Collateral Advantage: Exchange Rates, Capital Flows, and Global Cycles*

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Abstract

We construct a two-country New Keynesian model in which U.S. government debt has an advantage as a superior collateral asset on the balance sheets of banks. The model can account for the observed exchange rate and external position behavior of the U.S. In our model, the U.S. enjoys an "exorbitant privilege" as its government bonds are desired by banks both in the U.S. and abroad as superior collateral. In times of global stress, the dollar appreciates since the demand for high-quality collateral drives up the "convenience yield" earned by U.S. government bonds . There is "retrenchment" - each country reduces its holdings of foreign assets - a critical determinant of which is the endogenous response of prices and returns. In addition, the model displays a U.S. real exchange rate appreciation despite that domestic absorption in the U.S. falls relative to the rest of the world during a global downturn, thus addressing the "reserve currency paradox" highlighted by Maggiori (2017a).

JEL Classification Codes: F3, F4, G1

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1 Introduction

During periods of global financial stress such as the 2007 - 2009 crisis, the U.S. dollar tends to appreciate sharply even as U.S. monetary policy aggressively lowers interest rates. This appreciation is typically accompanied by significant reversals in capital flows—commonly referred to as "retrenchment"—and substantial improvements in the U.S. trade balance. These features of the dollar and capital flows have been a subject of great interest in the international macroeconomics literature.

Our aim is to reconcile the three major strands of research in the past 15 years in international macroeconomics, in a way that helps resolve many of the major puzzles that are left unaddressed by each branch of the literature. Moreover, the model we introduce has the virtue of being a standard workhorse New Keynesian model with a financial accelerator, extended to a global setting, with only one small but significant variation.

First is the work that has established that the U.S. enjoys an "exorbitant privilege", in that U.S. dollar debt pays an average lower rate of return than corresponding international liabilities of other countries. This is explained in part by the "safe haven" status of the dollar - its appreciation during times of global financial stress provides a useful hedge for foreign investors. An appreciation of the dollar during a global crisis is considered the "exorbitant duty" of the U.S., a phenomenon whereby foreign investors benefit from an increase in the value of their U.S. assets during a crisis. This amounts to a wealth transfer from the U.S. to the rest of the world. The exorbitant duty is the complement of the exorbitant privilege the U.S. enjoys during quiescent times.[1] Gourinchas and Rey (2022) describe the exorbitant duty as equivalent to an insurance payout made by the U.S. during a crisis. But this leaves open the question of why the dollar appreciates during downturns. If a global crisis is associated with a large wealth transfer from the U.S. to the rest of the world, and the real exchange rate is determined by differential spending patterns of U.S. versus rest of world households, we would expect a real depreciation of the U.S. dollar. This is the "Reserve Currency Paradox" identified by Maggiori (2017b).[2] Moreover, there is an apparent conflict between this theory and the evidence on capital flows, which might be called the "retrenchment puzzle": The theory seems to imply a large increase in demand for U.S. assets during a global financial crisis, which would imply a significant trade balance deterioration and foreign capital inflows to the U.S. However, this appears to be at odds with the evidence on the observed capital flow retrenchment and sizeable U.S. trade balance improvement.

[1] Gourinchas and Rey (2007a,b, 2022) and Eichengreen (2011) originate this idea, provide empirical evidence to support it, and build models to account for it.

[2] See Gourinchas and Rey (2022) who develop a model in which the covariance of returns on the dollar evolves as the state of the global economy changes. Hassan (2013), Richmond (2019), and Farhi and Gabaix (2016) and develop models in which nontraded goods in the U.S. become relatively scarce during global downturns, leading to an appreciation.

A second branch in international macroeconomics has made substantial progress in understanding exchange rate determination. Gabaix and Maggiori (2015a) and Itskhoki and Mukhin (2021a) among others develop models where limits to the risk-bearing capacity of financial intermediaries can explain numerous anomalies in exchange rate behavior. In these models, deviations from uncovered or covered interest rate parity (UIP or CIP) are related to levels of net external liabilities. As one country borrows more, global intermediaries must bear more risk, and thus require a higher expected rate of return from the borrower. As the banks' constraints tighten, the risk premiums for the borrowing countries should increase and their currencies should depreciate.[3] However, there are difficulties with these new vintage of models in providing a consistent description of the U.S. dollar during a crisis. The U.S. is the world's largest borrower and debtor. When global financial conditions tighten during a crisis, this suggests that the debtor's currency should depreciate,[4] which contradicts the evidence. Moreover, a central feature of this new generation of exchange rate models is the existence of a UIP or CIP wedge, explaining persistent differences between expected returns on countries' interest-bearing assets. But real economic downturns during financial crises appear to be more closely associated with a different wedge - the spread between the rate at which financial intermediaries are willing to lend to producers and the rate paid to the intermediaries' creditors.

The third major approach consists of studies that have highlighted the convenience yield on U.S. government liabilities, and made it the key mechanism that links the increase in the convenience yield to the appreciation of the dollar during global financial crises.[5] Our model incorporates elements of this strand, but contributes in several ways. We provide a microeconomic foundation for the convenience yield. Many previous studies have either assumed an exogenous convenience yield, or, more typically, that some bonds pay a lower expected return because households derive utility from holding those bonds. However, different studies have made a variety of assumptions about the way in which bonds enter the utility function - for example, differing assumptions about total bonds versus bonds as a fraction of portfolio wealth; about the substitutability of these bonds with other assets; about the substitutability of bonds for consumption of goods; etc. We can offer direct empirical evidence in support of our formulation, and with a microeconomic foundation, the model offers a more firm footing for policy analysis. Secondly, in our approach, the demand for liquidity rises endogenously. The cause of financial stress is not an exogenous increase in demand for liquidity. Rather, financial conditions tighten as the value of real assets are weakened, as in the housing bust in 2007-2009. Thirdly, while the U.S. dollar plays a special role in our model because it is globally accepted as the most preferred collateral,

[3] See also Greenwood et al. (2023), Akinci and Queralto (2024), Basu et al. (2023), and Gourinchas et al. (2022).

[4] For example, see Proposition 2 in Gabaix and Maggiori (2015a) or equation (29) in Itskhoki and Mukhin (2021).

[5] For example, Kekre and Lenel (2024b), Jiang et al. (2024a), Bianchi et al. (2021),

the source of the increase in demand for dollar assets is not necessarily country-specific. A global financial tightening that initially hits all countries symmetrically will lead to a dollar appreciation. Finally, we can directly address the "retrenchment puzzle" and the "reserve currency paradox" in a framework that is also consistent with the findings of the models on global financial intermediation.

We construct a two-country New Keynesian model in which U.S. government debt is superior collateral on the balance sheets of financial intermediaries. For a balance-sheet constrained financial intermediary, it is less costly to hold U.S. Treasury debt than safe assets of other countries. The higher pledgeability of U.S. Treasury debt creates a liquidity or "convenience" demand for the debt. When there is financial stress, the balance sheet constraint tightens endogenously, leading all financial intermediaries to shift demand towards U.S. Treasury debt. This increases the "convenience yield" for U.S. Treasury debt and causes a dollar appreciation. The appreciation of foreign bank's U.S. assets results in an effective wealth transfer from the U.S. such that the U.S. financial intermediaries demand more of the liquid assets than the foreign banks. This results in an endogenous capital flow retrenchment: the U.S. intermediaries end up holding more U.S. assets and the foreign intermediaries hold more foreign assets.[6] The model also features a persistent deviation from UIP due to a time varying convenience yield and simultaneously a long run "exorbitant privilege", as U.S. assets pay a lower interest rate than those of the rest of the world.

The financial sector is modeled as in Gertler and Kiyotaki (2010) and Gertler and Karadi (2011). In each country, households consume, provide labor services, and save by putting deposits in banks located in their own country. Firms in each country produce output using labor and capital. Banks in each country rent capital to firms in both countries, supply deposits to households, and hold government bonds from both countries. Governments issue debt and make transfers to households. Monetary policy in each country is modeled as a simple inflation-targeting rule.

Markets or regulators constrain the banks from acquiring too large a balance sheet, because financial intermediaries (which we call "banks") have private information about the value of their assets that is not observed by households or financial regulators. In order to prevent excessive risk taking, the leverage of banks is constrained. However, there is less private information about the value of government debt, and especially U.S. government debt which is widely traded globally in very deep markets. In our interpretation, U.S. Treasury debt has a "comparative advantage" in the sense that the relative constraint on this debt is lower globally than on foreign government debt. The fact that the value of U.S. Treasury debt is easily assessed in global markets is one sense in which these assets are very liquid. We draw a connection between liquidity and "safety". As Gorton (2017) states, "A safe asset is an asset that is (almost always) valued at face value without

[6] This prediction is consistent with the empirical findings of Milesi-Ferretti and Tille (2011), Forbes and Warnock (2012) and, with a particular focus on banks, Wang (2018). Tabova and Warnock (2021) in fact show that foreign holdings of U.S. Treasury bonds fell during the Global Financial Crisis, though their focus is on long-term bonds and much of that change in portfolios was driven by central bank holdings.

expensive and prolonged analysis. By design, there is no benefit to producing (private) information about its value, and this is common knowledge" This is precisely the motivation for our modeling of the special role of U.S. Treasury assets in bank balance sheets.

Following Gertler and Karadi (2011) and Gertler and Kiyotaki (2010), we model a global financial crisis as simultaneous fall in the quality of real bank assets for both domestic and foreign banks. The crisis is driven primarily by a meltdown in the balance sheets of the banking sector, which leads to a fall in net worth, an increase in spreads, and a fall in asset prices, all of which precipitate a global deleveraging cycle. In our model, this occurs simultaneously in the home and foreign banking sectors. The global downturn itself is not directly associated with the special role of the dollar or U.S. Treasury bills in bank balance sheets. Rather, the dollar appreciation and differential response of the U.S. and foreign economy is a consequence of the differential collateral requirements for U.S. and foreign government bonds.

Our mechanism can be understood in terms of three "wedges". First, when the value of assets held by intermediaries falls, balance sheet constraints on these intermediaries tighten. This leads to a reduction in lending for real productive assets, and a gap between the return on lending to producers and the return paid the intermediary depositors. This channel is enhanced through a financial accelerator, because as the economy slows down, financial constraints on the banks tighten more. Second, as financial intermediaries reduce their asset holdings when financial constraints tighten, the contractionary effects are magnified as they shift their portfolios away from loans to firms and toward holdings of liquid government bonds. It is reflected in the second wedge - the gap between returns on productive assets and that of liquid government bonds. The third wedge is the one that leads to UIP deviations. Because U.S. dollar bonds are relatively better collateral than foreign government bonds, there is a shift in demand toward dollar-denominated assets. It is the third wedge that is associated with the dollar appreciation and the failure of UIP., but the first two are more indicative of the accelerator effect that drives the global downturn in output, consumption, and investment.

Even abstracting from the insurance premium (as in Gourinchas and Rey (2022)) that U.S. Treasury debt might earn, the model exhibits an exorbitant privilege enjoyed by the U.S.. During normal times, U.S. debt pays a lower rate of monetary return because it constrains banks' balance sheets less than other assets. This channel is complementary to the risk channel. Because liquidity demand increases during global financial slumps, the dollar appreciates as global consumption falls. But that makes the dollar a good hedge. Average returns on dollar assets are low both because they earn a convenience yield, and because they are a hedge.[7]

In the model, the shift away from real lending is strongest in the U.S., where U.S. government

[7] We solve the model with a first-order log-linearization, so there is no risk premium in our dynamic solution, but the risk premium is present in the calibrated stochastic steady state.

bonds are relatively better collateral than abroad. The steeper drop in U.S. investment is the main driver behind an increase in the trade balance (a reduction in the trade balance deficit), which is consistent with the outcomes in the data in 2007-2009. The trade deficit shrinks despite a real appreciation of the dollar. The dollar appreciation is caused by the increased demand for liquidity. The relatively larger drop in investment demand in the U.S. than in the rest of the world is a response to the behavior of the financial intermediaries. The market for goods is equilibrated primarily by an adjustment in quantities produced rather than through terms of trade adjustment (which in fact are small in the model because of pricing to market/local-currency pricing.)[8]

While we emphasize the fluctuations in demand for liquidity during times of global financial pressure, we consider these episodes to be somewhat exceptional. During "normal" times, even though banks do face balance sheet constraints, the exchange rate and the global macroeconomy behave much as in a standard two-country open economy model. The dollar appreciates when U.S. real interest rates are relatively high, and output is driven by demand and productivity shocks, as well as capital quality shocks. It is only during episodes of global stress that we see the combinations of dollar appreciation, new wealth transfer, and retrenchment. To capture these different events, we model the exogenous driving variables as a multivariate Markov switching process in "capital quality", productivity, consumption demand, and deviations from an inflation-targeting rule, in which the capital quality shocks switch between regimes of high and low variance.

The "reserve currency paradox" of Maggiori (2017b) notes that during these times in which the dollar appreciates, the net international investment position of the U.S. deteriorates as the value of U.S. holdings of foreign assets falls relative to the value of foreign holdings of U.S. assets. The paradox is that if the real value of the dollar is determined through home bias in preferences (or through the presence of non-traded goods) by a rise in the price of goods favored by U.S. households, then a real appreciation of the dollar should be associated with an increase in relative demand by U.S. households. It is difficult to reconcile an increase in demand by U.S. households with a fall in their wealth. This paradox is resolved in our model because nominal goods prices are sticky in the currency of consumers (local-currency pricing, or LCP.) A real appreciation is not immediately associated with an increase in the relative price of U.S. goods.

Related Literature

Several recent papers have found a relationship between "convenience yields" and either exchange rates or deviations from uncovered interest rate parity. These include Jiang et al. (2021), Jiang et al. (2024b), Jiang et al. (2024a), Krishnamurthy and Lustig (2019), Engel and Wu (2023), Kekre and Lenel (2024b) Valchev (2020), and Bianchi et al. (2021). These papers all highlight the importance of deviations from uncovered interest parity for understanding exchange rates, which

[8]Throughout the paper, we use the term "terms of trade" to refer to the consumer price of imports relative to the price of consumer goods produced within the country.

Miyamoto et al. (2022) finds is the dominant driver of dollar exchange rates. These papers provide evidence that deviations from UIP may be attributable in part to liquidity or convenience yields, and that this return to liquidity also influences the level of the exchange rate. Much of the literature has noted especially the nexus between convenience yields on U.S. government bonds and the level of the dollar exchange rate as well as deviations from UIP for the dollar. These models follow earlier literature that takes the deviation from UIP due to the convenience yield either as exogenous, or because some assets are in the utility function, or from exogenously given bond demand functions.[9]An exception is Bianchi et al. (2021), which models the endogenous demand for assets from financial intermediaries during times of global stress, with emphasis on the liquidity return of dollar short-term assets. That model, however, is too stylized to take to a realistic quantitative open-economy macro setting.

The "exorbitant privilege" of the United States - that it earns a greater rate of return on its foreign investments than foreigners earn on investments in the U.S. - in conjunction with the persistent U.S. trade balance and current account deficits has been intensively investigated. Gourinchas and Rey (2007b), Gourinchas and Rey (2007a) and Bertaut et al. (2023) note the importance of these excess returns in the global financial adjustment process. Mendoza et al. (2009), Caballero et al. (2008). Caballero et al. (2016), and Sauzet (2023) build models to account for this global pattern of portfolio returns. A noted feature of this "exorbitant privilege" has been that the U.S. net international investment position, up to the late 2000's, was significantly less than the cumulated level of current account deficits since the early 1990's. However, recent work by Atkeson et al. (2022) has called attention to a reversal in this situation since the global financial crisis due to the superior performance of U.S. equities relative to those in the rest of the world. It is not obvious however if this reversal has affected the convenience yield on U.S. government bonds relative to those of other major sovereign borrowers.

The role of global financial intermediation is the focus of much contemporary research into exchange rates and capital flows. Notable contributions include Maggiori (2017a), Gabaix and

[9]Earlier papers that model the convenience yield as arising from assets in the utility function include Krishnamurthy and Vissing-Jorgensen (2012), Nagel (2016), and, in an international model, Engel (2016). A prominent recent example of a model with an exogenous UIP shock is Itskhoki and Mukhin (2021).) Greenwood et al. (2023) and Gourinchas et al. (2022) specify international portfolio choice models in which a "preferred habitat" as well as risk and return play a role in asset demand. Du et al. (2018a) provide measures of the convenience yield on U.S. bonds relative to government bonds of other countries. Brunnermeier et al. (2024) study a framework in which a safe debt provides service flow because it provides insurance for idiosyncratic risk. Coppola et al. (2023) study a model in which dollar-denominated debt is liquid and dominant. Garleanu and Pedersen (2011) study the asset pricing implications of a model in which assets have different margin requirements. Georgiadis et al. (2023) provides an interesting related framework to understand the global financial cycle also assuming differential financial constraints on asset types, but imposing more structural assumptions than in our paper. Kim (2023) studies the implication of quantitative easing and foreign exchange intervention using a money search model with differential financial constraints.

Maggiori (2015b), Itskhoki and Mukhin (2021), and Gopinath and Stein (2021).[10]

Some other recent studies have provided potential explanations for how dollar bonds can earn on average a lower return than foreign bonds, and how the dollar can appreciate during global downturns, and yet provide resolutions to the reserve currency paradox. In Maggiori (2017a), foreign banks face balance sheet constraints, while U.S. banks are unconstrained. This effectively makes foreigners more risk averse than investors in the U.S..[11] In equilibrium, the U.S. borrows from abroad and invests in equities, while the foreign country buys U.S. debt which acts as insurance during global downturns. Gourinchas and Rey (2022) build a model in which the global economy can be in one of three states at any time: normal, fragile, and disaster. That study associates times of global stress with the fragile state. U.S. bonds are less risky because of their payoffs in the fragile and disaster states, so they earn on average a lower rate of return. During disaster periods, which are rare, there is a large drop in global output, and in addition, there is partial default on foreign bonds. When the economy enters into a fragile state from a normal state, the probability of disaster increases. To hedge the risk that occurs from holding foreign bonds in the disaster state, investors purchase Home bonds during fragile times.

Jiang et al. (2024a) posit that there is an exogenously given demand from abroad for U.S. bonds because they are valued for their liquidity or some other special property. Bonds are issued by firms in the U.S., but these firms face a borrowing limit. Bonds are used to finance productive activity. The model can, for example, account for dynamics of real exchange rates in response to a monetary tightening in the U.S. As the U.S. raises interest rates, the debt issuing capacity of firms falls, reducing their output but also reducing their supply to the rest of the world of the liquid asset.

Kekre and Lenel (2024b) present a model of convenience yields and risk premia in a general equilibrium model of the global economy. The convenience yield arises from a model in which agents have some preference for bonds issued by the U.S.. The main drivers of global downturns are a disaster shock that is also correlated with a "safety shock" that changes the relative demand for U.S. assets. In addition, there is nominal wage stickiness and monetary policy set by a Taylor rule. The model is quite rich, but some intuition can be gleaned by considering the effect of the safety shock alone, as global demand for U.S. bonds tends to increase during global crises. The shift in demand toward U.S. bonds tends to lower their rate of return, which leads to a real appreciation of the dollar as the convenience yield is rising. On the goods market side, there is a drop in U.S. consumption induced by the higher real wage (due to the deflationary bond demand), which in turn induces producers to supply less. The drop in supply outstrips the drop in consumption, so

[10] See also Bruno and Shin (2015), Bruno and Shin (2017), Du et al. (2018b), Dedola and Lombardo (2012), Dedola et al. (2013), Banerjee et al. (2016), Devereux and Yu (2020), Amador et al. (2020), Fanelli and Straub (2021), Chahrour and Valchev (2022) and Fang and Liu (2021).

[11] See He and Krishnamurthy (2013) for a general survey of how financial constraints affect and magnify the effective risk aversion of investors.

the relative price of U.S. goods rises, consistent with the real appreciation given home bias in preferences.

Akinci et al. (2022) aims to explain the real appreciation of the dollar during times of uncertainty. The model features a U.S. financial sector that takes in saving from U.S. households and invests in U.S. equities and foreign debt and a unconstrained foreign financial sector (the opposite of the set-up in Maggiori (2017a).) There is no special role for U.S. government debt. An increase in the volatility of U.S. productivity leads to an increase in risk aversion in the U.S. relative to the rest of the world. This shock causes U.S. intermediaries to lower demand for foreign bonds, and they shed some of their holdings of foreign debt, contributing to a depreciation of the foreign currency.

Dahlquist et al. (2022) build a model in which agents have "deep habits" - an external habit for each good in the consumption basket. The key properties of these preferences is that they are not homothetic, and expenditure shares may vary as wealth and consumption levels change.

Section 2 presents an empirical exchange rate instrumental variable regression analysis. Section 3 presents the model. Section 3 presents the model. The calibrated parameters are described in section 4 and section **??** describes the steady state. Section 5 examines the responses to a global financial tightening, to a global productivity shock, and to some unconventional monetary policy experiments. Section 6 compares the model implied moments with the data. Section 7 concludes.

2 Motivating facts

Figure 1 shows some stylized patterns about the exchange rate and external position of the U.S. around the time of the global financial crisis that helps to motivate the model. It highlights that the dollar appreciation during the crisis is associated with a widening of the liquidity yield and capital flow retrenchment, both at the U.S. Treasury market level and country level.

The top left panel shows the strong relationship of liquidity returns and the U.S. dollar exchange rate. The scatter plot displays the change of the U.S. dollar price of the average of the rest of the G10 currencies on the y-axis and the change of liquidity yield measure of Du et al. (2018a) on the x-axis, defined as the difference between a market rate of return and the rate of return on short-term government bonds for the U.S. relative to the other country.[12] This measure captures the liquidity or convenience services of government bonds. The scatter plot clearly demonstrates a negative relationship between the exchange rate and liquidity returns, most notably reflected in the sharp appreciation of the U.S. dollar in the fourth quarter of 2008, accompanied by a substantial increase in the U.S. liquidity yield. This pattern suggests heightened demand for U.S. Treasuries during the

[12] This measure is used by Engel and Wu (2023) and Jiang et al. (2021). The G10 currencies are the U.S. dollar, the euro, Australian dollar, Canadian dollar, Japanese yen, New Zealand dollar, Norwegian krone, Swedish krona, Swiss franc, and U.K. pound. The exchange rate and price data is from DataStream.

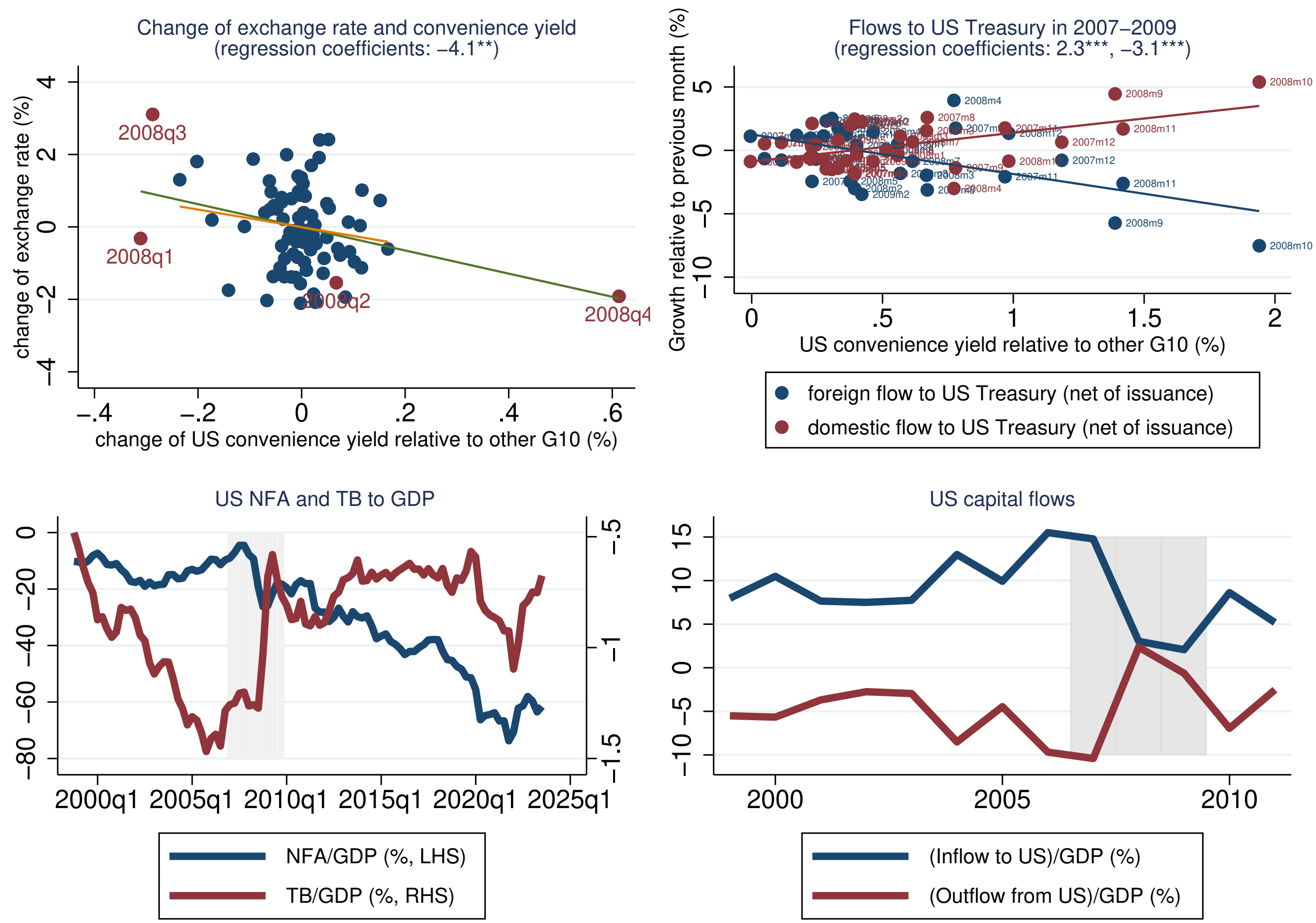
crisis. However, the negative relationship holds more generally beyond this specific period. The green best-fit line of the scatter plot and the orange best-fit line, which excludes data from 2008 and 2009, nearly overlap, reinforcing the robustness of this relationship.

The top-right panel plots the net investment flow into the U.S. Treasury market from both U.S. and foreign investors, after accounting for issuance, on the y-axis, and the liquidity yield measure on the x-axis. The flow measure is constructed by Chaudhary et al. (2024). The figure clearly illustrates that as the crisis unfolds, there is a significant inflow into the Treasury market from U.S. investors. In contrast, on net, foreign investors engage in a sell-off of U.S. Treasury securities. A similar pattern is observed during the COVID-19 crisis, as reported in Appendix [X].

The bottom-left panel presents the dynamics of the U.S. net foreign asset (NFA) position and the trade balance (plotted on the right-hand-side axis). The U.S. has maintained a persistent trade deficit since the beginning of the sample period, which is also reflected in its long-term negative NFA position—one of the key characteristics of the so-called "exorbitant privilege." Notably, during the Global Financial Crisis (GFC) period, highlighted in gray, there is a sharp improvement in the trade balance alongside a significant deterioration in the NFA position. Taken together, while net capital inflows to the U.S. decline, the worsening external position is primarily driven by a valuation channel, as emphasized by Gourinchas and Rey (2007c) and Gourinchas et al. (2017).

The bottom-right panel illustrates capital retrenchment during the crisis. The blue line represents capital inflows to the U.S. from foreign investors, while the red line represents capital outflows from the U.S. to foreign countries. (Note that positive outflows from the U.S. are plotted as negative values.) Before 2008, both inflows and outflows were relatively stable at approximately 10% of GDP. However, during the global financial crisis, a stark shift occurs. Inflows into the U.S. decline sharply, dropping from positive values to nearly zero. Similarly, U.S. investors reduce their holdings of foreign assets, as indicated by the outflow values turning positive.

Figure 1: Stylized facts during the Global Financial Crisis



Top left figure note: Quarterly data. Liquidity yield is defined as in Engel and Wu (2023), which is Home to Foreign market interest rate indifferential minus Home to Foreign government interest rate differential $(i_t^m - i_t^{m*} - (i_t^g - i_t^{g*}))$. The figure reports the simple average of variables across country. Top right figure note: Monthly data. Flows to US Treasury data is obtained from Chaudhary et al. (2024). Bottom left figure note: Quarterly data. NFA data is obtained from Atkeson et al. (2022) dataset. Bottom right figure note: Annual data. The capital flow data is from Bluedorn et al. (2013)

3 Model

We describe a two country model, denoted Home and Foreign. The countries are symmetric in all dimensions except for the pledgeablility of assets. Agents supply labor and consume goods from both countries. The world is populated with a unit mass of agents at Home and Foreign, respectively.

3.1 Households

Agents in the Home country have preferences over consumption and hours given by

$$E_t \sum_{s=t}^{\infty} (\beta_s)^s U_s \tag{1}$$

where:

$$U_t = \frac{(C_t)^{1-\sigma} - 1}{1-\sigma} - \frac{\chi}{1+\psi}(H_t)^{1+\psi} \tag{2}$$

Where β_s represents a discount factor shock. Financial markets are restricted for households. Households can interact only with domestic banks in the form of non-contingent domestic currency denominated deposits. Banks in turn hold domestic and foreign currency denominated government bonds as well as domestic and foreign equity. The environment for banks is described further below.

The household's budget constraint is

$$P_t C_t + B_t = W_t H_t + R_t B_{t-1} + \Pi_t + TR_t - T_{s,t} \tag{3}$$

where P_t is the CPI in Home currency, B_t represents households deposits of domestic currency in the Home banking system, Π_t represents the net receipts that households receive from production firms and banks, and TR_t is a transfer made from the Home government to the households. Here, R_t is the domestic currency interest rate received by households on bank deposits. Finally, $T_{s,t}$ is the startup capital transferred to new banks at time t.

Consumption is a CES aggregate over home- and foreign-produced goods:

$$C_t^j = \left(\omega^{\frac{1}{\mu}} (C_{h,t}^j)^{1-\frac{1}{\mu}} + (1-\omega)^{\frac{1}{\mu}} (C_{f,t}^j)^{1-\frac{1}{\mu}}\right)^{\frac{1}{1-\frac{1}{\mu}}} \tag{4}$$

where $\omega \geq n$, representing the possibility of home bias in preferences. Given this assumption, the Home CPI is written as

$$P_t = \left(\omega P_{h,t}^{1-\mu} + (1-\omega) P_{f,t}^{1-\mu}\right)^{\frac{1}{1-\mu}} \tag{5}$$

where $P_{h,t}$ ($P_{f,t}$) represents the Home currency price of Home (Foreign) goods.

Optimal consumption of Home and Foreign goods for the Home consumer is

$$C_{h,t} \quad = \quad \omega \left(\frac{P_{h,t}}{P_t}\right)^{-\mu} C_t \text{ and } C_{f,t} = (1-\omega)\left(\frac{P_{f,t}}{P_t}\right)^{-\mu} C_t \tag{6}$$

Optimal labor supply is described by

$$W_t = \chi P_t (C_t)^{\sigma} (H_t)^{\psi} \tag{7}$$

Given the return on deposits (R_{t+1}) and the utility discount factor (β_t), that are both known in time t, Home household's Euler equation is [13]

$$1 = E_t R_{t+1} \Omega_{t+1} \tag{8}$$

The preferences, budget constraints, and optimal choices for the Foreign economy are analogous. The presence of home bias in Foreign preferences then implies that the price index for the Foreign economy is

$$P_t^* = \left(\omega^* P_{f,t}^{*1-\mu} + (1-\omega^*) P_{h,t}^{*1-\mu}\right)^{\frac{1}{1-\mu}} \tag{9}$$

3.2 Firms

A unit measure of firms in the Home economy produce differentiated goods. The aggregate Home good is a composite of these differentiated goods, where the elasticity of substitution in demand between individual goods is denoted as $\varepsilon > 1$. The production function for firm i in the Home country is

$$Y_{i,t} = A_t (L_{i,t}^{1-\alpha} (\vartheta_t K_{i,t})^{\alpha}) \tag{10}$$

where A_t is an aggregate productivity term. $\vartheta_t K_{i,t}$ is the firm's use of capital and $L_{i,t}$ the use of labor.

The term ϑ_t is a capital quality shock, which we use as a representation of the driver of a global financial crisis, following Gertler and Karadi (2011), who introduce this shock in the analysis of the Global Financial Crisis. Our interpretation is that the shock that precipitated the Global Financial Crisis is a deterioration in the quality of assets of banks, which leads to a fall in banking net worth,

[13] $\Omega_{t+1} \equiv \beta_t (\frac{C_{t+1}^R}{C_t^R})^{-\sigma_R} \frac{P_t}{P_{t+1}}$. We allow for the possibility of a preference shock as a simple way to model a demand shock in our model.

an increase in spreads, a fall in asset prices, all of which precipitate a global deleveraging cycle. For example, during the global financial crisis, this shock represents the impact of the housing crisis, and at the outset of the COVID pandemic it captures the sudden loss in productive capacity of office and retail space, and other capital arising from supply-chain disruptions. The global downturn itself is not directly associated with the special role of the dollar or U.S. Treasury bills in bank balance sheets. The dollar appreciation and differential response of the U.S. and ROW economy is however a consequence of the differential collateral requirements for U.S. and ROW government bonds.

We assume that the firm in each country sets two prices, one for sales in the domestic market in the domestic currency, and one for sales in the export market in the local currency of the importer. Thus, both countries engage in 'local currency pricing' (LCP).

The profits of the Home firm i are then represented as

$$\Pi_{i,t} = \big((1+s_{i,t})(P_{i,h,t}Y_{i,h,t} + S_t P^*_{i,h,t} Y^*_{i,h,t}) - MC_t(Y_{i,h,t} + Y^*_{i,h,t})\big) \tag{11}$$

where $P_{i,h,t}$ is the price set in domestic currency for Home sales, and $P^*_{i,h,t}$ is the Foreign currency price, with S_t being the exchange rate (Home price of Foreign Currency). Also, MC_t denotes the firm's marginal cost, and $s_{i,t}$ represents a subsidy that may be given to the firm to offset the monopoly distortion in pricing. Cost minimization by the firm implies:

$$A_t(1-\alpha)(L_{i,t}^{1-\alpha}(\vartheta_t K_{i,t})^{\alpha})MC_t = W_t L_{i,t} \text{ and } A_t\alpha(L_{i,t}^{1-\alpha}(\vartheta_t K_{i,t})^{\alpha})MC_t = R_{K,t}(\vartheta_t K_{i,t}) \tag{12}$$

The firm chooses its Home and Foreign price to maximize the present value of expected profits, net of price adjustment costs

$$E_t \sum_{j=0} \Omega_t \left(\Pi_{i,t} - \xi\left(\frac{P_{i,h,t}}{P_{i,h,t-1}}\right) P_{h,t}Y_{h,t} - \xi\left(\frac{P^*_{i,h,t}}{P^*_{i,h,t-1}}\right) S_t P^*_{h,t} Y^*_{h,t} \right) \tag{13}$$

where $\xi(.)$ represents a price adjustment cost function for the firm. We assume that $\xi'(.) > 0$, and $\xi''(.) > 0$. In the calibration, $\xi = \frac{\phi_\pi}{2}(\frac{P_{i,h,t}}{P_{i,h,t-1}} - 1)^2$. Price adjustment costs are proportional to the nominal value of Home sales to each of the Home and Foreign markets, to be consistent with the nominal profit objective function of the firm.

The first order conditions for profit maximization for the Home firm i can be described as

$$\begin{aligned}(1+s_{i,t})Y_{i,h,t} = \quad & \varepsilon(P_{i,h,t}(1+s_{i,t}) - MC_t)\tfrac{Y_{i,h,t}}{P_{i,h,t}} + \xi'\left(\tfrac{P_{i,h,t}}{P_{i,h,t-1}}\right)\tfrac{1}{P_{i,h,t-1}} P_{h,t}Y_{h,t} \\ & -E_t\Omega_{t+1}\xi'\left(\tfrac{P_{i,h,t+1}}{P_{i,h,t}}\right)\tfrac{P_{i,h,t+1}}{P^2_{i,h,t}} P_{h,t+1}Y_{h,t+1}\end{aligned} \tag{14}$$

$$(1+s_{i,t})S_tY^*_{i,h,t} = \varepsilon(S_tP^*_{i,h,t}(1+s_{i,t})-MC_t)\frac{Y^*_{i,h,t}}{P^*_{i,h,t}} + \xi'\left(\frac{P^*_{i,h,t}}{P^*_{i,h,t-1}}\right)\frac{1}{P^*_{i,h,t-1}}S_tP^*_{h,t}Y^*_{h,t} - E_t\Omega_{t+1}\xi'\left(\frac{P^*_{i,h,t+1}}{P^*_{i,h,t}}\right)\frac{P^*_{i,h,t+1}}{P^{*2}_{i,h,t}}S_{t+1}P^*_{h,t+1}Y^*_{h,t+1} \tag{15}$$

3.3 Banks

Banks are modeled as in Gertler and Karadi (2011). A fraction of household members $1-\theta$ become bankers in any period, continue as bankers with probability θ, and revert to being consumers with probability $1-\theta$. When starting up, a bank receives some capital from households to establish its net worth, and borrows from households at fixed rates to invest in claims to Home and Foreign capital (or equity), and Home and Foreign currency denominated government bonds. Besides government, only banks operate in international financial markets. A Home banker i's balance sheet in period t is

$$B_{i,t}+N_{i,t} = Q_tK_{h,i,t+1}+S_tQ^*_tK_{f,i,t+1}+D_{h,i,t}+S_tD_{f,i,t} \tag{16}$$

where $B_{i,t}$ represents domestic currency deposits from households, $N_{i,t}$ is beginning net worth, Q_t and Q^*_t are the price of a unit of domestic and foreign capital, $K_{h,i,t+1}$ and $K_{f,i,t+1}$ are the holding of domestic and foreign capital, $D_{h,i,t}$ is the bank's purchase of Home denominated government bonds, and $D_{f,i,t}$ is its purchase of foreign currency denominated government bonds. This says that bankers use their net worth and new debt to invest in the Home and Foreign capital and Home and Foreign bonds. We calibrate so that banks will hold a positive position in all assets.[14]

Banker i chooses $K_{h,i,t+1}$, $K_{f,i,t+1}$, $D_{h,i,t}$, and $D_{f,i,t}$ to maximize her value evaluated using the SDF of Home households, $\Omega_{t+1}=\beta_t\frac{(C^R_{t+1})^{-\sigma}}{(C^R_t)^{-\sigma}}\frac{P_t}{P_{t+1}}$. Following Gertler and Karadi, conjecture that the value function of the bank is a time varying linear function of her net worth, so that $V_{i,t}=\upsilon_tN_{i,t}$

The banker's value function then satisfies:

$$V_{i,t} = E_t\Omega_{t+1}\left((1-\theta)N_{i,t+1}+\theta V_{i,t+1}\right) \tag{17}$$

This captures the fact that the banker will revert to being a consumer with probability $1-\theta$ and consume her net worth, and continue to be a banker with probability θ. The net worth dynamics must satisfy

[14] In order to narrow the focus of the model, we abstract from foreign currency funding of banks. This important channel has been explored by Bruno and Shin (2015) and Avdjiev et al. (2019) among many others.

$$
\begin{aligned}
N_{i,t+1} &= \tilde{R}_{k,t+1}Q_{t+1}\vartheta_{t+1}K_{h,i,t+1}+\tilde{R}^{*}_{k,t+1}Q^{*}_{t+1}S_{t+1}\vartheta^{*}_{t+1}K_{f,i,t+1}+R_{h,t+1}D_{h,i,t}+S_{t+1}R_{f,t+1}D_{f,i,t}-R_{t+1}B_{i,t}\\
&= (\tilde{R}_{k,t+1}\vartheta_{t+1}-R_{t+1})Q_tK_{i,t+1}+(\tfrac{S_{t+1}}{S_t}\tilde{R}^{*}_{k,t+1}\vartheta^{*}_{t+1}-R_{t+1})S_tQ^{*}_tK_{i,t+1}\\
&\quad +(R_{h,t+1}-R_{t+1})D_{h,i,t}+(\tfrac{S_{t+1}}{S_t}R_{f,t+1}-R_{t+1})S_tD_{f,i,t}+R_{t+1}N_{i,t}
\end{aligned} \tag{18}
$$

Here, $\tilde{R}_{K,t+1}\equiv\frac{R_{K,t+1}+(1-\delta)Q_{t+1}}{Q_t}$ and $\tilde{R}_{K,t+1}\equiv\frac{R^{*}_{K,t+1}+(1-\delta)Q^{*}_{t+1}}{Q^{*}_t}$ are the net return on equity capital where δ is the depreciation rate on capital, $R_{h,t+1}$ is the return on the domestic currency government bond and $R_{f,t+1}$ is the analogous return on the foreign government bond.

Banks maximize their value subject to (16) and subject to the participation constraint:

$$
\begin{aligned}
V_{i,t} \geq\ & \big((\kappa_{h1}+\kappa_{h2}\tilde{D}_{h,t})D_{h,i,t}+(\kappa_{f1}+\kappa_{f2}S_t\tilde{D}_{f,t})S_tD_{f,i,t}\big)\\
&+\big((\kappa_{Kh1}+\kappa_{Kh2}Q_t\tilde{K}_{h,t+1})Q_tK_{h,i,t+1}+(\kappa_{Kf1}+\kappa_{Kf2}S_tQ^{*}_t\tilde{K}_{f,t+1})S_tQ^{*}_tK_{f,i,t+1}\big)
\end{aligned} \tag{19}
$$

We introduce a set of asset-specific constraint parameters to allow for differential pledgeability as collateral across assets. Specifically, we have κ_{Kh1}, κ_{Kf1}, κ_{h1} and κ_{f1} as the constraint parameters for Home capital, foreign capital, Home bonds and Foreign bonds respectively[15]. As we discuss at length below, we posit that holdings of capital are more constrained than government bonds, and in turn, Foreign government bonds holdings are more constrained than Home bonds. The key idea is that government bonds are more pledgeable than equity or capital because of their safety and liquidity. In particular, the U.S. Treasury is the most pledgeable asset because of its safety and the depth of its market.

The bank's first order conditions for, respectively, Home and Foreign government bonds and Home and Foreign capital, are given by

$$
E_t\Lambda_{i,t+1}\left(R_{h,t+1}-R_{t+1}\right)=\lambda_{i,t}(\kappa_{h1}+\kappa_{h2}\tilde{D}_{h,t}) \tag{20}
$$

$$
E_t\Lambda_{i,t+1}\left(\frac{S_{t+1}}{S_t}R_{f,t+1}-R_{t+1}\right)=\lambda_{i,t}(\kappa_{f1}+\kappa_{f2}S_t\tilde{D}_{f,t}) \tag{21}
$$

$$
E_t\Lambda_{i,t+1}\left(\tilde{R}_{k,t+1}\vartheta_{t+1}-R_{t+1}\right)=\lambda_{i,t}(\kappa_{Kh1}+\kappa_{Kh2}Q_t\tilde{K}_{h,t+1}) \tag{22}
$$

$$
E_t\Lambda_{i,t+1}\left(\frac{S_{t+1}}{S_t}\tilde{R}^{*}_{k,t+1}\vartheta^{*}_{t+1}-R_{t+1}\right)=\lambda_{i,t}(\kappa_{Kf1}+\kappa_{Kf2}S_tQ^{*}_t\tilde{K}_{f,t+1}) \tag{23}
$$

[15] We also introduce κ_{Kh2}, κ_{Kf2}, κ_{h2} and κ_{f2} so the constraint depends on the aggregate bank holding of the assets (denoted with $\tilde{D}_{h,t}$,$\tilde{D}_{f,t}$, $\tilde{K}_{h,t+1}$ and $\tilde{K}_{f,t+1}$). The idea is that the monitoring cost is increasing with the asset size. We set these parameter values very small (0.005). The main purpose of these parameters is to pin down a determinate steady state portfolio. This is discussed further in section 4. Since these terms depend on aggregate values we assume that individual banks take these as given in their portfolio decisions. In equilibrium $\tilde{D}_{i,t}=D_{i,j,t}$ and $\tilde{K}_{i,t}=K_{i,j,t}$.

Here, $\lambda_{i,t}$ is the Lagrange multiplier on the bank's participation constraint (19) and

$$\Lambda_{i,t+1} \equiv \Omega_{t+1}\left((1-\theta)+\theta\upsilon_{i,t+1}\right)$$

is the banker's effective SDF. The bank's value function can be retrieved from the envelope condition:

$$\upsilon_{i,t} = \frac{E_t\Lambda_{i,t+1}R_{t+1}}{1-\lambda_{i,t}} \tag{24}$$

Now we can use the fact that banks are homogeneous, and aggregate across all Home banks, adding the start up capital that is given to new banks, which we assume is $\varphi\left(Q_tK_{h,t+1}+S_tQ_t^*K_{f,t+1}+D_{h,t}+S_tD_{f,t}\right)$, to get the dynamics of total net worth for the domestic banking sector as:

$$\begin{aligned} N_{t+1} = \quad & \theta[(\tilde{R}_{k,t+1}\vartheta_{t+1}-R_{t+1})Q_tK_{h,t+1}+(\tilde{R}^*_{k,t+1}\vartheta^*_{t+1}-R_{t+1})S_tQ_t^*K_{f,t+1} \\ & +(R_{h,t+1}-R_{t+1})D_{h,t}+(\tfrac{S_{t+1}}{S_t}R_{f,t+1}-R_{t+1})S_tD_{f,t}+R_{t+1}N_t] \\ & +\varphi\left(Q_tK_{h,t+1}+S_tQ_t^*K_{f,t+1}+D_{h,t}+S_tD_{f,t}\right) \end{aligned} \tag{25}$$

3.4 Capital Goods Producers

Capital goods producers buy the unused capital from banks, and engage in new investment, and sell the new capital to banks at price Q_t. The representative capital goods producer has the profit function

$$Q_tI_t - P_t(I_t + I_t\psi(\frac{I_t}{I_{t-1}})) \tag{26}$$

where $\psi(.)$ is an adjustment cost function, satisfying $\psi'(.)>0$ and $\psi''(.)>0$, with $\psi(\delta)=0$. In the calibration, $\psi=\frac{\phi_k}{2}(\frac{I_t}{I_{t-1}}-1)^2$. This implies that the price of capital is

$$Q_t = P_t(1+\psi'(\frac{I_t}{I_{t-1}})\frac{I_t}{I_{t-1}}+\psi(\frac{I_t}{I_{t-1}})) \tag{27}$$

3.5 Monetary policy

We assume a Taylor rule where the Central Bank targets the CPI inflation rate and uses the government interest rate as an instrument:

$$R_{h,t+1} = \frac{1}{R_{h,ss}}\left(\frac{P_t}{P_{t-1}}\right)^{\eta^\pi(1-\rho^R)}(R_{h,t})^{\rho^R}M_t \tag{28}$$

where M_t is an exogenous monetary shock, η^π and ρ^R are respectively the inflation targeting parameter and the interest rate smoothing parameter for the Central Bank

3.6 Fiscal policy

The Home and Foreign governments make transfers to the households and subsidize firms to eliminate the monopolistic distortion by issuing government debt. For the Home country we have

$$\bar{D}_{h,t} = R_{h,t}\bar{D}_{h,t-1} + s_t(P_{h,t}Y_{h,t} + S_t P^*_{h,t}Y^*_{h,t})) + TR_t \tag{29}$$

where $\bar{D}_{h,t}$ is the total outstanding debt of the Home government, assumed to be exogenous. In the baseline analysis, we assume governments issue a constant amount of debt every period.

3.7 Balance of Payments

The profit of the Home production firms are

$$\begin{aligned}\Pi^p_t = \quad & \Big((1+s_t)(P_{h,t}Y_{h,t} + S_t P^*_{f,t}Y^*_{h,t}) - MC_{h,t}(Y_{h,t} + Y^*_{h,t}) \\ & -\xi_t\left(\tfrac{P_{h,t}}{P_{h,t-1}}\right)P_{h,t}Y_{h,t} - \xi_t\left(\tfrac{P^*_{h,t}}{P^*_{h,t-1}}\right)S_t P^*_{h,t}Y^*_{h,t}\Big)\end{aligned} \tag{30}$$

Given constant returns to scale, we can write $MC_{h,t}(Y_{h,t} + Y^*_{h,t})$ as

$$W_t L_t + R_{K,t}\vartheta_t K_t$$

In equilibrium, labor supply must equal labor demand, so that

$$H_t = L_t$$

The profit of Home capital producing firms is:

$$\Pi^K_t = Q_t I_t - P_t(I_t + I_t\psi(\frac{I_t}{I_{t-1}})) \tag{31}$$

In addition, the capital stock accumulation equation must satisfy

$$K_{t+1} = [I_t + (1-\delta)\vartheta_t K_t]$$

where δ is the depreciation rate on capital.

Total profits from the corporate non-financial sector are then

$$\Pi^p_t + \Pi^K_t$$

In addition, the return on deposits to Home households may be expressed as

$$R_tB_{t-1} = R_{K,t}\vartheta_tK_{h,t} + (1-\delta)Q_t\vartheta_tK_{h,t} + r^*_{K,t}\vartheta^*_tK_{f,t} + (1-\delta)S_tQ^*_t\vartheta^*_tK_{f,t} + R_{h,t}D_{h,t-1} + S_tR_{f,t}D_{f,t-1} - N^e_t \tag{32}$$

where N^e_t represents the net worth of existing banks. The startup capital transferred from households to banks is

$$T_{s,t} = \varphi\left(Q_tK_{t+1} + D_{h,t} + S_tD_{f,t}\right) \tag{33}$$

So total net worth of the banking sector at time t is $N_t = N^e_t + T_{s,t}$

Finally, government transfers are:

$$TR_t = \bar{D}_h - R_{h,t}\bar{D}_h - s_t(P_{h,t}Y_{h,t} + S_tP^*_{h,t}Y^*_{h,t})) \tag{34}$$

Note that the net deposits from households to financiers can be defined as

$$B_t = Q_tK_{h,t+1} + S_tQ^*_tK_{f,t+1} + D_{h,t} + S_tD_{f,t} - N_t$$

Putting together (30), (31), (32), (33), (34), with the Home budget constraint (3), we get the balance of payments condition:

$$\begin{aligned} P_t(C_t + I_t + I_t\psi(\tfrac{I_t}{I_{t-1}})) + D_{h,t} - \bar{D}_h + S_tD_{f,t} + Q_t(K_{h,t} - K_t) + S_tQ^*_tK_{f,t} = \\ P_{h,t}Y_{h,t} - \xi(\tfrac{P_{h,t}}{P_{h,t-1}})P_{h,t}Y_{h,t} + S_tP^*_{h,t}Y^*_{h,t} - \xi(\tfrac{P^*_{h,t}}{P^*_{h,t-1}})S_tP^*_{h,t}Y^*_{h,t} \\ +R_{h,t-1}(D_{h,t-1} - \bar{D}_h) + S_tR_{f,t-1}D_{f,t-1} + \tilde{R}_{k,t}\vartheta_t(K_{h,t-1} - K_{t-1}) + S_t\tilde{R}^*_{k,t}\vartheta^*_tK_{f,t-1} \end{aligned} \tag{35}$$

where $\bar{D}_{h,t}$ is the total outstanding debt of the Home government.

3.8 Adjusted UIP condition

By combining equation (20) and (21) we get:

$$E_t\Lambda_{t+1}(\frac{S_{t+1}}{S_t}R_{f,t+1} - R_{h,t+1}) = \lambda_t(\kappa_{f1} - \kappa_{h1}) \tag{36}$$

Equation (36) indicates that the presence of differential balance sheet constraints leads to a deviation from UIP. Given that the U.S. bond requires less collateral than that of the Foreign country, there is a positive convenience yield on the U.S. asset.[16] Moreover, the convenience yield will

[16] We omit the second order terms from this illustration since they are negligible for our quantitative results.

be time varying, critically dependent on the degree of financial stress captured by the Lagrange multiplier on the bank's incentive constraint.

Log linearizing the conditions (20) and (21) and taking the difference, we have a UIP condition adjusted for the balance sheet friction:

$$E_t s_{t+1} - s_t = (r_{h,t+1} - r_{f,t+1}) + \hat{\eta}_t \tag{37}$$

where $\hat{\eta}_t$ is our definition of convenience yield.[17]

Our emphasis is on demand for liquidity rather than risk. Linearizing the equation eliminates the role of a time-varying risk premium, which also may play a role in driving exchange rates.[18] Forward iterating the equation gives:

$$s_t = -E_t \sum_{j=1}^{\infty} (r_{h,t+j} - r_{f,t+j} - (\overline{r_h - r_f})) - E_t \sum_{j=0}^{\infty} (\hat{\eta}_{t+j} - (\overline{\eta})) + \lim_{k\to\infty} (E_t s_{t+k} - k(\overline{s_{+1} - s})) \tag{38}$$

or in real terms:

$$rer_t = -E_t \sum_{j=1}^{\infty} (\tilde{r}_{h,t+j} - \tilde{r}_{f,t+j} - (\overline{\tilde{r}_h - \tilde{r}_f})) - E_t \sum_{j=0}^{\infty} (\tilde{\eta}_{t+j} - (\overline{\tilde{\eta}})) + \lim_{k\to\infty} (E_t rer_{t+k} - k(\overline{rer_{+1} - rer})) \tag{39}$$

where rer_t is the linearized real exchange rate and variables with tilde is the real variable normalized by the country's CPI.

This shows that the transitory component of the exchange rate appreciates in response to the sum of expected future (transitory) interest rate differentials, as is usual, but also to the sum of expected future (transitory) convenience yields.

4 Calibration and Steady-State Values

4.1 Calibration

The model frequency is quarterly. We calibrate the model to match U.S. moments. We think of Home as the U.S. and Foreign as the rest of the World. To highlight the important role of the asymmetric collateral value, we set all other parameters to be equal across Home and Foreign. The parameter values are summarized in Table 1.

[17] Specifically, $\hat{\eta}_t$ depends on the change in the bank's Lagrange multiplier, and the change in the conditional expectation of the bank's SDF. It is identically zero when $\kappa_{h1} = \kappa_{f1}$.

[18] See, for example, Kalemli-Özcan and Varela (2021); Akinci et al. (2022); Obstfeld and Zhou (2023) for empirical evidence linking risk, UIP deviations, and exchange rates.

The parameters can be partitioned into two blocs. The first bloc is externally set and mostly set to values that are in line with standard literature values. The second bloc is calibrated to match some long-term averages in the data. The relevant data series are reported in the Appendix Table [x].

On the household side, we set the discount factor (β) to be a constant and is 0.99. Home bias (ω, ω^*) parameters are set at 0.8. The cross-country elasticity of substitution of goods (μ) is set at 3.8, following Bajzik et al. (2020). The within-country elasticity of substitution of goods (ε) is assumed to be 6. The inverse of the Frisch elasticity (ψ) is set at 1 and we calibrate the disutility of labor χ to match a steady-state H^* of 0.33. The CRRA coefficient for households (σ) is set as 5.

On the production side, the country mass (n) is set at 0.5 to preserve symmetry. The Rotemberg price adjustment cost (ϕ_π) is set at 58.25, matching an annual probability of price change of 0.75 in a Calvo-type model of sticky prices. The investment adjustment cost (ϕ_k) is set at 7. The capital share (α) is set at 0.33 and depreciation rate (δ) is set at 0.04.

On the government side, the Taylor coefficient (η^π) is set at 1.78 with a smoothing parameter (ρ^R) equal to 0.92 (taken from Engel and Wu (2024)). Government debt is fixed ($\bar{D}_h$ and $\bar{D}_f$) at a constant value of 2.1, resulting in a steady state Home debt to GDP ratio ($\bar{D}_h/GDP$) of 65%, matching the long-run (1999-2023) average of the U.S. and Eurozone, excluding debt held by the central banks. The monopoly subsidy is set at 0.2 ($s = \frac{1}{\varepsilon - 1}$) to eliminate the steady state mark-up distortion. For simplicity, gross steady state inflation ($\bar{\pi}$) is set to zero.

On the banking side, we calibrate the constraint parameters to match the U.S. external positions. This is the only source of asymmetry between the two countries. We calibrate the four bond constraint parameters (κ_{h1},κ_{f1}, κ^*_{h1}, κ^*_{f1}) to 0.041, 0.44, 0.095 and 0.37, respectively to match a steady state convenience yield of 1% at an annual rate (which is the same as steady state Home minus Foreign interest rate differential of -1%), a steady state positive income account of +0.0011 ((current account - trade balance)/GDP of U.S. from 1983-2023, a steady state -14% NFA position and a steady state Foreign holding of U.S. government bond ($D^*_h/\bar{D}_h$) of 30% . While these are calibrated jointly, lowering the Home bond constraint parameter (κ_{h1} and κ^*_{h1}) relative to the Foreign bond constraint parameter (κ_{f1} and κ^*_{f1}) generates a positive convenience yield. Since the net foreign bond position is defined as $-D^*_{h,t} + S_t D_{f,t}$, a relatively low value of κ^*_{h1} to κ_{f1} is useful to generate a negative NFA position. A higher κ^*_{h1} (relative to κ_{h1}) helps to match the share of Foreign holdings of U.S. Treasury obligations. Finally, the relative values of κ_{h1} and κ_{f1} are useful for pinning down the positive income account. On the capital side, we maintain an agnostic view about the relative collateral values in generating the asymmetry of external positions. Instead, we calibrate the model such that $\kappa_{K,h} = \kappa^*_{Kf} < \kappa_{Kf} = \kappa^*_{Kh}$. That is, Home capital serves as better collateral than Foreign capital for Home banks and the opposite is true for Foreign banks. We set

$\kappa_{Kf}, \kappa^*_{Kh}$ to 0.471 and 0.38 and $\kappa_{Kh} = \kappa^*_{Kf} = 0.37$ to match a net equity return of 1.8% and equity Home share of 70% (average of 1990-2016 from Hnatkovska (2019)), which are in the range of estimates from the Home equity bias literature. Finally, we set the bank survival probability (θ) and capital injection rate (φ) to be at standard values of 0.95 and of 0.01 respectively, resulting in a steady state leverage of around 3.

The bank asset constraints also include the parameters (κ_{h2},κ_{f2}, κ^*_{h2}, κ^*_{f2}, κ_{Kh2},κ_{Kf2}, κ^*_{Kh2}, κ^*_{Kf2}). Our analysis is based on linearization around the non-stochastic steady state. In the non-stochastic steady state, in the absence of these parameters, the equilibrium portfolio would be indeterminate, as investors would be indifferent between assets that paid the same expected return inclusive of the liquidity yield. The problem is similar to the indeterminacy of portfolios in the non-stochastic steady state in the mean-variance framework (see Devereux and Sutherland (2010, 2011).) While it is necessary to introduce these terms, we set all four at very small values (0.005) so as to have effectively no influence on the dynamic adjustment process. This is somewhat analogous to the fix proposed by Schmitt-Grohé and Uribe (2003) of introducing a debt-elastic interest rate to solve the problem of the absence of a steady state in small-open economy models with incomplete markets. In the Appendix, we provide an alternative approach to solve the model with second order approximation and the "risky steady state" used in the closed economy model of Gertler et al. (2012). Our results are qualitatively and quantitatively robust to these adjustments. The steady-state portfolios in such a set-up would be chosen as the solution to a mean-variance criterion. But this type of model has proven to be notably unsuccessful in capturing important features of international portfolio holdings, specifically the high degree of home bias in equity holdings and the relatively higher return that the U.S. earns on its foreign portfolio compared to other countries. Our choices of (κ_{h1},κ_{f1}, κ^*_{h1}, κ^*_{f1}), as described above, are chosen to more nearly approximate those features of the data. This makes our calibration of the steady state closer in spirit to the models that introduce a makeshift "preferred habitat" into portfolio choice (such as in Greenwood et al. (2020) and Gourinchas et al. (2022)), or the empirical models in which the factors affecting portfolio choice are data-driven (Koijen and Yogo (2020); Jiang et al. (2022).)

We first focus on the analysis of global shocks in the impulse response analysis in section 5 and allow for country specific shocks in section 6. We first introduce three shocks. They are global productivity shocks (A_t^{Global}), global financial shocks (ϑ_t^{Global}), and global monetary shocks (M_t^{Global}). All shocks are modeled as AR(1) stochastic processes:

$$log(A_t) = log(A_t^*) = log(A_t^{Global}) = \rho^{A,Global} log(A_{t-1}^{Global}) + s^{A,Global} e_t^{A,Global}$$

$$log(\vartheta_t) = log(\vartheta_t^*) = log(\vartheta_t^{Global}) = \rho^{\vartheta,Global} log(\vartheta_{t-1}^{Global}) + s^{\vartheta,Global} e_t^{\vartheta,Global}$$

$$log(M_t) = log(M_t^*) = log(M_t^{Global}) = \rho^{M,Global} log(M_{t-1}^{Global}) + s^{M,Global} e_t^{M,Global}$$

We set the persistence of the TFP shock and financial shock to be 0.98 and the persistence of the monetary shock to be 0.25. In the impulse response analysis, we focus on 1% shocks unless otherwise specified.

Table 1: Parameter values

	Symbol	Value	Meaning / description	Target
	Households			
1	β	0.99	Discount factor	
2	σ	5	CRRA risk coefficient	
3	$\omega = \omega^*$	0.8	Home bias	
4	χ	14.85	Labor disutility	$L^* = 0.3$
5	ψ	1	Inverse of Frisch elasticity	
6	μ	3.8	Cross country elasticity of substitution	Bajzik et al. (2020)
7	ε	6.0	Within country elasticity of substitution	
	Firms			
8	n	0.5	Home country mass	
9	α	0.33	Capital share	
10	ϕ_π	155.88	Price adjustment cost	Calvo probability =0.75
11	ϕ_k	7	Investment adjustment cost	
	δ	0.03	Depreciation rate	
	Governments			
12	$\bar{\pi}$	1	Steady state inflation	
13	$s = s^*$	0.2	Monopoly subsidy ($\frac{1}{\varepsilon-1}$)	
14	$\bar{D}_h = \bar{D}_f$	2.1	Total government debt	Debt/GDP = 65%
15	η^π	1.78	Taylor rule coefficient	
16	ρ^R	0.92	Interest rate smoothing parameter	
	Banks			
17	$\vartheta = \vartheta^*$	1	Country-specific constraint value	
18	κ_{h1}	0.04015	Home bank constraint value on Home bond	Jointly targeting: $D_h^*/\bar{D}_h$ = 30%,
19	κ_{f1}	0.44	Home bank constraint value on Foreign bond	NFA/GDP = -14%,
20	κ_{h1}^*	0.095	Foreign bank constraint value on Home bond	Net foreign income/GDP = 0.11%,
21	κ_{f1}^*	0.37	Foreign bank constraint value on Foreign bond	1% convenience yield
22	κ_{Kh}	0.37	Home bank constraint value on Home capital	Equity premium 1.8%
23	κ_{Kf}	0.471	Home bank constraint value on Foreign capital	
24	κ_{Kh}^*	0.38	Foreign bank constraint value on Home capital	Home bias of equity 70%
25	κ_{Kf}^*	0.37	Foreign bank constraint value on Foreign capital	
26	θ	0.95	Bank survival prob.	
27	φ	0.01	Bank starting net worth	

Table 2: Steady state values

Symbol	Targeted steady state
$r_f - r_h$	1% (annualized)
Net foreign income: (CA-TB)/GDP	0.11% (annualized)
NFA/GDP	-14% (annualized)
$D_h^*/\bar{D}_h$	30%
$\bar{D}_h/Y$	65% (annualized)
Home bank's Home equity share ($\frac{K_h}{K_h+SK_f}$)	70%
Foreign bank's Foreign equity share ($\frac{K_f^*}{K_f^*+K_h^*/S}$)	71%
$\tilde{R}_k$	1.8% (annualized)

Symbol	Steady state value	Symbol	Steady state value
C	0.6228	Y	0.8015
C^*	0.6219	Y^*	0.8008
K	5.9845	d_h	1.57
K^*	5.9322	d_f	0.71
L	0.297	λ	0.0091
L^*	0.299	λ^*	0.0098
W	1.804	r_h	1.0111
W^*	1.796	r_f	1.0138
RER	0.9997	Home bank's leverage (asset/equity)	3.02
$r = r^*$	1.0101	Foreign bank's leverage (asset/equity)	2.93

4.2 Steady state values

Table 2 presents some steady state values using the parameterization listed above. The complete set of equations and steady state conditions provided in Appendix A and B.

The only asymmetry in the model is the differential in bond constraint parameters. As we noted above, we set the Home bond to be better collateral for both Home and Foreign banks ($\kappa_{h1}, \kappa_{h1}^* < \kappa_{f1}, \kappa_{f1}^*$). With this asymmetry alone, we are able to generate three important features of the U.S. external position. First, the U.S. has a government bond rate that is lower than the Foreign government bond rate by 1%. This can be understood by looking at the steady state version of equation (37). Since $E_t s_{t+1} - s_t = 0$ at the steady state, the excess monetary return of the Foreign bond reflects the additional non-pecuniary balance sheet cost of holding it. This reflects the convenience yield arising from the better pledgeability of U.S. debt.

Second, the U.S. has a negative NFA position, meaning that it has a net liability to the rest of the world. Third, despite the net liability, the U.S. has a steady state trade balance deficit and positive income account. This is because while it owes the rest of the world repayment, it pays a lower interest rate on its liability to the rest of the world than the rest of the world pays to the U.S..

Also, the external equity share of the Home country is higher than the Foreign country (defined as external equity divided by the sum of external equity and bond holdings). The means that the Home country earns a higher overall return on foreign assets due to the equity premium, as documented in Bertaut et al. (2023). The sum of these features leads the U.S. to an exorbitant privilege

5 Impulse responses

5.1 *Global Financial Shock*

In this section, we describe a series of impulse responses from the simulated model. As a baseline, in Figure 2 we allow for a uniform increase of ϑ and ϑ^*, the capital quality shock. We scale the size of the shock to four percent to produce a 10% U.S. dollar appreciation on impact, roughly the size of appreciation observed in 2008Q3. This represents a negative shock to the banking system in each country, as the value of each bank declines. In turn, this forces the the banks to de-lever as well as to adjust their investments across asset classes.

The shock to capital quality leads to an immediate appreciation of the U.S. real exchange rate, followed by an expected depreciation. As described in equation (39), the real exchange rate can be decomposed as the sum of expected future real interest rate differentials and convenience yield differentials. Column 3 of the first row of Figure 2 shows that this is predominantly associated with a rise in the convenience yield (defined as negative of $\tilde{r}_{ht} - \tilde{r}_{ft} - (rer_{t+1} - rer_t)$, the blue line in the top panel of the third column).[19] Thus, there is an increase in the deviation from UIP; the excess expected return on Foreign relative to U.S. government bonds rises in response to the global financial shock. To understand the mechanics of this response, take the difference between equation (20) and equation (21) for the Home bank, which gives the condition:

$$E_t \Lambda_{i,t+1} \left(R_{h,t+1} - R_{f,t+1} \frac{S_{t+1}}{S_t} \right) = \lambda_{i,t} (\kappa_{h1,t} - \kappa_{f,1,t}) \tag{40}$$

The term inside the parenthesis on the right hand side is negative, given that the Home bond is better collateral than the Foreign bond.[20] The expected return on the Home bond is less than that of the Foreign bond, so that on average, UIP will not hold, as in the data. The shock to the value of existing capital tightens the collateral constraint, leading to an increase in $\lambda_{i,t}$. The expected return on the Home bond must fall relative to that on the Foreign bond - hence the convenience yield

[19] Note that if we measure the relative convenience yield as in Engel and Wu (2023), the difference between the deposit rate in the U.S. and the government bond interest rate, relative to the same interest rate differential in the Foreign country, that also increases at the time of the financial shock as shown in Row 2 Column 2 of 2. This is in agreement with the empirical regularities plotted in Figure 1.

[20] In this description, we abstract from the quadratic terms in the collateral constraint and the first order conditions (20) and (21), since in practice these terms are very small, and do not affect the argument.

on U.S. government bonds rises further. While this explanation uses the first-order conditions for the Home bank alone, a similar explanation holds for the Foreign bank. Therefore a direct implication of the asymmetric collateral value of U.S. relative to Foreign government debt is that a global capital quality shock leads to an increase in the convenience yield on U.S. bonds and a real appreciation of the U.S. dollar. In fact, given the monetary rule, the relative interest rates on Home and Foreign bonds do not change very much, as can be seen in row 2, column 2 of Figure 2. Instead, the increase in the convenience yield on U.S. bonds is mostly achieved by an immediate appreciation and therefore an expected depreciation of the Home real exchange rate.

The response of λ_t and λ_t^* represent the endogenous increase in the Lagrange multipliers on the bank's collateral constraints. While these increase for both countries, it increases more for the Home bank than the Foreign bank. This is due to three different channels. First, the Home bank leverages more at the steady state and has a higher equity portfolio, resulting in a bigger fall in net worth following the financial tightening. Second, the dollar appreciation raises the value of the Foreign banks' Home investments but hurts the Home bank's Foreign investments. Third, the Home bank disinvests in physical capital more than the Foreign bank, given the advantage of Home bonds over Foreign bonds, and the fact that the relative balance sheet cost of Home bonds to capital for the Home bank is less than the equivalent relative cost for the Foreign bank. We can see the intuition behind this third channel by focusing on equations (22) and (20) above, and the equivalent conditions for the Foreign bank. This gives us the conditions:

$$E_t \Lambda_{i,t+1} \left(\tilde{R}_{k,t+1} - R_{ht+1} \right) = \lambda_{i,t} (\kappa_{Kh1} - \kappa_{h1}) \tag{41}$$

$$E_t \Lambda^*_{i,t+1} \left(\tilde{R}^*_{k,t+1} - R_{ft+1} \right) = \lambda^*_{i,t} (\kappa^*_{Kh1} - \kappa^*_{f1}) \tag{42}$$

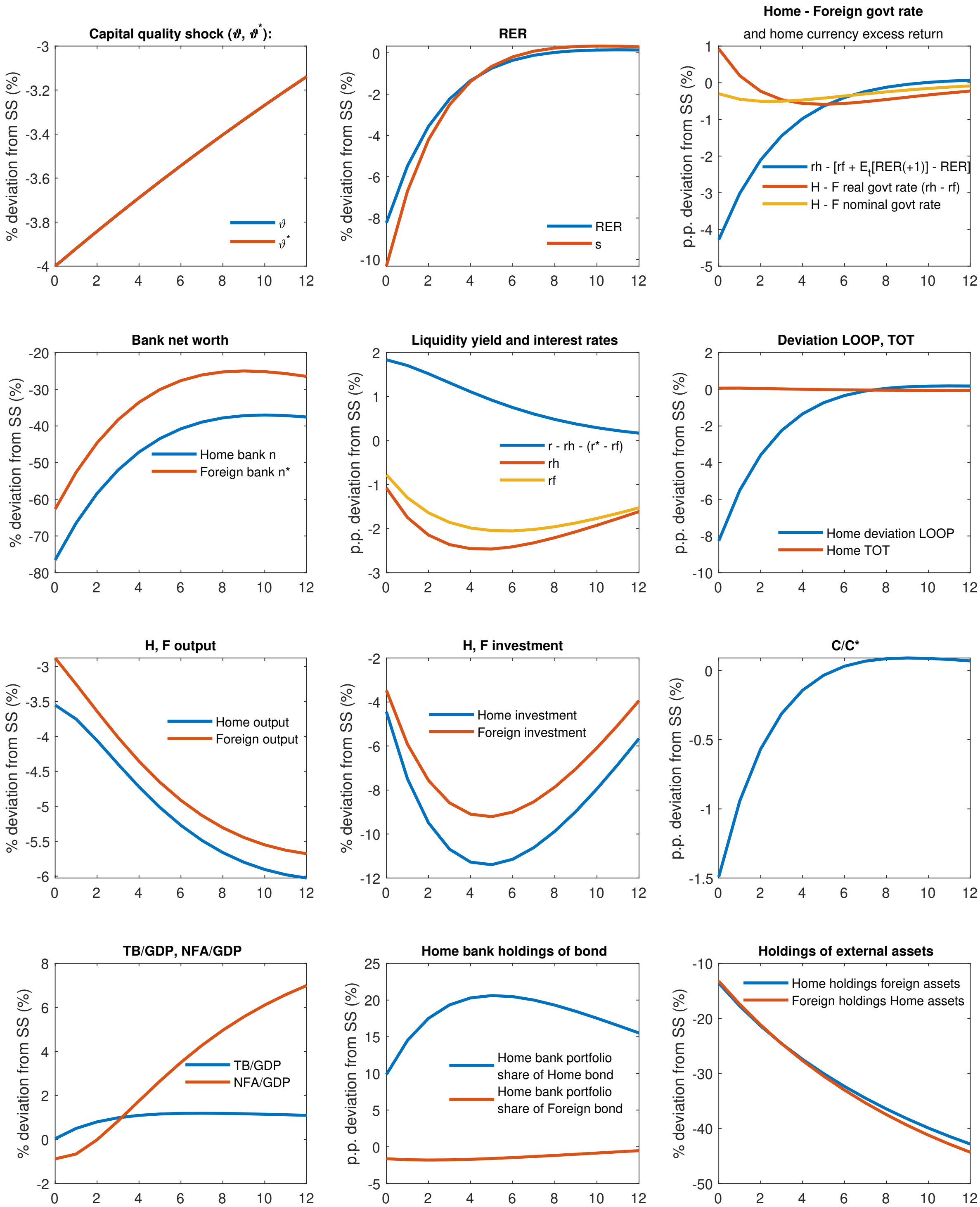
Equation (41) describes the Home bank's trade off between Home government bonds and Home capital (or equity), while equation (42) describes the analogous trade-off for the Foreign bank between Foreign government bonds and Foreign capital. The negative financial shock reduces investment in both countries, but investment falls by more in the Home country. The term $(\kappa_{Kh1} - \kappa_{h1})$ in parentheses on the right hand side of equation (41) is larger than the equivalent term $(\kappa^*_{Kh1} - \kappa^*_{f1})$ in equation (42) precisely because Home government bonds represent better collateral, relative to Home capital, than Foreign government bonds relative to Foreign capital. Hence the expected excess return on Home capital relative to Home bonds must rise more than that on Foreign capital relative to Foreign bonds, and the end result is that Home investment must fall relative to Foreign investment. With sticky prices and demand determined output, this translates to a greater fall in Home output relative to Foreign output.[21]

Figure 2 shows that U.S. NFA to GDP falls after the financial shock. This is primarily due to real appreciation of the U.S. dollar. We can interpret this as the U.S. effectively making a transfer to the rest of the world as part of its 'exorbitant duty' during a financial crisis. As part of this transfer, Home consumption falls relative to Foreign consumption, as shown in row 3 column 3. But despite the wealth transfer and the larger fall in Home consumption, we do not encounter the Maggiori (2017a) 'reserve currency paradox', which questions how the U.S. dollar country can appreciate during times when U.S. relative wealth falls, since in principle with home bias in preferences, the fall in relative consumption should cause a U.S. terms of trade depreciation. As we have shown here, the real dollar appreciation is driven in financial markets by the rise in the convenience yield. While this still has to be consistent with equilibrium in the goods market, LCP introduces a separation between the real exchange rate and terms of trade movement. As shown in the bottom right panel of Figure 2, the real exchange rate appreciation is almost wholly driven by deviations from the law of one price. This is similar to a 'trade wedge' explanation in Maggiori (2017a) whereby the deviations widened during the crisis. Here in fact the larger drop in Home output upon the global financial shock results in a small terms of trade improvement, rather than a deterioration[22] Note that even though the dollar appreciates, the U.S. trade balance improves slightly under LCP, as consumption and investment fall to a greater extent in the U.S., and the expenditure-switching effects of exchange rate movements is small.

[21] While this argument seems incomplete because both Home and Foreign banks invest in bonds and capital in each others country, the fact that in both equity capital and bond holdings banks have relative larger positions in their Home market ensures that the financial shock hits Home investment more than it does Foreign investment. Abbassi and Bräuning (2023) and Agarwal (2019) have recently empirically investigated how credit contractions in the financial sector influence investment in an international setting.

[22] We study the implications of different pricing in subsection 5.3. The real exchange rate appreciation and the fall in the value of Home capital translates into a greater fall in the net worth of Home banks relative to Foreign banks, as in row 2, column 1 of Figure 2, which can be interpreted as another way in which the U.S. acts as an implicit 'insurer' to the rest of the world in times of global crisis, given that banks are owned by domestic residents

Figure 2: Baseline with 4% global financial shock (ϑ, ϑ^*)



Notes: The figure shows IRF of a 4% global financial shock. Subtitles of the figure report the steady state value of the reporting variables.

The response to a global financial shock in our model helps to throw light on some outstanding puzzles in the literature on the role of the U.S. dollar in financial crises. First, we see an explanation for the appreciation of the dollar during times of financial contraction. If there were only risk motives for holding bonds, the reserve currency paradox arises. Under a pure risk-premium story, perhaps the dollar appreciates if its covariance with the household's stochastic discount factor increases during global downturns. The paradox is that the U.S. must make its insurance payment to foreigners during these global financial recessions, but that implies a reduction in U.S. wealth, which in a standard model ought to lead to a real depreciation. In our model, these difficulties are resolved. The demand for dollar assets increases in bad times because of the increase in demand for the asset that provides better collateral when financial constraints are tightened. And with local-currency pricing, the link between the terms of trade and the real exchange rate is broken, so even if U.S. relative wealth falls, a real appreciation is still possible.

The asymmetric response of Home and Foreign banks also has a striking implication for gross asset holding positions. Given that the Home bank increases its demand for Home bonds as it substitutes away from capital, there is an external portfolio retrenchment - Home banks increase their holding of Home bonds and decrease their holdings of Foreign bonds, and the opposite applies to the Foreign banks. Retrenchment is a common feature of financial crises and was clearly a feature of the Global Financial Crisis. Indeed, there is a retrenchment puzzle - the increase in foreign demand for U.S. assets during times of global financial stress appears to conflict with the empirical evidence on retrenchment.

To understand the forces driving retrenchment, it is instructive to look at the response to the same financial shock, except in the case when there is no difference in collateral requirements between the Home and Foreign bank. Figure 3 illustrates this case, where $\kappa_{h1} = \kappa^*_{h1} < \kappa_{f1} = \kappa^*_{f1}$. While the U.S. (i.e. Home) government bond still has a collateral advantage, the collateral constraints are identical for both Home and Foreign banks, so there is no home bias in bond holdings among banks. To understand the forces driving retrenchment, note first that because the banks in each country face identical constraints on U.S. and Foreign bonds, in essence at steady state their holdings of U.S. bonds and Foreign bonds are nearly identical.[23] The tightening of the credit constraint raises demand for U.S. bonds relative to Foreign bonds because U.S. bonds are preferred collateral. If all investors were identical and evaluated assets in the same currency, given that the supplies of bonds from both countries are fixed, the increase in demand would lower the expected return on U.S. bonds relative to Foreign bonds until investors were satisfied to hold the existing stock of both bonds. However, the appreciation of the dollar raises the foreign currency value of U.S. bonds, and by itself increases the share of those bonds in the Foreign bank's portfolio.

[23]There is a slight difference arising from the fact that U.S. wealth is somewhat higher in steady state because of the seignorage it earns from its exorbitant privilege.

Given that the Foreign bank has increased its share of U.S. bonds in this way, the U.S. bank can, in equilibrium, increase the share of U.S. bonds in its portfolio by buying some from the Foreign bank. The fact that in the baseline calibration, the U.S. bank has a stronger incentive to switch its portfolio out of capital and into Home bonds in the baseline calibration further reinforces the retrenchment. The relative reduction in demand for Foreign bonds works in the opposite way. The depreciation of the foreign currency automatically reduces the share of Foreign bonds in the U.S. bank's portfolio, so the Foreign bank balances the market by buying some Foreign bonds from U.S. banks.[24]

This helps towards a better understanding of asset flows. The literature has puzzled over how to reconcile the empirical finding of global retrenchment during times of financial stress with the observation that the dollar appreciates. Retrenchment seems to imply that while the U.S. is shifting its demand away from Foreign assets, the rest of the world is shifting its demand away from dollar assets. But as we have seen, that understanding of retrenchment mixes the equilibrium change in asset holdings with the change in demand. We see that Foreign banks do increase their demand for U.S. assets, as do U.S. financial intermediaries, and that contributes to the appreciation of the dollar. But it is the change in the exchange rate itself as well as the influence of changes in demand for other assets that leads to the equilibrium portfolio adjustment - with Foreign banks reducing their holdings of U.S. bonds, while U.S. banks increase theirs.[25]

We can compare these results to some of the stylized facts in the response to financial shocks, as described in Davis and van Wincoop (2022). They estimate the response of asset prices and capital flows after a global financial shock (their "GFC factor.") They find that this leads to a global fall in equity prices, a global fall in real interest rates, and a retrenchment in capital flows. As we've seen, all these are features of our model following a global financial shock. In addition, Davis and van Wincoop (2022) find asymmetric effects for countries that are net debtors of safe assets. That is, they find that for the U.S., the current account improves, savings increases relative to the rest of the world, investment declines relative to the rest of the world, the U.S. sells fewer Treasury bonds abroad, and the U.S. sheds holdings of risky foreign assets. Again, all these features are captured by our model.

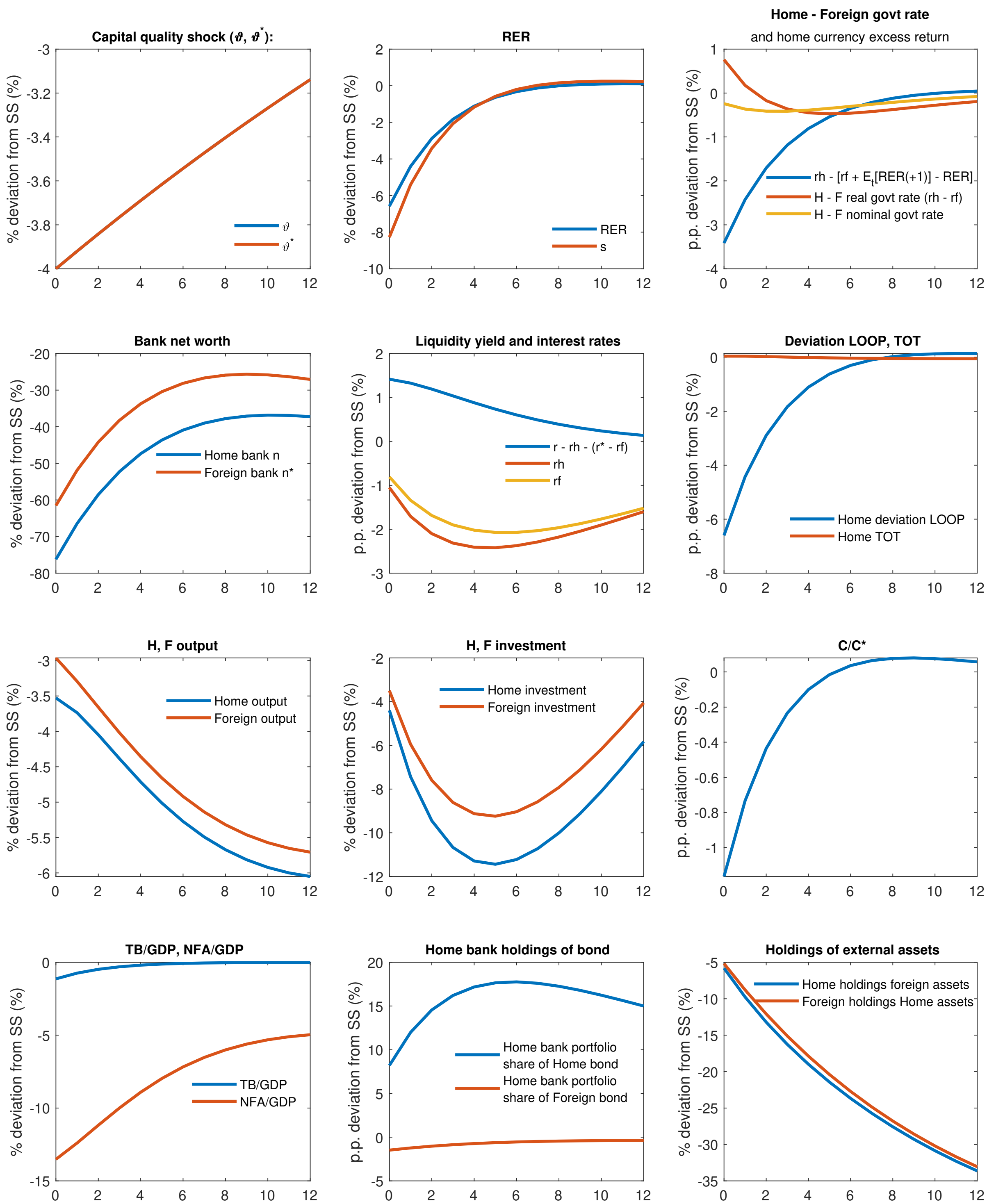
In the Appendix F, we discuss an alternative model of demand for liquid assets through a more standard bond in utility function framework. The bond in utility model can reconcile the relationship of exchange rate and convenience yield, but cannot rationalize the flow to the Treasury

[24] Portfolio dynamics upon the global financial shock are reported in Appendix C.3. We also show results are robust to a special case in which capital is not traded internationally in Figure 9 in the Appendix.

[25] In a panel study of 188 countries, Kim and Min (2022) find that relative valuation effects among countries are mostly associated with exchange-rate changes (rather than asset price changes), and that there tends to be a negative correlation between real exchange rates and trade balances (that is, the trade balance tends to rise into surplus when the currency appreciates, as above.)

market, gross cross country capital flows and trade balances as in the model analysis above.

Figure 3: 4% global financial shock (ϑ, ϑ^*) with $\kappa_{h1} = \kappa^*_{h1} = 0.095 < \kappa_{f1} = \kappa^*_{f1} = 0.37$



Notes: The figure shows IRF of a 1% global financial shock. Subtitles of the figure report the steady state value of the reporting variables.

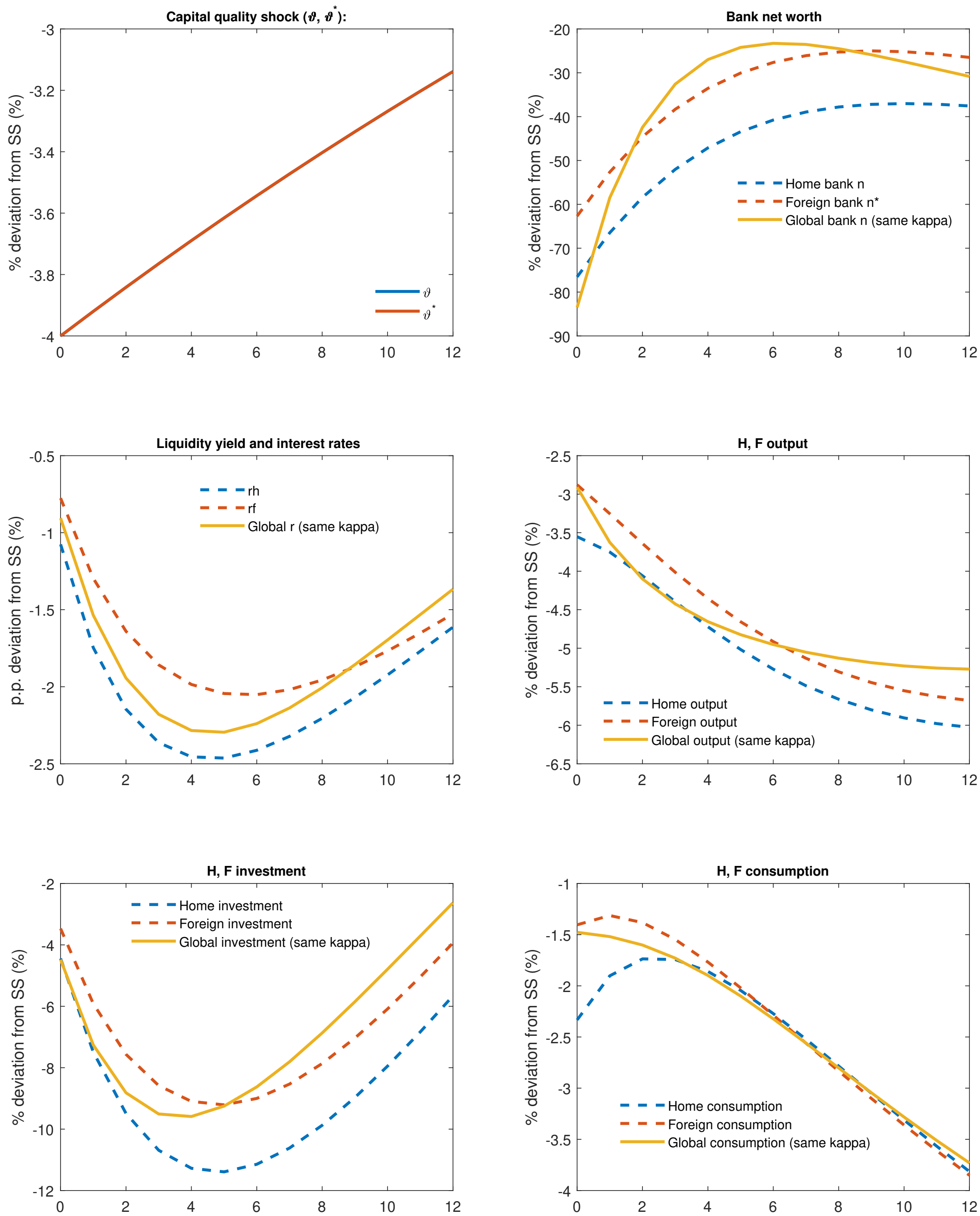
5.2 *What Causes the Global Downturn?*

In Figure 4, we highlight the roles of the funding spread - that is, the difference between the rate at which banks lend to producers and the rate paid to the creditors (depositors) - and the uncovered interest parity wedge. Here, we set the parameters of the two countries to be identical ($\kappa_{h1} = \kappa^*_{h1} = \kappa_{f1} = \kappa^*_{f1} = 0.15$,and $\kappa_{Kh1} = \kappa^*_{Kh1} = \kappa_{Kf1} = \kappa^*_{Kf1} = 0.35$), so the U.S. does not enjoy an exorbitant privilege. Government bonds in both countries are still considered to be better collateral than claims to capital, but there is no preference for U.S. bonds versus foreign bonds. Under this symmetric calibration, the UIP wedge disappears.

The figure plots impulse responses under the symmetric calibration (in gold) and compares them to the impulse responses under the baseline calibration (dash blue and red lines). The key takeaways are that, on the one hand, by the nature of the calibration, there are no effects of a global capital quality shock on relative U.S. to foreign variables. Relative output, consumption, and investment are unchanged. Interest rates and bank net worth change identically in both areas. Importantly, the real exchange rate does not change, nor do relative excess returns, the trade balance or net foreign assets.

However, the size of the global contraction is essentially the same under the symmetric calibration as under the baseline calibration. Output, consumption, and investment fall essentially just as much in the symmetric set-up as in the baseline calibration. The decline in real activity is driven by the overall contraction in asset holdings by banks, and the shift in their remaining portfolio of assets away from capital and toward government bonds. In short, the UIP wedge is not important in driving the global downturn. The wedge between the return on capital and the return to depositors rises - equally in both countries - which reflects the tightening of bank balance sheets. The underlying force for both wedges is the capital quality change, but both wedges are necessary to account for exchange rate and capital flow behavior on the one hand, and the global behavior of real output, consumption and investment on the other hand.

Figure 4: 4% global financial shock (ϑ, ϑ^*) with same capital κ and bond κ across country



Notes: The figure shows IRF of a 4% global financial shock. Subtitles of the figure report the steady state value of the reporting variables.

5.3 *Alternative Assumptions on Price Setting*

Figure 5 shows how the results are dependent on the assumption that retail prices are set in the currency of the buyer, i.e. LCP. The figure illustrates the impact of the same financial shock as in Figure 2 but now assuming that all goods prices are set in the seller's currency, (PCP), so that the firm in each country sets only one price in the domestic currency . The most notable difference from the baseline case is the much smaller response of the real exchange rate. With PCP, real exchange rate appreciation can occur only due to terms of trade appreciation, in combination with home bias in consumer preferences. In Figure 5, despite the fact that Home consumption falls relative to Foreign consumption, we do observe terms of trade appreciation in response to the financial shock. This is due to the larger drop in U.S. output. But the resultant real exchange rate appreciation is much smaller than in the baseline case. The Figure also shows that the real convenience yield is mostly driven by the differential in real interest rates across countries rather than expected real exchange rate depreciation, as in the baseline case. Of course, in this case, there is no deviation from the law of one price in traded goods. This exercise shows that while the collateral advantage and convenience yield channel alone are enough to generate a dollar appreciation, LCP is quantitatively important by allowing the dollar to appreciate via the deviation from LOOP instead of terms of trade movements.

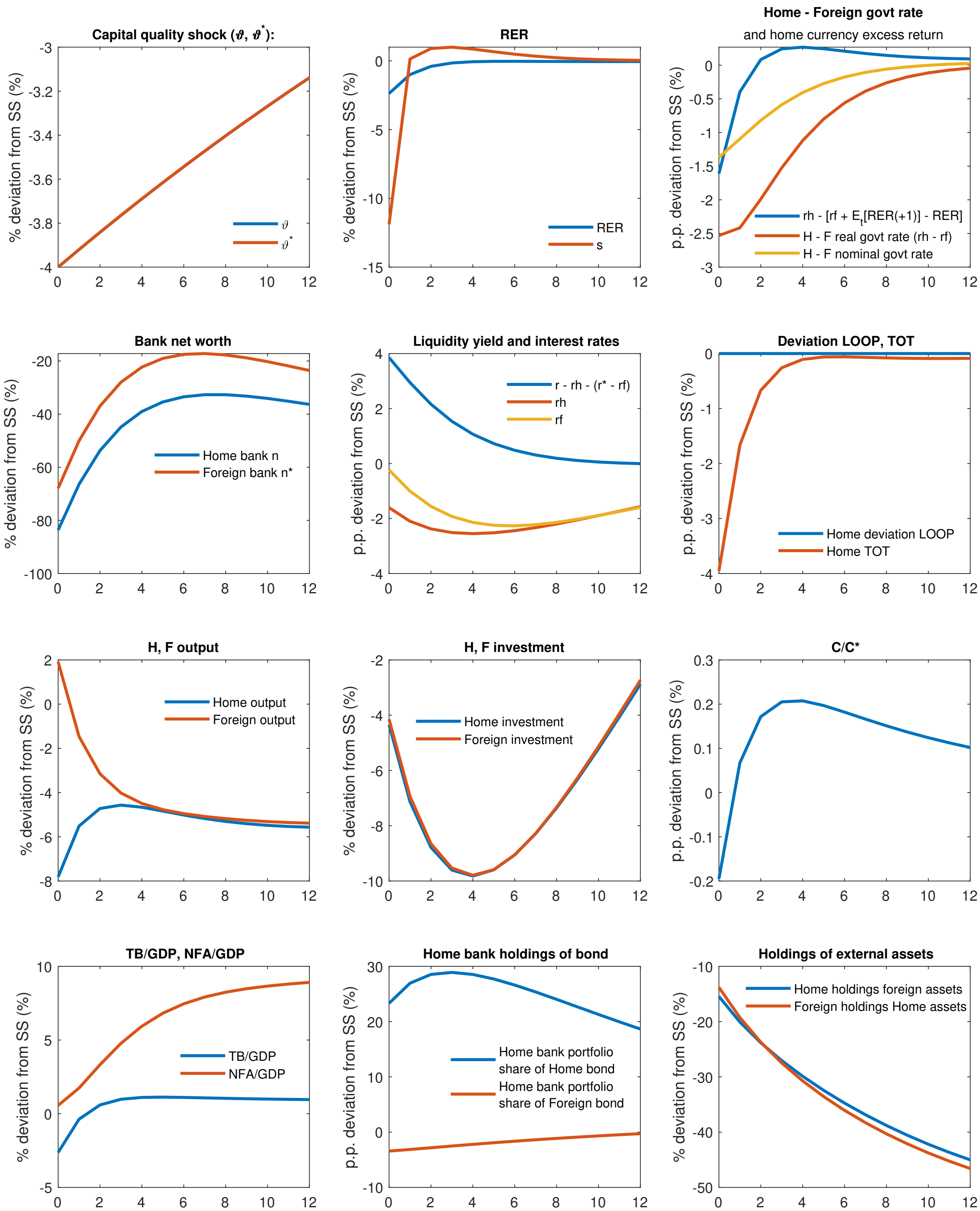
Figure 6 looks at the case with purely flexible prices. The Figure shows a very small real exchange rate appreciation. On the financial side, the appreciation happens because of a rise in the convenience yield. However, this is largely compensated by changes in government bond rates directly and therefore only partially accomplished through changes in the exchange rate. On the goods market side, this can occur only due to terms of trade appreciation. The terms of trade appreciates here because of a rise in Home consumption relative to Foreign consumption during the crisis. This highlights a "seignorage" effect similar to Jiang et al. (2024a). When the convenience yield rises during the crisis, the U.S. is able to finance its debt at a lower rate. When this effect is large enough, it boosts U.S. consumption and overturns the recession effect. While our production economy model is substantially different from Maggiori (2017a), this flexible price case illustrates the same 'reserve currency paradox'.[26]

We can conclude from these two figures that a complete analysis of the impact of a global financial shock that can account for the response of the U.S. convenience yield, the real appreciation of the U.S. dollar, and the feature of global portfolio retrenchment requires the combination of capital constrained banks, an advantage in collateral value for U.S. bonds, as well as sticky prices

[26] In Maggiori (2017a)'s endowment economy setting, the global financial crisis is represented by a uniform drop of Home and Foreign output. With home bias, terms of trade and exchange rate are tightly connected to relative consumption. When output is endogenous, Home and Foreign output might not drop uniformly but it is relatively close in the flexible prices case.

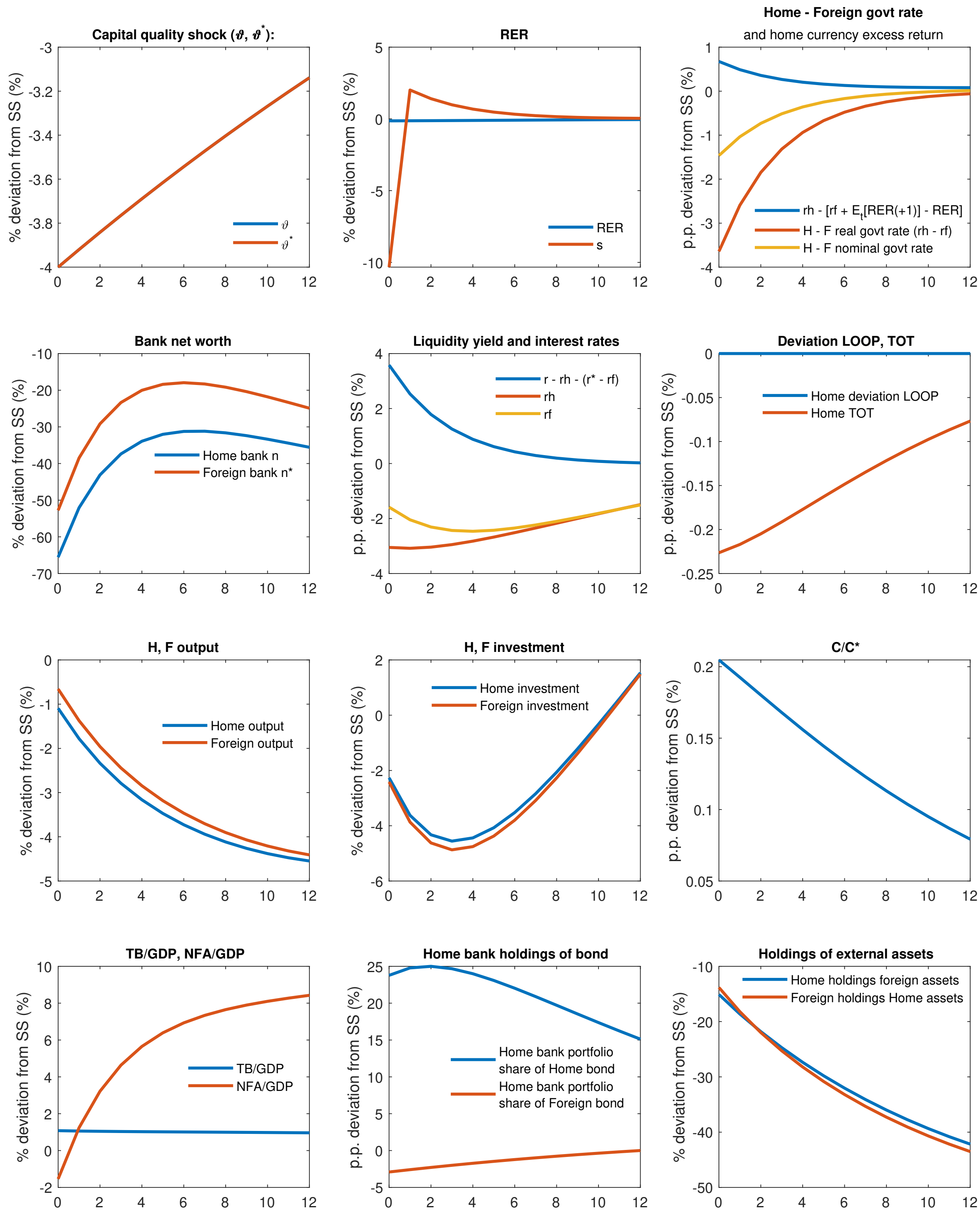
with limited exchange rate pass-through, captured by a local currency pricing rule for exporting firms.

Figure 5: 4% global financial shock (ϑ, ϑ^*) with baseline calibration in PCP case



Notes: The figure shows IRF of a 1% global financial shock. Subtitles of the figure report the steady state value of the reporting variables.

Figure 6: 4% global financial shock (ϑ, ϑ^*) with baseline calibration in flexible price case



Notes: The figure shows IRF of a 1% global financial shock. Subtitles of the figure report the steady state value of the reporting variables.

6 Model simulation

In this section, we compare the model-simulated moments with data moments to validate the model's relevance. The first exercise examines the model-implied regression by comparing it with empirical regressions, while the second exercise delves into unconditional exchange rate and macro moments. Finally, we simulate the model to fit the post-1999 sample.

Before turning to the exercises, we need to introduce additional shocks to explain the data moments. We allow for country-specific shocks to capital quality ($\vartheta_t, \vartheta_t^*$), TFP ($A_t, A_t^*$), and discount rate ($\delta_t, \delta_t^*$) to represent financial-driven, supply-driven and demand-driven business cycle movements, respectively.

For any shock $J \in \{\beta, \vartheta, A\}$, we have:

$$log(J_t) = log(J_t^{Global}) + log(J_t^H)\ ,\ log(J_t^*) = log(J_t^{Global}) + log(J_t^F),$$

$$log(J_t^{Global}) = \rho^{J,Global} log(J_{t-1}^{Global}) + s^{J,Global} e_t^{J,Global},$$

$$log(J_t^H) = \rho^{J,H} log(J_{t-1}^H) + s^{J,H} e_t^{J,H},$$

$$log(J_t^F) = \rho^{J,F} log(J_{t-1}^F) + s^{J,F} e_t^{J,F}$$

where $e_t^{J,H}$ and $e_t^{J,F}$ are Home and Foreign country specific shocks and $e_t^{J,Global}$ is a global shock, and $s^{i,j}$ represents a standard deviation scaling factor.

We assume that all Home and Foreign shocks have the same persistence and standard deviations. We use standard values for productivity shocks, setting the persistence to 0.98 and the standard deviations of H, F and *Global* shocks to be 0.0007, 0.0007 and 0.0029, respectively ($s^{A,H}, s^{A,F}, s^{A,Global} = 0.0007, 0.0007, 0.0029$), implying a 0.95 correlation between Home and Foreign TFP.

We follow Kekre and Lenel (2024a)'s calibration for the discount rate shock. The persistence is set at 0.98, the standard deviations of δ_t and δ_t^* are 0.002, and the correlation between the two shocks is 0.84. In the model, the discount rate shock explains about 70% of consumption changes, consistent with the estimation results of Smets and Wouters (2003).

Finally, we adopt a parsimonious approach to calibrating the capital quality shock, assuming it is global in nature. We set the standard deviation to 0.005 so that the model-implied correlation of bank equity values is 0.9, consistent with the data counterparts of the HP detrended U.S. and European bank equity indices (Dow Jones U.S. Banks Index and STOXX Banks Europe 500 Index).

To capture the possibility of crisis periods, we model the capital quality shock flexibly using a

Markov switching process with two states: a low-volatility state with the standard deviation values described above, and a high-volatility state in which the standard deviations for the capital quality shock are higher than those in the low state. We estimate the two regimes using HP-detrended bank equity performance indices in the U.S. (Dow Jones U.S. Banks Index) from June 2002 to June 2024.

The Markov transition matrix is

$$P^{MK} = \begin{matrix} L \\ H \end{matrix} \begin{bmatrix} 0.974, & 0.026 \\ 0.129, & 0.871 \end{bmatrix}$$

This implies that the half-life of the low-volatility state is roughly seven years, while the half-life of the high-volatility state is about five quarters. The estimated bank equity volatility in the high-volatility state is 1.8 times higher than in the low-volatility state. To generate the same ratio of model-implied bank equity volatility, we set the volatility of the capital quality shock in the high-volatility state to be 3.5 times that of the low-volatility state.

6.1 Regression Comparison

We follow the regression strategy from Engel and Wu (2023).[27] The regression specification is outlined as follows:

$$\Delta s_{j,t} = \alpha_j + \beta_1 s_{j,t-1} + \beta_2 \Delta \eta_{j,t} + \beta_3 \Delta (i - i^*)_{j,t} + \beta_4 \eta_{j,t-1} + \beta_5 (i - i^*)_{j,t-1} + u_{j,t} \tag{43}$$

where s is the nominal exchange rate of the dollar price of a unit of foreign currency, η is a measure of the convenience yield and $(i - i^*)$ is the U.S. minus Foreign government bond interest rate differential. For the empirical estimation we consider a panel exchange rate series of the U.S. dollar vs rest of the G10 currencies obtained from FRED. The convenience yield and interest rate data are obtained from Du et al. (2018a) and we use the 3-month tenor to match with the quarterly frequency. The sample starts from January 1999 to March 2021. The convenience yield is measured as the payoff of a synthetic dollar government bond that is constructed by buying the Foreign government bond and hedging the exchange rate exposure by entering a forward contract (covered interest parity deviation of government bonds). Since the U.S. government bond and the synthetic dollar government bond both pay dollar returns, the difference between the two gives a measure of the relative difference in liquidity services of the U.S. and Foreign government bonds.

We compare the results from this regression to the same regression estimated on model-simulated data. The quarterly model is simulated for 15,000 quarters, and the first 100 periods are dropped.

[27] Since one of the exercises is regression in daily frequency, the specification here differs slightly from that of Engel and Wu (2023) in that the error-correction term - the lagged exchange rate - is nominal rather than real.

Table 3 reports the coefficient estimates. In column (1), the empirical estimates for the changes in convenience and the interest rate differential are -1.65 and -2.61, respectively. This indicates that a 1% increase in convenience yield or interest rate differential (annualized) is associated with a 1.65% or 2.61% increase in the exchange rate compared to the previous quarter. In column (2), the model-implied coefficients for the changes in convenience yield and the interest rate differential are -1.32 and -2.47. These coefficients are reasonably close to, and within one standard deviation of the empirical counterparts. These untargeted moments provide support for our model and its quantitative calibration.

Table 3: Model implied regression and the empirical counterpart

$$\Delta s_{j,t} = \alpha_j + \beta_1 s_{j,t-1} + \beta_2 \Delta\eta_{j,t} + \beta_3 \Delta(i-i^*)_{j,t} + \beta_4 \eta_{j,t-1} + \beta_5 (i-i^*)_{j,t-1} + u_{j,t}$$

	Panel quarterly regression of G10 currenices	Model implied regression	Panel daily Rigobon regression of G10 currenices
	(1)	(2)	(3)
$\Delta\eta_{j,t}$	-1.65**	-1.32	-2.2***
	(0.76)		(0.53)
$\Delta(i-i^*)_{j,t}$	-2.61***	-2.47	-0.89***
	(0.97)		(0.17)
$\eta_{j,t-1}$	-2.08**	0.06	-0.01
	(0.87)		(0.02)
$(i-i^*)_{j,t-1}$	-0.44**	0.01	-0.001
	(0.22)		(0.005)
s_{t-1}	-0.06**	-0.01	-0.0012***
	(0.02)		(0.004)
Observations	739	14,900	37209

Notes: Standard errors in parentheses are clusted by time. * p<0.1, ** p<0.05, *** p<0.01. Model implied regression is performed with 15,000-quarter observations and burning the first 100 quarters.

To provide direct evidence of the mechanism from banking to exchange rates, we employ a daily Rigobon (2003) identification through heteroskedasticity regression.

The heteroskedasticity-based approach utilizes data from both event windows and periods outside these windows. The event dates we use are those identified by Ottonello and Song (2022), which correspond to days when U.S. financial intermediaries release their earnings announcements. The assumption is that earnings releases introduce fluctuations in banking net worth, leading to heightened volatility in the demand for liquid assets. The identification assumption is that exchange rate volatility remains the same across both sets of dates, while the volatility of the convenience yield differs.

In column (3), we report the results from the heteroskedasticity-based identification. For this exercise, we use daily data from January 1, 1999, to March 9, 2021. The regression specification follows equation (43). The estimated coefficient for $\Delta\eta_{j,t}$ is -2.2 and it is highly significant. It indicates a 1% increase in the convenience yield (annualized) is associated with 2.2% daily appreciation of the U.S. dollar. Once again, we find that both the change in the convenience yield and the change in the interest rate differential are significant explanatory variables for exchange rate movements. More importantly, the heteroskedastic approach highlights the differential convenience yield movement that is associated with the differential banking sector response across the earning release dates and non-earning release dates. We interpret this as evidence that banking demand for liquidity plays a crucial role in determining exchange rates through endogenous movements in the convenience yield.

In the Appendix D, we supplement this analysis with an instrumental variable regression. There we directly employ the high frequency identified shock in Ottonello and Song (2022) to obtain a measure of financial shocks during earnings announcement dates. We then use this financial shock to instrument changes in the convenience yield. The IV regression yields the same results, but the estimated coefficients for changes in the convenience yield and the interest rate differential are larger.

Next, we compare the data relationship between the convenience yield and flows to U.S. Treasuries with the model implied relationship. This provides a statistical evaluation to the top right subfigure in Figure 1. We regress the change of flows to U.S. Treasury from home investors and foreign investors on the convenience yield. While the underlying data from Chaudhary et al. (2024) is in monthly frequency, we aggregate it to quarterly frequency to be consistent with the model frequency. The data sample period is from 2003Q1 to 2021Q1.

Table 4 reports these regressions. Column (1) and (3) report the change of U.S. and foreign holding of U.S. Treasuries, respectively. They indicate a 1% increase in convenience yield is associated with 1.05% increase of home holding of U.S. Treasuries and -1.39% decrease of foreign holding of U.S. Treasuries. In column (2) and column (4), we report the same simulated model implied regression. The columns show that the model generates quantitatively similar coefficients to the data. This confirms our model mechanism that when the U.S. convenience rises, the more constrained U.S. investors demand, and end up holding, more of U.S. Treasury.

6.2 Moment Comparison

In the second exercise, we report long-run moments of the model in Table 5. Column (1) contains the empirical moments of the U.S. and Eurozone data from 1999Q1 to 2023Q1. Columns (2) to (4) represent the model-implied moments. As in the previous exercise, we simulate the model for 15,000 periods. Column (3) presents moments from a realized path that allows for the state to

Table 4: Model implied regression and the empirical counterpart

	Quarterly regression on US holding of US Treasury	Model regression on US holding of UST	Quarterly regression on Foreign holding of US Treasury	Model regression on Foreign holding of UST
	(1)	(2)	(3)	(4)
$\eta_{j,t}$	1.05***	0.78	-1.39***	-2.3
	(0.36)		(0.51)	
Observations	71	14,900	71	14,900

Notes: Robust standard errors in parentheses. * p<0.1, ** p<0.05, *** p<0.01. Model implied regression is performed with 15,000-quarter observations and burning the first 100 quarters.

switch according to the Markov transition matrix. Column (2) and column (4) display moments from realized paths where the simulated economy is conditional on the low volatility state and the high volatility state, respectively.

The unconditional moments in column (3) indicate that the model can generate volatile exchange rate movements. The standard deviation of exchange rate changes is 2.8 times and 2.6 times more volatile than output and consumption and is particularly high in the high volatility state (3.4 and 3.0). Additionally, the exchange rate is also much more volatile than the interest rate differential. The model can also generate a slightly negative regression coefficient (Fama's β) of Δs_{t+1} on $R_{h,t} - R_{f,t}$ that is consistent with the data. The coefficient is more negative when the model is conditional on the high volatility state. While it focuses on the global financial shock, Figure 2 provides some insight into the negative Fama's β. Following the shock, the Home - Foreign nominal interest rate falls because the Home economy has lower output and smaller inflation pressure than the Foreign economy. The dollar appreciates initially and is expected to depreciate afterwards. So when the financial shock is the dominant shock in the high volatility state, a fall in the Home - Foreign interest rate is associated with the expected depreciation of the dollar, resulting in a negative Fama's β.

Focusing on the low volatility state, the model is able to generate a negative correlation between the real exchange rate change and relative consumption growth (A negative Backus and Smith (1993) correlation, $\rho(\Delta q, \Delta c - \Delta c^*)$). This is driven by the discount rate shock. When Home households are relatively impatient, they experience higher consumption growth and currency appreciation due to home bias in consumption. When the financial shock becomes the dominant factor in the high volatility state, dollar appreciation goes hand-in-hand with a wealth transfer from the U.S. to the rest of the world. This risk-sharing mechanism, which we emphasize in the IRFs analysis, leads to a relative consumption drop in the U.S. and a positive Backus-Smith correlation.

The model also performs reasonably well for other moments, such as the persistence of the real exchange rate and realistic business cycle moments. Overall, the model can replicate important exchange rate and business cycle moments. The flexibility of the Markov switching modeling provides an explanation for various empirical estimates for some exchange rate moments such as Fama's β over different samples, as documented by Engel et al. (2022).

In Appendix E, we report the same table but with PCP setting and no collateral advantage of the U.S. bonds. We find that these specifications produce less realistic moments, such as a less volatile exchange rate, positive Fama's β (without collateral advantage) and much more volatile trade balance (with PCP). These robustness exercises highlight the importance of these key assumptions to generate realistic moments.

Table 5: Long-run moments

	Data moments of Eurozone vs US	Model moments conditional on the low volatility state	Model moments unconditional	Model moments conditional on the high volatility state
	(1)	(2)	(3)	(4)
Exchange rates				
$\sigma(\Delta s)/\sigma(\Delta GDP)$	3.6	2.2	2.8	3.4
$\sigma(\Delta s)/\sigma(\Delta c)$	3.3	2.1	2.6	3.0
$\sigma(i-i^*)/\sigma(\Delta s)$	0.07	0.23	0.16	0.11
Fama β	-0.18	-0.50	-1.12	-2.40
$\rho(\Delta q, \Delta c - \Delta c^*)$	0.05	-0.01	0.29	0.68
$\sigma(\Delta q)/\sigma(\Delta s)$	0.99	0.85	0.82	0.81
Persistence				
$\rho(\Delta s)$ (NER)	-0.03	-0.15	-0.16	-0.18
$\rho(q)$ (RER)	0.93	0.99	0.97	0.89
$\rho(i-i^*)$	0.95	0.99	0.98	0.97
$\rho(i)$	0.97	0.99	0.99	0.99
Trade balance				
$corr(\Delta nx, \Delta q)$	-0.06	0.27	0.27	0.36
$\sigma(\Delta nx)/\sigma(\Delta q)$	0.07	0.36	0.23	0.12
Business cycle				
$\sigma(\Delta c)/\sigma(\Delta GDP)$	1.1	1.04	1.07	1.1
$\rho(\Delta c, \Delta GDP)$	0.94	0.46	0.63	0.8
$\rho(\Delta I, \Delta GDP)$	0.81	0.48	0.55	0.60
$\rho(\Delta GDP, \Delta GDP^*)$	0.88	0.33	0.56	0.83
$\rho(\Delta c, \Delta c^*)$	0.90	0.48	0.62	0.81
$\rho(\Delta I, \Delta I^*)$	0.55	0.95	0.97	0.97

Notes: Data moments are computed quarterly from 1999Q1 to 2023Q1. Model implied moments are performed with 15,000-quarter observations and burning the first 100 quarters.

6.3 Simulation from 1999Q1 to 2023Q1

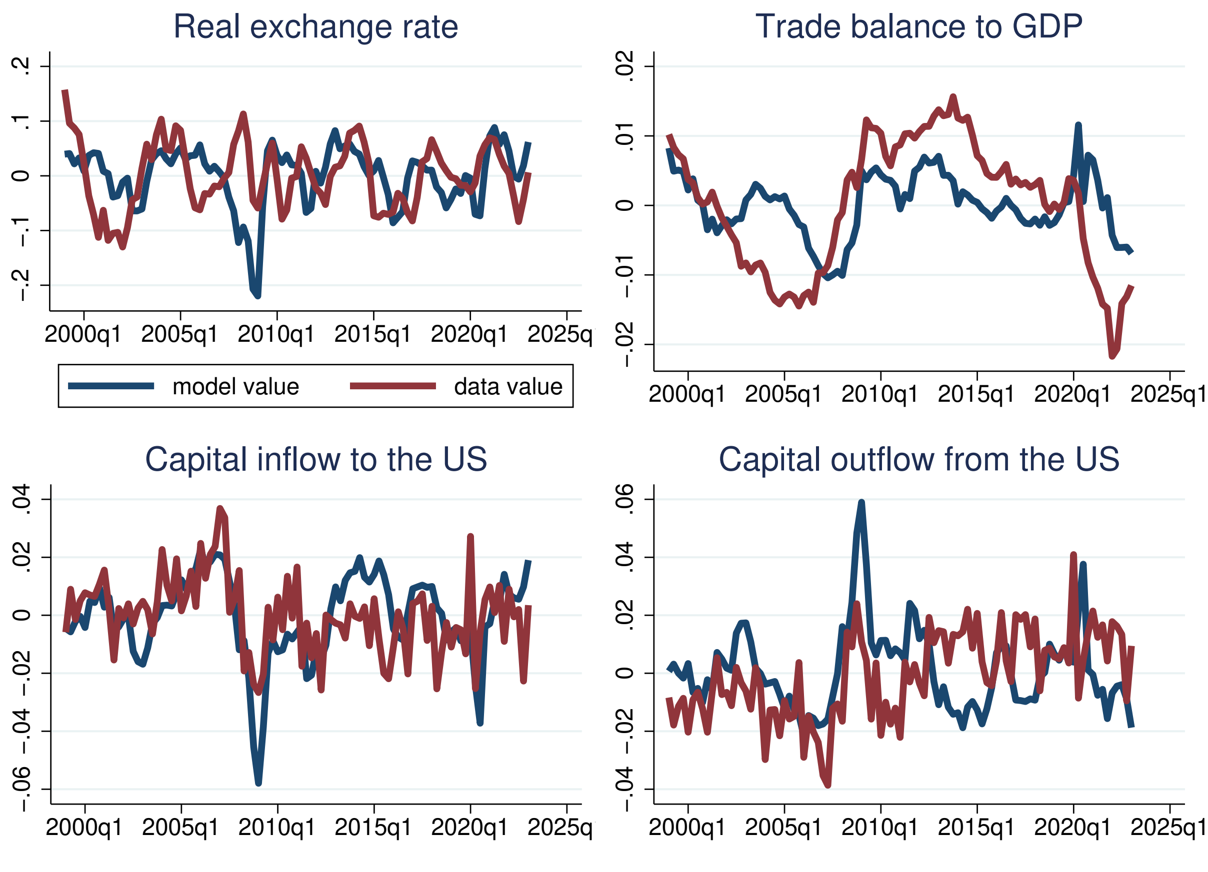
Our analysis in the last two sections focus on moments from a long period of simulation. In this subsection, we simulate the model to mimic the economies' path from 1999Q1 to 2023Q1 to investigate how well the model can do in terms of the exchange rate and capital flow variables. To avoid overfitting the model, we assume both TFP and capital quality shocks are global in nature and allow for home and foreign discount rate shocks. We jointly target four variables with the four set of shocks, namely home and foreign output, the foreign government interest rate and foreign bank equity value.

In Figure 7, we present the simulated variables in blue and their data counterparts in red for the real exchange rate, trade balance to GDP, capital inflows to the U.S., and capital outflows from the U.S. Overall, the model-implied variables and the data are broadly consistent with each other.

In the top-left panel, the model-implied exchange rate is of the same order of magnitude as the data and tracks the data pattern reasonably well. Both the model and the data show a roughly 15% appreciation of the dollar in 2008, during the peak of the global financial crisis. Similarly, in the top-right panel, the model and the data for the trade balance to GDP align well, with a gradual deterioration of the trade balance from 1999 to 2007 and a sharp improvement during 2008. In the lower panel, the model-implied capital flows closely mimic the data counterpart, showing a sharp retrenchment of capital flows during the crisis. This figure suggests that our model can effectively rationalize the relationship between exchange rates and external balances both during and outside of the crisis.

The model can also account for the relationship of convenience yield and exchange rates pattern observed in the data. In Table 6, we report the same regression exercise as in Table 3 and 4 but using the simulated data from 1999Q1 to 2023Q1. In column (1), the model implied exchange rate regression as in equation (43) produces very similar values to column (2) in Table 3 and are consistent with the empirical estimates. This suggests that an increase in the home country's convenience yield and interest rates, relative to the rest of the world, appreciates the home country's currency value. Column (2) and column (3) report the capital flow to the Home government bond from the Home investors and Foreign investors, respectively. These columns show that an increase in the convenience yield is associated with an inflow from home investors and an outflow from foreign investors.

Figure 7: Simulation from 1999Q1-2023Q1



Notes: The figure shows IRF of a 1% global financial shock. Subtitles of the figure report the steady state value of the reporting variables.

Table 6: Model implied regression from 1999Q1 to 2023Q1

	Model implied exchange rate regression		Model implied regression on Home holding of Home bond	Model implied regression on Foreign holding of Home bond
	(1)		(2)	(3)
$\Delta\eta_t$	-1.08	η_t	0.71	-1.57
$\Delta(i-i^*)_t$	-2.57			
η_{t-1}	0.06			
$(i-i^*)_{t-1}$	0.03			
s_{t-1}	-0.09			
Observations	96		96	96

Notes: Model implied regression is performed with 96-quarter observations along the simulated path mimicking the 1999Q1-2023Q1 period.

7 Conclusions

The special features of the U.S. dollar and U.S. financial assets in the world financial system have generated enormous academic interest over the last decade. The literature has established that the U.S. benefits from an ”exorbitant privilege”, with U.S. dollar denominated liabilities offering low returns to foreign investors in normal times, but on the flip side there is an “exorbitant duty” associated with a large U.S. dollar appreciation during global crises, particularly global financial crises. We take a standard New Keynesian open economy model with balance sheet constrained banks and make a minimal additional assumption by letting U.S. government assets have a higher collateral value than those of the rest of the world. We believe this is a highly realistic assumption. accurately characterizing the special liquidity features of U.S. Treasuries in the global financial system. In steady state, this model captures the “exorbitant privilege”, in that returns on U.S. Treasuries are below those of foreign governments, the U.S. is a net debtor, but has a negative trade balance due to a excess income flows on its foreign assets relative to liabilities. In response to a global financial shock coming from a sudden tightening of balance sheet constraints for all banks, we show that the model accurately captures the empirical observations discussed in the introduction. Notably, the U.S. dollar appreciates strongly, and the appreciation is associated with a spike in the convenience yield on U.S. Treasuries relative to foreign government assets. Moreover, this appreciation is achieved even though U.S. households have a diminished share of world wealth, as the appreciation of the U.S. dollar imposes the “exorbitant duty” on the U.S.. In addition, although the U.S. government bond represents better collateral and a global financial crisis leads to an increase in demand for the ‘safe asset’, in equilibrium we see an external retrenchment in capital flows, as in the data. The model implies separate roles and transmission mechanisms for U.S. monetary policy and liquidity provision, which have implications for understanding international spillovers of policies. We show that these results are robust to alternative calibrations of the model, and most results carry over to a case where a global downturn is precipitated by a uniform negative shock to all country’s productivity. Because minimal assumptions are required to endogenize the convenience yield and rationalize the exceptionality of the U.S., the framework presented can be readily extended for further analysis, including optimal policy considerations and implications for asset pricing.

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Online Appendix (not for publication)

A Collecting all the equations and rewriting the system in real terms

Define real debt holdings: $d_{h,t} = \frac{D_{h,t}}{P_t}$, $d_{f,t} = \frac{D_{f,t}}{P_t^*}$,

Terms of Trade: $\mathscr{S}_t = \frac{P_{f,t}}{P_{h,t}}$, $\mathscr{S}_t^* = \frac{P_{f,t}^*}{P_{h,t}^*}$,

Deviations from LOOP: $\mathscr{D}_t = \frac{S_t P_{h,t}^*}{P_{h,t}}$ $\mathscr{D}_t^* = \frac{S_t P_{f,t}^*}{P_{f,t}}$

Real Returns: $r_{h,t} = \frac{R_{h,t} P_{t-1}}{P_t}$, $r_{f,t} = \frac{R_{f,t} P_{t-1}^*}{P_t^*}$

Real marginal product of capital: $r_{K,t} = \frac{R_{K,t}}{P_t}$, $r_{K,t}^* = \frac{R_{K,t}^*}{P_t^*}$

Real net worth $n_t = \frac{N_t}{P_t}$, $n_t^* = \frac{N_t^*}{P_t^*}$

Real equity prices: $q_t = \frac{Q_t}{P_t}, q_t^* = \frac{Q_t^*}{P_t^*}$

Real marginal costs: $mc_t = \frac{MC_t}{P_{h,t}}$, $mc_t^* = \frac{MC_t^*}{P_{f,t}^*}$

Price indices: $P(1,\mathscr{S}_t) = \frac{P_t}{P_{h,t}}$, $P^*(1,\mathscr{S}_t^*) = \frac{P_t^*}{P_{h,t}^*}$

PPI inflation rates: $\pi_{h,t} = \frac{P_{h,t}}{P_{h,t-1}}$, $\pi_{h,t}^* = \frac{P_{h,t}^*}{P_{h,t-1}^*}$ $\pi_{f,t} = \frac{P_{f,t}}{P_{f,t-1}}$, $\pi_{f,t}^* = \frac{P_{f,t}^*}{P_{f,t-1}^*}$

Also impose bond market clearing: $d_{h,t}^* = \bar{d}_h - d_{h,t}$, $d_{f,t} = \bar{d}_f - d_{f,t}^*$

labor market clearing: $L_t = H_t$, $L_t^* = H_t^*$

Real wage $w_t = \frac{W_t}{P_t}$, $w_t^* = \frac{W_t^*}{P_t^*}$

Real deposit (policy) rate $r_{t+1} = \frac{R_{t+1} P_t}{P_{t+1}}$ $r_{t+1}^* = \frac{R_{t+1}^* P_t^*}{P_{t+1}^*}$

Real exchange rate is implied by $RER_t = \frac{S_t P_t^*}{P_t} = \frac{\mathscr{D}_t P^*(1,\mathscr{S}_t^*)}{P(1,\mathscr{S}_t)}$. That is, the real exchange rate depends on both deviations from LOOP as well as movements in the terms of trade. Also, set $\bar{\pi} = 0$

Balance of payments:

$$\begin{aligned}(C_t + I_t + I_t\phi(\tfrac{I_t}{I_{t-1}})) + d_{h,t} - \bar{d}_h + RER_t d_{f,t} + q_t(K_{h,t} - K_t) + RER_t q_t^* K_{f,t} \\ = \tfrac{Y_{h,t}}{P(1,\mathscr{S}_t)}(1 - \xi(\pi_{h,t})) + \tfrac{\mathscr{D}_t}{P(1,\mathscr{S}_t)} Y_{h,t}^*(1 - \xi(\pi_{h,t}^*)) \\ + r_{h,t}(d_{h,t-1} - \bar{d}_h) + RER_t r_{f,t} d_{f,t-1} + \tilde{r}_{k,t+1}(K_{h,t} - K_t) + RER_t \tilde{r}_{k,t+1}^* K_{f,t}\end{aligned} \tag{44}$$

Home household Euler equation:

$$1 = E_t \beta r_{t+1} (\frac{C_{t+1}^R}{C_t^R})^{-\sigma} \equiv E_t \beta r_{t+1} \tilde{\Omega}_{t+1} \tag{45}$$

Foreign household Euler equation:

$$1 = E_t \beta r^*_{t+1} (\frac{C^{R*}_{t+1}}{C^{R*}_t})^{-\sigma} \equiv E_t \beta r^*_{t+1} \tilde{\Omega}^*_{t+1} \tag{46}$$

Labor market clearing implies

$$L_t = H_t$$

Profit maximization for Home implies:

$$\begin{aligned} (1+s_t)Y_{h,t} - \varepsilon((1+s_t) - mc_t)Y_{h,t} \\ -\xi'(\pi_{h,t})\pi_{h,t}Y_{h,t} + E_t\beta\tilde{\Omega}_{t+1}\tfrac{P(1,\mathscr{S}_t)}{P(1,\mathscr{S}_{t+1})}\xi'(\pi_{h,t+1})\pi_{h,t+1}Y_{h,t+1} &= 0 \end{aligned} \tag{47}$$

$$\begin{aligned} (1+s_t)Y^*_{h,t} - \varepsilon((1+s_t) - \tfrac{mc_t}{\mathscr{D}_t})Y^*_{h,t} \\ -\xi'(\pi^*_{h,t})\pi^*_{h,t}Y^*_{h,t} + E_t\beta\tilde{\Omega}_{t+1}\tfrac{P(1,\mathscr{S}_t)}{P(1,\mathscr{S}_{t+1})}\tfrac{\mathscr{D}_{t+1}}{\mathscr{D}_t}\xi'(\pi^*_{h,t+1})\pi^*_{h,t+1}Y^*_{h,t+1} &= 0 \end{aligned} \tag{48}$$

Factor markets Home:

$$A_t(1-\alpha)(L_t^{1-\alpha}\vartheta_t^{1-\alpha}K_t^{\alpha})mc_t = w_t P(1,\mathscr{S}_t)L_t \tag{49}$$

$$A_t\alpha(L_t^{1-\alpha}\vartheta_t^{1-\alpha}K_t^{\alpha})mc_t = r_{K,t}P(1,\mathscr{S}_t)K_t \tag{50}$$

$$w_t = \chi C_t^{\sigma} L_t^{\psi} \tag{51}$$

Capital and Price of capital at Home:

$$K_{t+1} = I_t + (1-\delta)\vartheta_t K_t \tag{52}$$

$$q_t = 1 + \psi'(\frac{I_t}{I_{t-1}})\frac{I_t}{I_{t-1}} + \psi(\frac{I_t}{I_{t-1}}) \tag{53}$$

$$Y_{h,t} + Y^*_{h,t} = A_t(L_t^{\alpha}\vartheta_t^{1-\alpha}K_t^{1-\alpha}) \tag{54}$$

Profit Max Foreign:

$$\begin{aligned} (1+s^*_t)Y^*_{f,t} - \varepsilon((1+s_t) - mc^*_t)Y^*_{f,t} \\ -\xi'(\pi^*_{f,t})\pi^*_{f,t}Y^*_{f,t} + E_t\beta\tilde{\Omega}^*_{t+1}\tfrac{\mathscr{S}^*_{t+1}P^*(1,\mathscr{S}^*_t)}{\mathscr{S}^*_t P^*(1,\mathscr{S}^*_{t+1})}\xi'(\pi^*_{f,t+1})\pi^*_{f,t+1}Y^*_{f,t+1} &= 0 \end{aligned} \tag{55}$$

$$
\begin{aligned}
&(1+s_t^*)Y_{f,t} - \varepsilon((1+s_t^*) - \mathscr{D}_t^* mc_t^*)Y_{f,t} \\
-&\xi'(\pi_{f,t})\pi_{f,t}Y_{f,t} + E_t\beta\tilde{\Omega}_{t+1}^* \tfrac{\mathscr{D}_t^*}{\mathscr{D}_{t+1}^*} \tfrac{\mathscr{S}_{t+1}^* P^*(1,\mathscr{S}_t^*)}{\mathscr{S}_t^* P^*(1,\mathscr{S}_{t+1}^*)} \xi'(\pi_{f,t+1})\pi_{f,t+1}Y_{f,t+1} \quad = 0
\end{aligned} \tag{56}
$$

Foreign factor markets:

$$
A_t^*(1-\alpha)(L_t^{*(1-\alpha)} \vartheta_t^{*(1-\alpha)} K_t^{*\alpha}) mc_t^* = \frac{P^*(1,\mathscr{S}_t^*)}{\mathscr{S}_t^*} w_t^* L_t^* \tag{57}
$$

$$
A_t^* \alpha (L_t^{*(1-\alpha)} \vartheta_t^{*(1-\alpha)} K_t^{*\alpha}) mc_t^* = K_t^* \frac{P^*(1,\mathscr{S}_t^*)}{\mathscr{S}_t^*} r_{K,t}^* \tag{58}
$$

$$
w_t^* = \chi C_t^{*\sigma} L_t^{*\psi} \tag{59}
$$

Labor market clearing implies

$$
L_t^* = H_t^*
$$

Capital and Price of capital Foreign:

$$
K_{t+1}^* = I_t^* + (1-\delta)\vartheta_t^* K_t^* \tag{60}
$$

$$
q_t^* = (1 + \psi'(\frac{I_t^*}{I_{t-1}^*})\frac{I_t}{I_{t-1}} + \psi(\frac{I_t^*}{I_{t-1}^*})) \tag{61}
$$

$$
Y_{f,t}^* + Y_{f,t} = A_t^*(L_t^{*\alpha} \vartheta_t^{*(1-\alpha)} K_t^{*(1-\alpha)})) \tag{62}
$$

Market Clearing:

Bond market clearing:

$$
d_{h,t}^* + d_{h,t} = \bar{d}_{h,t}, \; d_{f,t} + d_{f,t}^* = \bar{d}_{f,t}
$$

Home good:

$$
Y_{h,t}(1-\xi(\pi_{h,t})) = \omega \left(\frac{1}{P(1,\mathscr{S}_t)} \right)^{-\mu} (C_t + I_t + I_t \phi(\frac{I_t}{I_{t-1}})) \tag{63}
$$

$$
Y_{h,t}^*(1-\xi(\pi_{h,t}^*)) = \frac{(1-n)}{n}(1-\omega^*) \left(\frac{1}{P^*(1,\mathscr{S}_t^*)} \right)^{-\mu} (C_t^* + I_t^* + I_t^* \phi(\frac{I_t^*}{I_{t-1}^*})) \tag{64}
$$

Foreign good:

$$
Y_{f,t}(1-\xi(\pi_{f,t})) = \frac{n}{1-n}(1-\omega) \left(\frac{\mathscr{S}_t}{P(1,\mathscr{S}_t)} \right)^{-\mu} (C_t + I_t + I_t \phi(\frac{I_t}{I_{t-1}})) \tag{65}
$$

$$Y^*_{f,t}(1-\xi(\pi^*_{f,t})) = \omega^* \left(\frac{\mathscr{S}^*_t}{P^*(1,\mathscr{S}^*_t)}\right)^{-\mu} (C^*_t + I^*_t + I^*_t\phi(\frac{I^*_t}{I^*_{t-1}})) \tag{66}$$

Home Bank:

$$E_t\tilde{\Lambda}_{t+1}\left(\tilde{r}_{k,t+1} - r_{t+1}\right) = \lambda_t\vartheta_t(\kappa_{Kh1} + \kappa_{Kh2}\tilde{K}_{h,t}) \tag{67}$$

$$E_t\tilde{\Lambda}_{t+1}\left(\frac{RER_{t+1}}{RER_t}\tilde{r}^*_{k,t+1} - r_{t+1}\right) = \lambda_t(\kappa_{Kf1} + \kappa_{Kf2}RER_t\tilde{K}_{f,t}) \tag{68}$$

$$E_t\tilde{\Lambda}_{t+1}\left(r_{h,t+1} - r_{t+1}\right) = \lambda_t(\kappa_{h1} + \kappa_{h2}\tilde{d}_{h,t}) \tag{69}$$

$$E_t\tilde{\Lambda}_{t+1}\left(\frac{RER_{t+1}}{RER_t}r_{f,t+1} - r_{t+1}\right) = \lambda_t(\kappa_{f1} + \kappa_{f2}RER_t\tilde{d}_{f,t}) \tag{70}$$

$$\tilde{\Lambda}_{t+1} = \tilde{\Omega}_{t+1}\frac{\pi_{h,t+1}P(1,\mathscr{S}_{t+1})}{P(1,\mathscr{S}_t)}((1-\theta)+\theta\upsilon_{t+1})$$

$$\tilde{r}_{K,t+1} = \frac{r_{K,t+1}+(1-\delta)q_{t+1}}{q_t}$$

Home envelope condition:

$$\upsilon_t = \frac{E_t\tilde{\Omega}_{t+1}\frac{\pi_{h,t+1}P(1,\mathscr{S}_{t+1})}{P(1,\mathscr{S}_t)}((1-\theta)+\theta\upsilon_{t+1})r_{t+1}}{1-\eta_t} \tag{71}$$

Home participation constraint:

$$\begin{aligned}\upsilon_t n_t \;=\; & ((\kappa_{Kh1} + \kappa_{Kh2}q_tK_{h,t+1})q_tK_{h,t+1} + (\kappa_{Kf1} + \kappa_{Kf2}RER_tq^*_tK_{f,t+1})RER_tq^*_tK_{f,t+1} \\ & +(\kappa_{h1} + \kappa_{h2}d_{h,t})d_{h,t} + (\kappa_{f1} + \kappa_{f2}RER_td_{f,t})RER_td_{f,t})\end{aligned} \tag{72}$$

Home net worth dynamics:

$$\begin{aligned}n_{t+1} = \; & \theta((\tilde{r}_{k,t+1}\vartheta_{t+1} - r_{t+1})q_tK_{h,t+1} \\ & +(r_{h,t+1} - r_{t+1})d_{h,t} \\ & +(\tfrac{RER_{t+1}}{RER_t}\tilde{r}_{kf,t+1}\vartheta^*_{t+1} - r_{t+1})RER_tK_{f,t+1} \\ & +(\tfrac{RER_{t+1}}{RER_t}r_{f,t+1} - r_{t+1})RER_td_{f,t} + r_{t+1}n_t) \\ & +\varphi\tfrac{P(1,\mathscr{S}_t)}{\pi_{h,t+1}P(1,\mathscr{S}_{t+1})}\left(q_tK_{t+1} + d_{h,t} + \tfrac{\mathscr{D}_tP(1,\mathscr{S}^*_t)}{P(1,\mathscr{S}_t)}d_{f,t}\right)\end{aligned} \tag{73}$$

Foreign Bank:

$$E_t\tilde{\Lambda}^*_{t+1}\left(\frac{RER_t}{RER_{t+1}}\tilde{r}_{k,t+1} - r^*_{t+1}\right) = \lambda_t{}^*(\kappa^*_{Kh1} + \kappa^*_{Kh2}\tilde{K}^*_{ht}/RER_t) \tag{74}$$

$$E_t\tilde{\Lambda}^*_{t+1}\left(\tilde{r}^*_{k,t+1}-r^*_{t+1}\right)=\lambda^*_t(\kappa^*_{Kf1}+\kappa^*_{Kf2}\tilde{K}^*_{ft}) \tag{75}$$

$$E_t\tilde{\Lambda}^*_{t+1}\left(\frac{RER_t}{RER_{t+1}}r_{h,t+1}-r^*_{t+1}\right)=\lambda^*_t(\kappa^*_{h1}+\kappa^*_{h2}\tilde{d}^*_{h,t}/RER_t) \tag{76}$$

$$E_t\tilde{\Lambda}^*_{t+1}\left(r_{f,t+1}-r^*_{t+1}\right)=\lambda^*_t(\kappa^*_{f1}+\kappa^*_{f2}\tilde{d}^*_{f,t}) \tag{77}$$

$$\tilde{\Lambda}^*_{t+1}=\tilde{\Omega}^*_{t+1}\pi^*_{h,t+1}\frac{P(1,\mathscr{S}^*_{t+1})}{P(1,\mathscr{S}^*_t)}\left((1-\theta)+\theta\upsilon^*_{t+1}\right)$$

$$\tilde{r}^*_{K,t+1}=\frac{r^*_{K,t+1}+(1-\delta)q^*_{t+1}}{q^*_t}$$

Foreign envelope condition:

$$\upsilon^*_t=\frac{E_t\Omega^*_{t+1}\pi^*_{h,t+1}\frac{P(1,\mathscr{S}^*_{t+1})}{P(1,\mathscr{S}^*_t)}\left((1-\theta)+\theta\upsilon^*_{t+1}\right)r^*_{t+1}}{1-\eta^*_t} \tag{78}$$

Foreign participation constraint:

$$\begin{aligned}\upsilon^*_t n^*_t \;=\; &((\kappa^*_{Kf1,t}+\kappa^*_{Kf2,t}q^*_tK^*_{ft+1})q^*_tK^*_{ft+1}+(\kappa^*_{Kh1,t}+\kappa^*_{Kh2,t}\tfrac{1}{RER_t}q_tK^*_{h,t+1})\tfrac{1}{RER_t}q_tK^*_{h,t+1}\\ &+(\kappa^*_{h1,t}+\kappa^*_{h2,t}\tfrac{1}{RER_t}d^*_{h,t})\tfrac{1}{RER_t}d^*_{h,t}+(\kappa^*_{f1,t}+\kappa^*_{f2,t}d^*_{f,t})d^*_{f,t})\end{aligned} \tag{79}$$

Foreign net worth dynamics:

$$\begin{aligned}n^*_{t+1}=\;&\theta((\tilde{r}^*_{k,t+1}\vartheta_{t+1}-r^*_{t+1})q^*_tK_{t+1}\\ &+(\tfrac{RER_t}{RER_{t+1}}(\tilde{r}_{k,t+1}\vartheta_{t+1}*-r^*_{t+1})\tfrac{1}{RER_t}K^*_{h,t+1}\\ &+(\tfrac{RER_t}{RER_{t+1}}r_{h,t+1}-r^*_{t+1})\tfrac{1}{RER_t}d^*_{h,t}\\ &+(r_{f,t+1}-r^*_{t+1})d^*_{f,t}+r^*_{t+1}n^*_t)\\ &+\varphi\tfrac{P(1,\mathscr{S}^*_t)}{\pi^*_{h,t+1}P(1,\mathscr{S}^*_{t+1})}\left(q^*_tK^*_{t+1}+\tfrac{P(1,\mathscr{S}_t)}{\mathscr{D}_tP(1,\mathscr{S}^*_t)}d^*_{h,t}+d^*_{f,t}\right)\end{aligned} \tag{80}$$

Home monetary Rule:

$$r_{h,t+1}=r_{h,ss}\left(\frac{P(1,\mathscr{S}_t)\pi_{h,t}}{P(1,\mathscr{S}_{t-1})}\right)^{\eta^{\pi}(1-\rho^R)}(r_{h,t})^{\rho^R}M_t \tag{81}$$

Foreign monetary Rule:

$$r_{f,t+1}=r_{f,ss}\left(\frac{\mathscr{S}^*_{t-1}P^*(1,\mathscr{S}^*_t)\pi^*_{f,t}}{\mathscr{S}^*_tP^*(1,\mathscr{S}^*_{t-1})}\right)^{\eta^{\pi}(1-\rho^R)}(r_{f,t})^{\rho^R}M^*_t \tag{82}$$

Definitions:

$$\pi_{h,t} = \pi_{f,t} \frac{\mathscr{S}_{t-1}}{\mathscr{S}_t} \tag{83}$$

$$\pi^*_{f,t} = \pi^*_{h,t} \frac{\mathscr{S}^*_t}{\mathscr{S}^*_{t-1}} \tag{84}$$

$$\mathscr{D}_t = \mathscr{D}^*_t \frac{\mathscr{S}_t}{\mathscr{S}^*_t} \tag{85}$$

Equations (44) - (85}) give 46 equations in

$$C^K_t, C^{K*}_t, C^R_t, C^{R*}_t, L^K_t, L^{K*}_t, L^R_t, L^{R*}_t, I_t, I^*_t, K_{h,t}, K^*_{h,t}, K_{f,t}, K^*_{f,t}$$

$$\pi_{h,t}, \pi^*_{h,t}, \pi_{f,t}, \pi^*_{f,t}, w_t, w^*_t, q_t, q^*_t, mc_t, mc^*_t$$

$$r_{K,t}, r^*_{K,t}, r_t, r^*_t, r_{h,t}, r_{f,t}, Y_{h,t}, Y^*_{h,t},$$

$$Y_{f,t}, Y^*_{f,t}, \upsilon_t, \upsilon^*_t, \eta_t, \eta^*_t,$$

$$d_{h,t}, d_{f,t}, \mathscr{S}_t, \mathscr{S}^*_t, \mathscr{D}_t, \mathscr{D}^*_t, n_t, n^*_t$$

Endogenous state variables:
$n_t, n^*_t, K_{h,t}, K_{f,t}, K^*_{h,t}, K^*_{f,t+}, d_{h,t}, d_{f,t}, \mathscr{S}_{t-1}, \mathscr{S}^*_{t-1}$

B Steady state equations

Define real debt holdings: $d_h,\ d_f$,

Terms of Trade: $\mathscr{S} = \mathscr{S}^*$,

Deviations from LOOP: $\mathscr{D} = 1\ \mathscr{D}^* = 1$

Real Returns: $r_h\ r_f$

Real equity prices: $q = 1, q^* = 1$

Real marginal product of capital: $r_K = R_K,\ r^*_K = R^*_K$

Real net worth $n,\ \ n^*$

Real marginal costs: $mc = mc^* = 1$ (Setting $A = A^* = 1$)

Price indices: $P(1, \mathscr{S}),\ P^*(1, \mathscr{S})$

PPI inflation rates: $\pi_h = 1,\ \pi^*_h = 1\ \pi_f = 1,\ \pi^*_f = 1$

Also impose bond market clearing: $d_h^* = \bar{d}_h - d_h,\ d_f = \bar{d}_f - d_f^*$

labor market clearing: $L = H,\ L^* = H^*$

Real wage $w,\ \ w^*$

Real deposit (policy) rate $r\ \ r^*$

Subsidy rate $s = \frac{1}{\varepsilon - 1}$

Capital Quality $\vartheta = \vartheta^* = 1$

Define the steady state real exchange rate as $RER = \frac{P^*(1,\mathscr{S})}{P(1,\mathscr{S})}$. So it depends only on the terms of trade and home bias in consumption aggregators.

Balance of payments:

$$C + I + \delta K = \frac{Y_h + Y_h^*}{P(1,\mathscr{S})} + (r_h - 1)(d_h - \bar{d}_h) + RER(r_f - 1)d_f + (\tilde{r}_k - 1)(K_h - K) + RER(\tilde{r}_k^* - 1)K_f \tag{86}$$

Home Euler equation:

$$1 = \beta r \tag{87}$$

Foreign Euler equation:

$$1 = \beta r \tag{88}$$

Profit max Home:

$$1 = mc \tag{89}$$

$$1 = mc \tag{90}$$

Factor markets Home:

$$(1-\alpha)(L^{1-\alpha}K^{\alpha}) = \chi C^{\sigma} L^{1+\psi} P(1,\mathscr{S}) \tag{91}$$

$$\alpha(L^{1-\alpha}K^{\alpha}) = r_K P(1,\mathscr{S}) K \tag{92}$$

Capital and Price of capital at Home:

$$K\delta = I \tag{93}$$

$$q = 1 \tag{94}$$

$$Y_h + Y_h^* = (L^\alpha K^{1-\alpha}) \tag{95}$$

Profit Max Foreign:

$$1 = mc^* \tag{96}$$

$$1 = mc^* \tag{97}$$

Foreign factor markets:

$$(1-\alpha)(L^{*(1-\alpha)}K^{*\alpha}) = \frac{P^*(1,\mathscr{S})}{\mathscr{S}}\chi C^{*\sigma} L^{*1+\psi} \tag{98}$$

$$\alpha(L^{*(1-\alpha)}K^{*\alpha})^{\zeta} X^{*(1-\zeta)} = \frac{P^*(1,\mathscr{S})}{\mathscr{S}} r_K^* \tag{99}$$

Capital and Price of capital Foreign:

$$K\delta^* = I^* \tag{100}$$

$$q^* = 1 \tag{101}$$

$$Y_f^* + Y_f = (L^{*\alpha} K^{*(1-\alpha)}) \tag{102}$$

Market Clearing:
Home good:

$$Y_h + Y_f = \omega \left(\frac{1}{P(1,\mathscr{S})}\right)^{-\mu} (C + \delta K) + \frac{(1-n)}{n}(1-\omega^*)\left(\frac{1}{P^*(1,\mathscr{S})}\right)^{-\mu} (C^* + \delta K^*) \tag{103}$$

Foreign good:

$$Y_f + Y_f^* = \frac{n}{1-n}(1-\omega)\left(\frac{\mathscr{S}}{P(1,\mathscr{S})}\right)^{-\mu} (C + \delta K) + \omega^* \left(\frac{\mathscr{S}}{P^*(1,\mathscr{S})}\right)^{-\mu} (C^* + \delta K) \tag{104}$$

Home Bank:

$$\tilde{\Lambda}(\tilde{r}_k - r) = \lambda(\kappa_{Kh1} + \kappa_{Kh2} K_h) \tag{105}$$

$$\tilde{\Lambda}(\tilde{r}_k^* - r) = \lambda(\kappa_{Kf1} + \kappa_{Kf2} K_f) \tag{106}$$

$$\tilde{\Lambda}(r_h - r) = \lambda(\kappa_{h1} + \kappa_{h2} d_h) \tag{107}$$

$$\tilde{\Lambda}\left(r_f - r\right) = \lambda(\kappa_{f1} + \kappa_{f2} d_f) \tag{108}$$

$$\tilde{\Lambda} = \beta\left((1-\theta)+\theta\upsilon\right) \tag{109}$$

$$\tilde{r}_K = r_K + (1-\delta) \tag{110}$$

Home envelope condition:

$$\upsilon = \frac{((1-\theta)+\theta\upsilon)}{1-\eta} \tag{111}$$

Home participation constraint:

$$\begin{aligned} \upsilon n \quad = \quad & ((\kappa_{Kh1}+\kappa_{Kh2}K_h)K_h + (\kappa_{Kf1}+\kappa_{Kf2}RERK_f)RERq^*K_f \\ & +(\kappa_{h1}+\kappa_{h2}d_h)d_h + (\kappa_{f1}+\kappa_{f2}RER_t d_f)RER_t d_f) \end{aligned} \tag{112}$$

Home net worth dynamics:

$$\begin{aligned} n = \quad & \theta((\tilde{r}_k - r)K + (r_h - r)d_h + (r_f - r)\mathcal{Q}d_f + rn) \\ & +\varphi\left(K + d_h + \mathcal{Q}d_f\right) \end{aligned} \tag{113}$$

Foreign Bank:

$$\tilde{\Lambda}^*\left(\tilde{r}_k - r^*\right) = \lambda^*(\kappa^*_{Kh1}+\kappa^*_{Kh1}K^*_h) \tag{114}$$

$$\tilde{\Lambda}^*\left(\tilde{r}^*_k - r^*\right) = \lambda^*(\kappa^*_{Kf1}+\kappa^*_{Kf1}K^*_f) \tag{115}$$

$$\tilde{\Lambda}^*\left(r_h - r^*\right) = \lambda^*(\kappa^*_{h1}+\kappa^*_{h2}d^*_h) \tag{116}$$

$$\tilde{\Lambda}^*\left(r_f - r^*\right) = \lambda^*(\kappa^*_{f1}+\kappa^*_{f2}d^*_f) \tag{117}$$

$$\tilde{\Lambda}^* = \beta\left((1-\theta)+\theta\upsilon^*\right) \tag{118}$$

$$\tilde{r}^*_K = r^*_K + (1-\delta) \tag{119}$$

Foreign envelope condition:

$$\upsilon^* = \frac{((1-\theta)+\theta\upsilon^*)}{1-\eta^*} \tag{120}$$

Foreign participation constraint:

$$\begin{aligned} \upsilon^* n^* \quad = \quad & ((\kappa^*_{Kf1}+\kappa^*_{Kf2}K^*_f)K^*_f + (\kappa^*_{Kh1}+\kappa^*_{Kh2}\tfrac{1}{RER}K^*_h)\tfrac{1}{RER}K^*_h \\ & +(\kappa^*_{h1}+\kappa^*_{h2}\tfrac{1}{RER}d^*_{h,t})\tfrac{1}{RER}d^*_h + (\kappa^*_{f1}+\kappa^*_{f2}d^*_f)d^*_f) \end{aligned} \tag{121}$$

Foreign net worth dynamics:

$$n^* = \begin{array}{c} \theta((\tilde{r}_k^* - r^*)K^* + (r_h - r^*)\frac{d_h^*}{RER} + (r_f - r^*)d_f^* + r^* n^*) \\ +\varphi\left(K^* + \frac{d_h^*}{RER} + d_f^*\right) \end{array} \tag{122}$$

Home monetary policy

$$r_h = r_{h,ss} \tag{123}$$

Foreign monetary policy

$$r_f = r_{f,ss} \tag{124}$$

Take mc, r, q, I, $\tilde{\Lambda}$ as given (and same for Foreign). Then we have (86), (91), (92), (**??**), (95),(98), (99), (**??**), (102), (103), (104), (105), (107), (108), (111), (112), (113), (115), (116), (117), (120), (121), (122),

Solve for C, C^*, K, K^*,X, X^*, L, L^*, Y, Y^*

(Note just add $Y_h + Y_h^* = Y$ together)

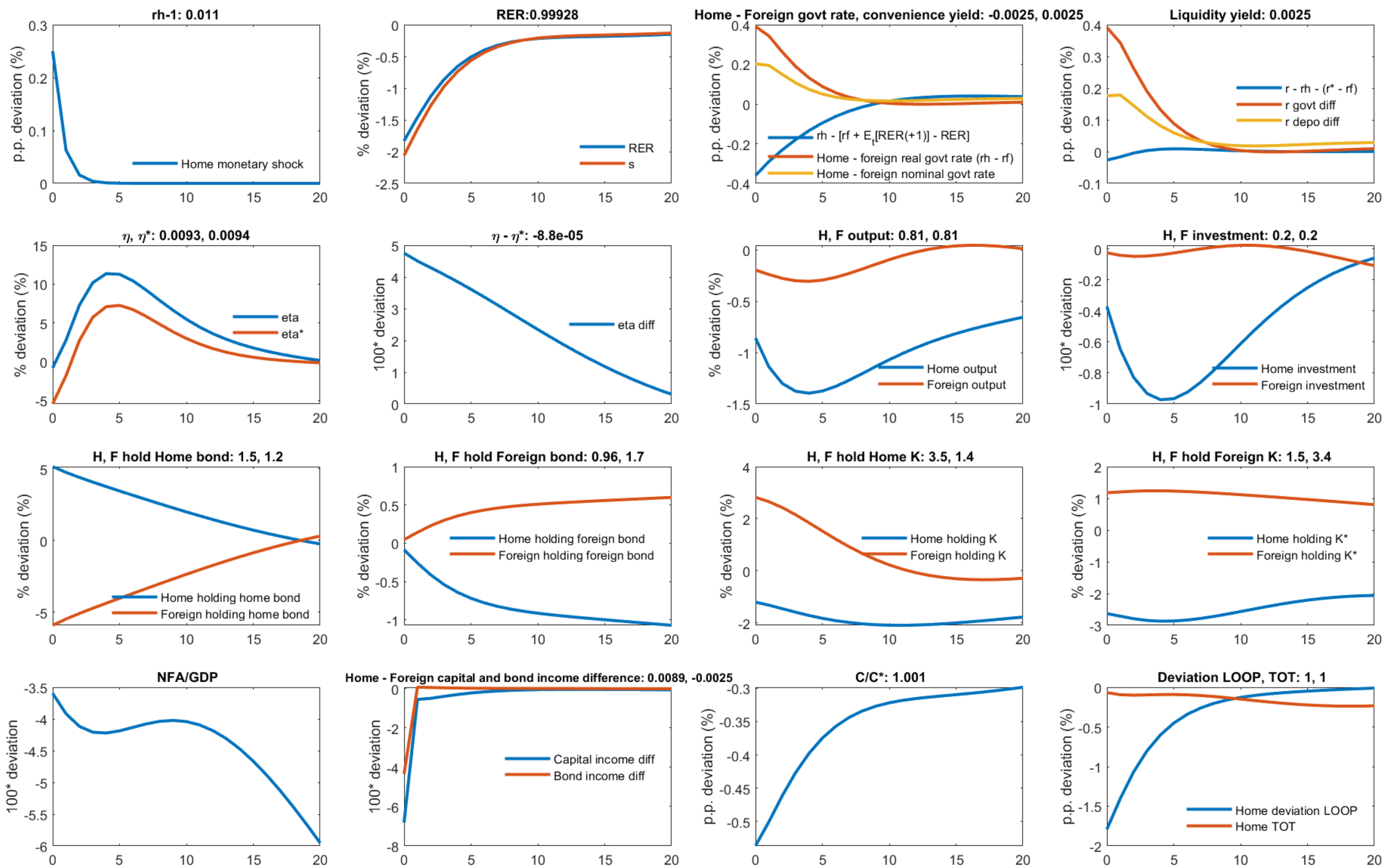
$\mathscr{S}$, d_h, d_f, n, n^*,υ, υ^* η, η^*, r_k, r_k^*, r_h, r_f

C Additional IRF analysis

C.1 U.S. Monetary Contraction

Figure 8 shows the response to a surprise monetary tightening in the U.S. Rey (2015), Rey (2016), Kalemli-Özcan (2019), Curcuru et al. (2018),and Miranda-Agrippino and Rey (2020) have emphasized the importance of spillovers from U.S. monetary policy in driving the business cycle and monetary policy choices of other countries. In this figure, we see the usual effects on the U.S. of a monetary contraction - increased real interest rates, a drop in investment, consumption and output. The monetary contraction leads to an appreciation through the usual channel of tight money, but also there is an increase in the convenience yield on U.S. Treasury bonds. As investment in capital becomes less attractive, U.S. banks switch their demand toward domestic bonds, which lowers their expected return relative to Foreign bonds - that is, an increase in the liquidity yield on U.S. bonds. We can also see that the gap between deposit rates and liquid bond rates in the U.S. widens relative to that in the rest of the world. As in the case of the global financial shock, U.S. NFA to GDP falls, and there is a net transfer to the rest of the world. The contraction in the U.S. spills over to the Foreign country through conventional channels, but also through financial channels that are unconventional. As U.S. banks demand switches from equities to U.S. Treasury bonds, lowering the return on those bonds, they acquire U.S. bonds from Foreign banks. There is a tightening of financial constraints in the Foreign country, which leads to a drop in investment demand there, and an increase in demand for local government bonds. However, the effects on the real economy are smaller in the Foreign country than in the U.S..

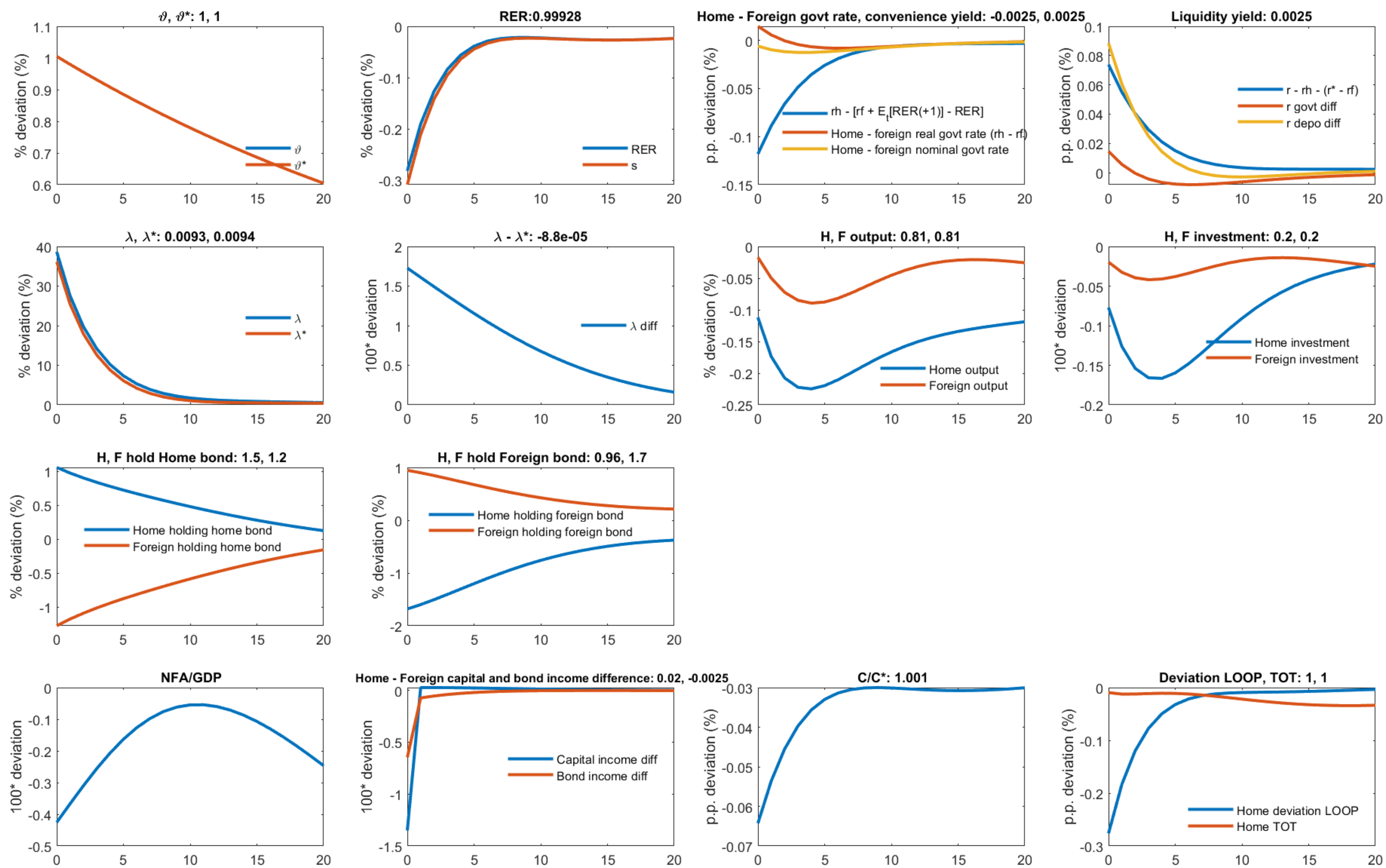
Figure 8: 25 basis point Home monetary shock with baseline calibration



Notes: The figure shows IRF of a 0.25% Home monetary shock. Subtitles of the figure report the steady state value of the reporting variables.

C.2 Baseline global financial shock without internatinal capital trade

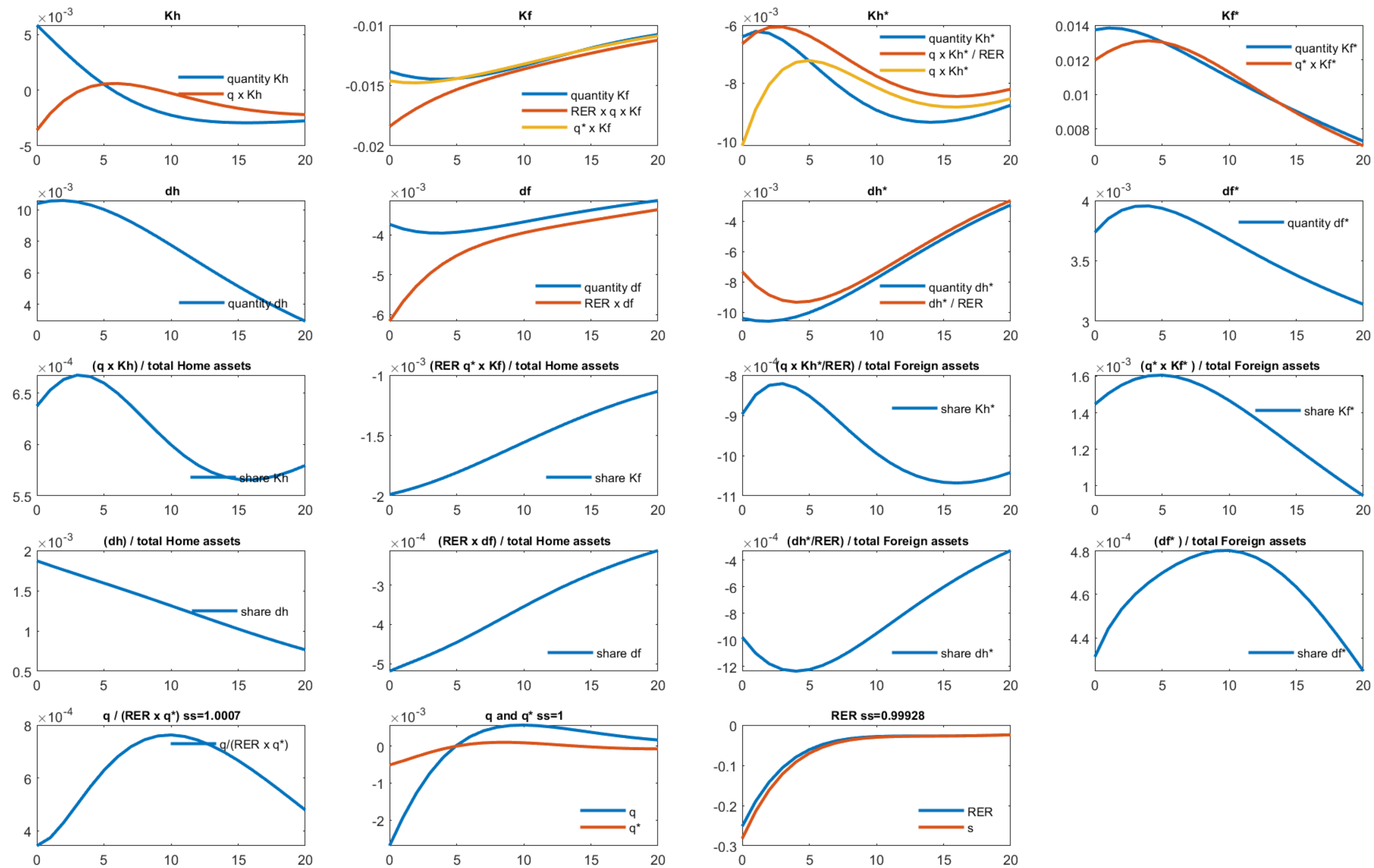
Figure 9: 1% global financial shock (ϑ, ϑ^*) with no capital trade



Notes: The figure shows IRF of a 1% global financial shock. Subtitles of the figure report the steady state value of the reporting variables.

C.3 Baseline global financial shock portfolio dynamics

Figure 10: Portfolio dynamics under baseline case with 1% global financial shock (ϑ, ϑ^*)



Notes: The figure shows IRF of a 1% global financial shock. Subtitles of the figure report the steady state value of the reporting variables.

C.4 *Global Monetary Contraction*

Figure 11 illustrates an equal unexpected monetary contraction in the U.S. and Foreign country.[28] This may provide insight into the aggressive monetary tightening cycle followed by many countries in 2022. In a symmetric environment a uniform monetary shock across the Home and Foreign country has no impact on the exchange rate when UIP holds. But here the model implies a dollar appreciation and a wider UIP deviation following the global shock. Even though the direct effect of the uniform shock is for both countries to raise their interest rates equally, the effects on the exchange rate, expected returns, and the policy instrument itself are not equal in equilibrium. The tightening monetary policy reduces aggregate demand and lowers the value of capital/equity. It also lowers the net worth of the banks that own capital, tightening the balance sheet constraint.[29] As with the global financial shock, the effect of the more stringent constraint is to raise the demand for U.S. dollar bonds globally. The convenience yield on these bonds increases, and result in a real dollar appreciation through the second term on the right hand side of equation (39) despite the fact that the sum of interest rate differentials hardly moves at all. The disinflationary effect is stronger in the U.S. because banks there are more incentivized to switch out of equities investments and into U.S. bonds, thus lowering aggregate demand to a greater extent. Figure 11 also illustrates that capital flow retrenchment is a feature of a global monetary contraction, just as in the case of a global financial tightening.

C.5 *Global Productivity Shock*

Figure 12 presents the effects of a 1% global decline in TFP, which illustrates how a global slowdown arising from a productivity slowdown may have similar effects on the value of the dollar and the dollar liquidity premium. The effects on exchange rates, asset prices, and capital flows is mostly very similar to the effects of a tightening of the financial constraint. That is because the drop in productivity reduces the profitability of the bank, and so endogenously tightens the lending constraint. As in the literature on the "financial accelerator" (e.g., Bernanke and Gertler (1989), Kiyotaki and Moore (1997), Bernanke et al. (1999), Gertler and Kiyotaki (2010), Gertler and Karadi (2011)), the financial squeeze resulting from a TFP decline reduces investment and exacerbates the effects of the original drop in productivity on real output and employment. As in the case of an increase in ϑ and ϑ^*, the drop in global productivity (a 1% initial decline in A_t and A_t^*) leads to a tightening of the lending constraint as can be seen by the increase in the multipliers, λ_t and λ_t^*.

[28] In Appendix C, we also present the case of U.S. monetary policy tightening.

[29] The collapse of Silicon Valley Bank serves as a pertinent example of this valuation channel. While the model accounts for valuation changes primarily through equity prices and exchange rate movements, the Silicon Valley Bank case involves a valuation change in long-maturity bonds, a factor which is absent in our model.

Because the U.S. bond is relatively less constrained, demand for it increases, which lowers the expected return on the bond. This is mainly accomplished through an appreciation of the dollar, leading to an expectation of a depreciation. There is a larger decline in investment in the U.S. for the same reason described above for a financial shock, leading to a larger decline in U.S. output.

C.6 *Quantitative tightening and exchange rate intervention*

We next examine the implications of quantitative tightening (QT) and exchange rate (FX) intervention in our model. The interesting insight of this exercise is that it demonstrates that the central bank effectively has two separate instruments at its disposal, which do not have identical influences on the domestic or global economy.[30] For example, in 2021-2022, the U.S. Federal Reserve responded to rising inflation by raising its policy rate, as our model for the monetary policy rule captures. At the same time, it also embarked on quantitative tightening. One effect of combining these two policies is a strong appreciation of the dollar because both the higher interest rate and the reduction in liquidity work to raise the value of the dollar. In fact, the dollar appreciated so strongly during this period that the exchange rate became a major concern of the rest of the world, and then unavoidably for U.S. policymakers. Our analysis suggests that a different menu of interest-rates and balance sheet polices may have improved outcomes.

We postulate that the Home country conducts quantitative tightening and the Foreign country conducts FX intervention. To do so, we define new variables for the central bank balance sheets, where $d_{h,t}^{CB}$ and $d_{h,t}^{CB*}$ are the Home and Foreign central bank holding of Home bonds, $d_{f,t}^{CB*}$ is the Foreign central bank holding of Foreign bonds, and $K_{h,t}^{CB}$ is the Home central bank holding of Home capital. We assume $d_{h,t}^{CB}$ and $d_{h,t}^{CB*}$ follow an log AR 1 process with a persistence parameter ρ of 0.7:

$$log(d_{h,t}^{CB}) = \rho log(d_{h,t-1}^{CB}) + \varepsilon_t^{d_h^{CB}} \text{ and } log(d_{f,t}^{CB*}) = \rho log(d_{f,t-1}^{CB*}) + \varepsilon_t^{d_f^{CB*}}$$

The modified market clearing conditions are:

$$\text{Home bond market clearing: } \bar{d}_h = d_{h,t} + d_{h,t}^* + d_{h,t}^{CB} + d_{h,t}^{CB*}$$

$$\text{Foreign bond market clearing: } \bar{d}_f = d_{f,t} + d_{f,t}^* + d_{f,t}^{CB*}$$

$$\text{Home capital market clearing: } K_t = K_{h,t} + K_{h,t}^* + K_{h,t}^{CB}$$

The central banks' balance sheet are:

$$\text{Home central bank: } d_{h,t}^{CB} + q_t K_{h,t}^{CB} = 0$$

[30] The potential for quantitative easing policies to operate separately from interest rate policy in the presence of financial frictions has been widely recognized, e.g. Gertler and Karadi, 2010, Bernanke, 2020.

$$\text{Foreign central bank: } d_{h,t}^{CB*} + RER_t d_{f,t}^{CB*} = 0$$

A quantitative tightening, or large-scale asset sale, in this model will be an increase in $d_{h,t}^{CB}$ and the equivalent sales of $q_t K_{h,t}^{CB}$. Normally, one specifies quantitative intervention by the central bank as altering the amount of reserves held in the system, but our set-up does not specifically include central bank reserves as an asset. However, we subscribe here to the argument of Rogoff (2017) that for the consolidated government budget, reserves held at the central bank are essentially identical to short-term bonds issued by the government. When reserves pay interest, they are a debt obligation of the central bank, which then reduces the amount of "profit" from its portfolio that the central bank remits to the general government revenue each year. In other words, the implications for the overall budget are identical to those from issuing short-term bonds. The fact that in the U.S. there have been only very slight differences between interest paid on reserves and interest on the shortest-term Treasury bonds suggests that these two assets are considered to be close substitutes. In our framework, when $d_{h,t}^{CB}$ increases, it is equivalent to the central bank reducing reserves held by the banking system. The central bank satisfies its balance sheet by selling off some of its less liquid assets, which in our model are represented by the government holdings of equities.[31]

Since the convenience of the Home bond is higher than capital, a QT operation is lowering the aggregate liquidity of assets in the private sector. On the other hand, a foreign exchange accumulation is an increase in $d_{h,t}^{CB*}$ and equivalent sales of $RER_t d_{f,t}^{CB}$. Figure 13 reports the IRFs of a 1% QT shock. As mentioned, the QT shock reduces aggregate liquidity. This results in a rise in the excess demand for the most pledgeable asset, therefore a rise of Home convenience yield and an appreciation of the U.S. dollar. The drain of liquidity is also associated with a drop in world output due to a fall in capital price that lowers the banking net worth.

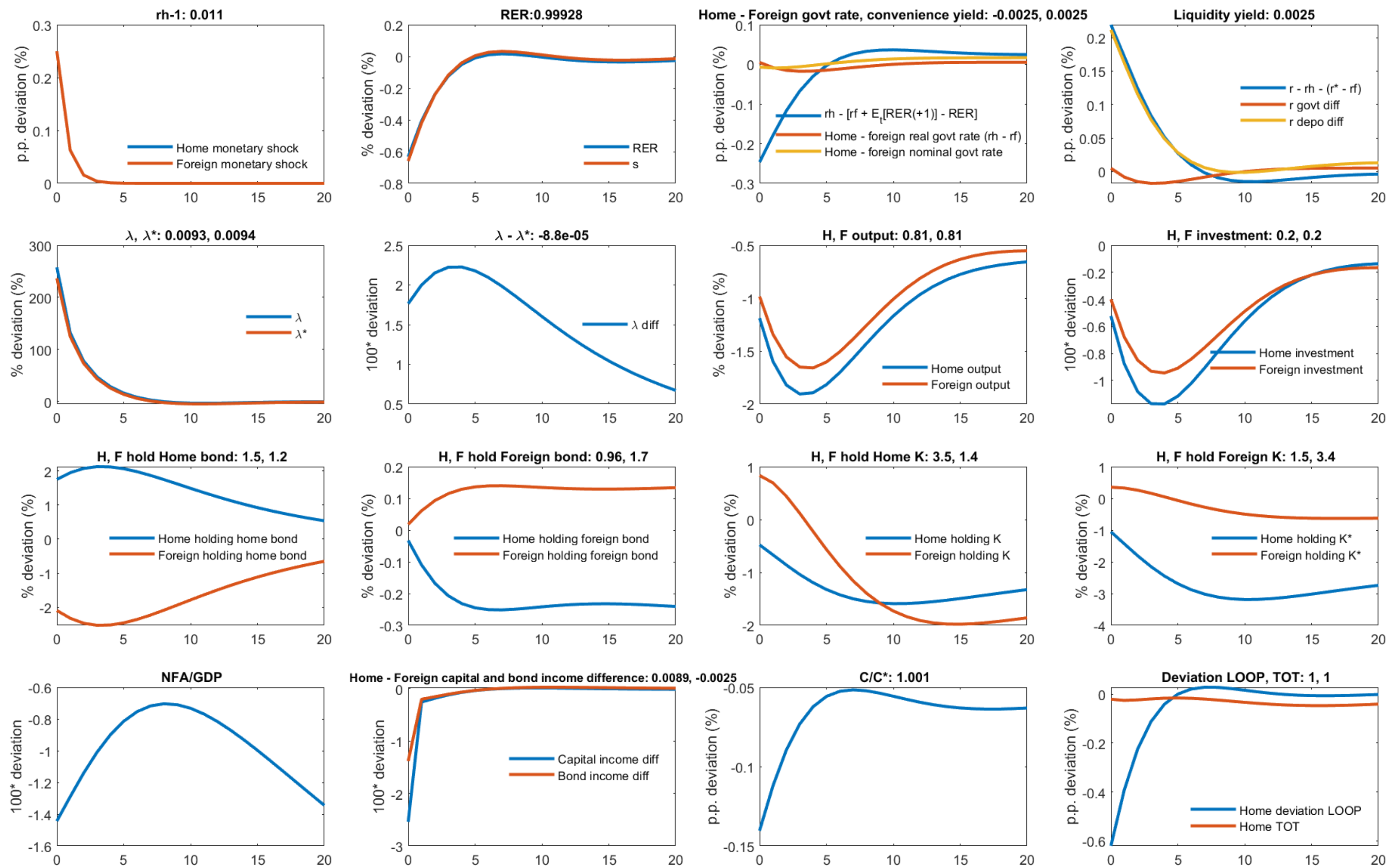
Figure 14 reports the IRFs of a 1% FXI shock where the Foreign central bank buys more bonds (accumulation of reserves). Similar to a QT shock, an FXI accumulation also reduces aggregate liquidity. Therefore there is a rise of Home convenience yield and an appreciation of the U.S. dollar. The drain of liquidity is also associated with a drop in world output because the banking

[31] Note also that in the U.S. QT is normally characterized by the central bank selling some of its holdings of Treasury bonds and reducing its reserve liabilities to private banks, while here we assume the central bank is selling equity and buying government bonds. But our interterpretation is consistent with actual QT in the sense that the central bank is swapping a less liquid asset (equity) for the more liquid asset (government bonds). See Dedola et al. (2021) for an empirical study of quantitative easing and its effects on exchange rates and international spillovers.

sector is more constrained than before.[32]

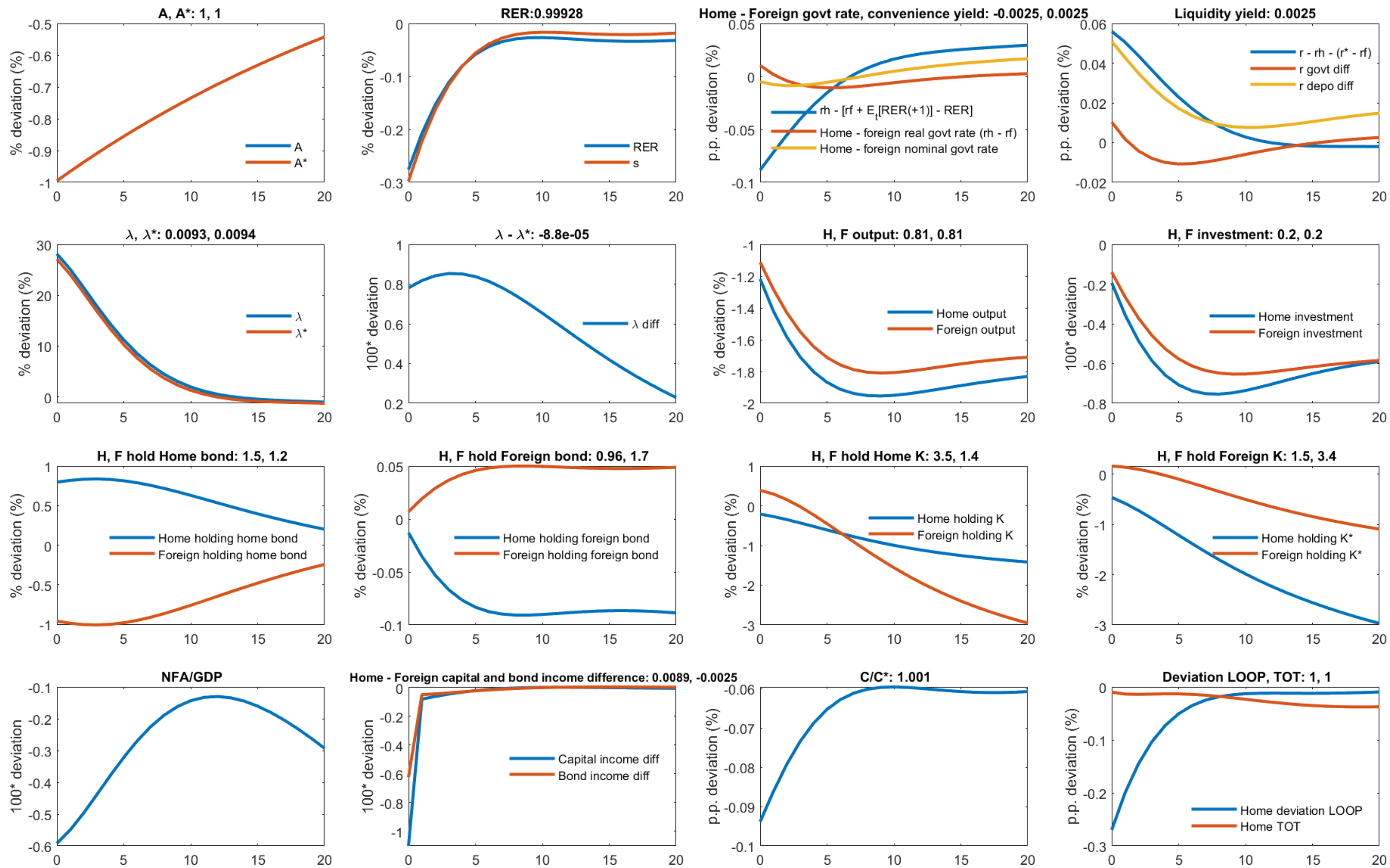
[32]There are some similarities of this analysis and that of Fanelli and Straub (2021). In both models, the central bank gains an additional instrument that allows it to conduct sterilized intervention because of balance sheet constraints facing the banking sector. However, in our set-up, the constraints take a different aspect because of the special role of the dollar, and our analysis is embedded in a two-country set-up that then permits us to see explicitly the spillover effects of sterilized intervention. Our analysis also bears some resemblance to that of Bianchi et al. (2021), who emphasize the liquidity demand for dollars from the financial intermediation sector. As we have mentioned above, that study lays down different microfoundations for liquidity demand and the general equilibrium model is very simplified, not allowing for in-depth analysis of the potential real effects of conventional and unconventional monetary policy.

Figure 11: 25 basis point both Home and Foreign monetary shock with baseline calibration



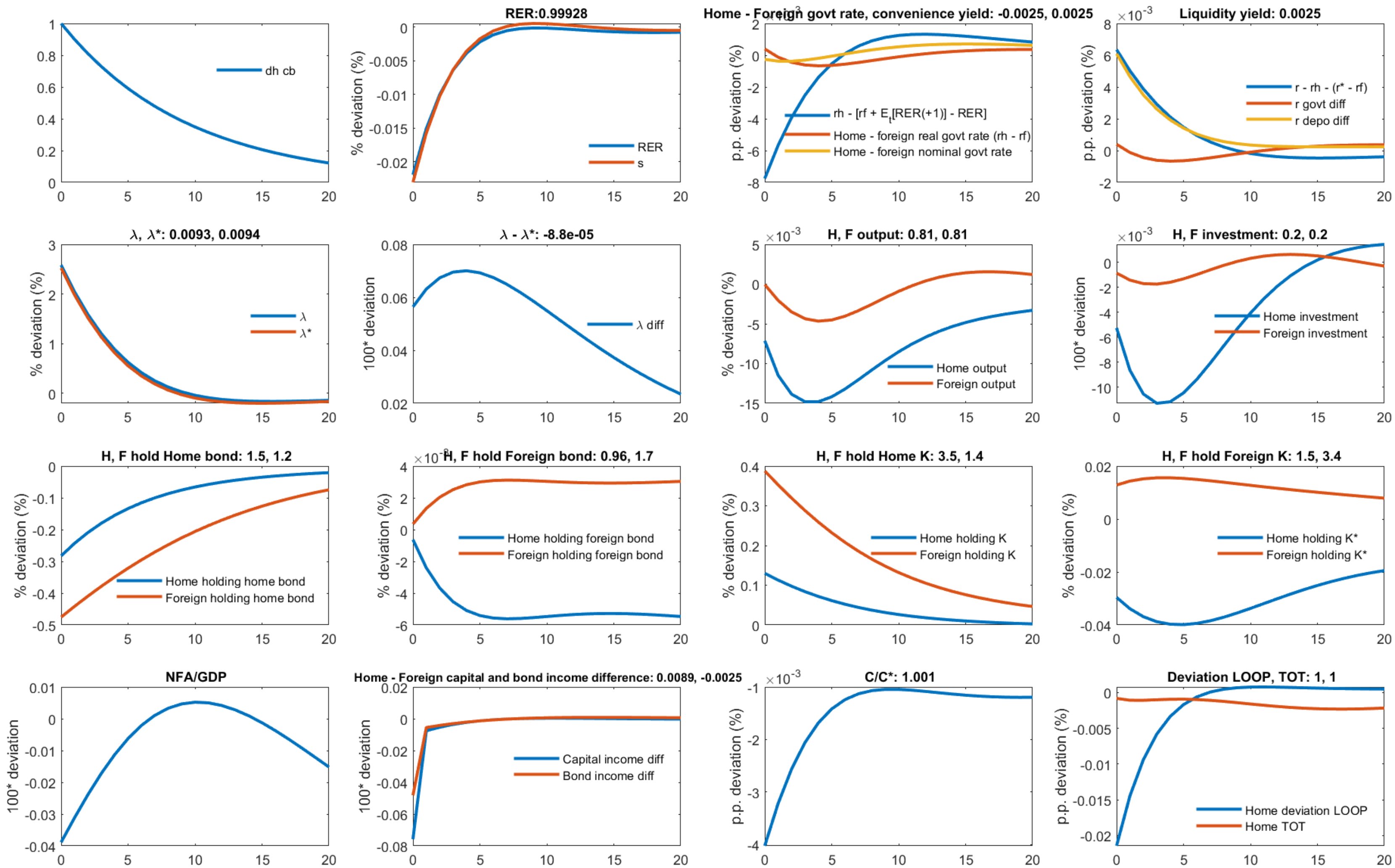
Notes: The figure shows IRF of a 0.25% global monetary shock. Subtitles of the figure report the steady state value of the reporting variables.

Figure 12: 1% TFP shock (A, A^*) with baseline calibration



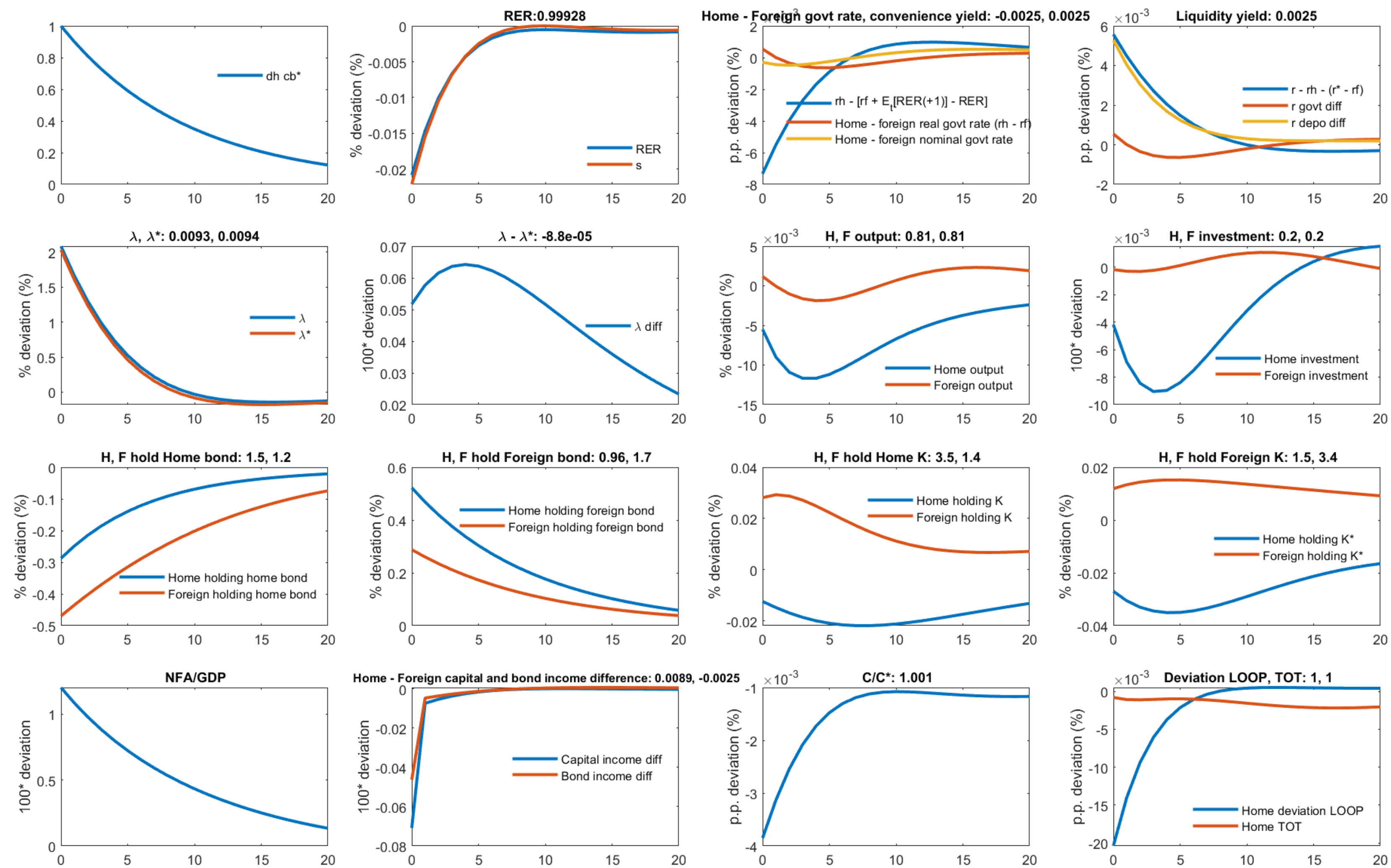
Notes: The figure shows IRF of a 1% global productivity shock. Subtitles of the figure report the steady state value of the reporting variables.

Figure 13: 1% QT shock with purchase of Home bonds and sales of Home capital by Home central bank



Notes: The figure shows IRF of a 1% QT shock. Subtitles of the figure report the steady state value of the reporting variables.

Figure 14: 1% FXI shock with purchase of Home bonds and sales of Foreign bonds by Foreign central bank



Notes: The figure shows IRF of a 1% QT shock. Subtitles of the figure report the steady state value of the reporting variables.

D IV regression

Table 7: Model implied regression and the empirical counterpart

$$\Delta s_{j,t} = \alpha_j + \beta_1 s_{j,t-1} + \beta_2 \Delta\eta_{j,t} + \beta_3 \Delta(i-i^*)_{j,t} + \beta_4 \eta_{j,t-1} + \beta_5 (i-i^*)_{j,t-1} + u_{j,t}$$

	Panal daily IV regression of G10 currenices
	(1)
$\Delta\eta_{j,t}$	-9.07**
	(4.53)
$\Delta(i-i^*)_{j,t}$	-8.58**
	(3.86)
$\eta_{j,t-1}$	-0.002
	(0.002)
$(i-i^*)_{j,t-1}$	-0.040
	(0.03)
s_{t-1}	-0.003
	(0.002)
Observations	1746

Notes: Standard errors in parentheses are clusted by time. * p<0.1, ** p<0.05, *** p<0.01. The first stage regression uses four financial shock measures in Ottonello and Song (2022) as the instruments for the change of convenience yield. The first stage F-statistics is 14.60.

To provide direct evidence of the mechanism from banking to exchange rates, we employ an instrumental variable regression. We instrument the change of convenience yield $\Delta\eta_{j,t}$ using financial shocks constructed by Ottonello and Song (2022), which are high-frequency changes in the market value of U.S. intermediaries' net worth in a narrow 60-min window around their earnings announcements. In our model, a financial shock changes the U.S. banks' net worth, which changes their demand for liquid and convenient assets, therefore creating a shift in the convenience yield. We make use of all four measures of financial shock in Ottonello and Song (2022) as our first stage instruments. They are the market value change of the earnings release bank around announcements, market value change of the all sample banks around announcements, and broader measures of these two which include earnings releases announced after market closed. For this exercise, we use daily changes in exchange rates (rather than quarterly in the first two columns) from 10-Jan-2001 to 29-Jul-2014.[33]

[33] Daily data helps to eliminate the effects of "left-out" variables in the regression that might play a role in exchange rate movements at longer frequencies, but do not much effect higher-frequency changes. In the first stage regression, the F-statistic for the joint significance of the instruments is 14.60. The Hansen J-statistic for correlation of the instruments with the error term in the second-stage regression is 7.21 with a p-value of 0.065. Our sample size is limited by the data we use as instruments described below, which was kindly provided to us by the authors of Ottonello and Song (2022). .

The regression estimates are reported in column 3 of Table 7. The coefficient on $\Delta\hat{\eta}_{j,t}$ is significantly negative. The coefficient of -9.07 indicates a 1% increase in the convenience yield driven by a global financial shock is associated with 9.07% appreciation of the U.S. dollar. Again, we find that both the change of the convenience yield and the change of the interest rate differential are significant explanatory variables for exchange rate movements. More importantly, the instrumental variable regression highlights the convenience yield movement that is driven by change in banking net worth. We interpret this as evidence that banking demand for liquidity plays an important role in determining exchange rates through endogenous movements in the convenience yield.

E Unconditional moments with different assumptions

In this section, we report the unconditional moments in Table 5 with alternative assumptions. In particular, we assume 1) no convenience yield channel by assuming no collateral advantage, 2) PCP rather than LCP and 3) Both PCP and no convenience yield.

In each of the tables below, we report the original model implied unconditional moment in column (1). Column (2)-(4) reports the conditional and unconditional moments under alternative assumptions.

In Table 8, we assume there is no collateral advantage for the U.S. Treasury. We assume $\kappa_{h1} = \kappa^*_{h1} = \kappa_{f1} = \kappa^*_{f1} = 0.025$ so all bonds are equally well to be served as collateral. The most obvious different from the original model is that the exchange rate becomes much less volatile. It is less volatile than output and consumption unconditionally. It is also less volatile in the high financial volatility state, which is at odd with the data. It also implies a positive Fama β.

Table 8: Long-run moments without convenience yield

		Model with no convenience yield		
	Original model moments unconditional	Model moments conditional on the low volatility state	Model moments unconditional	Model moments conditional on the high volatility state
	(1)	(2)	(3)	(4)
Exchange rates				
$\sigma(\Delta s)/\sigma(\Delta GDP)$	2.5	1.19	0.84	0.35
$\sigma(\Delta s)/\sigma(\Delta c)$	2.0	0.95	0.91	0.72
$\sigma(i-i^{*})/\sigma(\Delta s)$	0.19	0.22	0.22	0.22
Fama β	-0.03	1.36	1.36	1.35
$\rho(\Delta q, \Delta c - \Delta c^{*})$	0.16	-0.09	-0.09	-0.09
$\sigma(\Delta q)/\sigma(\Delta s)$	0.93	0.91	0.91	0.91
Persistence				
$\rho(\Delta s)$ (NER)	-0.09	-0.06	-0.06	-0.06
$\rho(q)$ (RER)	0.89	0.96	0.96	0.97
$\rho(i-i^{*})$	0.95	0.93	0.95	0.98
$\rho(i)$	0.99	0.99	0.99	0.99
Trade balance				
$corr(\Delta nx, \Delta q)$	0.76	0.6	0.6	0.6
$\sigma(\Delta nx)/\sigma(\Delta q)$	0.27	0.45	0.45	0.45
Business cycle				
$\sigma(\Delta c)/\sigma(\Delta GDP)$	1.2	1.3	0.92	0.49
$\rho(\Delta c, \Delta GDP)$	0.78	0.80	0.71	0.72
$\rho(\Delta I, \Delta GDP)$	0.66	0.69	0.85	0.96
$\rho(\Delta GDP, \Delta GDP^{*})$	0.56	0.78	0.88	0.98
$\rho(\Delta c, \Delta c^{*})$	0.05	0.1	0.16	0.47
$\rho(\Delta I, \Delta I^{*})$	0.54	0.89	0.97	0.99

Data moments are computed quarterly from 1999Q1 to 2023Q1. Model implied moments are performed with 15,000-quarter observations and burning the first 100 quarters.

In Table 9, we assume PCP so there is no deviation from LOOP ($D = D^* = 1$). The most obvious different from the original model is that the exchange rate becomes less volatile and also results in very volatile trade balance relative to real exchange rate.

Table 9: Long-run moments with PCP

		Model with PCP		
	Original model moments unconditional	Model moments conditional on the low volatility state	Model moments unconditional	Model moments conditional on the high volatility state
	(1)	(2)	(3)	(4)
Exchange rates				
$\sigma(\Delta s)/\sigma(\Delta GDP)$	2.5	1.27	1.62	1.88
$\sigma(\Delta s)/\sigma(\Delta c)$	2.0	1.22	2.24	6.07
$\sigma(i-i^*)/\sigma(\Delta s)$	0.19	0.23	0.22	0.22
Fama β	-0.03	-0.62	-1.49	-1.76
$\rho(\Delta q, \Delta c - \Delta c^*)$	0.16	-0.19	0.01	0.38
$\sigma(\Delta q)/\sigma(\Delta s)$	0.93	0.26	0.25	0.24
Persistence				
$\rho(\Delta s)$ (NER)	-0.09	-0.42	-0.44	-0.46
$\rho(q)$ (RER)	0.89	0.99	0.98	0.94
$\rho(i-i^*)$	0.95	0.92	0.85	0.82
$\rho(i)$	0.99	0.99	0.99	0.97
Trade balance				
$corr(\Delta nx, \Delta q)$	0.76	0.94	0.97	0.99
$\sigma(\Delta nx)/\sigma(\Delta q)$	0.27	1.92	1.71	1.62
Business cycle				
$\sigma(\Delta c)/\sigma(\Delta GDP)$	1.2	1.04	0.72	0.31
$\rho(\Delta c, \Delta GDP)$	0.78	0.64	0.42	0.05
$\rho(\Delta I, \Delta GDP)$	0.66	0.55	0.59	0.62
$\rho(\Delta GDP, \Delta GDP^*)$	0.56	-0.03	-0.52	-0.86
$\rho(\Delta c, \Delta c^*)$	0.05	0.06	0.07	0.15
$\rho(\Delta I, \Delta I^*)$	0.54	0.83	0.89	0.97

Data moments are computed quarterly from 1999Q1 to 2023Q1. Model implied moments are performed with 15,000-quarter observations and burning the first 100 quarters.

In Table 10, we assume there are PCP and no collateral advantage for the U.S. Treasury. That is, we assume $\kappa_{h1} = \kappa^*_{h1} = \kappa_{f1} = \kappa^*_{f1} = 0.025$ so all bonds are equally well to be served as collateral and also there is no deviation from LOOP ($D = D^* = 1$). The model then retains the caveats from the two previous table. The exchange rate becomes much less volatile than output consumption and trade balance unconditionally. The exchange rate is less volatile in the high financial volatility state. It also implies a positive Fama β.

Table 10: Long-run moments with PCP and without convenience yield

		Model with PCP and no convenience yield		
	Original model moments unconditional	Model moments conditional on the low volatility state	Model moments unconditional	Model moments conditional on the high volatility state
	(1)	(2)	(3)	(4)
Exchange rates				
$\sigma(\Delta s)/\sigma(\Delta GDP)$	2.5	1.00	0.73	0.32
$\sigma(\Delta s)/\sigma(\Delta c)$	2.0	0.90	0.86	0.64
$\sigma(i-i^*)/\sigma(\Delta s)$	0.19	0.11	0.11	0.11
Fama β	-0.03	0.42	0.41	0.40
$\rho(\Delta q, \Delta c - \Delta c^*)$	0.16	-0.31	-0.31	-0.31
$\sigma(\Delta q)/\sigma(\Delta s)$	0.93	0.27	0.27	0.27
Persistence				
$\rho(\Delta s)$ (NER)	-0.09	-0.4	-0.4	-0.4
$\rho(q)$ (RER)	0.89	0.99	0.99	0.99
$\rho(i-i^*)$	0.95	0.99	0.99	0.99
$\rho(i)$	0.99	0.97	0.97	0.97
Trade balance				
$corr(\Delta nx, \Delta q)$	0.76	0.92	0.92	0.92
$\sigma(\Delta nx)/\sigma(\Delta q)$	0.27	2.1	2.1	2.1
Business cycle				
$\sigma(\Delta c)/\sigma(\Delta GDP)$	1.2	1.12	0.86	0.50
$\rho(\Delta c, \Delta GDP)$	0.78	0.69	0.66	0.73
$\rho(\Delta I, \Delta GDP)$	0.66	0.62	0.80	0.95
$\rho(\Delta GDP, \Delta GDP^*)$	0.56	0.39	0.67	0.94
$\rho(\Delta c, \Delta c^*)$	0.05	0.11	0.19	0.55
$\rho(\Delta I, \Delta I^*)$	0.54	0.96	0.99	0.99

Data moments are computed quarterly from 1999Q1 to 2023Q1. Model implied moments are performed with 15,000-quarter observations and burning the first 100 quarters.

F Bond in utility model

In this section, we present a bond-in-utility model and calibrate it to match the same target as in the main text. The model can produce a sensible relationship between the exchange rate and the convenience yield, but it cannot reconcile the capital flow relationship observed in the data. The production and policy blocks of the model are identical to those in the baseline model. We modify the model so that households can directly invest in domestic and foreign government bonds and capital, similar to the banking sector in the main text.

The household utility function is:

$$E_t \sum_{s=t}^{\infty} \beta^s \delta_s U_s \tag{125}$$

where:

$$U_t = \frac{(C_t)^{1-\sigma} - 1}{1-\sigma} + v_h(D_{h,t}) + v_f(S_t D_{f,t}) + -\frac{\chi}{1+\psi}(H_t)^{1+\psi} \tag{126}$$

where $v_h(D_{h,t})$ and $v_f(S_t D_{f,t})$ are the utility that households derive from holding the government bond assets.

The budget constraint of households take the following form:

$$\begin{gathered} P_t C_t + B_t + D_{h,i,t} + S_{t+1} D_{f,i,t} + Q_t K_{h,t+1} + Q_t^* K_{f,t+1} = \\ W_t H_t + R_t B_{t-1} + R_{h,t+1} D_{h,t-1} + S_{t+1} R_{f,t+1} D_{f,t-1} + (\tilde{R}_{k,t} \vartheta_t) Q_t K_t + (S_t \tilde{R}_{k,t}^* \vartheta_t^*) Q_t^* K_{f,t} + \Pi_t + TR_t - T_{s,t} \end{gathered} \tag{127}$$

Specifically, we assume the bond utility functions are:

$$v_h(D_{h,t}) = \omega_t^h [\kappa_{h1} D_{h,t} - 1/2 \kappa_{h2} (D_{h,t})^2]$$

$$v_f(S_t D_{f,t}) = \omega_t^f [\kappa_{f1} S_t D_{f,t} - 1/2 \kappa_{f2} (S_t D_{f,t})^2]$$

where ω_t^h and ω_t^f are bond in utility shock and are assumed to be AR1 with a persistence parameter of 0.98.

Foreign households are modelled in the exact same way. The particular utility function specification allows us to obtain a similar first order condition as in the banking model. The corresponding first order condition of home and government bond for the home households are

$$E_t \Lambda_{i,t+1} \left(R_{h,t+1} - R_{t+1} \right) = \kappa_{h2} D_{h,t} - \kappa_{h1} \tag{128}$$

$$E_t \Lambda_{i,t+1} \left(\frac{S_{t+1}}{S_t} R_{f,t+1} - R_{t+1} \right) = \kappa_{f2} \frac{S_{t+1}}{S_t} D_{f,t} - \kappa_{f1} \tag{129}$$

To match the same target of steady state NFA/GDP, steady state net foreign income from abroad, steady state convenience yield and steady state foreign holding of U.S. Treasury, we set the

$$\kappa_{h1} = 0.0064, \kappa_{h1}^{*} = 0.0057, \kappa_{f1} = 0.003, \kappa_{f1}^{*} = 0.00397$$

$$\kappa_{h2} = \kappa_{h2}^{*} = \kappa_{f2} = \kappa_{f2}^{*} = 0.001$$

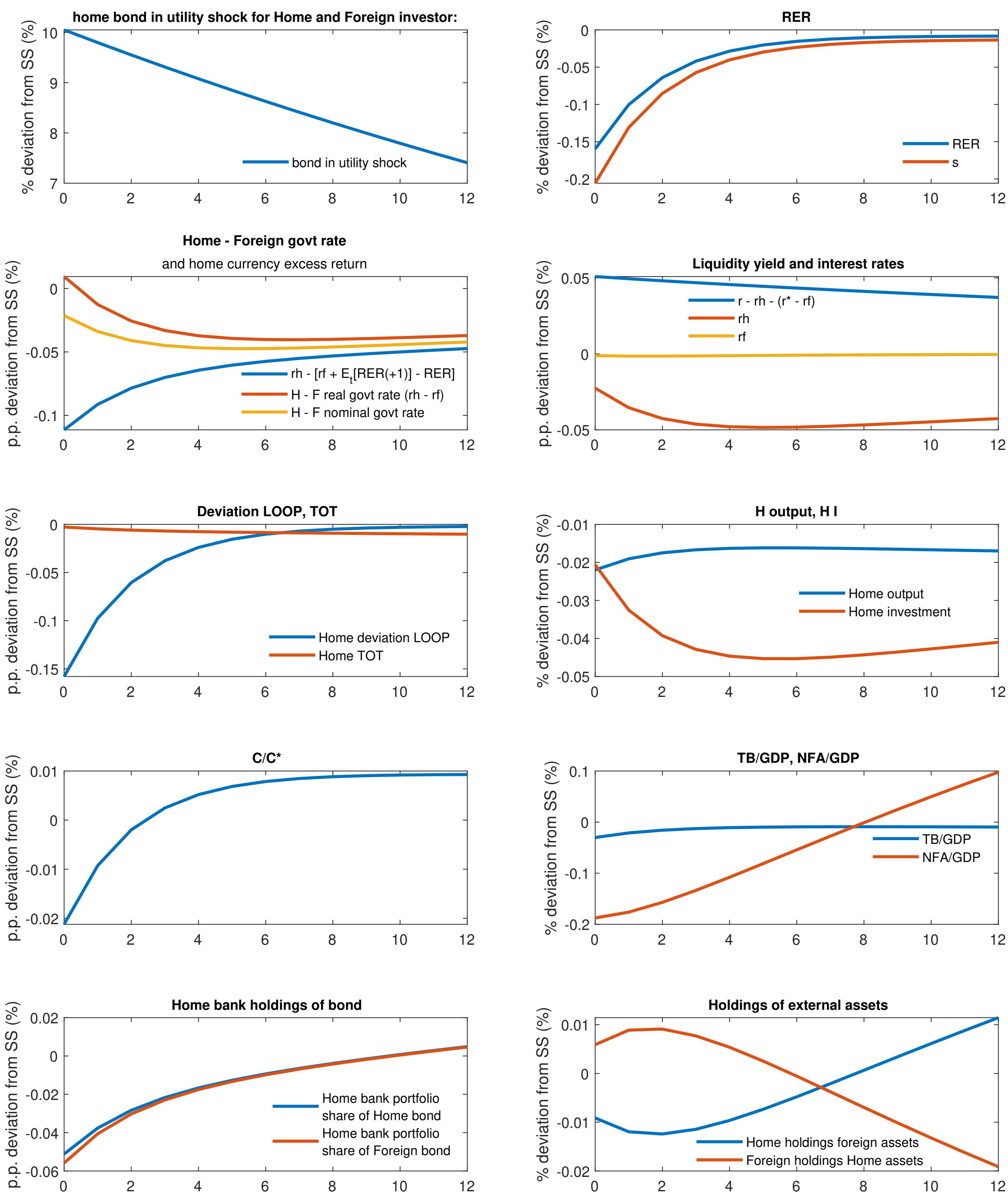
Figure 15 illustrates the impact of a 10% bond-in-utility shock on Home bonds for both Home and Foreign investors. Similar to the capital quality shock in the baseline model, the figure demonstrates that the bond-in-utility shock is associated with an initial appreciation of the dollar, followed by an expected depreciation (row 1, column 2). This appreciation corresponds to an increase in liquidity yield and Home currency excess returns (row 2).

On the goods market side, the dollar appreciation results in a minor change in relative prices but leads to a significant deviation from LOOP (row 3, column 1). Regarding output, the dollar appreciation is linked to a decline in Home output (row 3, column 2), as well as reductions in Home investment and the consumption ratio (C/C*) (row 4, column 1).

However, the bond-in-utility shock is associated with a persistent deterioration in the trade balance (row 4, column 2), which contradicts the empirical observations from the 2008 Global Financial Crisis. Furthermore, the model predicts a decline in Home households' holdings of Home bonds (row 5, column 1) and it does not indicate capital flow retrenchment.

The differential capital flow to Treasury market and cross country capital flow between bond in utility model and the baseline banking model highlight the banking mechanism of driving the results. As discussed in the main text, the Home banks contracts more than the Foreign banks because of a higher initial leverage, exchange rate valuation adjustment and a larger pledgability difference between bond and capital at home. These lead to a higher demand of the U.S. Treasury from the Home bank and also capital flow retrenchment across countries.

Figure 15: 10% increase of Home and Foreign investors utility to home bond ($\omega_t^h, \omega_t^{h*}$)



Since the bond in utility model is not directly linked to the banking moments, we re-calibrate the second moments. In particular, we set the volatility of the bond in utility shock such that it matches the standard deviation of the liquidity yield. The high and low state volatility ratio is also set to match the observed volatility ratio of liquidity yield of 2. We then adjust the TFP volatility such that the output standard deviation is 2% per year. We keep the correlation and persistence of shocks the unchanged. The standard deviation of TFP shock is set at 0.0107, the standard deviation of discount rate shock is set at 0.001 and the standard deviation of bond preference shock (ω_t^h and ω_t^f) is set at 0.15.

In Table 11, we report the regression tables as in 3. Similar to the baseline banking model, the bond in utility model produces realistic regression statistics when compare to the data. Both regression coefficients for change of interest rate differential and change of convenience yield are about 2 and within one standard deviation range of the data estimates.

Table 11: Model implied regression and the empirical counterpart

$$\Delta s_{j,t} = \alpha_j + \beta_1 s_{j,t-1} + \beta_2 \Delta\eta_{j,t} + \beta_3 \Delta(i-i^*)_{j,t} + \beta_4 \eta_{j,t-1} + \beta_5 (i-i^*)_{j,t-1} + u_{j,t}$$

	Panel quarterly regression of G10 currenices	Baseline Model implied regression	Bond in utility model implied regression
	(1)	(2)	(3)
$\Delta\eta_{j,t}$	-1.65**	-1.32	-2.00
	(0.76)		
$\Delta(i-i^*)_{j,t}$	-2.61***	-2.47	-2.16
	(0.97)		
$\eta_{j,t-1}$	-2.08**	0.06	-0.05
	(0.87)		
$(i-i^*)_{j,t-1}$	-0.44**	0.01	-0.03
	(0.22)		
s_{t-1}	-0.06**	-0.01	-0.008
	(0.02)		
Observations	739	14,900	14,900

Notes: Standard errors in parentheses are clusted by time. * p<0.1, ** p<0.05, *** p<0.01. Model implied regression is performed with 15,000-quarter observations and burning the first 100 quarters.

However, Table 12 reports the regression of Treasury flows on convenience yield. Unlikely the baseline banking model, the bond in utility model is not able to generate the relationship between convenience yield and flows to the Treasury market as observed in the data. In the bond in utility model, an increase in the convenience yield is associated with a reduction of flow from the U.S. investors and an inflow from the Foreign investors (colum 3 and colum 6).

Table 13 reports the unconditional moments. Relative to the data, the model produces a less volatile exchange rate. This is reflected in a counterfactually low exchange rate volatility relative to output and consumption volatility, as well as a counterfactually high interest rate differential volatility relative to exchange rate volatility and trade balance volatility relative to exchange rate volatility. These numbers are similar to those in the bond-in-utility model of Kekre and Lenel (2024b). The model produces a negative Backus-Smith correlation over the two volatility states, so it fails to generate risk-sharing behavior during the crisis period.

Table 12: Model implied regression and the empirical counterpart

	Quarterly regression on US holding of US Treasury	Baseline Model regression on US holding of US Treasury	Bond in utility model regression on US holding of US Treasury	Quarterly regression on Foreign holding of US Treasury	Baseline Model regression on Foreign holding of US Treasury	Bond in utility model regression on Foreign holding of US Treasury
	(1)	(2)	(3)	(4)	(5)	(6)
η_t	1.05***	0.78	-0.054	-1.39***	-2.3	0.11
	(0.36)			(0.51)		
Obs.	71	14,900	14,900	71	14,900	14,900

Notes: Robust standard errors in parentheses. * p<0.1, ** p<0.05, *** p<0.01. Model implied regression is performed with 15,000-quarter observations and burning the first 100 quarters.

Table 13: Long-run moments

	Data moments of Eurozone vs US	Model moments conditional on the low volatility state	Model moments unconditional	Model moments conditional on the high volatility state
	(1)	(2)	(3)	(4)
Exchange rates				
$\sigma(\Delta s)/\sigma(\Delta GDP)$	3.6	1.05	1.18	1.69
$\sigma(\Delta s)/\sigma(\Delta c)$	3.3	0.98	1.11	1.60
$\sigma(i-i^{*})/\sigma(\Delta s)$	0.07	0.79	0.89	0.95
Fama β	-0.18	-0.07	-0.08	-0.09
$\rho(\Delta q, \Delta c-\Delta c^{*})$	0.05	-0.73	-0.67	-0.50
$\sigma(\Delta q)/\sigma(\Delta s)$	0.99	0.99	0.96	0.89
Persistence				
$\rho(\Delta s)$ (NER)	-0.03	-0.05	-0.08	-0.14
$\rho(q)$ (RER)	0.93	0.98	0.98	0.97
$\rho(i-i^{*})$	0.95	0.99	0.99	0.99
$\rho(i)$	0.97	0.99	0.99	0.99
Trade balance				
$corr(\Delta nx, \Delta q)$	-0.06	0.55	0.45	0.18
$\sigma(\Delta nx)/\sigma(\Delta q)$	0.07	0.69	0.62	0.43
Business cycle				
$\sigma(\Delta c)/\sigma(\Delta GDP)$	1.1	1.07	1.06	1.05
$\rho(\Delta c, \Delta GDP)$	0.94	0.61	0.61	0.60
$\rho(\Delta I, \Delta GDP)$	0.81	0.42	0.42	0.43
$\rho(\Delta GDP, \Delta GDP^{*})$	0.88	0.45	0.45	0.43
$\rho(\Delta c, \Delta c^{*})$	0.90	0.72	0.72	0.72
$\rho(\Delta I, \Delta I^{*})$	0.55	0.94	0.93	0.92

Notes: Data moments are computed quarterly from 1999Q1 to 2023Q1. Model implied moments are performed with 15,000-quarter observations and burning the first 100 quarters.