exchange rate is nearly constant in response to QE shocks under the UIP-related cases, associated with an abnormally large amount of net capital flows. The impulse responses of net capital flows under the UIP-1 and UIP-2 cases are approximately 4.5 times larger than those under the baseline case in Figure D12, and 7.3 times larger in Figure D13. These results align with those in Figure 7 and highlight that FX dealers' limited risk-bearing capacity is crucial to explain QE shocks' strong impact on exchange rates and global portfolio flows. Second, Figures D14 and D15 reveal that the asymmetry in the impulse responses of domestic and foreign real economic variables is much smaller under the UIP-related cases compared to the baseline cases. Over the first 12 months, the average increase in domestic output under the UIP-1 and UIP-2 cases is around 69% and 82% of the increase under the baseline case in Figure D14, while they are 82% and 83% in Figure D15, respectively. In contrast, the increase in foreign output under the UIP-1 and UIP-2 cases is about 1.79 and 1.45 times larger than the increase under the baseline case in Figure D14, and 1.29 and 1.28 times larger in Figure D15. Hence, under the UIP-related cases with $\Gamma \to 0$, the stimulation effect of domestic QE policy on the domestic economy is much less effective than the baseline case, while its impact on the foreign economy is much stronger. These results are consistent with the findings from Figure 8 and justify the importance of FX dealers' limited risk-bearing capacity for the effectiveness of QE on the domestic real economy.

In summary, the additional quantitative analysis of QE shocks further justifies that FX dealers' limited risk-bearing capacity Γ is sufficiently large under the baseline case in the sense that the quantitative results under the baseline case are closer to the financial autarky case but significantly different from the UIP case. Across all model specifications, the key conclusion based on the quantitative analysis always holds; that is, Γ plays a crucial role in explaining the QE policy's impact on the global financial market and its effectiveness on the domestic real economy. All these results further reaffirm the failure of UIP condition and provide robust quantitative evidence for the crucial role of FX dealers' binding constraints in the global transmission of unconventional monetary policy.

Quantitative Analysis of Long- and Short-term Bond Demand Shocks. As a supplement to the analysis in Section 4.3, we simulate the model with a long- or short-term bond demand shock, which directly affects the yield curve slope or interest rate differentials. We distinguish a long-term bond demand shock from a QE shock by modeling it as an AR(1) process. We report the responses of associated variables in (15) to domestic long- and short-term bond demand shocks in Figures D22 to D27 under different specifications. Specifically, following Greenwood et al. (2023) and Gourinchas, Ray, and Vayanos (2022), we specify the exogenous long-term bond demand shock as an AR(1) process:

$$B_{qt} = \rho_q B_{q,t-1} + \sigma_q \varepsilon_{qt} \text{ and } \varepsilon_{qt} \sim N(0,1).$$

Similar to Itskhoki and Mukhin (2021), we assume that the exogenous short-term dollar bond demand shock is generated by a group of noise traders with zero capital, i.e.,

$$D_{nt} = \rho_n D_{n,t-1} + \sigma_n \varepsilon_{nt} \text{ and } \varepsilon_{nt} \sim N(0,1).$$

Consistent with the analysis in Section 3.3, we simulate the model with a positive demand shock for domestic long- or short-term bonds, which leads to a steeper foreign yield curve or higher foreign short-term interest rate, as shown in Figures D22 to D27. Figures D22 to D24 show that in the baseline cases, the shock increases the foreign and domestic term premia differential due to lower domestic bond term premia. Following the shock, foreign currency's expected excess return, i.e., long (short) position on foreign (home) currency, is decreasing. This is because FX dealers seize profits by shorting and appreciating foreign currency to intermediate the imbalances from banks' substitution towards foreign bonds after the shock. Notably, if equity trading is shut down, our quantitative results imply a larger increase in bond term premia differential relative to the decline in currency risk premium, which leads to positive but much smaller long-term bond carry trade risk premia. All of these results are consistent with the empirical findings in Lustig, Stathopoulos, and Verdelhan (2019) and also confirm the analysis in Section 3.3.

Following a positive demand shock for domestic short-term bonds, foreign and domestic interest rate differential rises due to a decline in the domestic short-term interest rate, as shown in Figures D25 to D27. The foreign currency risk premium rises because FX dealers take long positions in foreign currency and short positions in home currency to intermediate the imbalances resulting from noise traders' excess demand for domestic short-term bonds. Since the domestic short-term interest rate is relatively lower, domestic banks increase their demand for risky assets, and the expected return on domestic long-term bonds decreases by a smaller magnitude relative to the decline in short-term rate. Therefore, we observe a decline in bond local currency term premia differential in Figures D25 to D27. The rise in foreign currency risk premium dominates the decline in bond term premia differential such that there are positive long-term bond carry trade risk premia in Figures D25 to D27, consistent with the empirical findings in Lustig, Stathopoulos, and Verdelhan (2019).

Lastly, under the UIP-related cases, there is no significant response of currency risk premium to either a positive long- or short-term bond demand shock, as shown in Figures D22 to D27. Although there are significant responses of bond term premia differentials and long-term bond carry trade risk premia under some UIP-related cases, it is still far from explaining the whole puzzle in Lustig, Stathopoulos, and Verdelhan (2019). Hence, our results provide further quantitative evidence for the importance of FX dealers' financial constraints in explaining the downward term structure of currency carry trade risk premia.

In summary, our model simulation with a long- or short-term bond demand shock is able to explain the puzzling downward term structure of currency carry trade risk premia uncovered by Lustig, Stathopoulos, and Verdelhan (2019). Our key idea is based on the separation of FX dealers' currency exchange and banks' long-term bond trading, which is different from the integrated bond and FX markets as in Greenwood et al. (2023) and Gourinchas, Ray, and Vayanos (2022). The quantitative results confirm FX dealers' role in explaining the puzzling downward term structure of currency carry trade risk premia discussed in Section 3.3.

Additional Moments Matching. This part presents details on the procedures for model simulation and moment matching with additional matching results. We report the results under the PCP scheme without households holding risky assets in Section 4.3 of the main text. In this appendix, we conduct and report model simulations and moment matching under the following specifications: the PCP scheme with households holding risky assets, the LCP scheme with households holding risky assets, and the PCP scheme with sticky nominal wages and without households holding risky assets.

For each specification, we simulate the model with the calibrated parameters in Table D1 and the estimates from IRF matching under the baseline case with a constant Γ. The simulations are with shocks to the following variables: domestic and foreign banks' financial constraints ($\theta_t, \theta_t^*, \Delta_t, \Delta_t^*$), FX dealers' risk-bearing capacity (Γ_t), noise traders' demand

(D_{nt}), domestic and foreign aggregate productivity (A_t, A_t^*), and domestic and foreign nominal interest rates (i_t, i_t^*). We assume that shocks of different types are orthogonal to each other, while shocks of the same type have a common variance and are correlated due to a type-specific global shock. Specifically, we model banks' financial shocks as

$$\ln \mathcal{Z}_t = \ln \mathcal{Z} + \rho \left(\ln \mathcal{Z}_{t-1} - \ln \mathcal{Z}\right) + \sigma_{\mathcal{Z}} \varepsilon_{\mathcal{Z}t} + \sigma_{\mathcal{Z}}^g \varepsilon_{\mathcal{Z}t}^g,$$
$$\ln \mathcal{Z}_t^* = \ln \mathcal{Z} + \rho \left(\ln \mathcal{Z}_{t-1}^* - \ln \mathcal{Z}\right) + \sigma_{\mathcal{Z}} \varepsilon_{\mathcal{Z}t}^* + \sigma_{\mathcal{Z}}^g \varepsilon_{\mathcal{Z}t}^g,$$

where $\mathcal{Z} \in \{\theta, \Delta\}$, $\varepsilon_{\mathcal{Z}t}$ and $\varepsilon_{\mathcal{Z}t}^*$ are country-specific shocks, $\varepsilon_{\mathcal{Z}t}^g$ is a global shock, and $\sigma_{\mathcal{Z}}$ and $\sigma_{\mathcal{Z}}^g$ are shock volatilities. We specify the shocks to FX dealers' risk-bearing capacity as

$$\ln \Gamma_t = \ln \bar{\Gamma} + \rho \left(\ln \Gamma_{t-1} - \ln \bar{\Gamma}\right) + \sigma_\Gamma \varepsilon_{\Gamma t},$$

the noise traders' demand shocks as

$$D_{nt} = \rho D_{n,t-1} + \sigma_n \varepsilon_{nt},$$

and the aggregate productivity shocks as

$$\ln A_t = \rho \ln A_{t-1} + \sigma_A \varepsilon_{At} + \sigma_A^g \varepsilon_{At}^g, \;\; \ln A_t^* = \rho \ln A_{t-1}^* + \sigma_A \varepsilon_{At}^* + \sigma_A^g \varepsilon_{At}^g.$$

Lastly, we model the nominal interest rate shocks as ε_{it} in the Taylor rule of (19), with an additional global shock ε_{it}^g:

$$i_t = (1-\rho_r)\left[i_{ss} + \phi_\pi \left(\ln \Pi_t - \ln \Pi_{ss}\right) + \phi_y \left(\ln Y_t - \ln Y_{ss}\right)\right] + \rho_r i_{t-1} + \sigma_r \varepsilon_{it} + \sigma_r^g \varepsilon_{it}^g,$$
$$i_t^* = (1-\rho_r)\left[i_{ss}^* + \phi_\pi \left(\ln \Pi_t^* - \ln \Pi_{ss}^*\right) + \phi_y \left(\ln Y_t^* - \ln Y_{ss}^*\right)\right] + \rho_r i_{t-1}^* + \sigma_r \varepsilon_{it}^* + \sigma_r^g \varepsilon_{it}^g.$$

Following Itskhoki and Mukhin (2021), we set $\rho^3 = 0.97$ at a monthly frequency. We assume that all ε shocks follow a standard normal distribution and are independent mutually and also across time. For simulations with a constant Γ, we solve the model with a linear approximation around the non-stochastic steady state. For simulations with Γ_t shocks, we use a second-order approximation, as the first-order approximation of FX dealers' dollar liquidity supply D_{st} with respect to Γ_t around the steady state is zero.

In each simulation, we randomly draw shocks each period, simulate the model for 720 periods, and use the first 360 periods for burn-in. We use the last 360 periods of simulation to compute the moments related to exchange rate puzzles, international business cycles, and terms of trade. For the regression coefficients on the term structure of currency carry trade, we use the last 252 periods of simulation, which is consistent with the sample period of the regressions. Model simulated moments reported in tables and used in moment matching are the median values across 10,000 simulations.

In the exercise of moment matching, we estimate the volatilities of all specified shocks by matching model simulated moments to the following empirical moments: six international business cycle moments in Column "Data" of Panel E in Table 3, and the term structure regression coefficients for "Bond local currency return diff." and "Currency excess return" in Column "Data" of Table 4. The moment matching minimizes the squared distance between the vector of model simulated moments and the vector of empirical moments with equal weights to each moment. Specifically, we normalize the volatility of country-specific bank financial shocks, $\varepsilon_{\Delta t}$ and $\varepsilon^*_{\Delta t}$, to be $\sigma_\Delta \equiv 1$. Let $\boldsymbol{\sigma}$ be the vector of the other shock volatilities, $\mathbf{M}(\boldsymbol{\sigma})$ the mapping from $\boldsymbol{\sigma}$ to the model simulated moments, and $\hat{\mathbf{M}}$ the empirical moments. The moment matching estimates $\boldsymbol{\sigma}$ around its initial value $\boldsymbol{\sigma}_0$ by minimizing

$$\left(\hat{\mathbf{M}} - \mathbf{M}(\boldsymbol{\sigma})\right)' \mathbf{W}^{-1} \left(\hat{\mathbf{M}} - \mathbf{M}(\boldsymbol{\sigma})\right),$$

where $\mathbf{W}$ is an identity matrix.

The target empirical moments are obtained as follows. First, we estimate the international business cycle moments following Chari, Kehoe, and McGrattan (2002) and Itskhoki and Mukhin (2021). We use the quarterly country-level data over 1973 to 2019 from OECD Quarterly National Account Database, and estimate the moments for the US against a PPP-weighted sum of France, Germany, Italy and the UK. The data include seasonally adjusted GDP, consumption, and gross capital formation, all measured in PPP-adjusted USD in 2015. We also compare the international business cycle moments across three sample periods: 1973-1994, 1981-2017, and 1995-2019. The first two sample periods correspond to Table A2 in the Online Appendix of Itskhoki and Mukhin (2021), and the last sample period corresponds to our BP-SVAR estimation. Table D13 reports our estimation results, which is close to the results of Table A2 in the Online Appendix of Itskhoki and Mukhin (2021). We target the empirical moments from Column "95-19" in Table D13. Second, we run regressions on the term structure of currency carry trade based on data from January 1995 to December 2015 in Lustig, Stathopoulos, and Verdelhan (2019). The estimated regression coefficients are reported in Column "Data" of Table 4. Based on this dataset, we run Fama regressions and compute the Sharpe ratio of currency carry trade. The estimated Fama β, R^2, and the Sharpe ratio are reported in Panel D of Column "Data" in Table 3. In Panels A, B, C, and F of Column "Data" in Table D7, we show the details of other moments related to exchange rate dynamics and terms of trade with values from Itskhoki and Mukhin (2021).

Tables D7 to D9 report the simulated moments on exchange rate puzzles, international business cycles, and terms of trade based on the estimated shock volatilities across different specifications. Tables D10 to D12 present the corresponding simulated regression coefficients for the term structure of currency carry trade. In all these tables, the "Single-Type Shocks" columns show the results from simulations with single-type shocks to $\varepsilon_{\Delta t}$, $\varepsilon_{\theta t}$, or ε_{nt}. In the "Domestic" column we simulate the model with only domestic country-specific shocks and noise trader shocks: $\{\varepsilon_{\Delta t}, \varepsilon_{\theta t}, \varepsilon_{nt}, \varepsilon_{At}, \varepsilon_{it}\}$. The "Global-1" column presents the results of simulations with all shocks except $\varepsilon_{\Gamma t}$, and the "Global-2" column reports the results of simulations with all shocks.

As reported in Tables D7 to D12 under different specifications, our model is able to match the target moments closely, and the main conclusions in Section 4.3 continue to hold. Tables D7 to D9 show that the model simulations with single-type shocks $\varepsilon_{\Delta t}$, $\varepsilon_{\theta t}$, or ε_{nt} effectively account for the major exchange rate puzzles, while noise trader shocks generate much higher volatility of nominal exchange rates relative to aggregate output or consumption growth than the other shocks. Similar to the results in main text, the estimated volatilities of banks' financial shocks $\varepsilon_{\Delta t}$ and noise trader shocks ε_{nt} are significantly larger than those of macroeconomic shocks across all specifications. Tables D10 to D12 also show that banks' financial shocks Δ_t primarily account for the puzzling downward term structure of currency carry trade risk premia, and the model simulations with multiple shocks align well with the target regression coefficients across all specifications. Lastly, our model simulations in Tables D7 to D12 show that currencies with higher interest rates tend to appreciate, and the impulse responses in Figures D3 to D5 display an instant overshooting of exchange rates. Hence, our model is also robust to different specifications in reconciling the seeming inconsistency between forward premium puzzle and instant exchange rate overshooting.

In particular, we also report the simulation results under the PCP scheme with sticky nominal wages in Table D9. The model simulations align well with the relative volatility and correlation between the log changes of wage-based real exchange rate $\Delta\hat{e}_t^w$ and nominal exchange rate $\Delta\hat{\mathcal{E}}_t$, while the results are absent in Table 3 of Section 4.3. In addition, under the LCP scheme in Table D8, the Sharpe ratios of currency carry trade are lower than those under the PCP scheme.

In summary, the model simulation results in Tables D7 to D12 are consistent with the findings from Tables 3 and 4 and justify the model's robustness to different specifications in terms of rationalizing major exchange rate puzzles, explaining the puzzling downward term structure of currency carry trade, and matching international business cycle moments.

Table D7: Model moments under PCP scheme with households holding risky assets

Moments	Data	Single-Type Shocks			Multiple Shocks		
		D_{nt}	Δ_t	θ_t	Domestic	Global-1	Global-2
A. Exchange rate disconnect (quarterly):							
$\rho\left(\Delta\hat{\mathcal{E}}\right)$	≈ 0	−0.13	−0.12	−0.09	−0.11	−0.11	−0.11
		(0.08)	(0.08)	(0.09)	(0.09)	(0.08)	(0.08)
$\sigma\left(\Delta\hat{\mathcal{E}}\right)/\sigma\left(\Delta\hat{Y}\right)$	5.20	6.88	2.72	1.37	3.57	3.54	3.47
$\sigma\left(\Delta\hat{\mathcal{E}}\right)/\sigma\left(\Delta\hat{C}\right)$	6.30	61.44	13.31	3.79	5.06	4.18	3.99
B. Real exchange rate and the PPP (quarterly):							
$\rho\left(\hat{e}\right)$	0.94	0.72	0.73	0.84	0.82	0.81	0.80
		(0.06)	(0.06)	(0.07)	(0.07)	(0.07)	(0.07)
$\sigma\left(\Delta\hat{e}\right)/\sigma\left(\Delta\hat{\mathcal{E}}\right)$	0.99	1.00	1.00	0.99	0.99	0.99	0.99
$\text{corr}\left(\Delta\hat{e},\Delta\hat{\mathcal{E}}\right)$	0.99	1.00	1.00	1.00	0.99	0.99	0.99
$\sigma\left(\Delta\hat{e}^{w}\right)/\sigma\left(\Delta\hat{\mathcal{E}}\right)$	1.01	0.92	0.86	0.86	0.71	0.75	0.78
$\text{corr}\left(\Delta\hat{e}^{w},\Delta\hat{\mathcal{E}}\right)$	0.99	0.99	0.99	0.99	0.82	0.86	0.89
C. Backus-Smith (quarterly):							
$\text{corr}\left(\Delta\hat{e},\Delta\hat{C}-\Delta\hat{C}^{*}\right)$	−0.40	−0.49	−0.49	−0.57	−0.41	−0.43	−0.41
		(0.04)	(0.04)	(0.04)	(0.07)	(0.07)	(0.07)
$\sigma\left(\hat{i}-\hat{i}^{*}\right)/\sigma\left(\Delta\hat{\mathcal{E}}\right)$	0.06	0.06	0.06	0.12	0.16	0.15	0.13
$\rho\left(\hat{i}-\hat{i}^{*}\right)$	0.90	0.96	0.96	0.97	0.96	0.97	0.97
$\rho\left(\hat{i}\right)$	0.97	0.96	0.96	0.97	0.97	0.96	0.97
D. Forward premium (monthly):							
Fama β	−0.81	−4.88	−4.51	−2.78	−0.48	−0.72	−0.92
		(2.51)	(2.30)	(1.51)	(0.93)	(1.16)	(1.28)
Fama R^2	0.01	0.03	0.04	0.06	0.01	0.02	0.02
		(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)
Carry trade SR	0.35	0.46	0.47	0.51	0.23	0.24	0.24
		(0.15)	(0.16)	(0.24)	(0.14)	(0.15)	(0.15)
E. International business cycle moments (quarterly):							
$\sigma\left(\Delta\hat{C}\right)/\sigma\left(\Delta\hat{Y}\right)$	0.81	0.11	0.20	0.36	0.71	0.85	0.87
$\text{corr}\left(\Delta\hat{C},\Delta\hat{Y}\right)$	0.64	−0.89	−0.95	−0.97	−0.15	0.38	0.39
$\text{corr}\left(\Delta\hat{I},\Delta\hat{Y}\right)$	0.76	0.91	1.00	1.00	0.94	0.81	0.80
$\text{corr}\left(\Delta\hat{Y},\Delta\hat{Y}^{*}\right)$	0.50	−1.00	0.92	0.99	0.03	0.45	0.46
$\text{corr}\left(\Delta\hat{C},\Delta\hat{C}^{*}\right)$	0.54	−1.00	0.98	0.99	0.64	0.77	0.82
$\text{corr}\left(\Delta\hat{I},\Delta\hat{I}^{*}\right)$	0.45	−1.00	0.99	1.00	0.69	0.72	0.73
F. Terms of trade and net exports (quarterly):							
$\sigma\left(\Delta\hat{s}\right)/\sigma\left(\Delta\hat{\mathcal{E}}\right)$	0.25	0.97	0.97	0.98	0.98	0.98	0.98
$\text{corr}\left(\Delta\hat{c},\Delta\hat{\mathcal{E}}\right)$	0.20	−0.99	−0.99	−0.98	−0.99	−0.99	−0.99
$\sigma\left(\Delta\widehat{NX}\right)/\sigma\left(\Delta\hat{e}\right)$	0.09	0.12	0.11	0.08	0.11	0.11	0.11
$\text{corr}\left(\Delta\widehat{NX},\hat{e}\right)$	0.35	0.65	0.63	0.55	0.67	0.67	0.66

Note: The moments in Column "Data" are from Itskhoki and Mukhin (2021) except that the moments on forward premium puzzle are from Lustig, Stathopoulos, and Verdelhan (2019) as Table 4. Column "Δ_t" reports the simulated moments with a single "$\varepsilon_{\Delta t}$" shock, similar for Columns "θ_t" and "D_{nt}". Column "Domestic" reports the simulated moments with shocks $(\varepsilon_{\theta t}, \varepsilon_{\Delta t}, \varepsilon_{nt}, \varepsilon_{At}, \varepsilon_{it})$ by matching six moments in Panel D and regression coefficients in Column "Data" of Table 4, and the estimates are: $\sigma_\theta = 0.0001$, $\sigma_n = 0.12$, $\sigma_A = 0.023$, $\sigma_r = 0.0004$; Column "Global-1" matches the same moments as "Domestic" with all specified shocks excluding $\varepsilon_{\Gamma t}$, and the estimates are: $\sigma_\Delta^g = 0.050$, $\sigma_\theta = 0.022$, $\sigma_\theta^g = 0.0001$, $\sigma_n = 0.30$, $\sigma_A = 0.026$, $\sigma_A^g = 0.036$, $\sigma_r = 0.0001$, $\sigma_r^g = 0.0012$; Column "Global-2" matches the same moments as "Domestic" based on all shocks with estimates: $\sigma_\Delta^g = 0.014$, $\sigma_\theta = 0.0043$, $\sigma_\theta^g = 0.0016$, $\sigma_n = 0.34$, $\sigma_A = 0.024$, $\sigma_A^g = 0.041$, $\sigma_r = 0.0001$, $\sigma_r^g = 0.0012$, $\sigma_\Gamma = 0.81$. Monthly variables are translated into quarterly values in Panels A, B, C, E, F.

Table D8: Model moments under LCP scheme with households holding risky assets

Moments	Data	Single-Type Shocks			Multiple Shocks		
		D_{nt}	Δ_t	θ_t	Domestic	Global-1	Global-2
A. Exchange rate disconnect (quarterly):							
$\rho\left(\Delta\hat{\mathcal{E}}\right)$	≈ 0	-0.09	-0.08	-0.07	-0.08	-0.07	-0.07
		(0.09)	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)
$\sigma\left(\Delta\hat{\mathcal{E}}\right)/\sigma\left(\Delta\hat{Y}\right)$	5.20	5.70	2.39	2.64	2.96	2.50	2.50
$\sigma\left(\Delta\hat{\mathcal{E}}\right)/\sigma\left(\Delta\hat{C}\right)$	6.30	81.96	15.96	10.83	9.77	6.17	6.19
B. Real exchange rate and the PPP (quarterly):							
$\rho\left(\hat{e}\right)$	0.94	0.79	0.79	0.80	0.81	0.82	0.82
		(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
$\sigma\left(\Delta\hat{e}\right)/\sigma\left(\Delta\hat{\mathcal{E}}\right)$	0.99	1.00	1.00	0.99	0.99	0.99	0.99
$\text{corr}\left(\Delta\hat{e},\Delta\hat{\mathcal{E}}\right)$	0.99	1.00	1.00	1.00	1.00	1.00	1.00
$\sigma\left(\Delta\hat{e}^w\right)/\sigma\left(\Delta\hat{\mathcal{E}}\right)$	1.01	0.80	0.76	0.80	0.68	0.64	0.64
$\text{corr}\left(\Delta\hat{e}^w,\Delta\hat{\mathcal{E}}\right)$	0.99	1.00	1.00	1.00	0.65	0.51	0.50
C. Backus-Smith (quarterly):							
$\text{corr}\left(\Delta\hat{e},\Delta\hat{C}-\Delta\hat{C}^*\right)$	-0.40	-0.68	-0.69	-0.71	-0.18	-0.27	-0.35
		(0.04)	(0.04)	(0.04)	(0.09)	(0.08)	(0.07)
$\sigma\left(\hat{i}-\hat{i}^*\right)/\sigma\left(\Delta\hat{\mathcal{E}}\right)$	0.06	0.02	0.02	0.03	0.06	0.07	0.07
$\rho\left(\hat{i}-\hat{i}^*\right)$	0.90	0.98	0.98	0.98	0.96	0.96	0.97
$\rho\left(\hat{i}\right)$	0.97	0.98	0.98	0.98	0.96	0.92	0.92
D. Forward premium (monthly):							
Fama β	-0.81	-16.55	-7.95	-5.60	-0.55	-0.68	-0.97
		(10.61)	(8.38)	(7.24)	(1.71)	(1.65)	(1.82)
Fama R^2	0.01	0.02	0.01	0.01	0.01	0.01	0.01
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Carry trade SR	0.35	0.34	0.13	0.09	0.09	0.10	0.11
		(0.15)	(0.16)	(0.15)	(0.14)	(0.14)	(0.14)
E. International business cycle moments (quarterly):							
$\sigma\left(\Delta\hat{C}\right)/\sigma\left(\Delta\hat{Y}\right)$	0.81	0.07	0.15	0.24	0.30	0.40	0.40
$\text{corr}\left(\Delta\hat{C},\Delta\hat{Y}\right)$	0.64	-0.95	-0.96	-0.97	-0.18	0.52	0.50
$\text{corr}\left(\Delta\hat{I},\Delta\hat{Y}\right)$	0.76	1.00	1.00	1.00	0.98	0.97	0.97
$\text{corr}\left(\Delta\hat{Y},\Delta\hat{Y}^*\right)$	0.50	-1.00	0.98	-0.96	-0.50	0.46	0.47
$\text{corr}\left(\Delta\hat{C},\Delta\hat{C}^*\right)$	0.54	-1.00	0.99	0.99	0.35	0.80	0.82
$\text{corr}\left(\Delta\hat{I},\Delta\hat{I}^*\right)$	0.45	-1.00	1.00	1.00	0.35	0.57	0.57
F. Terms of trade and net exports (quarterly):							
$\sigma\left(\Delta\hat{s}\right)/\sigma\left(\Delta\hat{\mathcal{E}}\right)$	0.25	1.00	0.99	0.99	1.00	1.00	1.00
$\text{corr}\left(\Delta\hat{c},\Delta\hat{\mathcal{E}}\right)$	0.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
$\sigma\left(\Delta\widehat{NX}\right)/\sigma\left(\Delta\hat{e}\right)$	0.09	0.09	0.08	0.08	0.08	0.07	0.07
$\text{corr}\left(\Delta\widehat{NX},\hat{e}\right)$	0.35	0.75	0.76	0.76	0.76	0.76	0.77

Note: The moments in Column "Data" are from Itskhoki and Mukhin (2021) except that the moments on forward premium puzzle are from Lustig, Stathopoulos, and Verdelhan (2019) as Table 4. Column "Δ_t" reports the simulated moments with a single "$\varepsilon_{\Delta t}$" shock, similar for Columns "θ_t" and "D_{nt}". Column "Domestic" reports the simulated moments with shocks $(\varepsilon_{\theta t}, \varepsilon_{\Delta t}, \varepsilon_{nt}, \varepsilon_{At}, \varepsilon_{it})$ by matching six moments in Panel D and regression coefficients in Column "Data" of Table 4, and the estimates are: $\sigma_\theta = 0.11$, $\sigma_\psi = 0.60$, $\sigma_A = 0.028$, $\sigma_r = 0.0004$; Column "Global-1" matches the same moments as "Domestic" with all specified shocks excluding $\varepsilon_{\Gamma t}$, and the estimates are: $\sigma_\Delta^g = 0.052$, $\sigma_\theta = 0.13$, $\sigma_\theta^g = 0.0054$, $\sigma_n = 0.23$, $\sigma_A = 0.030$, $\sigma_A^g = 0.0044$, $\sigma_r = 0.0003$, $\sigma_r^g = 0.0010$; Column "Global-2" matches the same moments as "Domestic" based on all shocks with estimates: $\sigma_\Delta^g = 0.053$, $\sigma_\theta = 0.15$, $\sigma_\theta^g = 0.0056$, $\sigma_n = 0.20$, $\sigma_A = 0.035$, $\sigma_A^g = 0.0042$, $\sigma_r = 0.0003$, $\sigma_r^g = 0.0011$, $\sigma_\Gamma = 0.21$. Monthly variables are translated into quarterly values in Panels A, B, C, E, F.

Table D9: Model moments under PCP scheme with sticky wage and without households holding risky assets

Moments	Data	Single-Type Shocks D_{nt}	Δ_t	θ_t	Multiple Shocks Domestic	Global-1	Global-2
A. Exchange rate disconnect (quarterly):							
$\rho\left(\Delta\hat{\mathcal{E}}\right)$	≈ 0	-0.12	-0.12	-0.11	-0.11	-0.11	-0.11
		(0.09)	(0.09)	(0.09)	(0.09)	(0.08)	(0.08)
$\sigma\left(\Delta\hat{\mathcal{E}}\right)/\sigma\left(\Delta\hat{Y}\right)$	5.20	7.68	4.04	3.14	5.42	4.46	4.46
$\sigma\left(\Delta\hat{\mathcal{E}}\right)/\sigma\left(\Delta\hat{C}\right)$	6.30	38.70	16.85	9.15	4.71	4.89	4.76
B. Real exchange rate and the PPP (quarterly):							
$\rho\left(\hat{e}\right)$	0.94	0.74	0.74	0.79	0.83	0.83	0.83
		(0.06)	(0.06)	(0.07)	(0.07)	(0.07)	(0.07)
$\sigma\left(\Delta\hat{e}\right)/\sigma\left(\Delta\hat{\mathcal{E}}\right)$	0.99	1.00	1.00	0.99	0.99	0.99	0.99
$\text{corr}\left(\Delta\hat{e},\Delta\hat{\mathcal{E}}\right)$	0.99	1.00	1.00	1.00	0.99	0.99	0.99
$\sigma\left(\Delta\hat{e}^{w}\right)/\sigma\left(\Delta\hat{\mathcal{E}}\right)$	1.01	1.00	1.00	1.00	0.97	0.97	0.97
$\text{corr}\left(\Delta\hat{e}^{w},\Delta\hat{\mathcal{E}}\right)$	0.99	1.00	0.99	0.99	0.99	0.99	0.99
C. Backus-Smith (quarterly):							
$\text{corr}\left(\Delta\hat{e},\Delta\hat{C}-\Delta\hat{C}^{*}\right)$	-0.40	-0.60	-0.57	-0.60	-0.47	-0.47	-0.47
		(0.04)	(0.04)	(0.04)	(0.06)	(0.06)	(0.06)
$\sigma\left(\hat{i}-\hat{i}^{*}\right)/\sigma\left(\Delta\hat{\mathcal{E}}\right)$	0.06	0.07	0.07	0.09	0.16	0.15	0.16
$\rho\left(\hat{i}-\hat{i}^{*}\right)$	0.90	0.96	0.96	0.96	0.96	0.97	0.97
$\rho\left(\hat{i}\right)$	0.97	0.96	0.95	0.96	0.97	0.89	0.90
D. Forward premium (monthly):							
Fama β	-0.81	-4.15	-4.14	-3.59	-0.61	-0.73	-0.72
		(2.18)	(2.04)	(1.82)	(0.98)	(1.10)	(1.10)
Fama R^2	0.01	0.04	0.04	0.05	0.02	0.02	0.02
		(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)
Carry trade *SR*	0.35	0.48	0.51	0.50	0.25	0.26	0.26
		(0.15)	(0.16)	(0.18)	(0.15)	(0.15)	(0.15)
E. International business cycle moments (quarterly):							
$\sigma\left(\Delta\hat{C}\right)/\sigma\left(\Delta\hat{Y}\right)$	0.81	0.20	0.24	0.34	1.15	0.91	0.94
$\text{corr}\left(\Delta\hat{C},\Delta\hat{Y}\right)$	0.64	-0.97	-0.97	-0.98	0.15	0.54	0.55
$\text{corr}\left(\Delta\hat{I},\Delta\hat{Y}\right)$	0.76	0.94	1.00	1.00	0.82	0.82	0.81
$\text{corr}\left(\Delta\hat{Y},\Delta\hat{Y}^{*}\right)$	0.50	-1.00	-0.93	-0.75	-0.21	0.38	0.39
$\text{corr}\left(\Delta\hat{C},\Delta\hat{C}^{*}\right)$	0.54	-1.00	0.92	0.95	0.84	0.63	0.64
$\text{corr}\left(\Delta\hat{I},\Delta\hat{I}^{*}\right)$	0.45	-1.00	1.00	1.00	0.59	0.72	0.72
F. Terms of trade and net exports (quarterly):							
$\sigma\left(\Delta\hat{s}\right)/\sigma\left(\Delta\hat{\mathcal{E}}\right)$	0.25	0.97	0.97	0.98	0.98	0.98	0.98
$\text{corr}\left(\Delta\hat{c},\Delta\hat{\mathcal{E}}\right)$	0.20	-0.99	-0.99	-0.99	-0.99	-0.99	-0.99
$\sigma\left(\Delta\widehat{NX}\right)/\sigma\left(\Delta\hat{e}\right)$	0.09	0.12	0.11	0.11	0.12	0.12	0.12
$\text{corr}\left(\Delta\widehat{NX},\hat{e}\right)$	0.35	0.66	0.65	0.64	0.68	0.68	0.68

Note: The moments in Column "Data" are from Itskhoki and Mukhin (2021) except that the moments on forward premium puzzle are from Lustig, Stathopoulos, and Verdelhan (2019) as Table 4. Column "Δ_t" reports the simulated moments with a single "$\varepsilon_{\Delta t}$" shock, similar for Columns "θ_t" and "D_{nt}". Column "Domestic" reports the simulated moments with shocks $(\varepsilon_{\theta t}, \varepsilon_{\Delta t}, \varepsilon_{nt}, \varepsilon_{At}, \varepsilon_{it})$ by matching six moments in Panel D and regression coefficients in Column "Data" of Table 4, and the estimates are: $\sigma_\theta = 0.052$, $\sigma_n = 0.30$, $\sigma_A = 0.029$, $\sigma_r = 0.0004$; Column "Global-1" matches the same moments as "Domestic" with all specified shocks excluding $\varepsilon_{\Gamma t}$, and the estimates are: $\sigma_\Delta^g = 0.12$, $\sigma_\theta = 0.045$, $\sigma_\theta^g = 0.0001$, $\sigma_n = 0.50$, $\sigma_A = 0.030$, $\sigma_A^g = 0.018$, $\sigma_r = 0.0001$, $\sigma_r^g = 0.0028$; Column "Global-2" matches the same moments as "Domestic" based on all shocks with estimates: $\sigma_\Delta^g = 0.15$, $\sigma_\theta = 0.040$, $\sigma_\theta^g = 0.0064$, $\sigma_n = 0.46$, $\sigma_A = 0.029$, $\sigma_A^g = 0.019$, $\sigma_r = 0.0001$, $\sigma_r^g = 0.0026$, $\sigma_\Gamma = 0.45$. Monthly variables are translated into quarterly values in Panels A, B, C, E, F.

Table D10: Regressions coefficients matching on term structure of currency carry trade under PCP scheme with households holding risky assets

		Single-Type Shocks			Multiple Shocks		
Moments	Data	Δ_t	θ_t	D_{nt}	Domestic	Global-1	Global-2
A. Short-term interest rate diff. (foreign-minus-home):							
Bond local currency return diff.	-0.78	-4.29	-0.68	-0.22	-0.50	-0.43	-0.46
	(0.32)	(4.42)	(0.25)	(0.04)	(1.17)	(1.05)	(1.12)
Currency excess return	1.81	5.51	3.78	5.88	1.48	1.72	1.92
	(1.47)	(2.30)	(1.51)	(2.51)	(0.93)	(1.16)	(1.28)
Bond dollar return diff.	1.03	1.22	3.11	5.66	0.99	1.31	1.46
	(1.51)	(2.16)	(1.32)	(2.53)	(1.10)	(1.21)	(1.28)
B. Yield curve slope diff. (foreign-minus-home):							
Bond local currency return diff.	2.18	2.93	0.76	-0.48	2.26	2.24	2.25
	(0.50)	(1.58)	(0.06)	(0.12)	(1.02)	(1.00)	(1.01)
Currency excess return	-1.23	-1.93	-3.71	3.19	-1.27	-1.24	-1.28
	(1.99)	(1.08)	(1.11)	(3.75)	(0.67)	(0.75)	(0.78)
Bond dollar return diff.	0.95	1.02	-2.95	2.73	1.00	0.98	0.95
	(2.00)	(0.64)	(1.08)	(3.78)	(0.81)	(0.94)	(0.95)

Note: Variables of the first column are defined in (15). Column "Data" is the panel regression results of the US dollar against AE currencies from Table 1 in Lustig, Stathopoulos, and Verdelhan (2019) with the sample period "Jan 1995-Dec 2015". Similar to Table D7, Columns "Δ_t", "θ_t", "D_{nt}", "Domestic", "Global-1" and "Global-2" report the regression results based on simulated data. Standard deviations are reported in bracket.

Table D11: Regressions coefficients matching on term structure of currency carry trade under LCP scheme with households holding risky assets

		Single-Type Shocks			Multiple Shocks		
Moments	Data	Δ_t	θ_t	D_{nt}	Domestic	Global-1	Global-2
A. Short-term interest rate diff. (foreign-minus-home):							
Bond local currency return diff.	-0.78	-5.84	-1.81	-3.37	-0.33	-0.39	-0.48
	(0.32)	(21.05)	(1.69)	(1.47)	(1.81)	(1.78)	(1.66)
Currency excess return	1.81	8.95	6.60	17.55	1.55	1.68	1.97
	(1.47)	(8.38)	(7.24)	(10.61)	(1.71)	(1.65)	(1.82)
Bond dollar return diff.	1.03	3.02	4.82	14.18	1.24	1.28	1.52
	(1.51)	(12.94)	(5.62)	(9.15)	(1.92)	(1.88)	(1.86)
B. Yield curve slope diff. (foreign-minus-home):							
Bond local currency return diff.	2.18	3.16	2.17	4.14	2.20	2.16	2.07
	(0.50)	(1.61)	(0.76)	(1.67)	(1.09)	(1.05)	(0.99)
Currency excess return	-1.23	-1.52	-8.58	-21.07	-1.27	-1.30	-1.34
	(1.99)	(0.78)	(3.94)	(11.37)	(1.07)	(0.98)	(1.00)
Bond dollar return diff.	0.95	1.66	-6.42	-16.93	0.89	0.82	0.68
	(2.00)	(0.89)	(3.18)	(9.70)	(1.11)	(1.02)	(1.02)

Note: Variables of the first column are defined in (15). Column "Data" is the panel regression results of the US dollar against AE currencies from Table 1 in Lustig, Stathopoulos, and Verdelhan (2019) with the sample period "Jan 1995-Dec 2015". Similar to Table D8, Columns "Δ_t", "θ_t", "D_{nt}", "Domestic", "Global-1" and "Global-2" report the regression results based on simulated data. Standard deviations are reported in bracket.

Table D12: Regressions coefficients matching on term structure of currency carry trade under PCP scheme with sticky wage and without households holding risky assets

Moments	Data	Single-Type Shocks Δ_t	θ_t	D_{nt}	Multiple Shocks Domestic	Global-1	Global-2
A. Short-term interest rate diff. (foreign-minus-home):							
Bond local currency return diff.	-0.78	-4.78	-0.93	-0.48	-0.42	-0.40	-0.42
	(0.32)	(4.58)	(0.39)	(0.06)	(0.90)	(0.88)	(0.92)
Currency excess return	1.81	5.14	4.59	5.15	1.61	1.73	1.72
	(1.47)	(2.04)	(1.82)	(2.18)	(0.98)	(1.10)	(1.10)
Bond dollar return diff.	1.03	0.34	3.66	4.67	1.19	1.33	1.31
	(1.51)	(2.57)	(1.44)	(2.14)	(1.07)	(1.15)	(1.15)
B. Yield curve slope diff. (foreign-minus-home):							
Bond local currency return diff.	2.18	2.95	1.23	-0.05	2.19	2.27	2.29
	(0.50)	(1.55)	(0.29)	(0.26)	(0.98)	(1.01)	(1.02)
Currency excess return	-1.23	-1.73	-5.23	-2.85	-1.31	-1.39	-1.38
	(1.99)	(0.90)	(1.68)	(2.77)	(0.79)	(0.84)	(0.83)
Bond dollar return diff.	0.95	1.24	-4.01	-2.86	0.87	0.85	0.90
	(2.00)	(0.74)	(1.40)	(2.73)	(0.99)	(1.06)	(1.03)

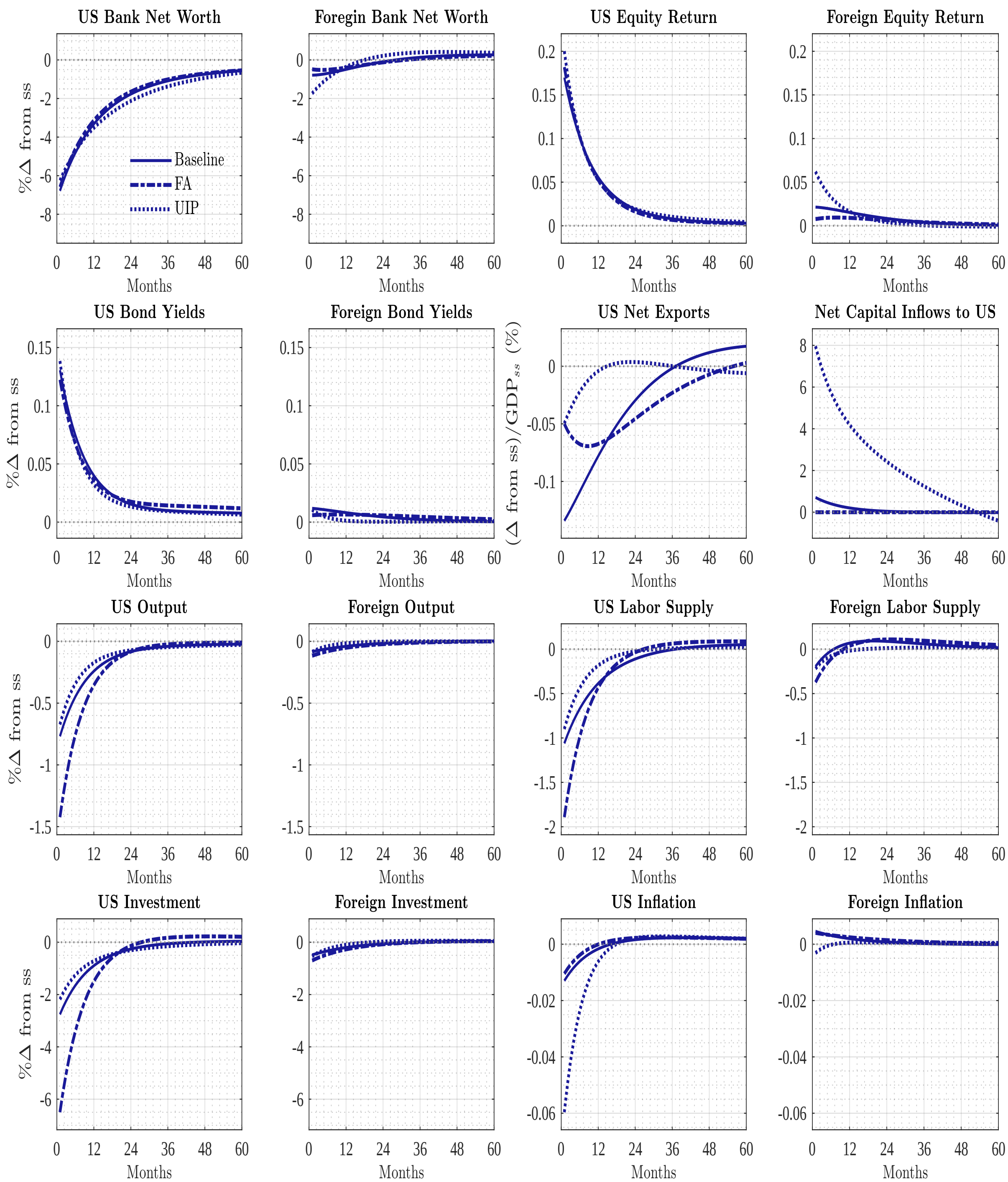
Note: Variables of the first column are defined in (15). Column "Data" is the panel regression results of the US dollar against AE currencies from Table 1 in Lustig, Stathopoulos, and Verdelhan (2019) with the sample period "Jan 1995-Dec 2015". Similar to Table D9, Columns "Δ_t", "θ_t", "D_{nt}", "Domestic", "Global-1" and "Global-2" report the regression results based on simulated data. Standard deviations are reported in bracket.

Table D13: Empirical moments of international business cycles

Moments	CKM	IM	73-94	81-17	95-19
$\sigma\left(\Delta\hat{C}\right)/\sigma\left(\Delta\hat{Y}\right)$	0.82	0.81	0.81	0.80	0.81
$\text{corr}\left(\Delta\hat{C},\Delta\hat{Y}\right)$	0.64	0.63	0.63	0.61	0.64
$\text{corr}\left(\Delta\hat{I},\Delta\hat{Y}\right)$	0.81	0.75	0.82	0.74	0.76
$\text{corr}\left(\Delta\hat{Y},\Delta\hat{Y}^*\right)$	0.35	0.42	0.33	0.40	0.50
$\text{corr}\left(\Delta\hat{C},\Delta\hat{C}^*\right)$	0.30	0.40	0.26	0.40	0.54
$\text{corr}\left(\Delta\hat{I},\Delta\hat{I}^*\right)$	0.27	0.32	0.27	0.32	0.45

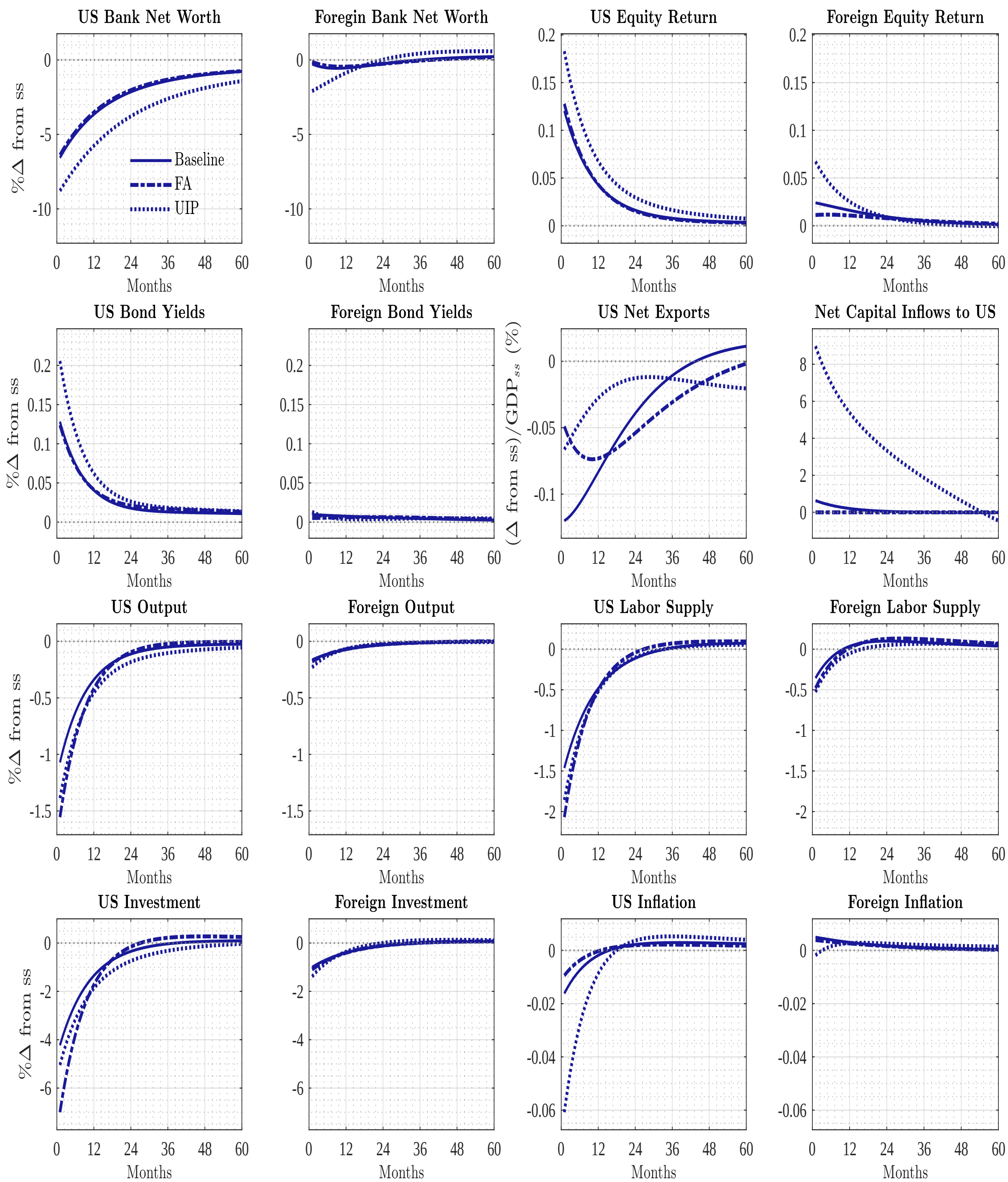
Note: Columns "CKM" and "IM" are the empirical moments of international business cycles from Table A2 in Itskhoki and Mukhin (2021) for the periods 1973-1994 and 1981-2017, respectively. Columns "73-94", "81-17", and "95-19" report our estimates for the periods 1973-1994, 1981-2017, and 1995-2019, respectively.

Figure D7: IRFs to conventional monetary policy shocks under the baseline, financial autarky and UIP cases of PCP scheme without households holding risky assets



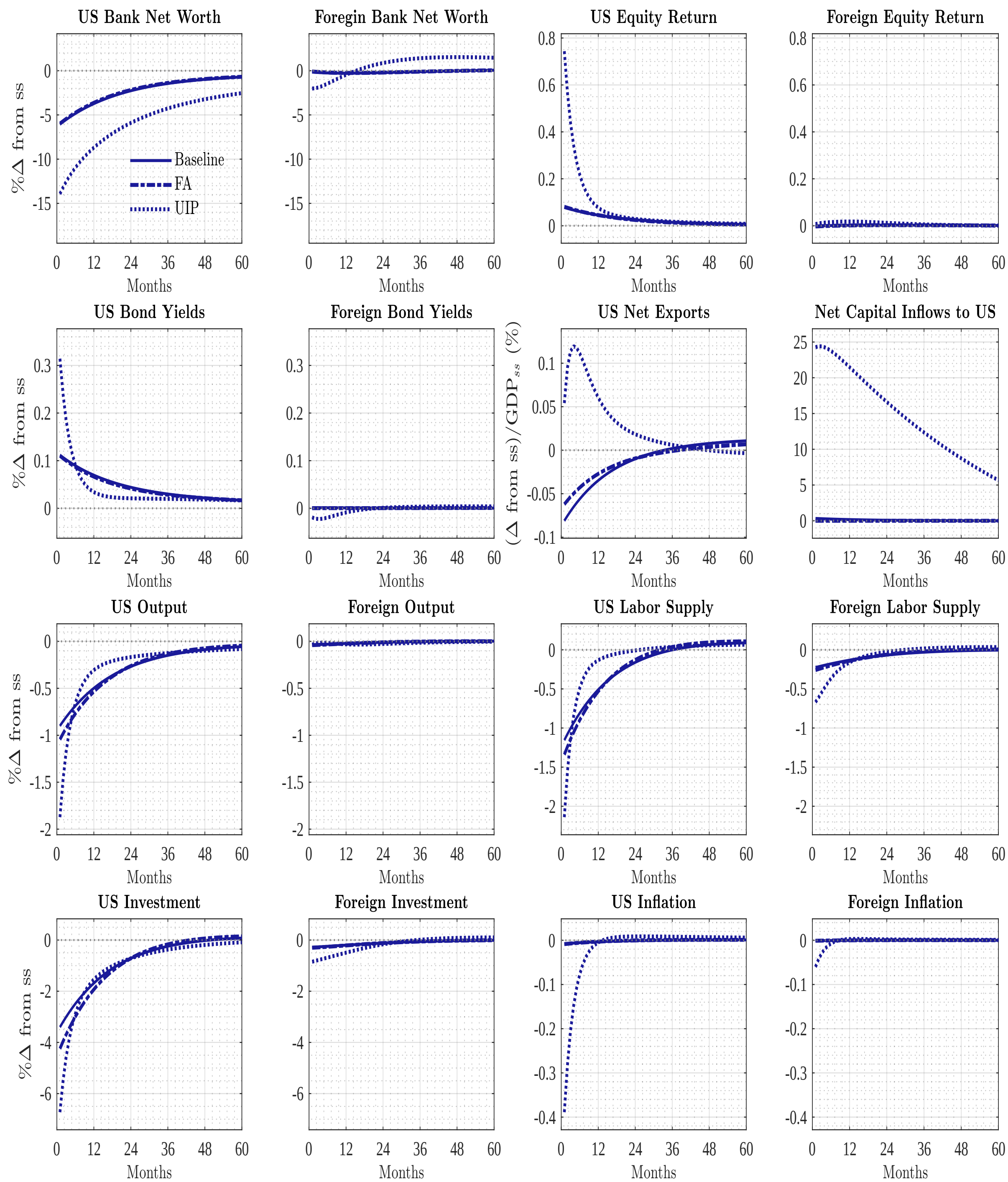
Note: The simulation results are based on the posterior mode of parameters in Table D2. In Panels "US Net Exports" and "Net Capital Inflows to US", the IRFs are reported as % of deviations from steady-state values relative to steady-state GDP. In the other panels, the IRFs are reported as % deviations from steady-state values.

Figure D8: IRFs to conventional monetary policy shocks under the baseline, financial autarky and UIP cases of PCP scheme with households holding risky assets



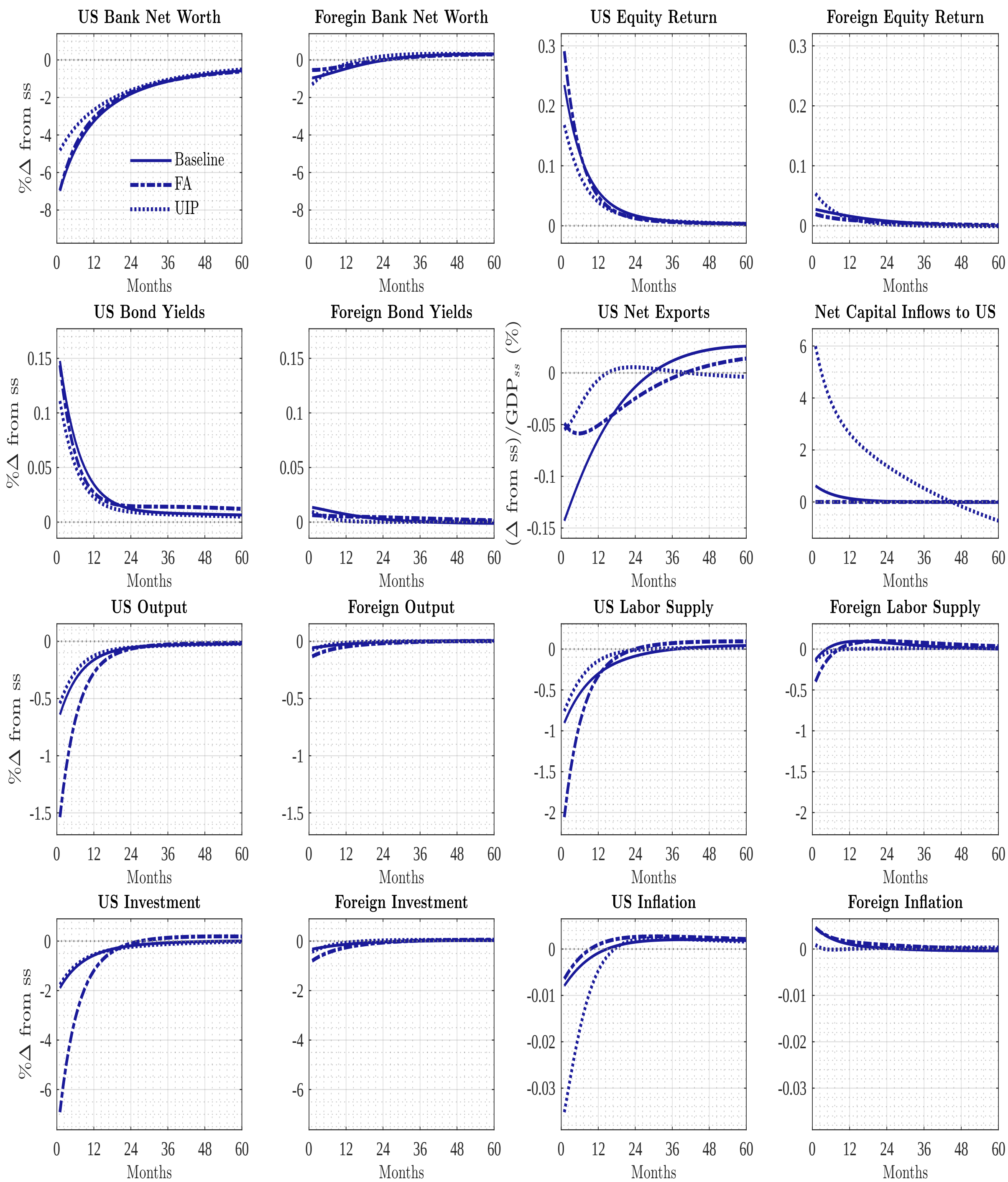
Note: The simulation results are based on the posterior mode of parameters in Table D3. In Panels "US Net Exports" and "Net Capital Inflows to US", the IRFs are reported as % of deviations from steady-state values relative to steady-state GDP. In the other panels, the IRFs are reported as % deviations from steady-state values.

Figure D9: IRFs to conventional monetary policy shocks under the baseline, financial autarky and UIP cases of LCP scheme with households holding risky assets



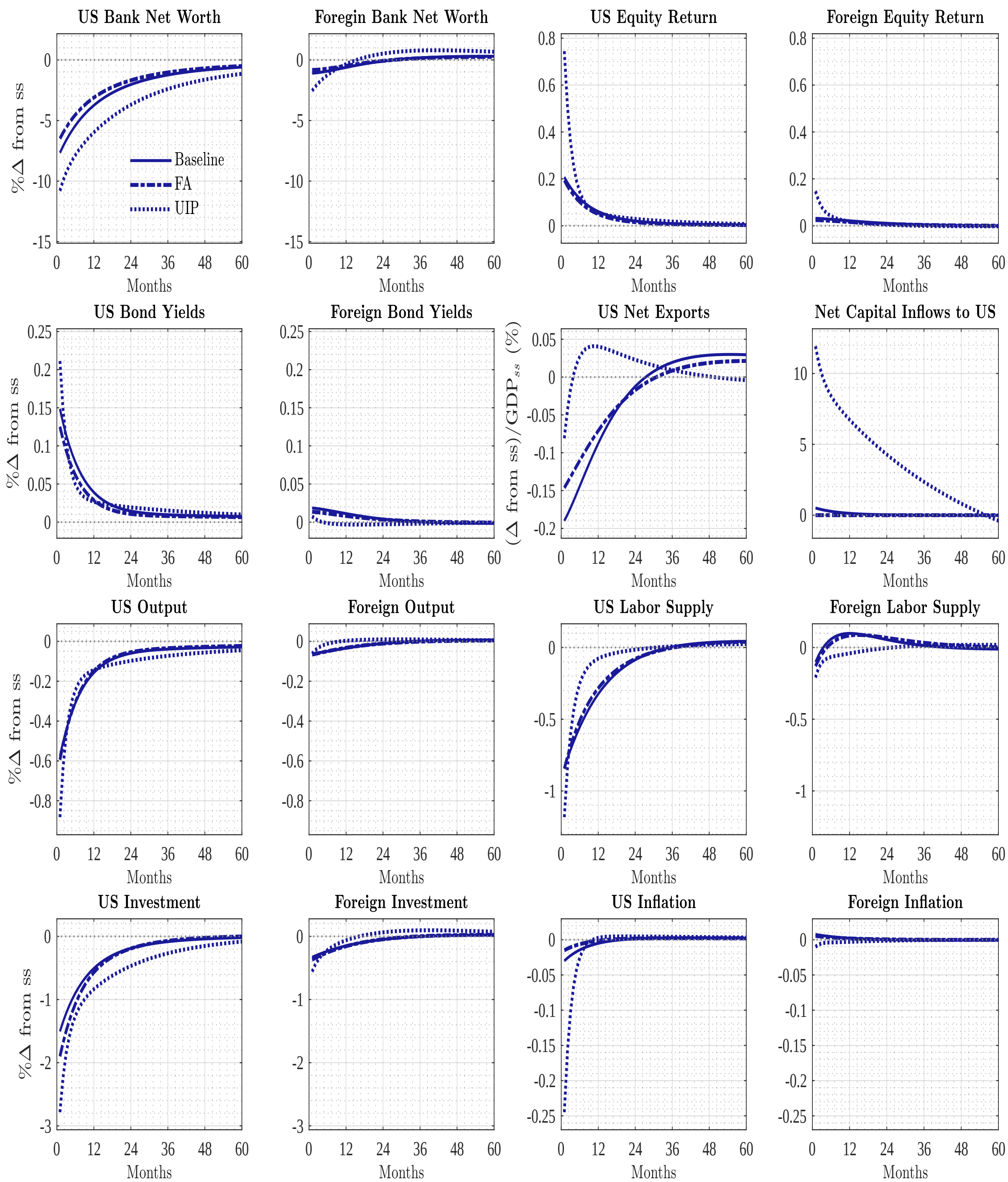
Note: The simulation results are based on the posterior mode of parameters in Table D4. In Panels "US Net Exports" and "Net Capital Inflows to US", the IRFs are reported as % of deviations from steady-state values relative to steady-state GDP. In the other panels, the IRFs are reported as % deviations from steady-state values.

Figure D10: IRFs to conventional monetary policy shocks under the baseline, financial autarky and UIP cases of PCP scheme with sticky wage and without households holding risky assets



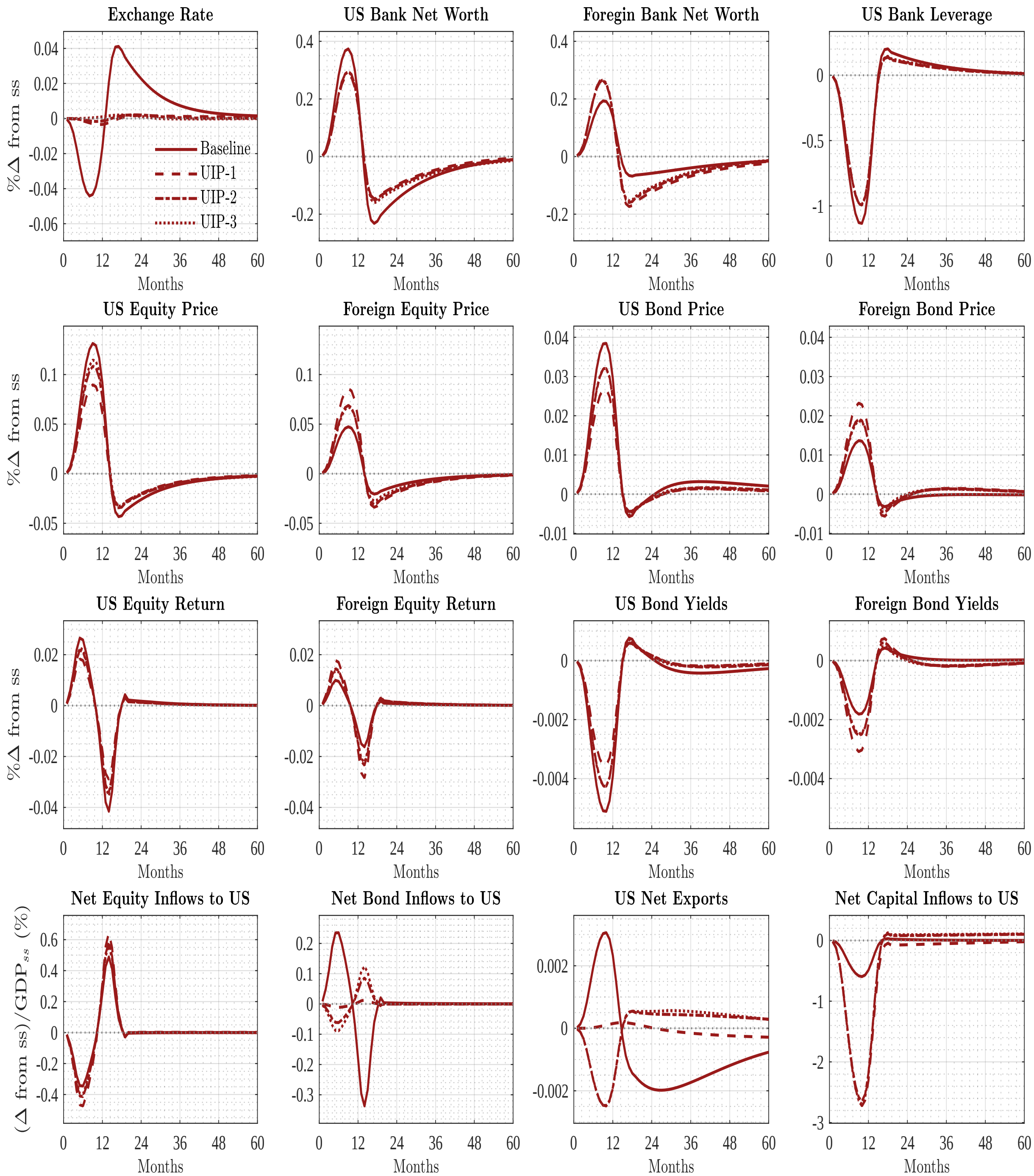
Note: The simulation results are based on the posterior mode of parameters in Table D5. In Panels "US Net Exports" and "Net Capital Inflows to US", the IRFs are reported as % of deviations from steady-state values relative to steady-state GDP. In the other panels, the IRFs are reported as % deviations from steady-state values.

Figure D11: IRFs to conventional monetary policy shocks under the baseline, financial autarky and UIP cases of PCP scheme without households holding risky assets for the US against the EU



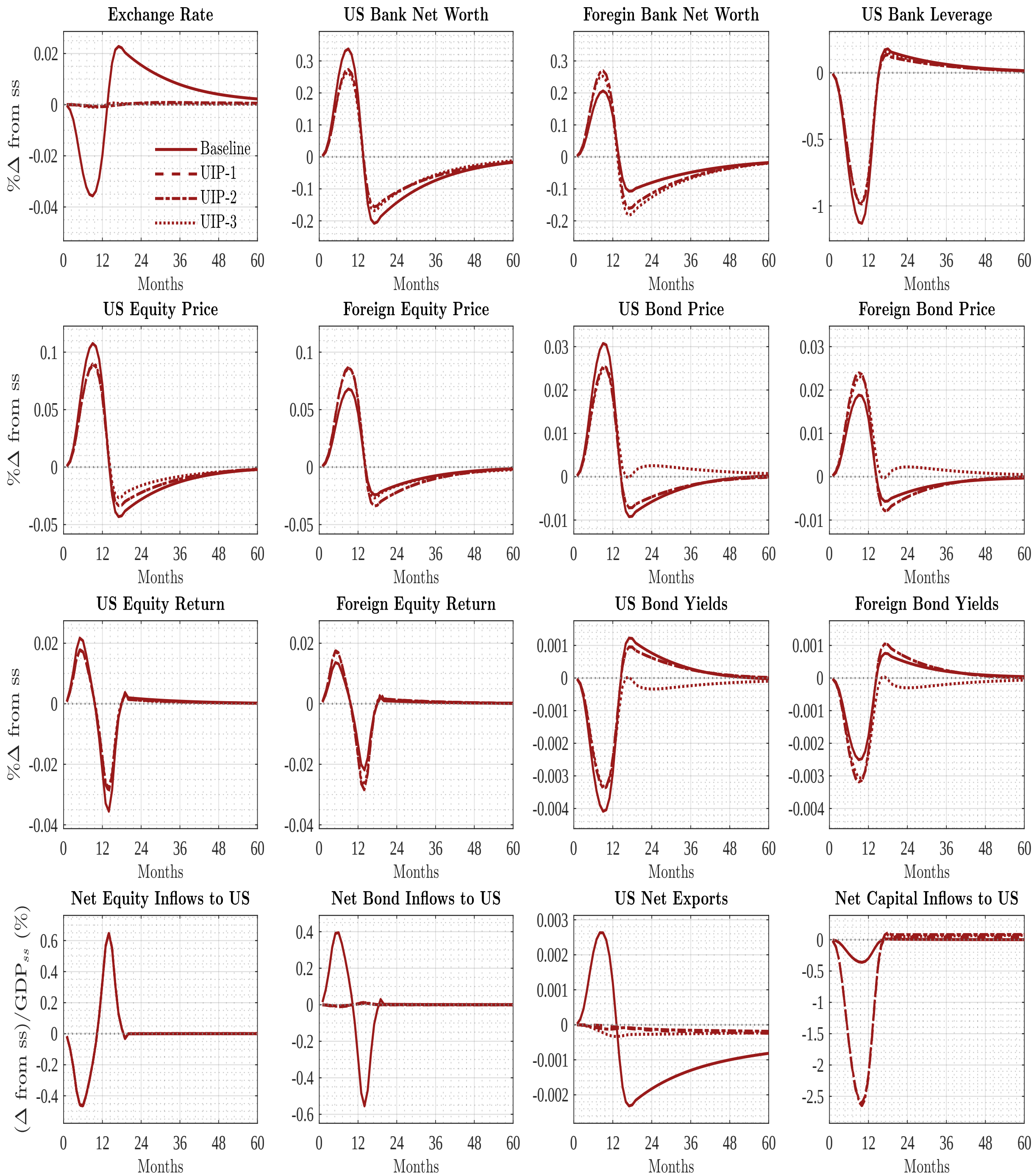
Note: The simulation results are based on the posterior mode of parameters in Table D6. In Panels "US Net Exports" and "Net Capital Inflows to US", the IRFs are reported as % of deviations from steady-state values relative to steady-state GDP. In the other panels, the IRFs are reported as % deviations from steady-state values.

Figure D12: IRFs of financial variables to "QE2" shocks under the baseline and UIP cases with ZLB constraints of PCP scheme with households holding risky assets



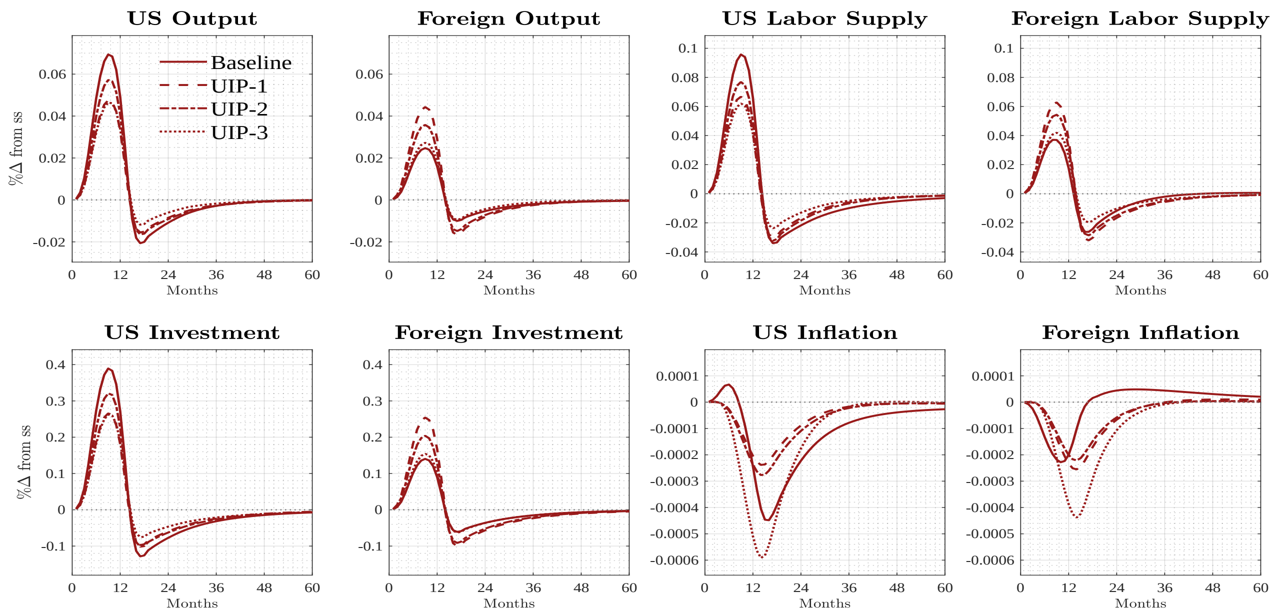
Note: The simulation results are based on the posterior mode of parameters from Columns "Baseline" and "UIP" in Table D3. In the last row, the IRFs are reported as % of deviations from steady-state values relative to steady-state GDP. In the other rows, the IRFs are reported as % deviations from steady-state values.

Figure D13: IRFs of financial variables to "QE2" shocks under the baseline and UIP cases with ZLB constraints of LCP scheme with households holding risky assets



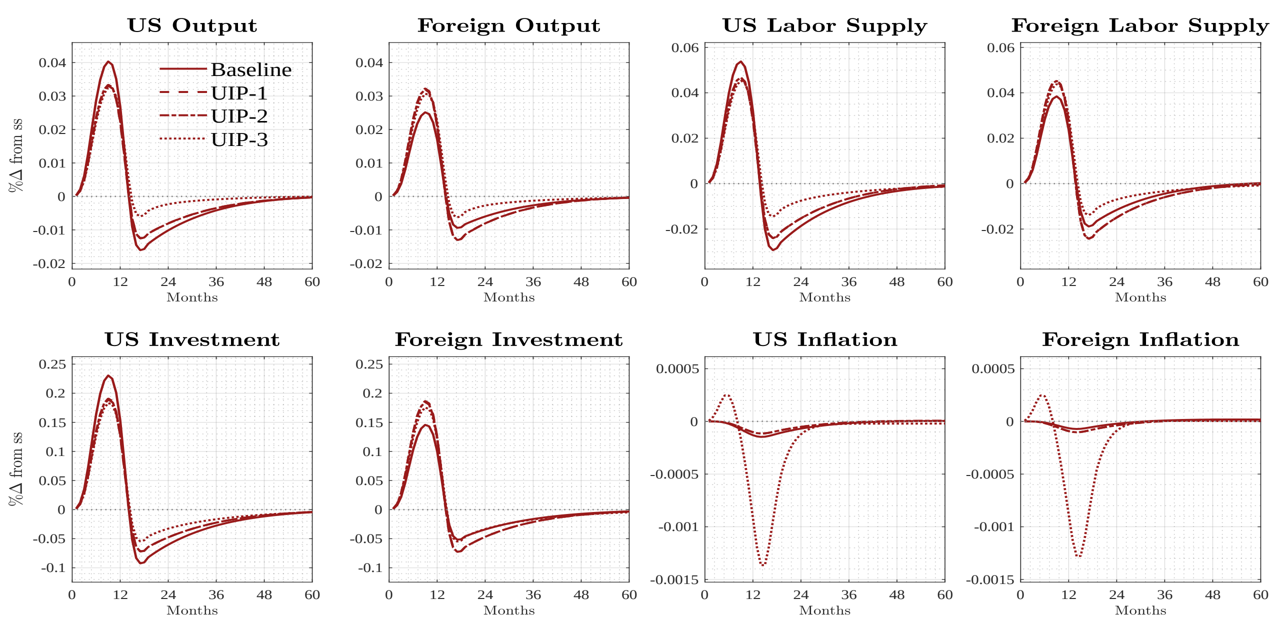
Note: The simulation results are based on the posterior mode of parameters from Columns "Baseline" and "UIP" in Table D4. In the last row, the IRFs are reported as % of deviations from steady-state values relative to steady-state GDP. In the other rows, the IRFs are reported as % deviations from steady-state values.

Figure D14: IRFs of real economic variables to "QE2" shocks under the baseline and UIP cases with ZLB constraints of PCP scheme with households holding risky assets



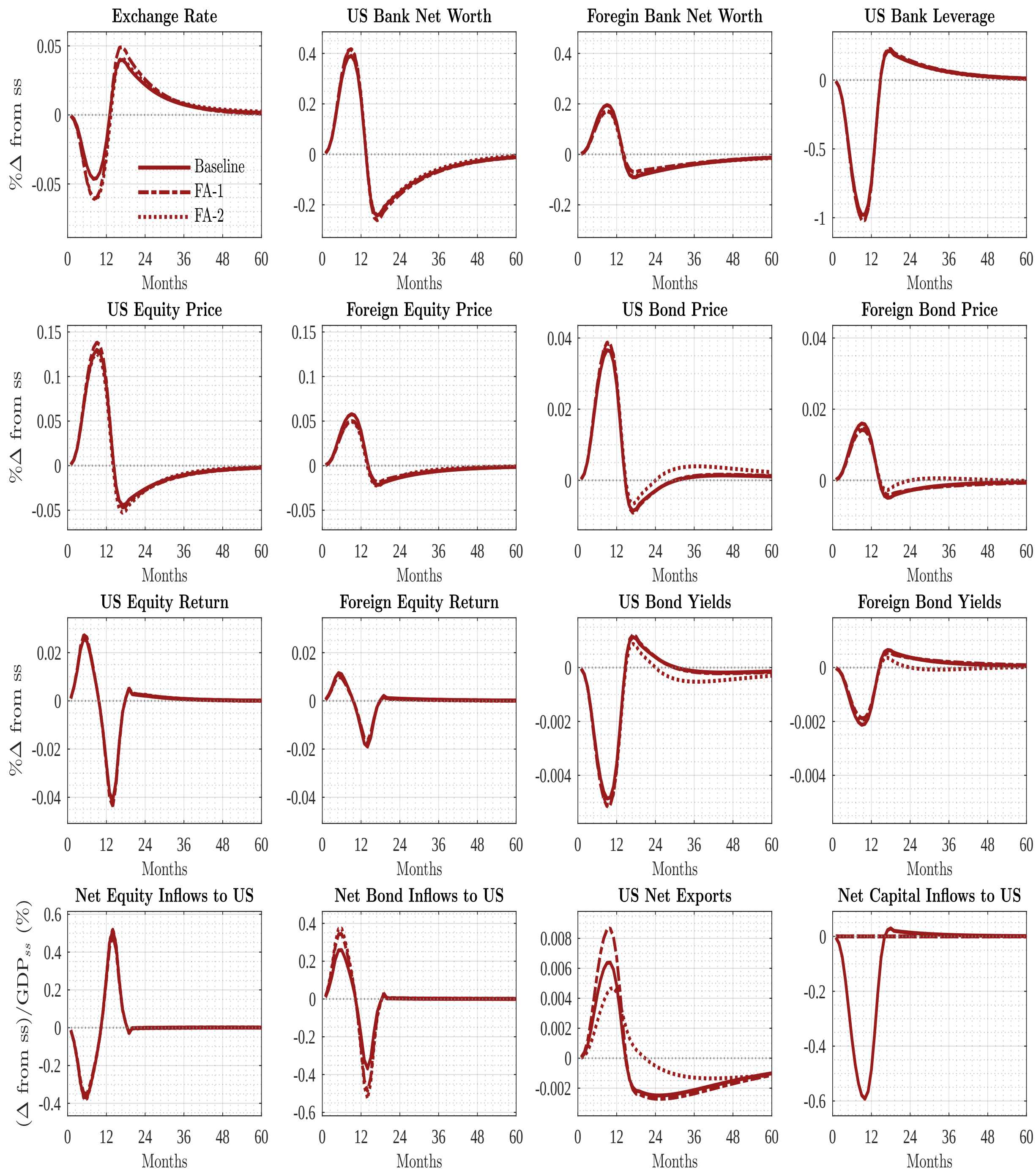
Note: The simulation results are based on the posterior mode of parameters from Columns "Baseline" and "UIP" in Table D3. The IRFs are reported as % deviations from steady-state values.

Figure D15: IRFs of real economic variables to "QE2" shocks under the baseline and UIP cases with ZLB constraints of LCP scheme with households holding risky assets



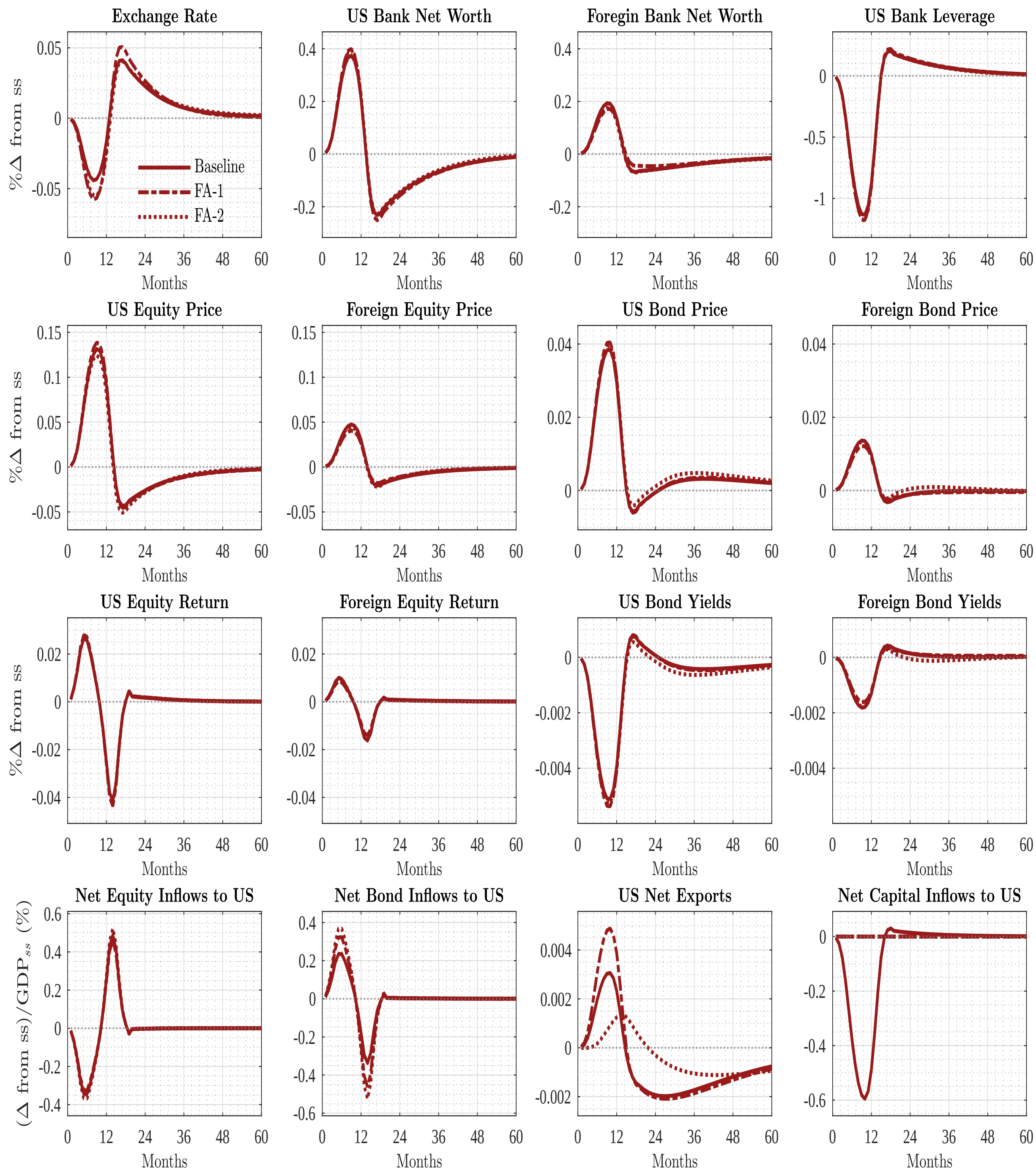
Note: The simulation results are based on the posterior mode of parameters from Columns "Baseline" and "UIP" in Table D4. The IRFs are reported as % deviations from steady-state values.

Figure D16: IRFs of financial variables to "QE2" shocks under the baseline and financial autarky cases with ZLB constraints of PCP scheme without households holding risky assets



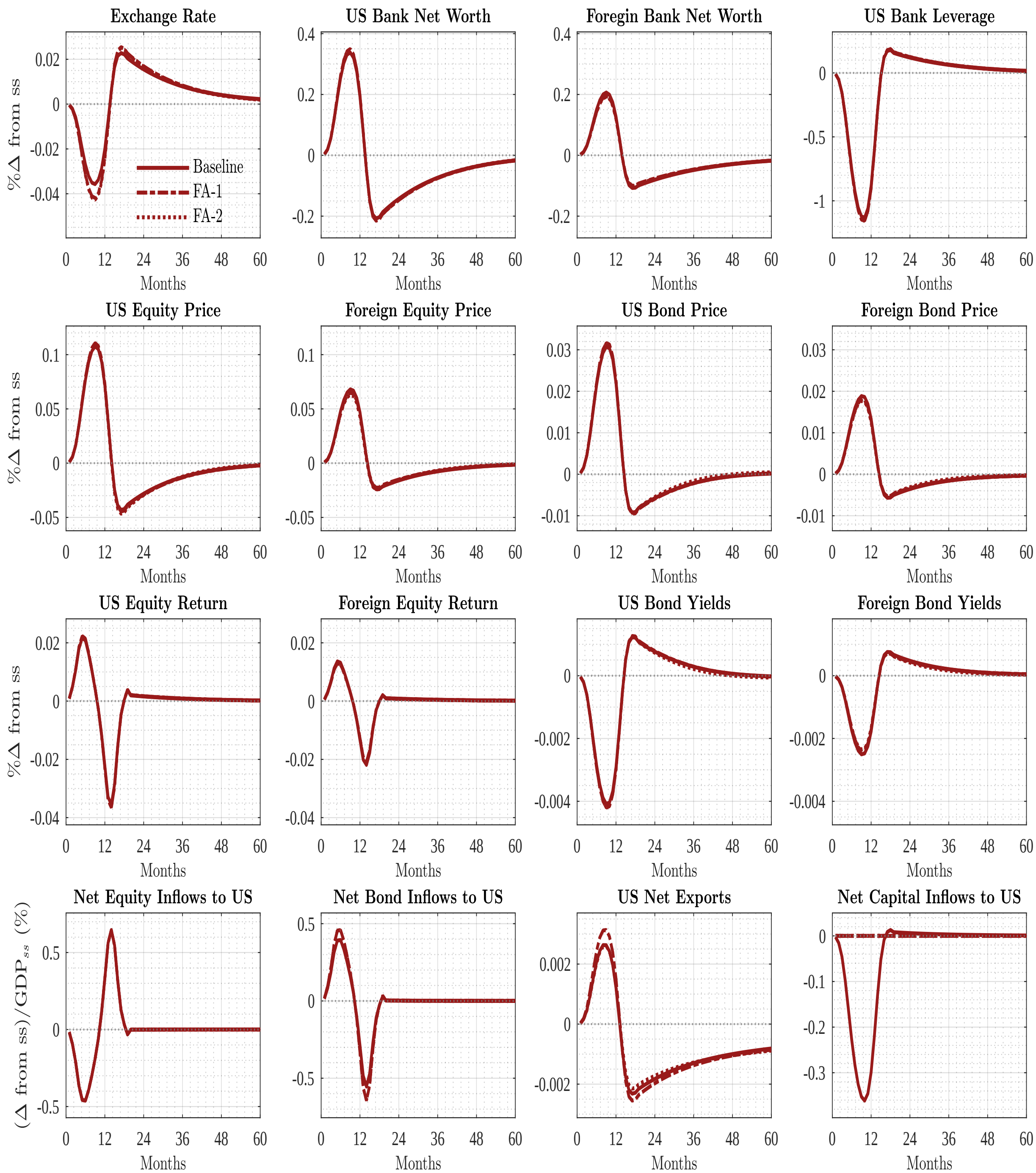
Note: The simulation results are based on the posterior mode of parameters from Columns "Baseline" and "FA" in Table D2. In the last row, the IRFs are reported as % of deviations from steady-state values relative to steady-state GDP. In the other rows, the IRFs are reported as % deviations from steady-state values.

Figure D17: IRFs of financial variables to "QE2" shocks under the baseline and financial autarky cases with ZLB constraints of PCP scheme with households holding risky assets



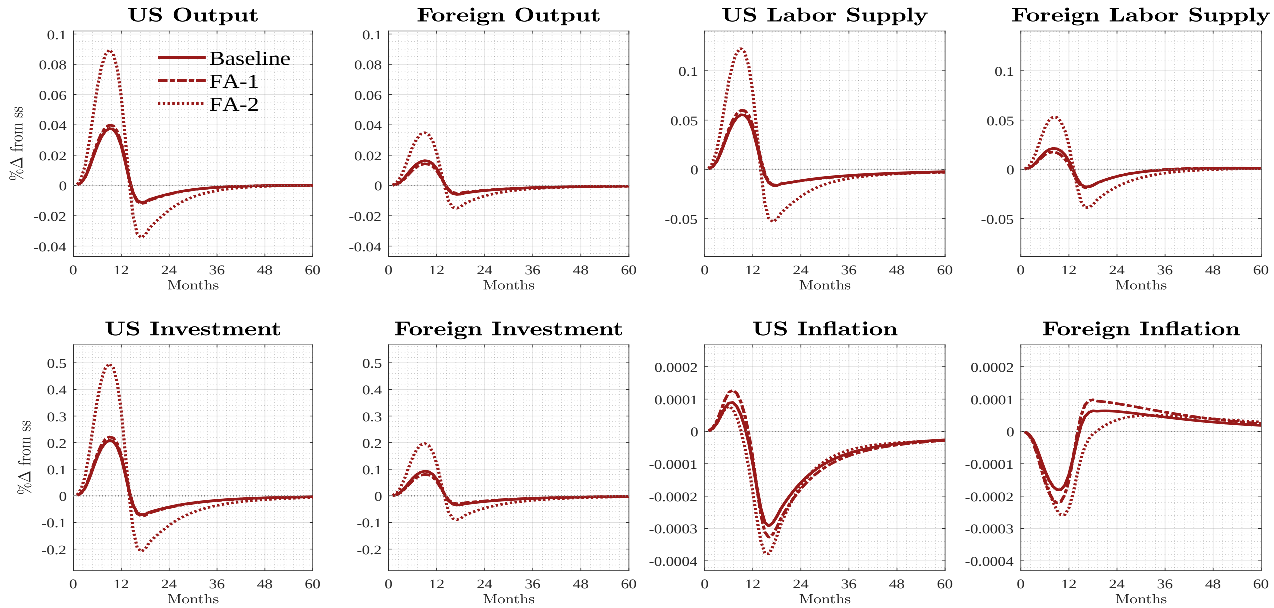
Note: The simulation results are based on the posterior mode of parameters from Columns "Baseline" and "FA" in Table D3. In the last row, the IRFs are reported as % of deviations from steady-state values relative to steady-state GDP. In the other rows, the IRFs are reported as % deviations from steady-state values.

Figure D18: IRFs of financial variables to "QE2" shocks under the baseline and financial autarky cases with ZLB constraints of LCP scheme with households holding risky assets



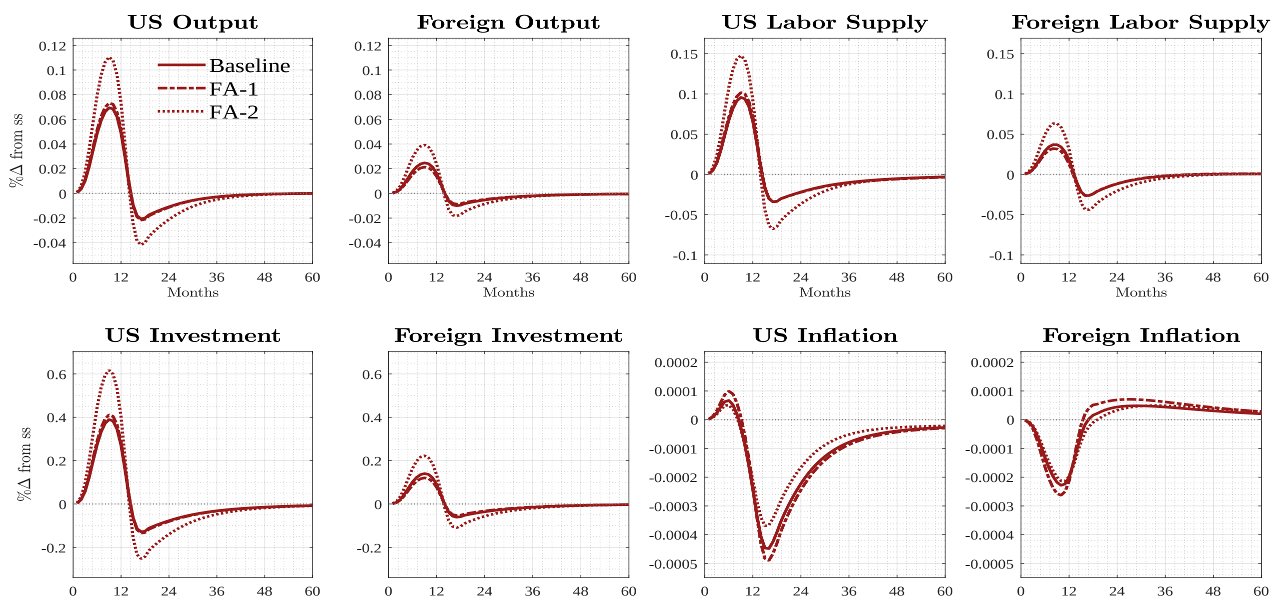
Note: The simulation results are based on the posterior mode of parameters from Columns "Baseline" and "FA" in Table D4. In the last row, the IRFs are reported as % of deviations from steady-state values relative to steady-state GDP. In the other rows, the IRFs are reported as % deviations from steady-state values.

Figure D19: IRFs of real economic variables to "QE2" shocks under the baseline and financial autarky cases with ZLB constraints of PCP scheme without households holding risky assets



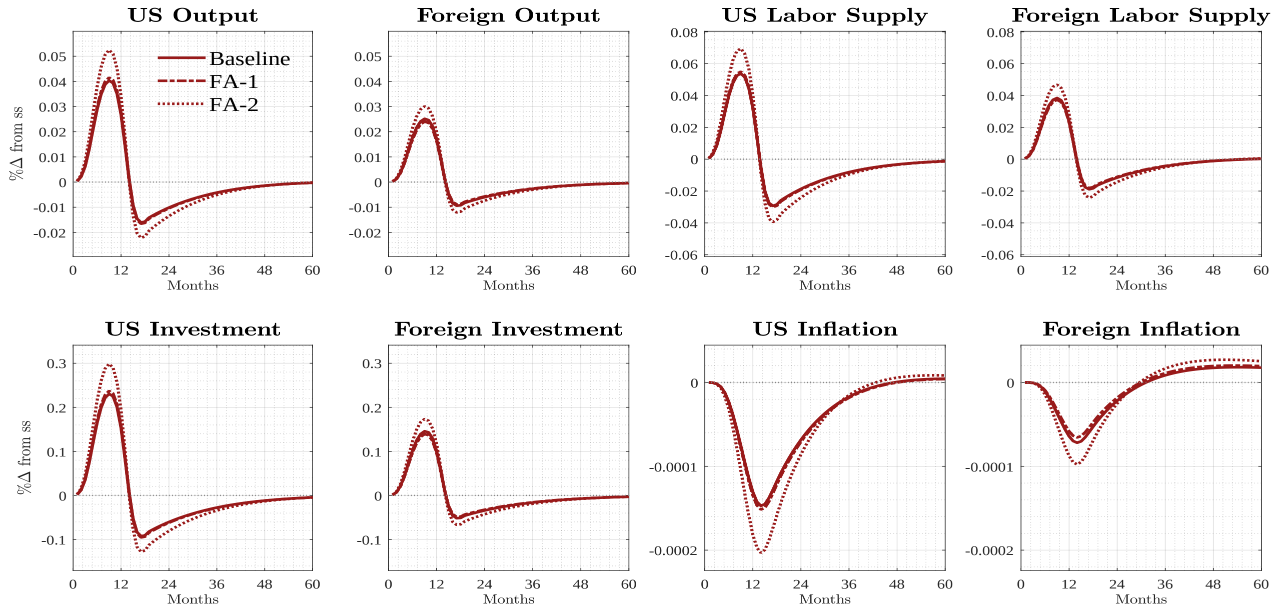
Note: The simulation results are based on the posterior mode of parameters from Columns "Baseline" and "FA" in Table D2. The IRFs are reported as % deviations from steady-state values.

Figure D20: IRFs of real economic variables to "QE2" shocks under the baseline and financial autarky cases with ZLB constraints of PCP scheme with households holding risky assets



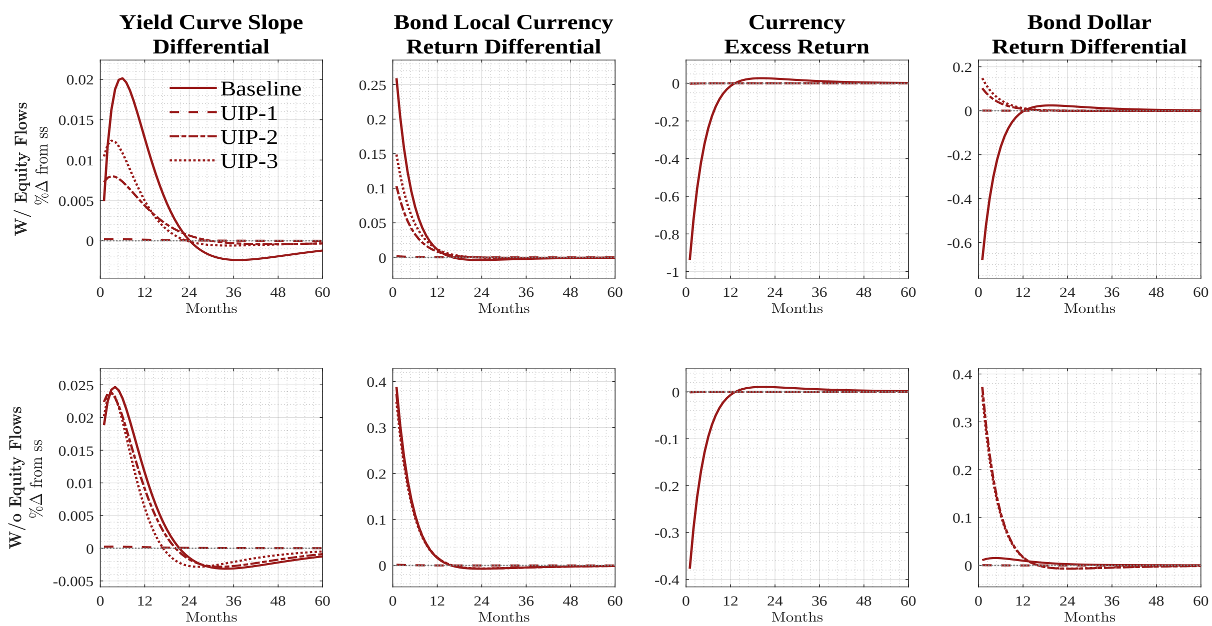
Note: The simulation results are based on the posterior mode of parameters from Columns "Baseline" and "FA" in Table D3. The IRFs are reported as % deviations from steady-state values.

Figure D21: IRFs of real economic variables to "QE2" shocks under the baseline and financial autarky cases with ZLB constraints of LCP scheme with households holding risky assets



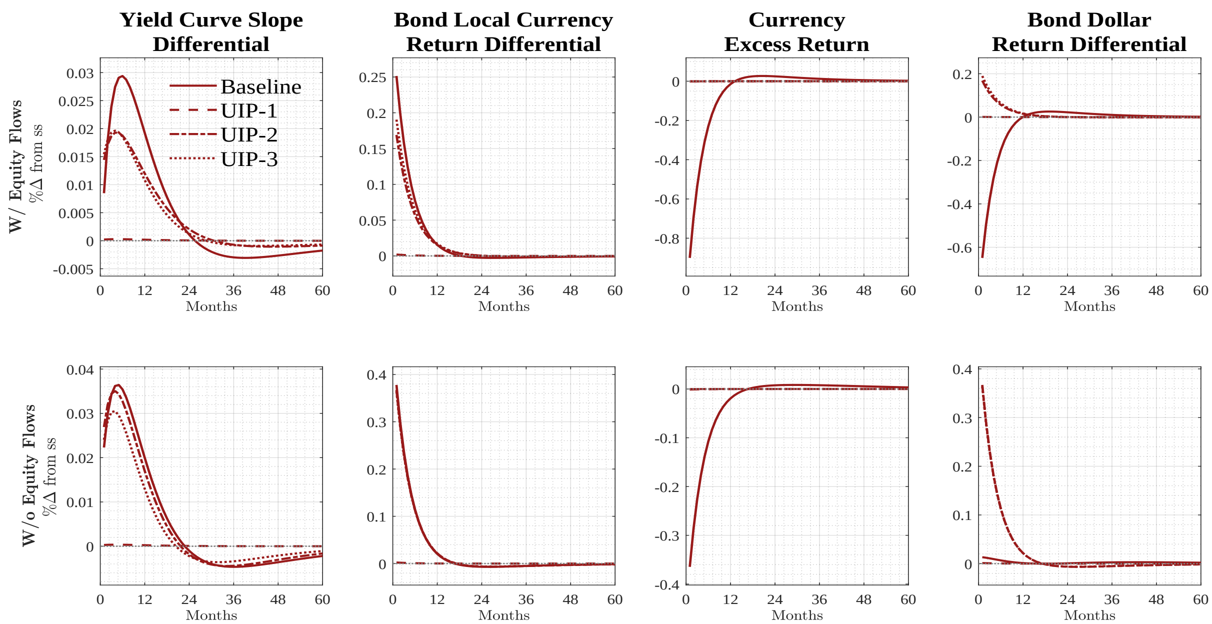
Note: The simulation results are based on the posterior mode of parameters from Columns "Baseline" and "FA" in Table D4. The IRFs are reported as % deviations from steady-state values.

Figure D22: The response of risk premia to "QE2" shocks under the baseline and UIP cases of PCP scheme without households holding risky assets



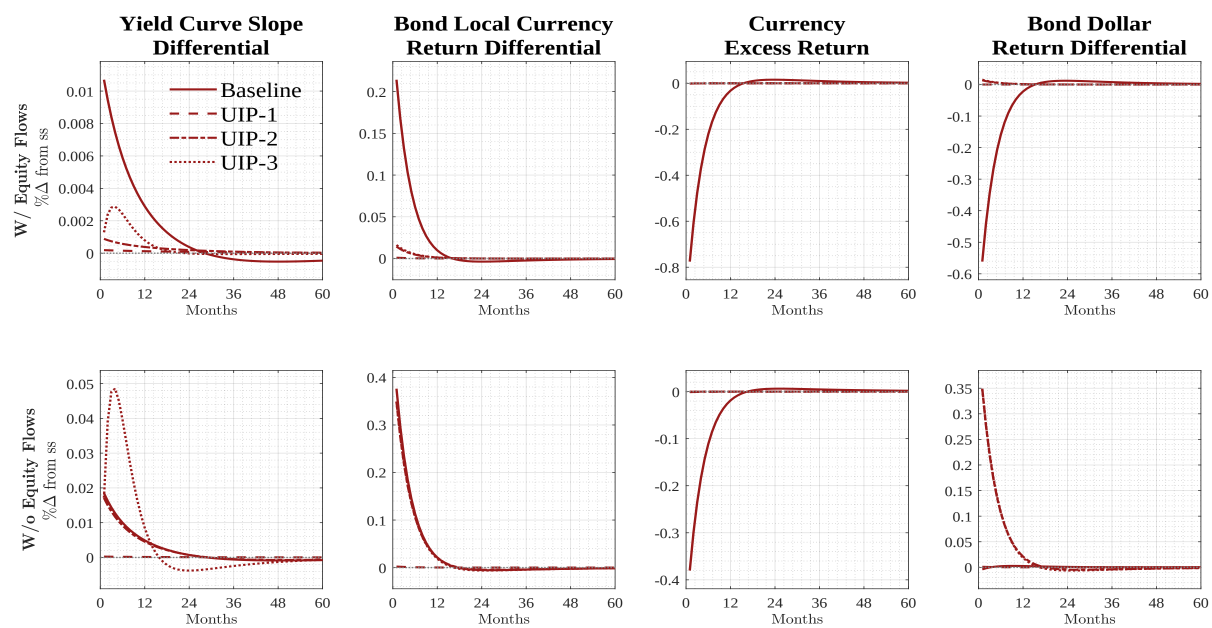
Note: The simulation results are based on the posterior mode of parameters from Columns "Baseline" and "UIP" in Table D2. The IRFs are reported as % deviations from steady-state values.

Figure D23: The response of risk premia to "QE2" shocks under the baseline and UIP cases of PCP scheme with households holding risky assets



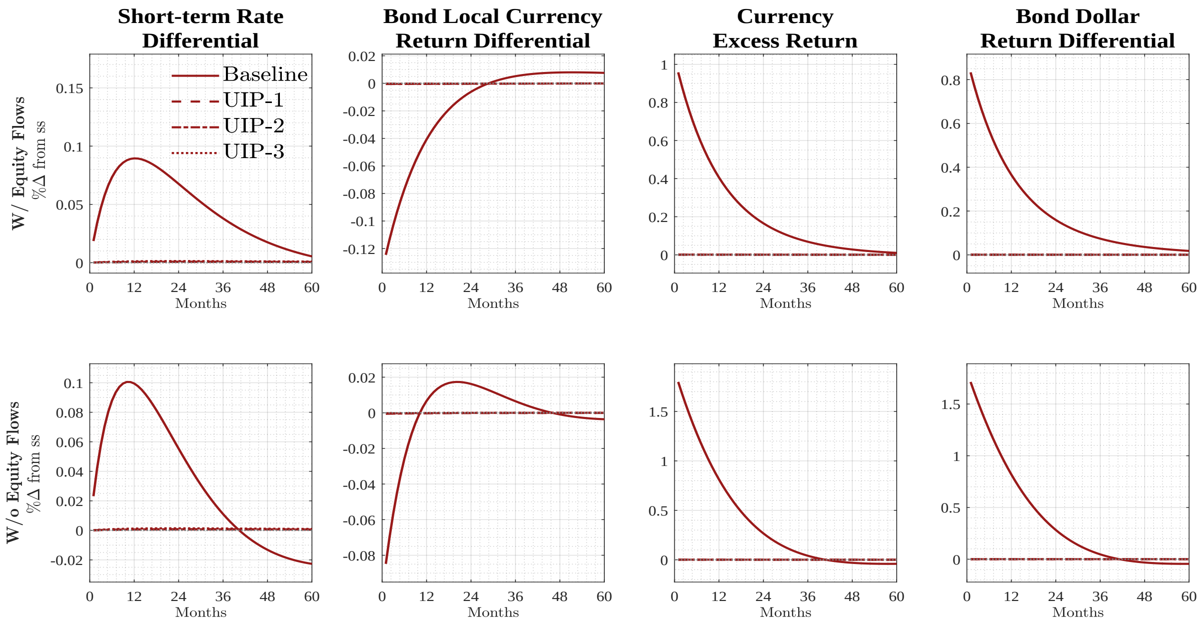
Note: The simulation results are based on the posterior mode of parameters from Columns "Baseline" and "FA" in Table D3. The IRFs are reported as % deviations from steady-state values.

Figure D24: The response of risk premia to "QE2" shocks under the baseline and UIP cases of LCP scheme with households holding risky assets



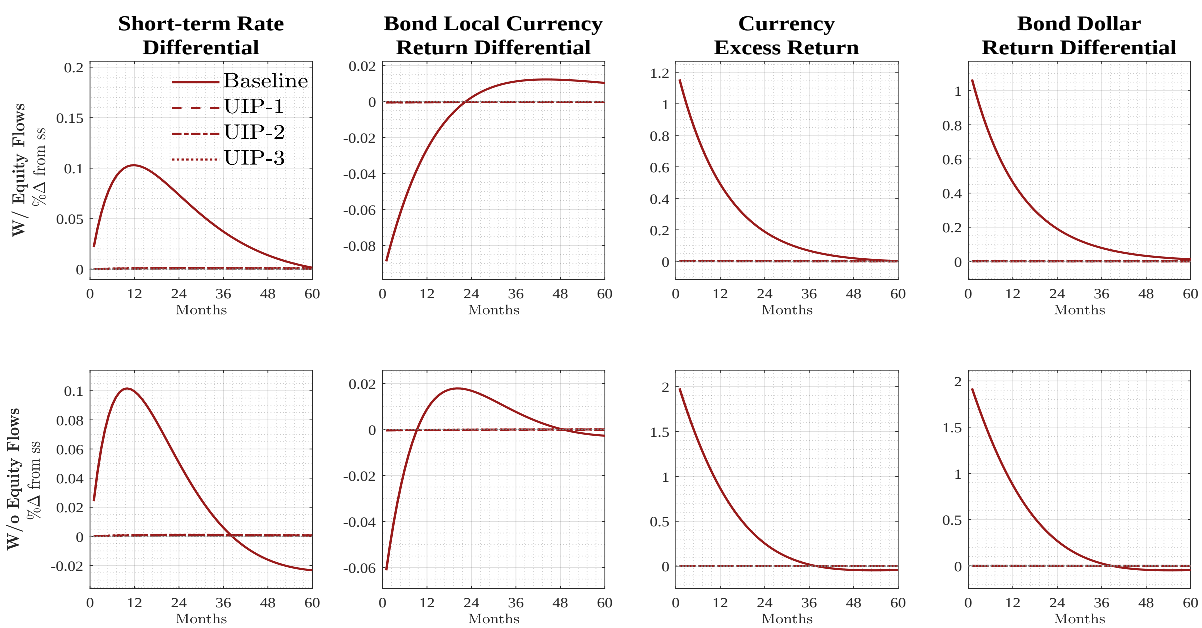
Note: The simulation results are based on the posterior mode of parameters from Columns "Baseline" and "UIP" in Table D4. The IRFs are reported as % deviations from steady-state values.

Figure D25: The response of risk premia to financial shocks under the baseline and UIP cases of PCP scheme without households holding risky assets



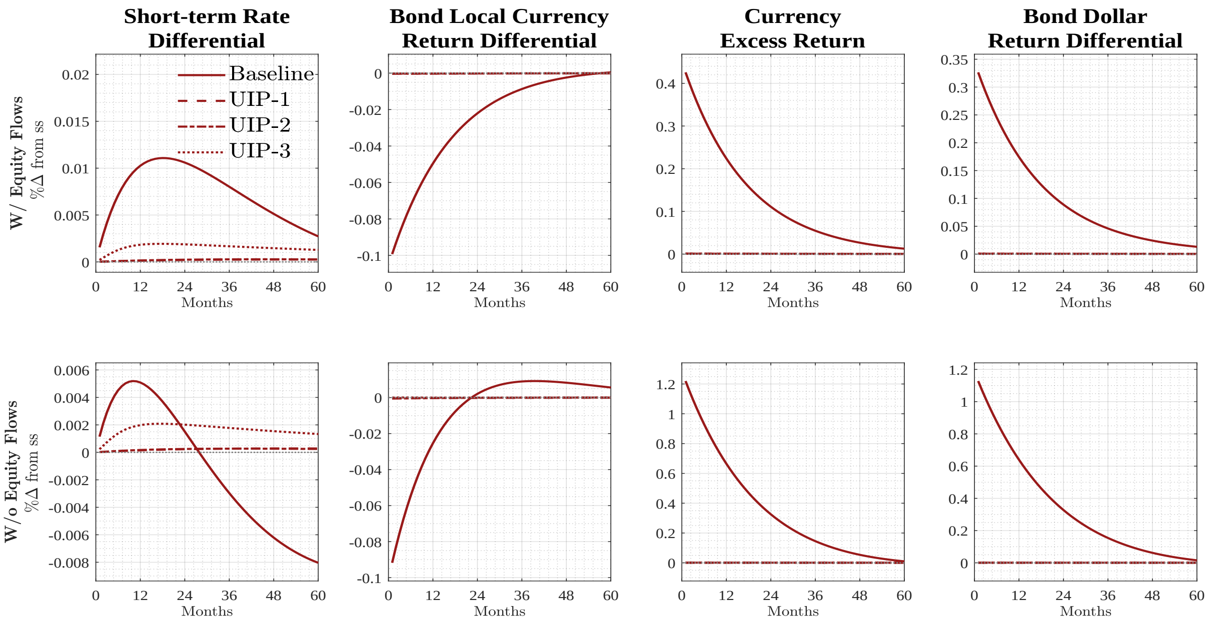
Note: The simulation results are based on the posterior mode of parameters from Columns "Baseline" and "UIP" in Table D2. The IRFs are reported as % deviations from steady-state values.

Figure D26: The response of risk premia to financial shocks under the baseline and UIP cases of PCP scheme with households holding risky assets



Note: The simulation results are based on the posterior mode of parameters from Columns "Baseline" and "UIP" in Table D3. The IRFs are reported as % deviations from steady-state values.

Figure D27: The response of risk premia to financial shocks under the baseline and UIP cases of LCP scheme with households holding risky assets



Note: The simulation results are based on the posterior mode of parameters from Columns "Baseline" and "UIP" in Table D4. The IRFs are reported as % deviations from steady-state values.

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