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

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Abstract

We construct a two-country New Keynesian model in which 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. The model can account for the observed exchange rate and external position behavior of the U.S. While the model incorporates only a small change from a workhorse New Keynesian model with segmented financial markets, it synthesizes and reconciles three major perspectives: on exorbitant privilege, global financial intermediation, and convenience yields.

JEL Classification Codes: F3, F4

Key words: Exchange rates, financial frictions, liquidity, convenience yield, dollar dominance

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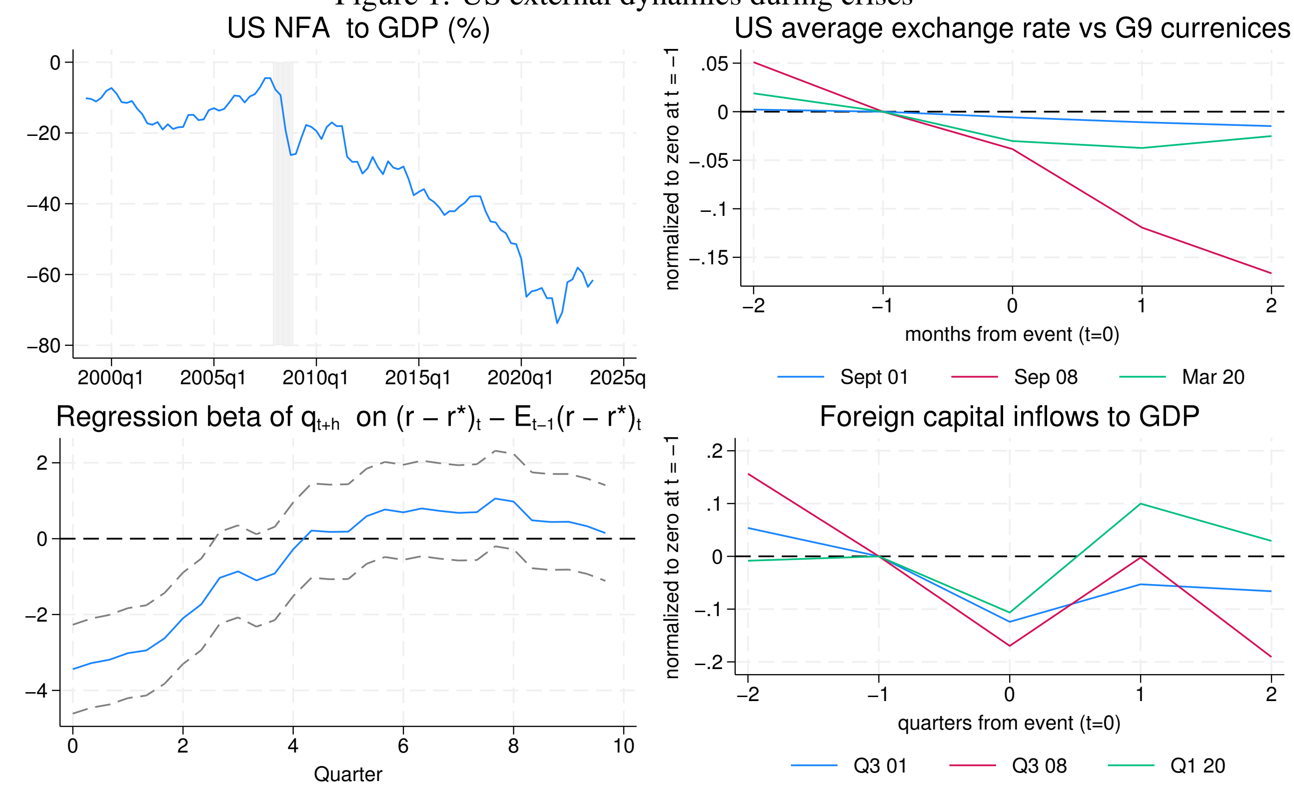
1 Introduction

What makes the U.S. dollar so special in the world economy? And what drives U.S. dollar dynamics and capital flows during normal times and crises? Unraveling the dynamics of the U.S. dollar and the United States' international financial position poses significant challenges. For example, the U.S. is the world's largest net debtor, yet its Treasury debt functions as a global safe asset. Typically, the currency of a large debtor should be risky—it should depreciate when interest rates rise or when global financial conditions tighten. In contrast, U.S. Treasury debt consistently commands low borrowing costs, serves as the world's safe-haven asset, and the U.S. dollar appreciates in crises—even amid capital outflows. The central challenge is to develop a coherent framework that simultaneously accounts for the stock (external debt position), flow (capital movements), and price (exchange rate and interest rate) dimensions of this global hegemon.

Figure 1 illustrates the issue using three crises in the 21st century. Take the 2008 Global Financial Crisis as an example. The top-left panel plots the net foreign asset (NFA) position of the United States. The U.S. has long been a net debtor, with an average NFA of about –10% of GDP before 2008. A debtor's currency is typically expected to depreciate during a crisis, as it is perceived as a risky asset. Yet, as shown in the top-right panel, the dollar sharply appreciated during the 2008 crisis—by about 15% over three months (from $t = -1$ to $t = 2$). This contrast highlights a tension between the U.S. NFA position and the exchange rate prediction.

Figure 1: US external dynamics during crises



The sharp dollar appreciation during crisis helps account for why the dollar is considered a safe haven. But if U.S. assets are a safe haven, one might think the greater demand for U.S. bonds would drive down the real interest rate during these crises when the dollar appreciates. But the bottom left panel reports the slope coefficient from a panel regression of the log of the real exchange rate for the U.S. dollar against each of the other G10 currencies at time $t+h$ against a measure of shocks of monthly real interest rate in the U.S. relative to the other countries, from January 1999 to August 2023. It shows that when there is an unexpected increase in the relative U.S. real interest, the dollar actually appreciates (the real exchange rate falls) and returns to the long run only after around one year.[1] This contrast highlights the relationship between two asset prices, exchange rates and interest rates.

More concretely, these difficulties extend to reconciling exchange rate behavior with capital flows, as shown in the bottom-right panel, which depicts foreign capital inflows to the U.S.. The bottom-left panel shows evidence of “retrenchment”—in particular, foreign investors sell U.S. assets during these periods. If the dollar appreciates because it serves as a safe haven, why does foreign capital flow out of the United States?

In this paper, we propose a unified framework to explain the external stock, flow, and price dynamics of the United States. Rather than relying on risk or safety premia, we develop a two-country New Keynesian model in which U.S. government debt serves as superior collateral on the balance sheets of financial intermediaries, thereby providing liquidity or convenience services. We then examine how this feature shapes the external dynamics of the U.S. economy.

The central modeling assumption is grounded in well-known institutional and market facts. Markets and regulators constrain the banks from acquiring too large a balance sheet, because financial intermediaries have private information about the value of their assets that is not observed by households or financial regulators. 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 and well-functioning markets with minimal counterparty, settlement, liquidity and default risk. In our interpretation, U.S. Treasury debt has an “advantage” in the sense that the relative constraint on this debt is lower globally than on foreign government debt and capital. This advantage is reflected empirically in the data, as U.S. Treasuries consistently receive the lowest haircuts in collateralized transactions and the most favorable risk weights in banking regulations. We draw a close connection between liquidity and “safety.” As Gorton (2017) observes, “A safe asset is an asset that is (almost always) valued at face value without expensive and prolonged analysis.” This

[1] This is a robust feature of the data as documented by Engel (2016), and holds, for example, when the sample is longer (beginning in 1973), when different tenors for the interest rates are used, or in a simple regression of the real exchange rate on the level (rather than the surprise) in the relative real interest rate.

captures precisely the motivation for our modeling of the special role of U.S. Treasury assets on bank balance sheets.

Our model preserves the structure of a standard New Keynesian workhorse framework with financial accelerators. The crucial asymmetry between the two countries is the differential pledgeability of government bonds. The financial sector is modeled following Gertler and Kiyotaki (2010). 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.

In the model, for a balance-sheet-constrained financial intermediary, holding U.S. Treasury debt is less costly than holding other countries' safe assets. The higher pledgeability of U.S. Treasury debt generates an endogenous, time-varying liquidity or convenience demand for this debt. Over the long run, this convenience yield allows the U.S. to borrow at lower interest rates, sustain its position as a debtor, and maintain a persistent trade deficit.

We model a global financial crisis as a simultaneous and uniform decline in the quality of real bank assets across both domestic and foreign banks. This setup mirrors the 2008 crisis, which was driven primarily by a collapse in bank balance sheets (and can similarly capture events such as the sudden loss of productive capacity in office and retail sectors in 2020.) The global downturn itself is not directly tied to the special role of U.S. Treasury bills. Rather, the dollar appreciation and differential response of the U.S. and foreign economy arise from differences in the collateral quality of U.S. versus foreign government bonds.

The very same feature that lowers U.S. borrowing costs in normal times also underpins the dollar's appreciation in crises. When financial stress arises and balance-sheet constraints tighten, intermediaries worldwide shift their demand toward the most pledgeable asset—U.S. Treasury debt. This surge in convenience demand raises the convenience yield of US Treasuries and strengthens the U.S. dollar.

The appreciation of foreigners' U.S. assets confirms the safe-currency property of the dollar and shields them from the full impact of the global shock. As a result, U.S. intermediaries are relatively more affected and have a higher demand for liquid assets than their foreign counterparts, and shift away more from productive investments. Consequently, U.S. output and consumption decline relative to those abroad, leading to lower inflationary pressure and a higher real interest rate on impact. 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) The stronger demand for liquid assets by U.S. intermediaries also induces a retrenchment of capital flows: U.S. intermediaries increase their holdings of domestic assets, while foreign intermediaries do the same in their own countries.[2] All of these patterns align closely with the observed outcomes during 2008.

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 widening gap between the return on lending to producers and the return paid to 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 uncovered interest parity (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.

We subject the calibrated model to a comprehensive set of tests and examine the relationship between exchange rates and convenience yields using a wide range of regression approaches, including the identification strategies of Rigobon (2003) and instrumental variables. The model reproduces realistic unconditional moments and quantitatively matches the covariances of exchange rates, convenience yields, and capital flows implied by the empirical regressions. It also replicates the observed dynamics of exchange rates, external positions, and capital flows in the United States since 1999. While our main focus is on fluctuations in liquidity demand during periods of global financial stress, we view these episodes as exceptional. To capture different states of the world during normal times and crises, we model the economy as a two-state Markov-switching process in which shocks alternate between high- and low-variance regimes. This structure allows for realistic, state-dependent, and time-varying relationships among exchange rates and other variables, such as the consumption–exchange rate relationship documented by Backus and Smith (1993).

Related Literature. Our paper contributes to three strands of literature by providing a unified framework that jointly and consistently accounts for the behavior of the U.S. external position and the exchange rate.

The first strand is the work that has established that the U.S. enjoys an "exorbitant privilege", in that U.S. dollar debt pays an average lower interest rate than corresponding international liabilities

[2]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 debt with more than 1 year maturity.

of other countries. Gourinchas and Rey (2007b), Gourinchas and Rey (2007a), Eichengreen (2011) 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), Dahlquist et al. (2022) 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 "exorbitant privilege" 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 the dollar appreciation as they hold U.S. assets during a crisis. This amounts to a wealth transfer from the U.S. to the rest of the world. Gourinchas and Rey (2022) describe the exorbitant duty as equivalent to an insurance payout made by the U.S. through dollar appreciation. 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 in a typical model. This is the "reserve currency paradox" identified by Maggiori (2017).[3] There is also a conflict between this theory and the evidence on capital flows, which might be called the "retrenchment puzzle": The theory implies an increase in demand for U.S. safe assets during a global crisis, which would imply a trade balance deterioration and foreign capital inflows to the U.S. However, this appears to be at odds with the observed capital flow retrenchment and sizeable U.S. trade balance improvement.

Even abstracting from the insurance premium (as in Gourinchas and Rey (2022)) that U.S. Treasury debt may earn, our model exhibits the exorbitant privilege enjoyed by the United States and establishes a tight connection between that privilege and its corresponding "duty." During normal times, U.S. debt pays a lower monetary return because it relaxes banks' balance sheet constraints more effectively than other assets. When global liquidity demand rises during financial slumps, the dollar appreciates as global consumption falls. This mechanism is complementary to

[3]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.

the insurance or risk channel that makes the dollar a good hedge. Average returns on dollar assets are low both because they earn a convenience yield and because they serve as a hedge.[4]

The key issue of "reserve currency paradox" of Maggiori (2017) 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 depreciation of the dollar should be associated with a decrease in relative demand by U.S. households during the 2008 crisis. 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, but rather determined by the finanical forces, such as liquidity demands.

A second branch in international macroeconomics has made substantial progress in understanding exchange rate determination. Gabaix and Maggiori (2015) and Itskhoki and Mukhin (2021) 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 (See also Greenwood et al. (2023), Fang and Liu (2021), Akinci and Queralto (2024), Basu et al. (2023), and Gourinchas et al. (2022).). 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,[5] yet the U.S dollar appreciates during a crisis in the data.

To make concrete the difficulties of understanding the regularities in Figure 1, consider the general equilibrium model of Itskhoki and Mukhin (2021). In that two-country framework, there is extreme financial segmentation that allows households in each country to borrow or save internationally only by making transactions with risk averse global financial intermediaries. Noise-trader shocks are a key driver of exchange rates. Suppose the noise traders in the U.S. decide to sell U.S. bonds. The financial intermediary must absorb some of these, which increases their riskiness in the intermediaries' portfolios and leads to a dollar depreciation. U.S. households also must be induced to hold more of the U.S. bonds, requiring an increase in their real returns. Hence, the main mechanism driving exchange rates in this model requires real interest rates to rise as the

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

[5] For example, see Proposition 2 in Gabaix and Maggiori (2015). In Itskhoki and Mukhin (2021), a financial tightening represented by an increase in the risk aversion of bankers increases the risk premium on the debtor's currency, as seen in equation (16).

dollar depreciates, contradicting Figure 1. The model stresses the importance of financial market segmentation and the limited risk-bearing capacity of global financial intermediaries. Since the U.S. is the world's largest debtor, during times of financial pressure, these global banks should be shedding U.S. debt, leading to a dollar depreciation, which again is refuted by Figure 1.

We contribute to this literature by developing a unified framework consistent with the joint dynamics of U.S. exchange rates, capital flows, and external debt positions. Like this branch of research, we emphasize the central role of financial intermediation and deviations from UIP as drivers of exchange rates. However, our interpretation differs. In our model, UIP deviations arise endogenously and depends on the financial health of the banking sector. By explicitly modeling both home and foreign intermediaries, we can account for and match the empirical dynamics of gross capital flows—offering a coherent explanation for why the U.S. dollar appreciates, rather than depreciates, during periods of financial stress.

The third major approach consists of studies that have highlighted the convenience yield on U.S. government liabilities. 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), Jiang (2024), 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 Miyamoto et al. (2022) finds is the dominant empirical 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.[6]

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

[6] 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. Brunnermeier et al. (2024) study a framework in which a safe debt provides service flow because it provides insurance for idiosyncratic risk. 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.

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 leads to a real appreciation of the dollar as the convenience yield rises. Monetary policy is insufficiently expansionary, so U.S. consumption falls relative to the rest of the world. Real product wages rise and output declines. The drop in supply outstrips the drop in consumption, so the relative price of U.S. goods rises, consistent with the real appreciation given home bias in preferences.

Two relevant papers in the literature also endogenize the convenience yield. Bianchi et al. (2021), which models the endogenous demand for assets from financial intermediaries with emphasis on the liquidity return of dollar short-term assets. Coppola et al. (2023) also model endogenous demand for assets as a store of value in a three-period settings to understand long-history of international currency denomination competition. However, these modesl are too stylized to take to a realistic quantitative open-economy macro setting.

Chaudhary et al. (2024) develop a demand system model to estimate the demand elasticity of different investors in the U.S. Treasury market, finding that overall demand for U.S. Treasuries is highly inelastic. Consistent with our motivating facts, they show that U.S. investors are the primary drivers of bond flows and yields during a flight-to-safety scenario.

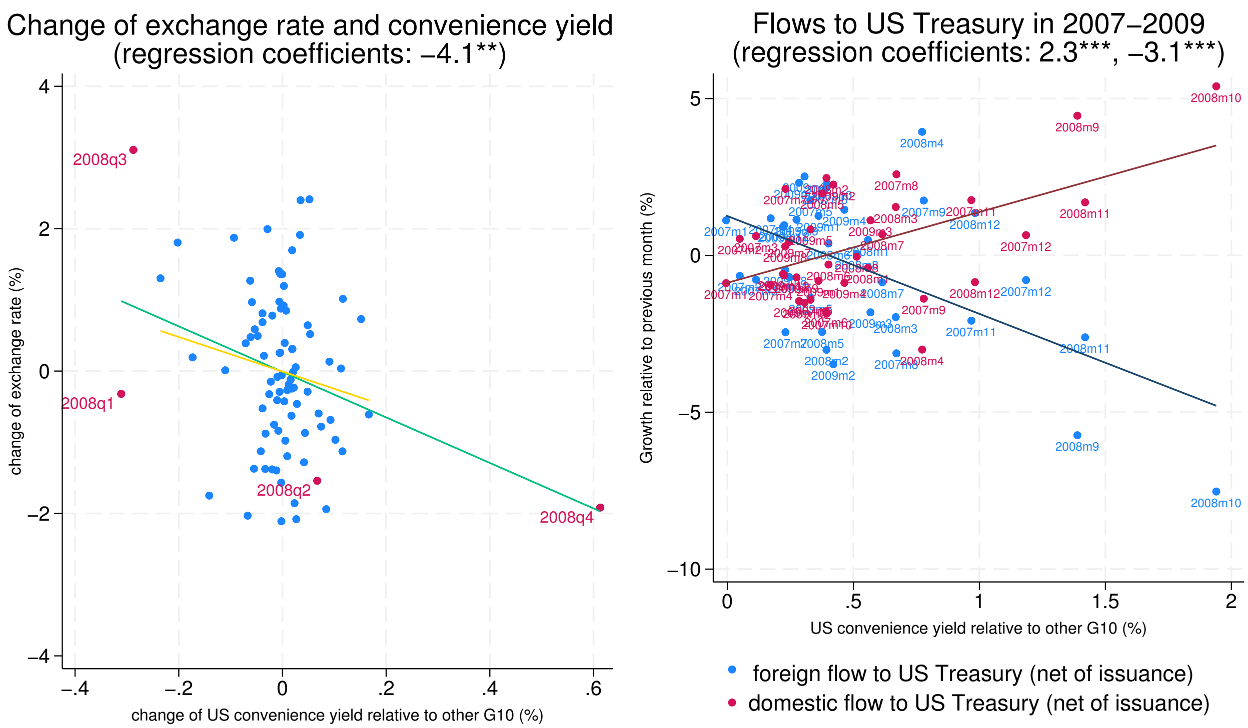
Our model contributes to the third strand of literature on the convenience yield, but adds to this in several ways. First we provide a microeconomic foundation for the convenience yield. We offer direct empirical evidence in support of our linkage between banking liquidity demand and convenience yield. This offers a firmer micro-founded footing for welfare-based 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, 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 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.

Section 2 presents some motivating facts to describe the U.S. external position and exchange rate. Section 3 presents the model. The calibrated parameters and the steady state are described in section 4. Section 5 examines the responses to a global financial tightening as a representation for the global financial crisis. Section 6 compares the model implied moments with the data. Section 7 concludes.

2 Motivating facts

We present two sets of motivating facts. The first set provides a description of the relationship of convenience yields with exchange rates and investment flow to the US Treasury market. This helps to illustrate the empirical pattern and discipline the model. Later in the paper we show the model can quantitatively be consistent with the empirics, along many other dimensions. The second set of motivating facts discusses why the US Treasury is the most plegdeable assets in the international financial system.

Figure 2: Stylized facts during the Global Financial Crisis



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. Right figure note: Monthly data. Flows to US Treasury data is obtained from Chaudhary et al. (2024).

The left panel of Figure 2 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/convinence yield measure of Du et al. (2018) 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.[7] This mea-

[7]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 FRED.

sure 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 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 rise in the convenience yield is often interpreted as an indication that foreigners want to purchase more insurance or demand more liquid and safe assets during a crisis. However, it is not the case as we show in the right panel. The 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 same convenience 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 Figure 14. These two figures are at odds with the hypothesis in the existing literature, which often suggests that the convenience yield rises and the dollar appreciates due to foreign inflows into U.S. Treasuries.

In sum, these figures characterize the price and quantity dynamics of U.S. safe assets during the Global Financial Crisis. The value of the U.S. Treasury convenience yield rises and the dollar appreciates, while foreign investment flows into U.S. Treasuries decline and are instead absorbed by U.S. domestic investor demand.

The model we present in the next section hypothesizes that U.S. government bonds are the most pledgeable assets. The second set of evidence discusses some plausible reasons why US Treasuries are more pledgeable. In Table 1, we present evidence on haircuts or margins in collateralized transactions from the Chicago Mercantile Exchange (CME) and the Federal Reserve Bank of New York's repo market data,[8] covering the period from May 2010 to the end of 2024. The table shows that U.S. government and agency debt is highly pledgeable, with minimal and stable haircuts—a median value of about 2%. Notably, these haircuts exhibit remarkable stability, with the daily 10th–90th percentile range tightly clustered around 1–3%. This stability reflects a high and predictable collateral quality, even during periods of financial distress. In contrast, foreign government securities and equities carry significantly higher haircuts, ranging from about 6% for foreign government bonds to 30% in the CME data and 8% in the repo survey median for eq-

[8] Data source: https://www.newyorkfed.org/data-and-statistics/data-visualization/tri-party-repo#interactive/margins and Review of Collateral Haircuts from CME: https://www.cmegroup.com/notices.html?redirect=/tools-information/advisory

uity. Unlike U.S. government securities, these haircuts fluctuate more widely over time, indicating that the pledgeability of these assets could deteriorate during episodes of market stress. Note that these haircuts are separate from currency risk, as additional 5-20% haircut rules apply to foreign currencies—for example, as explicitly specified in CME collateral requirements.

Table 1: Haircuts of collateral in financial transactions

Median haircuts from 2010 - 2024	CME	New York Fed repo survey	Fedwire Eligible?
Treasury notes	1%	2% (1 - 3%)	Yes
U.S. Agency debt	3%	2% (2 - 3%)	
Foreign sovereign	6%	3% (1 - 7%)	No
Equity	30%	8% (5- 14%)	

Notes: These are median of monthly value from CME and median of daily value from New York Fed repo survey. Numbers in parenthesis reports the median value of daily 10-90%tile range.

In the New York Fed's repo survey, collateral assets are classified into Fedwire-eligible and non-Fedwire-eligible categories. Fedwire is the Federal Reserve's real-time gross settlement system. It is responsible for the settlement of U.S. Treasuries and agency securities, as well as for collateral transfers for repos. Ideally, collateral should be free from credit, settlement, and liquidity risk. Treasury and agency securities that are Fedwire-eligible benefit from deep markets and a well-functioning settlement infrastructure. The market value of such collateral is relatively certain, meaning it can be easily sold with minimal price impact or uncertainty about payment delay even under stressed market conditions.

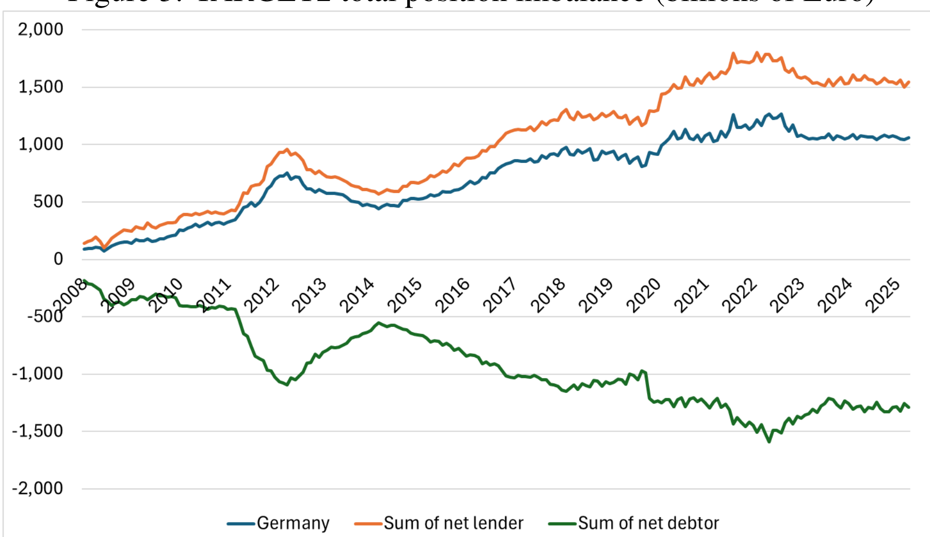
The U.S. Treasury could be more pledgeable for various reasons, such as its price stability, homogeneous and deep market, and reliable settlement system. In Table 2, we report the standard deviation of daily yield changes since 1999 for Treasury securities in the U.S. and the three largest economies in the Euro area—Germany, France, and Italy. The table clearly shows that across maturities, U.S. Treasury securities exhibit the lowest price volatility, thanks to their deep and liquid market and the credible backstop provided by the Federal Reserve, as suggested by Williams (2021), Vissing-Jorgensen (2021) and Duffie (2025).

Table 2: Standard deviation of daily Treasury yield change across maturities (basis points)

	3-month	1-year	5-year	10-year
US	4.2	3.9	5.7	5.7
Germany	4.3	6.8	9.6	9.3
France	4.8	6.9	7.8	7.6
Italy	7.1	9.0	10.6	9.8

Another reason the U.S. Treasury market differs from the European government debt market is the degree of homogeneity across countries. In Europe, markets are segmented and heterogeneous due to legal, linguistic, and most importantly different financial positions. Figure 3 reports the total net claims for the sum of net debtors and net creditors in the Trans-European Automated Real-time Gross Settlement Express Transfer System 2 (TARGET2)—the euro area's counterpart to Fedwire and the principal platform for interbank payments and the settlement of government securities. TARGET2 is critical to the smooth functioning of bank transactions: according to its 2023 annual report, roughly 60% of TARGET2 transactions by value are interbank, and 80% involve a bank on at least one side of the transaction. The figure shows that since data became available in 2008, both net debtor and net creditor exposures have increased rapidly—first during the European debt crisis, and again at an unprecedented pace since 2015—raising various concerns and prompting active discussions even at the ECB and European Parliament about Eurozone fragmentation risk, uneven liquidity allocation, and the effectiveness of monetary policy (Horst and Neyer (2022); Eisenschmidt et al. (2024); De Grauwe et al. (2017)).

Figure 3: TARGET2 total position imbalance (billions of Euro)



Notes: Numbers are in billions of Euro. The figure plots the total position of European countries in the TARGET2 system, defined as the total claims on other countries minus the total liabilities to other countries. The sum of net lenders plots the total position of countries with positive positions, while the sum of net debtors plots the total position of countries with negative positions.

In short, the value of the collateral for creditors to the banks depends on their ability to recover their lending in the event of some financial distress. The market for U.S. Treasury securities is deep, stable, and backstopped by the Fed, so there is little doubt about the value of these securities. In Gorton (2017)'s words, they are "almost always valued at face value." European government bonds certainly are better collateral than many privately-issued securities, but compared to the market for U.S. government liabilities, the market is not as deep (for individual country bonds), and the settlement system is perceived to be possibly vulnerable in rare events.

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. In Appendix H, a simplified version of the model is derived to highlight a few key insights in the model.

3.1 Households

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

$$E_t \sum_{t=s}^{\infty} (\beta_t)^t \left\{ \frac{(C_t)^{1-\sigma}-1}{1-\sigma} - \frac{\chi}{1+\psi}(H_t)^{1+\psi} \right\} \tag{1}$$

where β_t represents a discount factor shock.[9] 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

$$P_t C_t + B_t = W_t H_t + R_t B_{t-1} + \Pi_t + TR_t - T_{s,t} \tag{2}$$

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:

$$C_t = \left(\omega^{\frac{1}{\mu}} (C_{h,t})^{1-\frac{1}{\mu}} + (1-\omega)^{\frac{1}{\mu}} (C_{f,t})^{1-\frac{1}{\mu}} \right)^{\frac{1}{1-\frac{1}{\mu}}} \tag{3}$$

where $\omega \geq 0.5$, represents home bias in preferences. Given this assumption, the Home CPI is

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

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

[9]We allow for the possibility of a preference shock as a simple way to model a demand shock in our model.

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

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

Optimal labor supply is described by

$$W_t = \chi P_t (C_t)^{\sigma} (H_t)^{\psi} \tag{6}$$

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

$$1 = E_t R_{t+1}\Omega_{t+1} \text{ with } \Omega_{t+1} \equiv \beta_t (\frac{C_{t+1}}{C_t})^{-\sigma} \frac{P_t}{P_{t+1}} \tag{7}$$

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

$$P_t^* = \left(\omega^* P_{f,t}^{*1-\mu} + (1-\omega^*) P_{h,t}^{*1-\mu}\right)^{\frac{1}{1-\mu}} \tag{8}$$

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

$$Y_{i,t} = A_t (L_{i,t}^{1-\alpha} (\vartheta_t K_{i,t})^{\alpha}) \tag{9}$$

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, 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 ability for U.S. and ROW government bonds.[10]

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

$$\Pi_{i,t} = (1+s_{i,t})(P_{i,h,t}Y_{i,h,t} + S_t P^*_{i,h,t}Y^*_{i,h,t}) - MC_t(Y_{i,h,t} + Y^*_{i,h,t}) \tag{10}$$

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:

$$(1-\alpha)Y_t MC_t = W_t L_{i,t} \text{ and } \alpha Y_t MC_t = R_{K,t}(\vartheta_t K_{i,t}) \tag{11}$$

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

$$E_t \sum_{j=0} \Omega_t \left(\Pi_{i,t} - \xi\left(\frac{P_{i,h,t}}{P_{i,h,t-1}}\right) P_{h,t}Y_{h,t} - \xi\left(\frac{P^*_{i,h,t}}{P^*_{i,h,t-1}}\right) S_t P^*_{h,t} Y^*_{h,t} \right) \tag{12}$$

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

$$\begin{aligned}(1+s_{i,t})Y_{i,h,t} = \quad & \varepsilon(P_{i,h,t}(1+s_{i,t}) - MC_t)\tfrac{Y_{i,h,t}}{P_{i,h,t}} + \xi'\left(\tfrac{P_{i,h,t}}{P_{i,h,t-1}}\right)\tfrac{1}{P_{i,h,t-1}} P_{h,t}Y_{h,t} \\ & -E_t\Omega_{t+1}\xi'\left(\tfrac{P_{i,h,t+1}}{P_{i,h,t}}\right)\tfrac{P_{i,h,t+1}}{P^2_{i,h,t}} P_{h,t+1}Y_{h,t+1}\end{aligned} \tag{13}$$

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

[10] The capital quality shock differs from a standard TFP shock. As we show below, it also directly enters banking net worth and the first-order conditions.

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 depositors at fixed rates to invest in claims to Home and Foreign capital (or equity), and Home and Foreign currency denominated government bonds.[11] Besides government, only banks operate in international financial markets. A Home banker i's balance sheet in period t is

$$B_{i,t}+N_{i,t}=Q_tK_{h,i,t+1}+S_tQ_t^*K_{f,i,t+1}+D_{h,i,t}+S_tD_{f,i,t} \tag{15}$$

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.[12]

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, Ω_{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:

$$V_{i,t}=E_t\Omega_{t+1}\left((1-\theta)N_{i,t+1}+\theta V_{i,t+1}\right) \tag{16}$$

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

$$\begin{aligned} N_{i,t+1} &= \tilde{R}_{k,t+1}\vartheta_{t+1}Q_tK_{h,i,t+1}+\tilde{R}^*_{k,t+1}S_{t+1}\vartheta^*_{t+1}Q_t^*K_{f,i,t+1} \\ &\quad +R_{h,t+1}D_{h,i,t}+S_{t+1}R_{f,t+1}D_{f,i,t}-R_{t+1}B_{i,t} \\ &= (\tilde{R}_{k,t+1}\vartheta_{t+1}-R_{t+1})Q_tK_{i,t+1}+(\tfrac{S_{t+1}}{S_t}\tilde{R}^*_{k,t+1}\vartheta^*_{t+1}-R_{t+1})S_tQ_t^*K_{i,t+1} \\ &\quad +(R_{h,t+1}-R_{t+1})D_{h,i,t}+(\tfrac{S_{t+1}}{S_t}R_{f,t+1}-R_{t+1})S_tD_{f,i,t}+R_{t+1}N_{i,t} \end{aligned} \tag{17}$$

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 cap-

[11] In practice, depositors include funding from money market funds and hedge funds.

[12] 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.

ital 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 (15) and subject to the participation constraint:

$$V_{i,t} \geq \begin{array}{c} \left((\kappa_{h1}+\kappa_{h2}\tilde{D}_{h,t})D_{h,i,t}+(\kappa_{f1}+\kappa_{f2}S_t\tilde{D}_{f,t})S_tD_{f,i,t}\right) \\ +\left((\kappa_{Kh1}+\kappa_{Kh2}Q_t\tilde{K}_{h,t+1})Q_tK_{h,i,t+1}+(\kappa_{Kf1}+\kappa_{Kf2}S_tQ_t^*\tilde{K}_{f,t+1})S_tQ_t^*K_{f,i,t+1}\right) \end{array} \tag{18}$$

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.[13] 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

$$E_t\Lambda_{i,t+1}\left(R_{h,t+1}-R_{t+1}\right)=\lambda_{i,t}(\kappa_{h1}+\kappa_{h2}\tilde{D}_{h,t}) \tag{19}$$

$$E_t\Lambda_{i,t+1}\left(\frac{S_{t+1}}{S_t}R_{f,t+1}-R_{t+1}\right)=\lambda_{i,t}(\kappa_{f1}+\kappa_{f2}S_t\tilde{D}_{f,t}) \tag{20}$$

$$E_t\Lambda_{i,t+1}\left(\tilde{R}_{k,t+1}\vartheta_{t+1}-R_{t+1}\right)=\lambda_{i,t}(\kappa_{Kh1}+\kappa_{Kh2}Q_t\tilde{K}_{h,t+1}) \tag{21}$$

$$E_t\Lambda_{i,t+1}\left(\frac{S_{t+1}}{S_t}\tilde{R}^*_{k,t+1}\vartheta^*_{t+1}-R_{t+1}\right)=\lambda_{i,t}(\kappa_{Kf1}+\kappa_{Kf2}S_tQ_t^*\tilde{K}_{f,t+1}) \tag{22}$$

Here, $\lambda_{i,t}$ is the Lagrange multiplier on the bank's participation constraint (18) 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:

$$\upsilon_{i,t}=\frac{E_t\Lambda_{i,t+1}R_{t+1}}{1-\lambda_{i,t}} \tag{23}$$

Now we can use the fact that banks are homogeneous, and aggregate across all Home banks,

[13] 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. 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 $\tilde{K}_{i,t}=K_{i,j,t}$.

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:

$$\begin{aligned} N_{t+1} = \; & \theta[(\tilde{R}_{k,t+1}\vartheta_{t+1}-R_{t+1})Q_tK_{h,t+1}+(\tilde{R}^*_{k,t+1}\tfrac{S_{t+1}}{S_t}\vartheta^*_{t+1}-R_{t+1})S_tQ_t^*K_{f,t+1} \\ & +(R_{h,t+1}-R_{t+1})D_{h,t}+(\tfrac{S_{t+1}}{S_t}R_{f,t+1}-R_{t+1})S_tD_{f,t}+R_{t+1}N_t] \\ & +\varphi\left(Q_tK_{h,t+1}+S_tQ_t^*K_{f,t+1}+D_{h,t}+S_tD_{f,t}\right) \end{aligned} \tag{24}$$

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

$$Q_tI_t-P_t(I_t+I_t\psi(\frac{I_t}{I_{t-1}})) \tag{25}$$

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

$$Q_t=P_t(1+\psi'(\frac{I_t}{I_{t-1}})\frac{I_t}{I_{t-1}}+\psi(\frac{I_t}{I_{t-1}})) \tag{26}$$

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:

$$R_{h,t+1}=\frac{1}{R_{h,ss}}\left(\frac{P_t}{P_{t-1}}\right)^{\eta^\pi(1-\rho^R)}(R_{h,t})^{\rho^R} \tag{27}$$

where 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

$$\bar{D}_{h,t}=R_{h,t}\bar{D}_{h,t-1}+s_t(P_{h,t}Y_{h,t}+S_tP^*_{h,t}Y^*_{h,t}))+TR_t \tag{28}$$

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

$$\begin{aligned}\Pi_t^p = \; & \Big((1+s_t)(P_{h,t}Y_{h,t} + S_t P^*_{f,t} Y^*_{h,t}) - MC_{h,t}(Y_{h,t} + Y^*_{h,t}) \\ & -\xi_t\left(\tfrac{P_{h,t}}{P_{h,t-1}}\right) P_{h,t}Y_{h,t} - \xi_t\left(\tfrac{P^*_{h,t}}{P^*_{h,t-1}}\right) S_t P^*_{h,t} Y^*_{h,t}\Big)\end{aligned} \tag{29}$$

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:

$$\Pi_t^K = Q_t I_t - P_t (I_t + I_t \psi(\frac{I_t}{I_{t-1}})) \tag{30}$$

Total profits from the corporate non-financial sector are then $\Pi_t^p + \Pi_t^K$. 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.

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

$$R_t B_{t-1} = R_{K,t}\vartheta_t K_{h,t} + (1-\delta)Q_t\vartheta_t K_{h,t} + R^*_{K,t} S_t \vartheta^*_t K_{f,t} + (1-\delta) S_t Q^*_t \vartheta^*_t K_{f,t} + R_{h,t} D_{h,t-1} + S_t R_{f,t} D_{f,t-1} - N^e_t \tag{31}$$

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

$$T_{s,t} = \varphi\left(Q_t K_{t+1} + D_{h,t} + S_t D_{f,t}\right) \tag{32}$$

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

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

$$B_t = Q_t K_{h,t+1} + S_t Q^*_t K_{f,t+1} + D_{h,t} + S_t D_{f,t} - N_t$$

Putting together (29), (30), (31), (32), (28), with the budget constraint (2), the balance of payments condition is :

$$
\begin{aligned}
P_t(C_t + I_t + I_t\psi(\tfrac{I_t}{I_{t-1}})) + D_{h,t} - \bar{D}_h + S_t D_{f,t} + Q_t(K_{h,t} - K_t) + S_t Q_t^* K_{f,t} = \\
P_{h,t}Y_{h,t} - \xi(\tfrac{P_{h,t}}{P_{h,t-1}})P_{h,t}Y_{h,t} + S_t P_{h,t}^* Y_{h,t}^* - \xi(\tfrac{P_{h,t}^*}{P_{h,t-1}^*})S_t P_{h,t}^* Y_{h,t}^* \\
+R_{h,t-1}(D_{h,t-1} - \bar{D}_h) + S_t R_{f,t-1} D_{f,t-1} + \tilde{R}_{k,t}\vartheta_t(K_{h,t-1} - K_{t-1}) + S_t \tilde{R}_{k,t}^* \vartheta_t^* K_{f,t-1}
\end{aligned}
\tag{33}
$$

3.8 Adjusted UIP condition

By combining equation (19) and (20), we get:

$$
E_t \Lambda_{t+1}(\frac{S_{t+1}}{S_t} R_{f,t+1} - R_{h,t+1}) = \lambda_t(\kappa_{f1} - \kappa_{h1}) \tag{34}
$$

Equation (34) 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.[14] Moreover, the convenience yield will 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 (19) and (20) and taking the difference, we have a UIP condition adjusted for the balance sheet friction:

$$
E_t s_{t+1} - s_t = (r_{h,t+1} - r_{f,t+1}) + \hat{\eta}_t \tag{35}
$$

where $\hat{\eta}_t$ is our definition of convenience yield.[15]

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.[16] Forward iterating the equation gives:

$$
s_t = -E_t \sum_{j=1}^{\infty}(r_{h,t+j} - r_{f,t+j} - (\overline{r_h - r_f})) - E_t \sum_{j=0}^{\infty}(\hat{\eta}_{t+j} - (\overline{\eta})) + \lim_{k\to\infty}(E_t s_{t+k} - k(\overline{s_{+1} - s})) \tag{36}
$$

or in real terms:

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

[15]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 $\kappa_{h1} = \kappa_{f1}$.

[16]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.

$$rer_t = -E_t \sum_{j=1}^{\infty} (\tilde{r}_{h,t+j} - \tilde{r}_{f,t+j} - (\overline{\tilde{r}_h - \tilde{r}_f})) - E_t \sum_{j=0}^{\infty} (\tilde{\eta}_{t+j} - (\overline{\tilde{\eta}})) + \lim_{k \to \infty} (E_t rer_{t+k} - k(\overline{rer_{+1} - rer})) \tag{37}$$

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 Euro area. 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 3. 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 and sample used are reported in the Appendix Table 10.

On the household side, we set the discount factor (β) to be 0.99 but is subject to shocks. 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 set the disutility of labor χ to match a steady-state H^* of 0.3. The CRRA coefficient for households (σ) is set as 5.

On the production side, 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), capital share (α) and depreciation rate (δ) are set at 5, 0.33 and 0.03.

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 debt to GDP ratio 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.

Table 3: 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	58.25	Price adjustment cost	Calvo probability =0.75
11	ϕ_k	5	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	Engel and Wu (2024)
16	ρ^R	0.92	Interest rate smoothing parameter	Engel and Wu (2024)
	Banks			
17	κ_{h1}	0.05	Home bank constraint value on Home bond	Jointly targeting: $D_h^*/\bar{D}_h$ = 26%,
18	κ_{f1}	0.418	Home bank constraint value on Foreign bond	govt bond - deposit spread of 0.24%
19	κ_{h1}^*	0.0681	Foreign bank constraint value on Home bond	Net foreign income/GDP = 0.12%,
20	κ_{f1}^*	0.37	Foreign bank constraint value on Foreign bond	1% convenience yield
21	κ_{Kh}	0.37	Home bank constraint value on Home capital	Equity premium 1.3%
22	κ_{Kf}	0.47	Home bank constraint value on Foreign capital	
23	κ_{Kh}^*	0.38	Foreign bank constraint value on Home capital	Home bias of equity 65%
24	κ_{Kf}^*	0.37	Foreign bank constraint value on Foreign capital	
25	θ	0.95	Bank survival prob.	
26	φ	0.01	Bank starting net worth	

We calibrate the four bond constraint parameters (κ_{h1},κ_{f1}, κ_{h1}^*, κ_{f1}^*) to 0.05, 0.418, 0.0681 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 domestic deposit rate and government bond rate wedge of 0.24% (difference between average FDIC deposit rate and 3m government bond rate), a steady state positive income account of +0.0012 ((current account - trade balance)/GDP of U.S.,[17] and a steady state Foreign holding of U.S. government bond ($D_h^*/\bar{D}_h$) of 26% . While these are calibrated jointly, κ_{h1} pins down the wedge between domestic deposit rate and government bond rate. Lowering the Home bond constraint parameter (κ_{h1} and κ_{h1}^*)

[17] The model has a zero current account at the steady state, which implies a negative trade balance.

relative to the Foreign bond constraint parameter (κ_{f1} and κ^*_{f1}) generates a positive convenience yield. 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. We calibrate the model such that 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 0.4709 and 0.38 and $\kappa_{Kh} = \kappa^*_{Kf} = 0.37$ to match a net equity return of 1.3% and equity Home share of 65% , which are in the range of estimates from the Home equity bias literature (Hnatkovska (2019)). This constraint parameter calibration results in an untargeted NFA to GDP of 8%. We set the bank survival probability (θ) and capital injection rate (φ) to be at standard values of 0.95 and of 0.01, 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 (2011).) While it is necessary to introduce these terms, we set all of them to the same small value (0.025) 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 reports all of the main results with an alternative approach to linearize the model around the "risky steady state" used in the closed economy model of Coeurdacier et al. (2011) and Gertler et al. (2012). Our results are qualitatively and quantitatively robust to these adjustments. The steady-state portfolio decision in such a set-up would take into account the covariance risk and in fact, feature a safe currency premium for the US dollar, further amplifying the "exorbitant privilege" of the U.S.. But this type of model with risk considerations 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 capital quality shocks in the impulse response analysis in section 5 and allow for more shocks and also country specific shocks in section 6. The global capital quality shock is modeled as an AR(1) stochastic process:

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

We set the persistence of the capital quality shock to be 0.98.

4.2 Steady state values

Table 4 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.

Table 4: Steady state values

Symbol	Targeted steady state
$r_f - r_h$	1% (annualized)
Net foreign income: (CA-TB)/GDP	0.12% (annualized)
NFA/GDP	-8% (annualized)
$D_h^*/\bar{D}_h$	26%
$\bar{D}_h/Y$	65% (annualized)
Home bank's Home equity share ($\frac{K_h}{K_h+SK_f}$)	65%
Foreign bank's Foreign equity share ($\frac{K_f^*}{K_f^*+K_h^*/S}$)	70%
$\tilde{R}_k$	1.3% (annualized)

Symbol	Steady state value	Symbol	Steady state value	Symbol	Steady state value
C	0.6244	Y	0.8081	RER	0.9997
C^*	0.6234	Y^*	0.8078	$r = r^*$	1.0101
K	6.1601	d_h	1.5513	r_h	1.0107
K^*	6.1114	d_f	0.776	r_f	1.0131
L	0.2972	λ	0.0079		
L^*	0.2982	λ^*	0.0088		
W	1.8222	Home bank's leverage	3.2022		
W^*	1.815	Foreign bank's leverage	3.1094		

The only asymmetry in the model is the differential in 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 (35). 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..

5 Impulse responses

5.1 *Global Capital Quality Shock*

In this section, we describe a series of impulse responses from the simulated model. As a baseline, in Figure 4 we allow for a uniform decrease of ϑ and ϑ^*, the capital quality shock. We scale the size of the shock to 3.15 percent to produce a 10% U.S. dollar appreciation on impact, the size of appreciation observed in 2008Q4. This represents a negative shock to the banking system in each country, as the value of each bank declines. In turn, this forces 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 (37), the real exchange rate can be decomposed as negative of the sum of expected future real interest rate differentials and convenience yield differentials. Column 3 of the first row of Figure 4 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).[18] 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 capital quality shock. To understand the mechanics of this response, take the difference between equation (19) and equation (20) for the Home bank, which gives the condition:

$$E_t \Lambda_{i,t+1} \left(R_{h,t+1} - R_{f,t+1} \frac{S_{t+1}}{S_t} \right) = \lambda_{i,t} (\kappa_{h1,t} - \kappa_{f,1,t}) \tag{38}$$

The term inside the parenthesis on the right hand side is negative, given that the Home bond is better collateral than the Foreign bond.[19] 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 on U.S. government bonds rises further. While this explanation uses the first-order conditions

[18] Note that if we measure the relative liquidity 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 capital quality shock as shown in Row 2 Column 2 of Figure 4. This is in agreement with the empirical regularities plotted in Figure 2.

[19] In this description, we abstract from the quadratic terms in the collateral constraint and the first order conditions (19) and (20), since in practice these terms are very small, and do not affect the argument.

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 the first row of column 3 of Figure 4. 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.

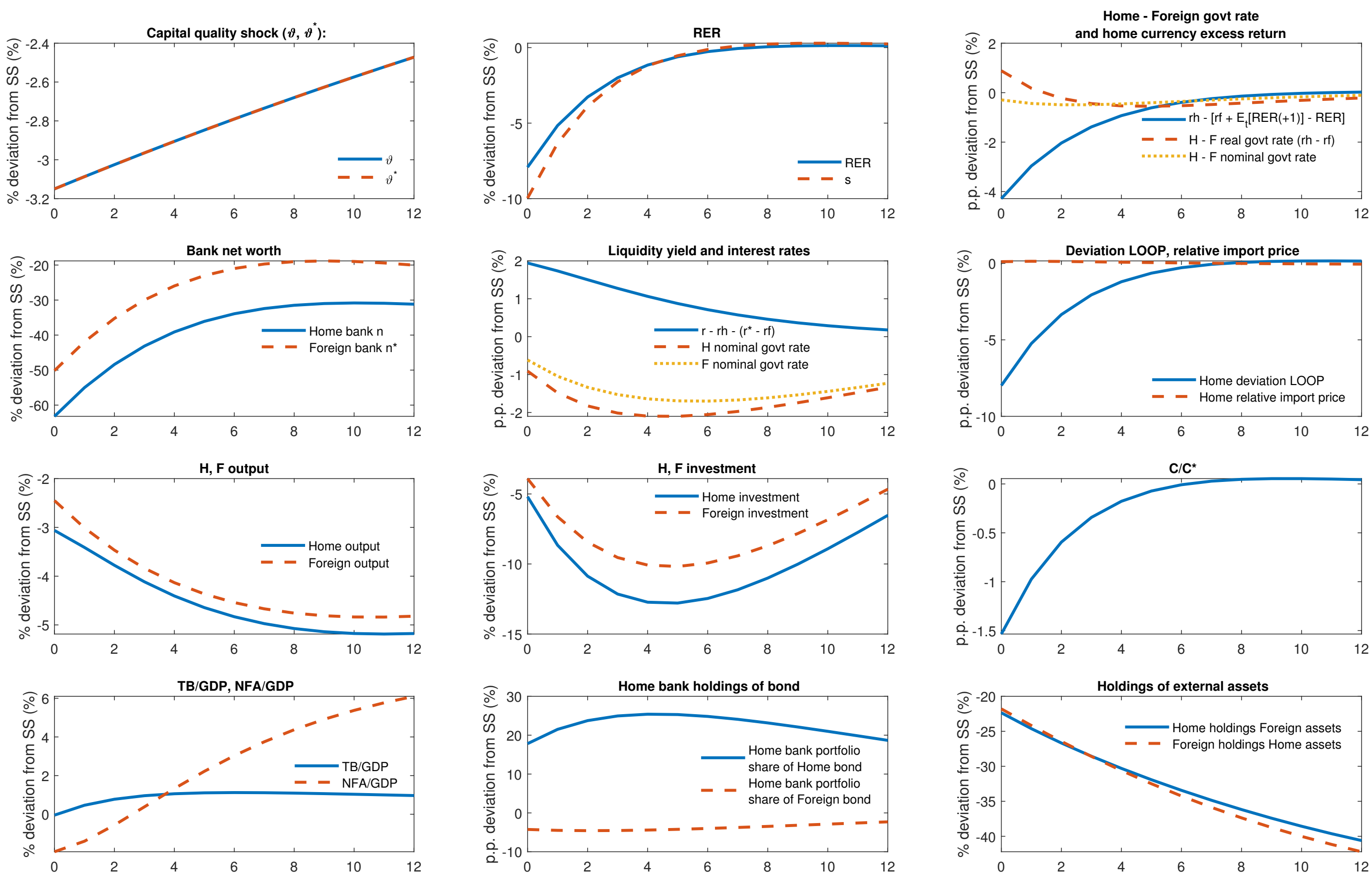
The response of λ_t and λ_t^* represent the endogenous increase in the Lagrange multipliers on the bank's collateral constraints. While these increase for both countries, it increases more for the Home bank than the Foreign bank. This is due to three different channels. First, the Home bank leverages 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 (21) and (19) above, and the equivalent conditions for the Foreign bank. This gives us the conditions:

$$E_t \Lambda_{i,t+1} \left(\tilde{R}_{k,t+1} \vartheta_{t+1} - R_{ht+1} \right) = \lambda_{i,t} (\kappa_{Kh1} - \kappa_{h1}) \tag{39}$$

$$E_t \Lambda^*_{i,t+1} \left(\tilde{R}^*_{k,t+1} \vartheta^*_{t+1} - R_{ft+1} \right) = \lambda^*_{i,t} (\kappa^*_{Kh1} - \kappa^*_{f1}) \tag{40}$$

Equation (39) describes the Home bank's trade off between Home government bonds and Home capital (or equity), while equation (40) describes the analogous trade-off for the Foreign bank between Foreign government bonds and Foreign capital. The negative capital quality 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 (39) is larger than the equivalent term $(\kappa^*_{Kh1} - \kappa^*_{f1})$ in equation (40) 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.[20]

Figure 4: Baseline with 3.15% global capital quality shock (ϑ, ϑ^*)



Notes: The figure shows impulse response functions of a 3.15% global capital quality shock. Home bank portfolio share of Home bond (and Foreign bond) is measured as $D_h/\bar{D}_h$ (and $D_f/\bar{D}_f$).

[20] While this argument seems incomplete because both Home and Foreign banks invest in bonds and capital in each other's country, the fact that in both equity capital and bond holdings banks have relative larger positions in their Home market ensures that the capital quality 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.

Figure 4 (bottom left) shows that U.S. NFA to GDP falls after the capital quality 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 (2017) "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 second row of column 3 of Figure 4, 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 (2017) whereby the deviations widened during the crisis. Here in fact the larger drop in Home output upon the global capital quality shock results in a small relative import price improvement,[21] 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.

The response to a global capital quality 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 relative import price 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

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

[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 4, 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

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.

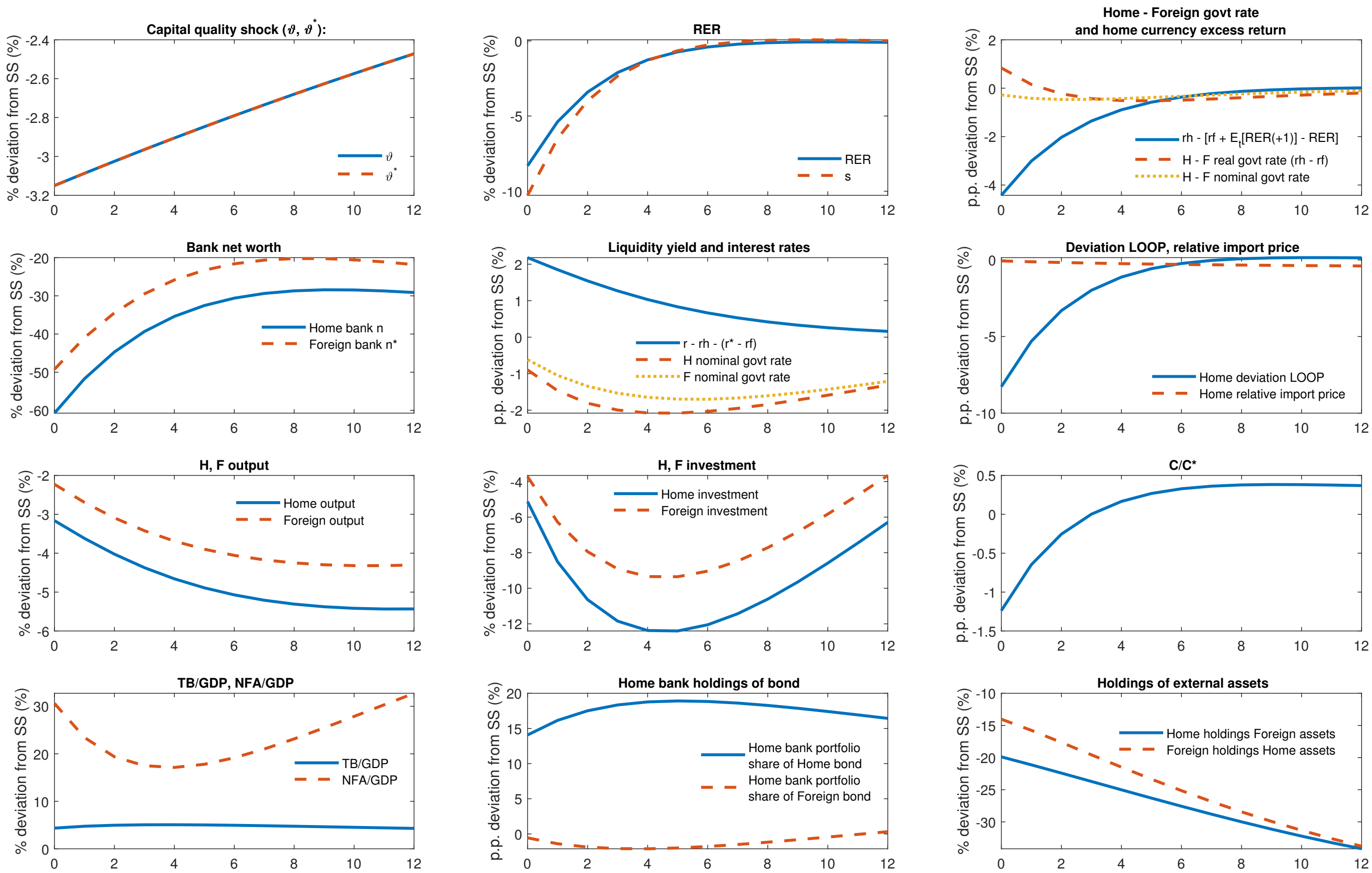
To understand the forces driving retrenchment, it is instructive to look at the response to the same capital quality shock, except in the case when there is no difference in collateral requirements between the Home and Foreign bank. Figure 5 illustrates this case, where $\kappa_{h1} = \kappa^*_{h1} < \kappa_{f1} = \kappa^*_{f1}$. 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.

The appreciation helps to relax the credit constraint for the Foreign bank, which is specified in foreign-currency terms. 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. In the baseline calibration, the U.S. bank has a stronger incentive to switch its portfolio out of capital and into Home bonds, further reinforcing 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]

[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.

[24] Portfolio dynamics upon the global capital quality shock are reported in Appendix D.2.

Figure 5: 3.15% global capital quality shock (ϑ, ϑ^*) with $\kappa_{h1} = \kappa_{h1}^* = 0.0681 < \kappa_{f1} = \kappa_{f1}^* = 0.418$



Notes: The figure shows impulse response functions of a 3.15% global capital quality shock. Home bank portfolio share of Home bond (and Foreign bond) is measured as $D_h/\bar{D_h}$ (and $D_f/\bar{D_f}$).

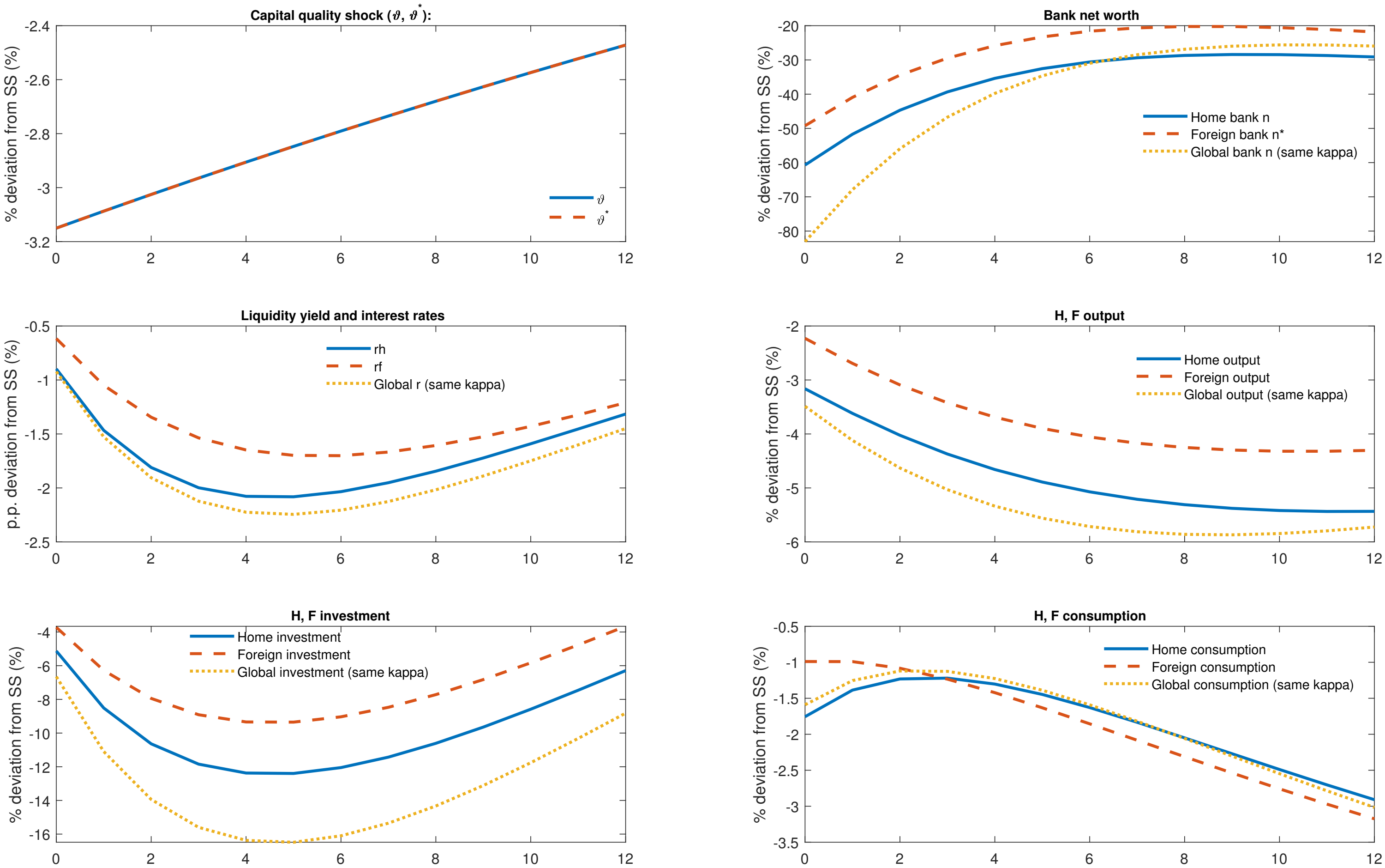
This helps towards a better understanding of asset flows. The literature has puzzled over how to reconcile the empirical finding of global retrenchment during times of financial stress with the observation that the dollar appreciates. Retrenchment seems to imply that while the U.S. is shifting its demand 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 G, 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 market, gross cross country capital flows and trade balances as in the model analysis above.

[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.)

Figure 6: 3.15% global capital quality shock (ϑ, ϑ^*) with same capital κ and bond κ across country



Notes: The figure shows impulse response functions of a 3.15% global capital quality shock. The dash lines indicate the IRF reported in the baseline Figure 4. The dotted golden lines indicate the case when all κ_1 values are assumed to be the same.

5.2 *What Causes the Global Downturn?*

In Figure 6, 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 ($\kappa_{h1} = \kappa_{h1}^* = \kappa_{f1} = \kappa_{f1}^* = 0.07$,and $\kappa_{Kh1} = \kappa_{Kh1}^* = \kappa_{Kf1} = \kappa_{Kf1}^* = 0.4$), 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.

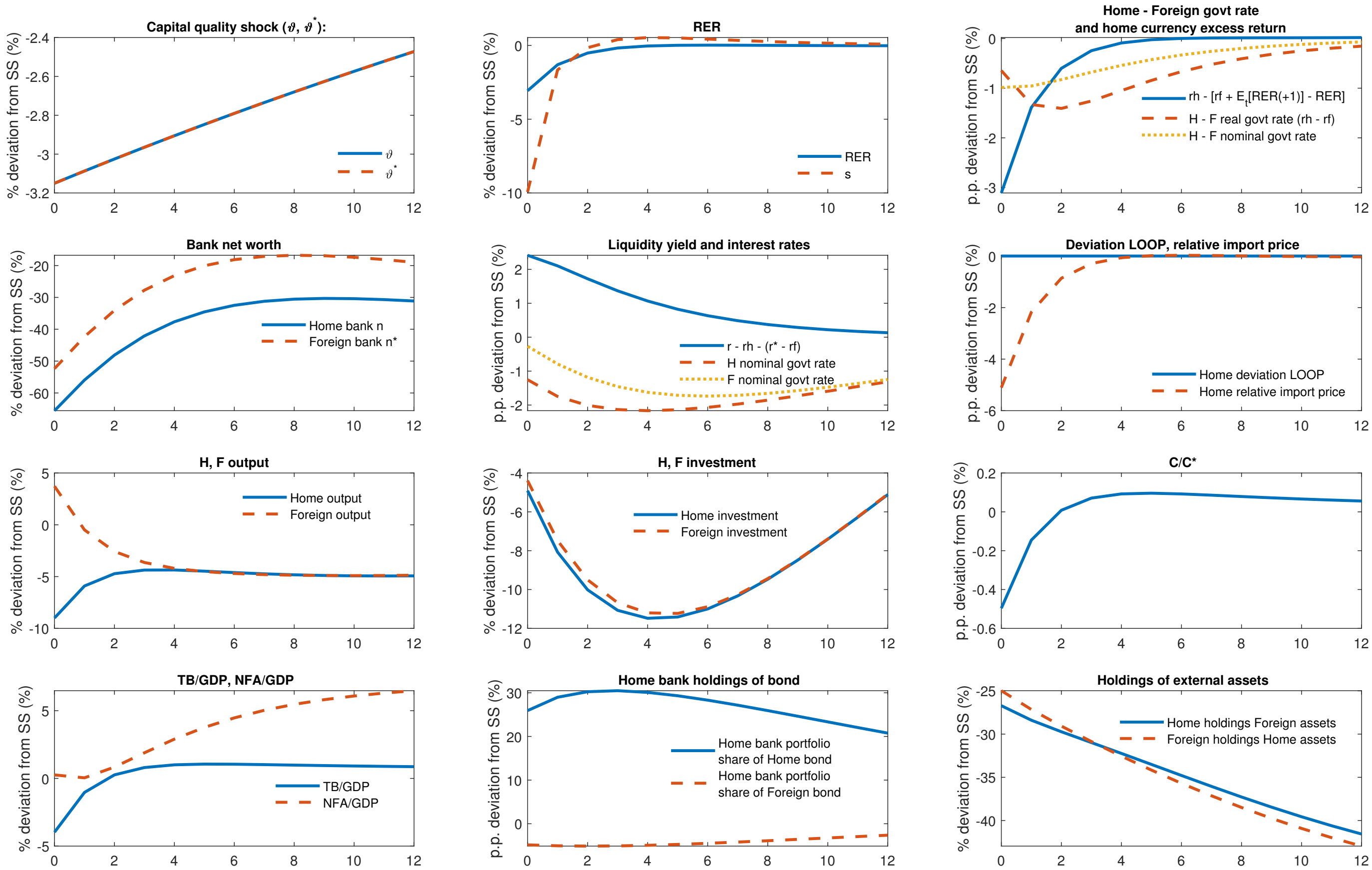
The figure plots impulse responses under the symmetric calibration (in gold) and compares them to the impulse responses under the baseline calibration (dash blue and red lines). The key takeaways are that, on the one hand, by the nature of the calibration, there are no effects of a global capital quality 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.

5.3 *Alternative Assumptions on Price Setting*

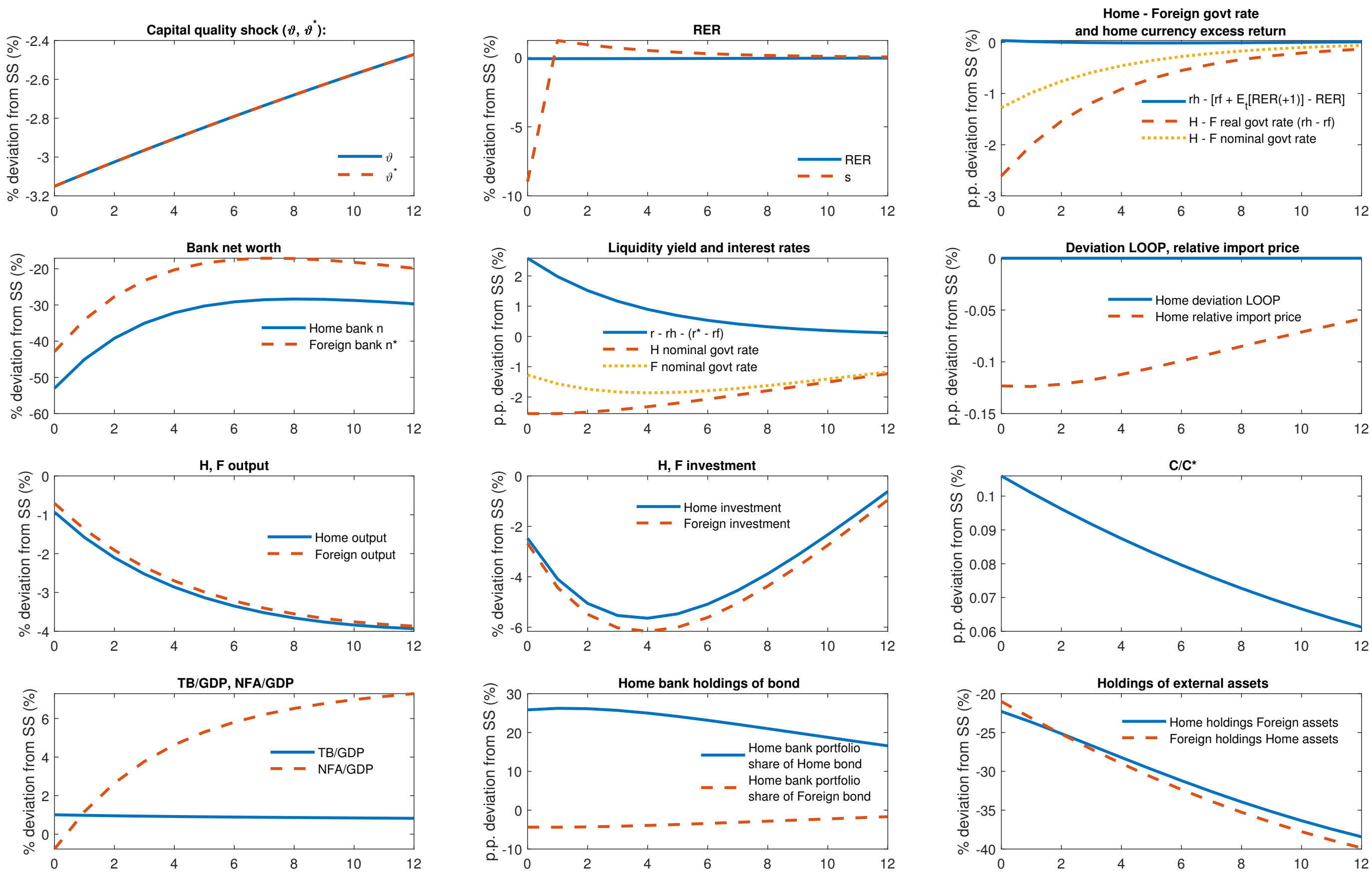
Figure 7 shows how the results are dependent on the assumption that retail prices are set in the currency of the buyer, i.e. LCP. The figure illustrates the impact of the same capital quality shock as in Figure 4 but now assuming that all goods prices are set in the seller's currency, (PCP), so that 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 relative import price appreciation, in combination with home bias in consumer preferences.

Figure 7: 3.15% global capital quality shock (ϑ, ϑ^*) with baseline calibration in PCP case



Notes: The figure shows impulse response functions of a 3.15% global capital quality shock. Home bank portfolio share of Home bond (and Foreign bond) is measured as $D_h/\bar{D}_h$ (and $D_f/\bar{D}_f$).

Figure 8: 3.15% global capital quality shock (ϑ, ϑ^*) with baseline calibration in flexible price case



Notes: The figure shows impulse response functions of a 3.15% global capital quality shock. Home bank portfolio share of Home bond (and Foreign bond) is measured as $D_h/\bar{D}_h$ (and $D_f/\bar{D}_f$).

In Figure 7, despite the fact that Home consumption falls relative to Foreign consumption, we do observe relative import price appreciation in response to the capital quality 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 relative import price movements.

Figure 8 looks at the case with purely flexible prices. It 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 only partially accomplished through changes in the exchange rate. On the goods market side, this can occur only due to relative import price appreciation. The relative import price 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 baseline model is quite different from Maggiori (2017), this flexible price case illustrates the "reserve currency paradox".[26]

We can conclude from these two figures that a complete analysis of the impact of a global capital quality 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 with limited exchange rate pass-through, captured by a local currency pricing rule for exporting firms. In Appendix D, we report IRFs of various other shocks in the model.

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

[26] In Maggiori (2017)'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 but prices are flexible, Home and Foreign output might not drop uniformly but it is relatively close in the flexible prices case.

moments. We allow for country-specific shocks to capital quality ($\vartheta_t, \vartheta_t^*$), TFP ($A_t, A_t^*$), and discount rate ($\beta_t, \beta_t^*$) to represent financial-driven, supply-driven and demand-driven business cycle movements, respectively. For any shock $J \in \{\beta, \vartheta, A\}$, we have:

$$
\begin{aligned}
log(J_t) &= log(J_t^{Global}) + log(J_t^H), \qquad log(J_t^*) = log(J_t^{Global}) + log(J_t^F), \\
log(J_t^{Global}) &= \rho^{J,Global} log(J_{t-1}^{Global}) + s^{J,Global} e_t^{J,Global}, \\
log(J_t^H) &= \rho^{J,H} log(J_{t-1}^H) + s^{J,H} e_t^{J,H}, \qquad log(J_t^F) = \rho^{J,F} log(J_{t-1}^F) + s^{J,F} e_t^{J,F}
\end{aligned}
$$

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 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 0.99, 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 0.0049 so that the model-implied correlation of bank equity values is 0.9, consistent with the data counterparts of 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

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

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). The regression specification is outlined as follows:

$$\Delta s_{j,t} = \alpha_j + \beta_1 s_{j,t-1} + \beta_2 \Delta \eta_{j,t} + \beta_3 \Delta (i - i^*)_{j,t} + \beta_4 \eta_{j,t-1} + \beta_5 (i - i^*)_{j,t-1} + u_{j,t} \tag{41}$$

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. (2018) 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.

Table 5 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 -1.41 and -3.07. 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.

To provide direct evidence of the mechanism from banking to exchange rates, we employ two daily Rigobon (2003) identification through heteroskedasticity regressions. For these exercises, we use daily data from January 1, 1999, to March 9, 2021.

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. In the first exercise (column (3)), we directly estimate equation (41) using the Rigobon estimation. The identification assumption is that exchange rate volatility remains the same across both sets of dates, while the volatility of the convenience yield differs. The idea is that earnings

Table 5: 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 regression of G10 currenices (quarterly)	Model implied regression (quarterly)	Rigobon regression (daily)	Rigobon regression with fitted $\hat{\eta}$ (daily)	Model implied regression (capital quality shocks)
	(1)	(2)	(3)	(4)	(5)
$\Delta\eta_{j,t}$	-1.65**	-1.41	-0.98***	-2.72***	-1.43
	(0.76)		(0.10)	(0.61)	
$\Delta(i-i^*)_{j,t}$	-2.60***	-3.07	-1.66***	-1.04***	–2.53
	(0.97)		(0.10)	(0.23)	
$\eta_{j,t-1}$	-2.08**	0.03	-0.02	0.01	-0.06
	(0.87)		(0.01)	(0.03)	
$(i-i^*)_{j,t-1}$	-0.44**	0.02	-0.005***	0.001	-0.04
	(0.22)		(0.003)	(0.007)	
s_{t-1}	-0.06**	-0.005	-0.001***	-0.002***	-0.11
	(0.02)		(0.0002)	(0.001)	
Observations	739	14,900	37209	29955	14,900

Notes: Standard errors in parentheses are clusted by time. * p<0.1, ** p<0.05, *** p<0.01. The data sample starts from 1999Q1 - 2021Q1. Model implied regression is performed with 15,000-quarter observations and burning the first 100 quarters.

releases could introduce heightened volatility in the demand for liquid assets. Similar to the quarterly regressions in column (1) and (2), coefficient estimate in column (3) indicates a 1% increase in the convenience yield (annualized) is associated with a 0.98% dollar appreciation, and this can be interpreted as a causal relationship that is driven by financial shocks.

In column (4), we provide evidence on the banking-driven demand with an alternative heteroskedasticity-based identification. We still focus on U.S. financial intermediaries earning release announcements, but in this exercise, we first estimate a causal relationship from bank equity performance to convenience yield using the daily Rigobon estimation:

$$\eta_{j,t} = \alpha_j + \delta_1 ln(\text{US bank equity index}) + e_{j,t}$$

The coefficient δ_1 is estimated to be -0.0109 with a t-statistics of -4.27 and a F statistic of 18. We then use the fitted value from this regression as the convenience yield variables in equation (41). The idea is that these are identified financially driven convenience yield movements and we can trace out how these identified movements affect exchange rates. The estimated coefficient for $\Delta\eta_{j,t}$ is -2.72 and it is highly significant. It indicates a 1% increase in the convenience yield (annualized) is associated with 2.72% 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.

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.

To make a meaningful comparison between the data and the model, in column (5), we simulate the model but allow for capital quality shock. The model again generates coefficients that are broadly consistent with the identified financial shock driven regression in the data.

In the Appendix E.2, we supplement this analysis with an instrumental variable regression. We directly employ the high frequency identified shock in Ottonello and Song (2022) as a measure of financial shocks during earnings dates. We then use this financial shock to instrument changes in the convenience yield. The IV regression yields the same message, 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 motivational Figure 2. 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 6 reports these regressions. Column (1) and (3) report the change of U.S. and foreign holding of U.S. Treasuries in the data, respectively. They indicate a 1% increase in convenience yield is associated with 1.06% increase of home holding of U.S. Treasuries and -1.40% 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.

Table 6: Model implied regression and the empirical counterpart

	Quarterly empirical regression of US holding of US Treasury	Model regression of US holding of UST	Quarterly empirical regression of Foreign holding of US Treasury	Model regression of Foreign holding of UST
	(1)	(2)	(3)	(4)
$\eta_{j,t}$	1.06***	1.12	-1.40***	-3.17
	(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. Data regression sample is from 2003Q1 to 2021Q1. Model implied regression is performed with 15,000-quarter observations and burning the first 100 quarters.

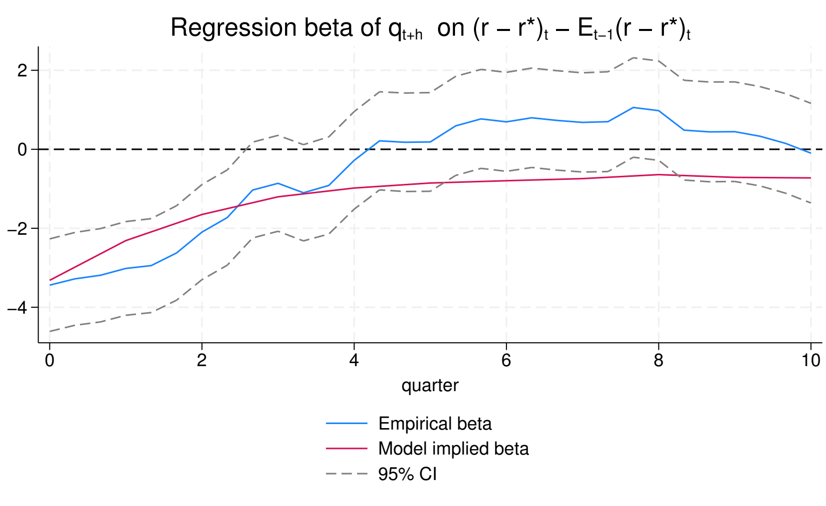
Finally, we investigate the model-implied relationship between interest rates and exchange rates. We reproduce the local projection shown in the bottom left panel of Figure 1. Empirically, to estimate innovations to the interest rate differential, we estimate a VAR system including the real exchange rate, the real interest rate differential, and the inflation differential ($\Delta q_t, r_t - r_t^*$ and $\pi_t - \pi_t^*$) with one lag. The expected interest rate differential, $E_{t-1}(r_t - r_t^*)$, is then obtained from the one-period-ahead forecast generated by the VAR system. We perform this estimation separately for each of the G10 currencies using monthly data from January 1999 to August 2023. Similar to Engel (2016), we then estimate a panel local projection of the real exchange rate on the real interest rate differential:

$$q_{i,t+h} = \alpha_i + \beta[(r - r^*)_{i,t} - E_{t-1}(r - r^*)_{i,t}] + u_{i,t}$$

We conduct the same VAR estimation and local projection using the model-simulated data. The empirical and simulated regression results are reported in Figure 9. The blue line shows the estimated coefficient from the data, along with the 95% confidence interval based on standard errors clustered by time. The red line presents the corresponding estimate from the model-simulated data. The model closely replicates the immediate appreciation of the U.S. dollar following an unexpected interest rate increase, as well as the subsequent gradual depreciation back toward its original level.

Exercises in this section demonstrate that the model can quantitatively capture the joint behavior of the exchange rate, interest rate, convenience yield, and investment flows into U.S. Treasuries—key moments for understanding the dynamics of exchange rates and safe-asset behavior.

Figure 9: Local projection of $q_{i,t+h} = \alpha_i + \beta[(r - r^*)_{i,t} - E_{t-1}(r - r^*)_{i,t}] + u_{i,t}$



Notes: Dash line indicates 95% confidence interval with time-clustered standard errors. The data sample starts from Jan 1999 - Aug 2023. Model implied regression is performed with 15,000-quarter observations and burning the first 100 quarters.

6.2 Moment Comparison

In the second exercise, we report long-run moments of the model in Table 7. 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 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 2.9 times more volatile than output and consumption and is particularly high in the high volatility state (3.53 and 3.38). Additionally, the exchange rate is also much more volatile than the interest rate differential. The model can also generate a 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 capital quality shock, Figure 4 provides some insight into the negative 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 capital quality 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 capital quality 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. Appendix Figure 11 shows how the correlation of relative consumption and the real exchange rate between the U.S. and the Euro area has fluctuated over time, looking at the evolution of the correlation in five-year windows.

The model also performs reasonably well for other moments, such as the persistence of the real exchange rate, realistic business cycle moments and close to zero FX share as documented by Hassan et al. (2024). 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.3, we report the same table but with PCP setting and no collateral advantage of the U.S. bonds. These specifications produce less realistic moments, such as a less volatile exchange rate, positive Fama's β and much more volatile trade balance. These robustness exercises highlight the importance of these key assumptions to generate realistic moments.

Table 7: 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	2.25	2.92	3.53
$\sigma(\Delta s)/\sigma(\Delta c)$	3.3	2.27	2.89	3.38
$\sigma(i-i^*)/\sigma(\Delta s)$	0.07	0.23	0.16	0.11
Fama β	-0.18	-0.53	-1.14	-2.22
$\rho(\Delta q, \Delta c - \Delta c^*)$	0.05	-0.01	0.3	0.7
$\sigma(\Delta q)/\sigma(\Delta s)$	0.99	0.83	0.81	0.81
FX share ($\frac{E\Delta s}{E(excess\ return)}$)	~0	-0.01	-0.01	-0.02
Persistence				
$\rho(\Delta s)$ (NER)	-0.03	-0.15	-0.16	-0.18
$\rho(q)$ (RER)	0.93	0.99	0.98	0.94
$\rho(i-i^*)$	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	0.29	0.28	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	0.99	1.01	1.04
$\rho(\Delta c, \Delta GDP)$	0.94	0.38	0.56	0.75
$\rho(\Delta I, \Delta GDP)$	0.81	0.55	0.63	0.69
$\rho(\Delta GDP, \Delta GDP^*)$	0.88	0.27	0.52	0.82
$\rho(\Delta c, \Delta c^*)$	0.90	0.38	0.53	0.74
$\rho(\Delta I, \Delta I^*)$	0.55	0.94	0.96	0.99

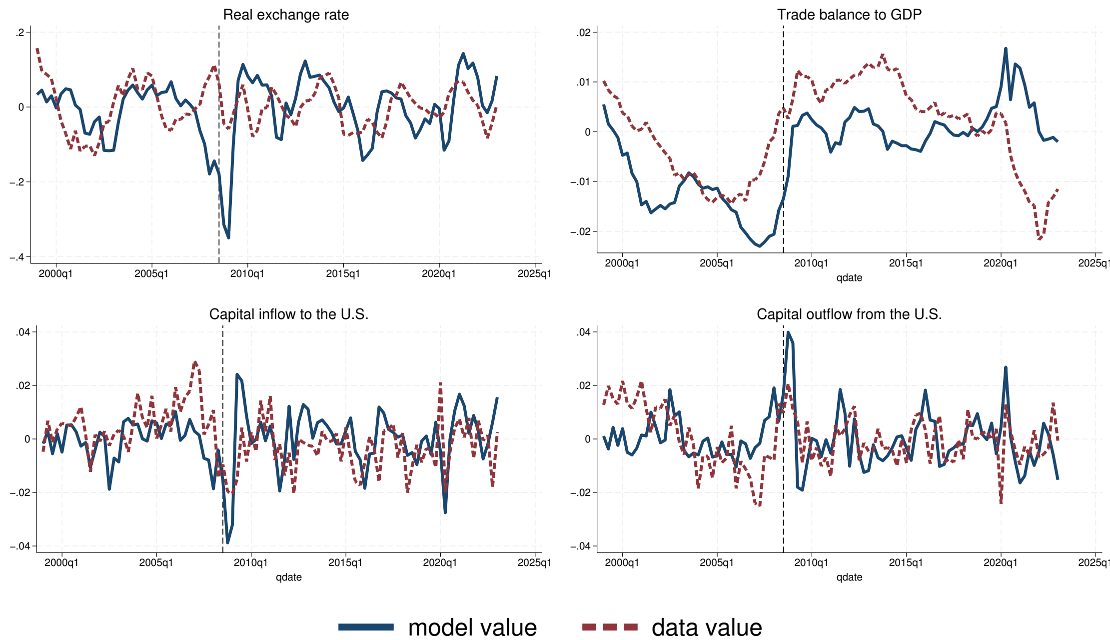
Notes: Data moments: 1999Q1 to 2023Q1. Model moments are performed with 15,000-quarter observations and burning the first 100 quarters.

6.3 Simulation from 1999Q1 to 2023Q1

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.[27]

[27]The home and foreign discount shocks and the TFP shock will effectively jointly target the home and foreign GDP and the nominal interest rate. It makes little difference whether we target the foreign, or the U.S., or an average of the interest rates. We choose to target foreign bank values rather than the U.S. to avoid "hard-wiring" into our model evaluation the effect of the 2008 crisis on U.S. bank values.

Figure 10: Simulation from 1999Q1-2023Q1



Notes: The figure shows time series plot of real exchange rate, trade balance to GDP and capital flow to GDP of the US. Blue lines indicate the model implied values and the red lines indicates the data values. Black dash lines indicate 2008Q3.

In Figure 10, we present the simulated variables in blue and their data counterparts in red for the real exchange rate, trade balance, capital inflows to the U.S., and capital outflows from the U.S (relative to GDP for the latter three). 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 2008Q3 (indicated by the black dash lines), 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 8, we report the same regression exercise as in Table 5 of estimating equation (41) but using the simulated data from 1999Q1 to 2023Q1. In column (2), the model implied exchange rate regression produces very similar values to the empirical counterpart in column (1) . 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.

Table 8: Model implied regression from 1999Q1 to 2023Q1

	Panel regression of G10 currenices (quarterly)	Model implied exchange rate regression
	(1)	(2)
$\Delta\eta_t$	-1.65**	-1.20
	(0.76)	
$\Delta(i-i^*)_t$	-2.61***	-2.36
	(0.97)	
η_{t-1}	-2.08**	0.07
	(0.87)	
$(i-i^*)_{t-1}$	-0.44**	0.04
	(0.22)	
s_{t-1}	-0.06**	-0.11
	(0.02)	
Observations	739	96

Notes: Model regression is performed with 96-quarter along the simulation mimicking 1999Q1-2023Q1 period.

Finally, Table 9 reports the counterpart of Table 6. These columns show that an increase in the convenience yield is associated with an inflow from home investors and an outflow from foreign investors, which are consistent with the data counterpart reported in motivational Figure 2.

Table 9: Model implied regression from 1999Q1 to 2023Q1

	Quarterly empirical regression of US holding of US Treasury	Model regression of US holding of UST	Quarterly empirical regression of Foreign holding of US Treasury	Model regression of Foreign holding of UST
	(1)	(2)	(3)	(4)
$\eta_{j,t}$	1.06***	0.83	-1.40***	-2.33
	(0.36)		(0.51)	
Observations	71	96	71	96

Notes: Model implied regression is performed with 96-quarter observations along the simulated path mimicking the 1999Q1-2023Q1 period. Data regression sample is 2003Q1 to 2021Q1.

7 Conclusions

The unique role of the U.S. dollar and U.S. financial assets in the global system has drawn enormous attention. The literature highlights the "exorbitant privilege" of low-return liabilities in normal times and the "exorbitant duty" of sharp dollar appreciation in global crises. Empirically, financial stress brings dollar appreciation, a narrower U.S. trade deficit, but declining net foreign assets and global retrenchment. We capture these facts in a standard New Keynesian open economy model with balance sheet–constrained banks, adding only that U.S. government bonds have superior collateral value. This realistic feature reflects the specialness of Treasuries. In response to global shocks, the model reproduces the dollar's appreciation, the spike in Treasury convenience yield, and external retrenchment, even as U.S. households' world wealth share falls. The framework rationalizes the dollar's exceptional status and supports policy and asset-pricing analysis.

Data Availability

Code replicating the tables and figures in this article can be found in Devereux et al. (2026) in the HarvardDataverse, https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/9NBJXB

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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: $d_{h,t} = \frac{D_{h,t}}{P_t}$, $d_{f,t} = \frac{D_{f,t}}{P_t^*}$, relative import price: $\mathscr{S}_t = \frac{P_{f,t}}{P_{h,t}}$, $\mathscr{S}_t^* = \frac{P_{f,t}^*}{P_{h,t}^*}$, 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 relative import price. Also, set $\bar{\pi} = 0$

Balance of payments:

$$\begin{aligned}(C_t + I_t + I_t\phi(\tfrac{I_t}{I_{t-1}})) + d_{h,t} - \bar{d}_h + RER_t d_{f,t} + q_t(K_{h,t} - K_t) + RER_t q_t^* K_{f,t} \\ = \tfrac{Y_{h,t}}{P(1,\mathscr{S}_t)}(1 - \xi(\pi_{h,t})) + \tfrac{\mathscr{D}_t}{P(1,\mathscr{S}_t)} Y_{h,t}^*(1 - \xi(\pi_{h,t}^*)) \\ + r_{h,t}(d_{h,t-1} - \bar{d}_h) + RER_t r_{f,t} d_{f,t-1} + \tilde{r}_{k,t+1}\vartheta_t(K_{h,t} - K_t) + RER_t \tilde{r}_{k,t+1}^* \vartheta_t^* K_{f,t}\end{aligned} \tag{42}$$

Home household Euler equation:

$$1 = E_t \beta r_{t+1} (\frac{C_{t+1}}{C_t})^{-\sigma} \equiv E_t \beta r_{t+1} \tilde{\Omega}_{t+1} \tag{43}$$

Foreign household Euler equation:

$$1 = E_t \beta r_{t+1}^* (\frac{C_{t+1}^*}{C_t^*})^{-\sigma} \equiv E_t \beta r_{t+1}^* \tilde{\Omega}_{t+1}^* \tag{44}$$

Labor market clearing implies $L_t = H_t$

Profit maximization for Home implies:

$$\begin{aligned}(1+s_t)Y_{h,t} - \varepsilon((1+s_t) - mc_t)Y_{h,t} \\ -\xi'(\pi_{h,t})\pi_{h,t}Y_{h,t} + E_t\beta\tilde{\Omega}_{t+1}\tfrac{P(1,\mathscr{S}_t)}{P(1,\mathscr{S}_{t+1})}\xi'(\pi_{h,t+1})\pi_{h,t+1}Y_{h,t+1} \quad &= 0\end{aligned} \tag{45}$$

$$\begin{aligned}(1+s_t)Y_{h,t}^* - \varepsilon((1+s_t) - \tfrac{mc_t}{\mathscr{D}_t})Y_{h,t}^* \\ -\xi'(\pi_{h,t}^*)\pi_{h,t}^*Y_{h,t}^* + E_t\beta\tilde{\Omega}_{t+1}\tfrac{P(1,\mathscr{S}_t)}{P(1,\mathscr{S}_{t+1})}\tfrac{\mathscr{D}_{t+1}}{\mathscr{D}_t}\xi'(\pi_{h,t+1}^*)\pi_{h,t+1}^*Y_{h,t+1}^* \quad &= 0\end{aligned} \tag{46}$$

Factor markets Home:

$$A_t(1-\alpha)(L_t^{1-\alpha}(\vartheta_t K_t)^{\alpha} mc_t = w_t P(1,\mathscr{S}_t) L_t \tag{47}$$

$$A_t \alpha L_t^{1-\alpha}(\vartheta_t K_t)^{\alpha} mc_t = r_{K,t} P(1,\mathscr{S}_t)\vartheta_t K_t \tag{48}$$

$$w_t = \chi C_t^{\sigma} L_t^{\psi} \tag{49}$$

Capital and Price of capital at Home:

$$K_{t+1} = I_t + (1-\delta)\vartheta_t K_t \tag{50}$$

$$q_t = 1 + \psi'(\frac{I_t}{I_{t-1}})\frac{I_t}{I_{t-1}} + \psi(\frac{I_t}{I_{t-1}}) \tag{51}$$

$$Y_{h,t} + Y_{h,t}^{*} = A_t L_t^{1-\alpha}(\vartheta_t K_t)^{\alpha} \tag{52}$$

Profit Max Foreign:

$$\begin{aligned} (1+s_t^*)Y_{f,t}^* - \varepsilon((1+s_t) - mc_t^*)Y_{f,t}^* \\ -\xi'(\pi_{f,t}^*)\pi_{f,t}^* Y_{f,t}^* + E_t\beta\tilde{\Omega}_{t+1}^* \tfrac{\mathscr{S}_{t+1}^* P^*(1,\mathscr{S}_t^*)}{\mathscr{S}_t^* P^*(1,\mathscr{S}_{t+1}^*)}\xi'(\pi_{f,t+1}^*)\pi_{f,t+1}^* Y_{f,t+1}^* \quad &= 0 \end{aligned} \tag{53}$$

$$\begin{aligned} (1+s_t^*)Y_{f,t} - \varepsilon((1+s_t^*) - \mathscr{D}_t^* mc_t^*)Y_{f,t} \\ -\xi'(\pi_{f,t})\pi_{f,t} Y_{f,t} + E_t\beta\tilde{\Omega}_{t+1}^* \tfrac{\mathscr{D}_t^*}{\mathscr{D}_{t+1}^*}\tfrac{\mathscr{S}_{t+1}^* P^*(1,\mathscr{S}_t^*)}{\mathscr{S}_t^* P^*(1,\mathscr{S}_{t+1}^*)}\xi'(\pi_{f,t+1})\pi_{f,t+1} Y_{f,t+1} \quad &= 0 \end{aligned} \tag{54}$$

Foreign factor markets:

$$A_t^*(1-\alpha)(L_t^{*(1-\alpha)}(\vartheta_t^* K_t^*)^{\alpha}) mc_t^* = \frac{P^*(1,\mathscr{S}_t^*)}{\mathscr{S}_t^*} w_t^* L_t^* \tag{55}$$

$$A_t^* \alpha (L_t^{*(1-\alpha)}(\vartheta_t^* K_t^*)^{\alpha} mc_t^* = \vartheta_t^* K_t^* \frac{P^*(1,\mathscr{S}_t^*)}{\mathscr{S}_t^*} r_{K,t}^* \tag{56}$$

$$w_t^* = \chi C_t^{*\sigma} L_t^{*\psi} \tag{57}$$

Labor market clearing implies $L_t^* = H_t^*$
Capital and Price of capital Foreign:

$$K_{t+1}^* = I_t^* + (1-\delta)\vartheta_t^* K_t^* \tag{58}$$

$$q_t^* = (1 + \psi'(\frac{I_t^*}{I_{t-1}^*})\frac{I_t}{I_{t-1}} + \psi(\frac{I_t^*}{I_{t-1}^*})) \tag{59}$$

$$Y_{f,t}^* + Y_{f,t} = A_t^*(L_t^{*\alpha}\vartheta_t^{*(1-\alpha)} K_t^{*(1-\alpha)})) \tag{60}$$

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:

$$Y_{h,t}(1-\xi(\pi_{h,t}))=\omega\left(\frac{1}{P(1,\mathscr{S}_t)}\right)^{-\mu}(C_t+I_t+I_t\phi(\frac{I_t}{I_{t-1}})) \tag{61}$$

$$Y_{h,t}^{*}(1-\xi(\pi_{h,t}^{*}))=\frac{(1-n)}{n}(1-\omega^{*})\left(\frac{1}{P^{*}(1,\mathscr{S}_t^{*})}\right)^{-\mu}(C_t^{*}+I_t^{*}+I_t^{*}\phi(\frac{I_t^{*}}{I_{t-1}^{*}})) \tag{62}$$

Foreign good:

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

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

Home Bank:

$$E_t\tilde{\Lambda}_{t+1}\left(\tilde{r}_{k,t+1}\vartheta_{t+1}-r_{t+1}\right)=\lambda_t\vartheta_t(\kappa_{Kh1}+\kappa_{Kh2}\tilde{K}_{h,t}) \tag{65}$$

$$E_t\tilde{\Lambda}_{t+1}\left(\frac{RER_{t+1}}{RER_t}\tilde{r}_{k,t+1}^{*}\vartheta_{t+1}^{*}-r_{t+1}\right)=\lambda_t(\kappa_{Kf1}+\kappa_{Kf2}RER_t\tilde{K}_{f,t}) \tag{66}$$

$$E_t\tilde{\Lambda}_{t+1}\left(r_{h,t+1}-r_{t+1}\right)=\lambda_t(\kappa_{h1}+\kappa_{h2}\tilde{d}_{h,t}) \tag{67}$$

$$E_t\tilde{\Lambda}_{t+1}\left(\frac{RER_{t+1}}{RER_t}r_{f,t+1}-r_{t+1}\right)=\lambda_t(\kappa_{f1}+\kappa_{f2}RER_t\tilde{d}_{f,t}) \tag{68}$$

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

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

Home envelope condition:

$$\upsilon_t=\frac{E_t\tilde{\Omega}_{t+1}\frac{\pi_{h,t+1}P(1,\mathscr{S}_{t+1})}{P(1,\mathscr{S}_t)}((1-\theta)+\theta\upsilon_{t+1})r_{t+1}}{1-\eta_t} \tag{69}$$

Home participation constraint:

$$\begin{aligned}\upsilon_t n_t \quad = \quad & ((\kappa_{Kh1}+\kappa_{Kh2}q_tK_{h,t+1})q_tK_{h,t+1}+(\kappa_{Kf1}+\kappa_{Kf2}RER_tq_t^{*}K_{f,t+1})RER_tq_t^{*}K_{f,t+1}\\ & +(\kappa_{h1}+\kappa_{h2}d_{h,t})d_{h,t}+(\kappa_{f1}+\kappa_{f2}RER_td_{f,t})RER_td_{f,t})\end{aligned} \tag{70}$$

Home net worth dynamics:

$$
\begin{aligned}
n_{t+1} = \quad & \theta((\tilde{r}_{k,t+1}\vartheta_{t+1} - r_{t+1})q_t K_{h,t+1} \\
& +(r_{h,t+1} - r_{t+1})d_{h,t} \\
& +(\tfrac{RER_{t+1}}{RER_t}\tilde{r}_{kf,t+1}\vartheta^*_{t+1} - r_{t+1})RER_t K_{f,t+1} \\
& +(\tfrac{RER_{t+1}}{RER_t} r_{f,t+1} - r_{t+1})RER_t d_{f,t} + r_{t+1}n_t) \\
& +\varphi\tfrac{P(1,\mathscr{S}_t)}{\pi_{h,t+1}P(1,\mathscr{S}_{t+1})}\left(q_t K_{t+1} + d_{h,t} + \tfrac{\mathscr{D}_t P(1,\mathscr{S}^*_t)}{P(1,\mathscr{S}_t)}d_{f,t}\right)
\end{aligned} \tag{71}
$$

Foreign Bank:

$$
E_t\tilde{\Lambda}^*_{t+1}\left(\frac{RER_t}{RER_{t+1}}\tilde{r}_{k,t+1}\vartheta_{t+1} - r^*_{t+1}\right) = \lambda_t^*(\kappa^*_{Kh1} + \kappa^*_{Kh2}\tilde{K}^*_{ht}/RER_t) \tag{72}
$$

$$
E_t\tilde{\Lambda}^*_{t+1}\left(\tilde{r}^*_{k,t+1}\vartheta^*_{t+1} - r^*_{t+1}\right) = \lambda_t^*(\kappa^*_{Kf1} + \kappa^*_{Kf2}\tilde{K}^*_{ft}) \tag{73}
$$

$$
E_t\tilde{\Lambda}^*_{t+1}\left(\frac{RER_t}{RER_{t+1}}r_{h,t+1} - r^*_{t+1}\right) = \lambda_t^*(\kappa^*_{h1} + \kappa^*_{h2}\tilde{d}^*_{h,t}/RER_t) \tag{74}
$$

$$
E_t\tilde{\Lambda}^*_{t+1}\left(r_{f,t+1} - r^*_{t+1}\right) = \lambda_t^*(\kappa^*_{f1} + \kappa^*_{f2}\tilde{d}^*_{f,t}) \tag{75}
$$

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

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

Foreign envelope condition:

$$
\upsilon^*_t = \frac{E_t\Omega^*_{t+1}\pi^*_{h,t+1}\frac{P(1,\mathscr{S}^*_{t+1})}{P(1,\mathscr{S}^*_t)}\left((1-\theta) + \theta\upsilon^*_{t+1}\right)r^*_{t+1}}{1-\eta^*_t} \tag{76}
$$

Foreign participation constraint:

$$
\begin{aligned}
\upsilon^*_t n^*_t \quad = \quad & ((\kappa^*_{Kf1,t} + \kappa^*_{Kf2,t}q^*_t K^*_{ft+1})q^*_t K^*_{ft+1} + (\kappa^*_{Kh1,t} + \kappa^*_{Kh2,t}\tfrac{1}{RER_t}q_t K^*_{h,t+1})\tfrac{1}{RER_t}q_t K^*_{h,t+1} \\
& +(\kappa^*_{h1,t} + \kappa^*_{h2,t}\tfrac{1}{RER_t}d^*_{h,t})\tfrac{1}{RER_t}d^*_{h,t} + (\kappa^*_{f1,t} + \kappa^*_{f2,t}d^*_{f,t})d^*_{f,t})
\end{aligned} \tag{77}
$$

Foreign net worth dynamics:

$$
\begin{aligned}
n^*_{t+1} = \quad & \theta((\tilde{r}^*_{k,t+1}\vartheta_{t+1} - r^*_{t+1})q^*_t K_{t+1} \\
& +(\tfrac{RER_t}{RER_{t+1}}(\tilde{r}_{k,t+1}\vartheta_{t+1} * - r^*_{t+1})\tfrac{1}{RER_t}K^*_{h,t+1} \\
& +(\tfrac{RER_t}{RER_{t+1}}r_{h,t+1} - r^*_{t+1})\tfrac{1}{RER_t}d^*_{h,t} \\
& +(r_{f,t+1} - r^*_{t+1})d^*_{f,t} + r^*_{t+1}n^*_t) \\
& +\varphi\tfrac{P(1,\mathscr{S}^*_t)}{\pi^*_{h,t+1}P(1,\mathscr{S}^*_{t+1})}\left(q^*_t K^*_{t+1} + \tfrac{P(1,\mathscr{S}_t)}{\mathscr{D}_t P(1,\mathscr{S}^*_t)}d^*_{h,t} + d^*_{f,t}\right)
\end{aligned} \tag{78}
$$

Home monetary Rule:

$$r_{h,t+1} = r_{h,ss}\left(\frac{P(1,\mathscr{S}_t)\pi_{h,t}}{P(1,\mathscr{S}_{t-1})}\right)^{\eta^{\pi}(1-\rho^R)}(r_{h,t})^{\rho^R}M_t \tag{79}$$

Foreign monetary Rule:

$$r_{f,t+1} = r_{f,ss}\left(\frac{\mathscr{S}^*_{t-1}P^*(1,\mathscr{S}^*_t)\pi^*_{f,t}}{\mathscr{S}^*_t P^*(1,\mathscr{S}^*_{t-1})}\right)^{\eta^{\pi}(1-\rho^R)}(r_{f,t})^{\rho^R}M^*_t \tag{80}$$

Definitions:

$$\pi_{h,t} = \pi_{f,t}\frac{\mathscr{S}_{t-1}}{\mathscr{S}_t},\ \pi^*_{f,t} = \pi^*_{h,t}\frac{\mathscr{S}^*_t}{\mathscr{S}^*_{t-1}},\ \mathscr{D}_t = \mathscr{D}^*_t\frac{\mathscr{S}_t}{\mathscr{S}^*_t} \tag{81}$$

Equations (42) - (81) give 42 equations in

$$C_t, C^*_t, L_t, L^*_t, I_t, I^*_t, K_{h,t}, K^*_{h,t}, K_{f,t}, K^*_{f,t}, \pi_{h,t}, \pi^*_{h,t}, \pi_{f,t}, \pi^*_{f,t}, w_t, w^*_t, q_t, q^*_t, mc_t, mc^*_t$$

$$r_{K,t}, r^*_{K,t}, r_t, r^*_t, r_{h,t}, r_{f,t}, Y_{h,t}, Y^*_{h,t}, Y_{f,t}, Y^*_{f,t}, \upsilon_t, \upsilon^*_t, \eta_t, \eta^*_t, d_{h,t}, d_{f,t}, \mathscr{S}_t, \mathscr{S}^*_t, \mathscr{D}_t, \mathscr{D}^*_t$$

$$n_t, n^*_t$$

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: $d_h,\ d_f$, relative import price: $\mathscr{S} = \mathscr{S}^*$, 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 relative import price and home bias in consumption aggregators.

Balance of payments:

$$C + I + \delta K = \frac{Y_h + Y^*_h}{P(1,\mathscr{S})} + (r_h - 1)(d_h - \bar{d}_h) + RER(r_f - 1)d_f + (\tilde{r}_k - 1)(K_h - K) + RER(\tilde{r}^*_k - 1)K_f \tag{82}$$

Home Euler equation:

$$1 = \beta r \tag{83}$$

Foreign Euler equation:

$$1 = \beta r^* \tag{84}$$

Profit max Home:

$$1 = mc \tag{85}$$

Factor markets Home:

$$(1-\alpha)(L^{1-\alpha}K^{\alpha}) = \chi C^{\sigma} L^{1+\psi} P(1,\mathscr{S}) \tag{86}$$

$$\alpha(L^{1-\alpha}K^{\alpha}) = r_K P(1,\mathscr{S}) K \tag{87}$$

Capital and Price of capital at Home:

$$K\delta = I \tag{88}$$

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

$$Y_h + Y_h^* = (L^{\alpha}K^{1-\alpha}) \tag{90}$$

Profit Max Foreign:

$$1 = mc^* \tag{91}$$

Foreign factor markets:

$$(1-\alpha)(L^{*(1-\alpha)}K^{*\alpha}) = \frac{P^*(1,\mathscr{S})}{\mathscr{S}} \chi C^{*\sigma} L^{*1+\psi} \tag{92}$$

$$\alpha(L^{*(1-\alpha)}K^{*\alpha})^{\zeta} X^{*(1-\zeta)} = \frac{P^*(1,\mathscr{S})}{\mathscr{S}} r_K^* \tag{93}$$

Capital and Price of capital Foreign:

$$K\delta^* = I^* \tag{94}$$

$$q^* = 1 \tag{95}$$

$$Y_f^* + Y_f = (L^{*\alpha}K^{*(1-\alpha)})) \tag{96}$$

Market Clearing:
Home good:

$$Y_h + Y_f = \omega \left(\frac{1}{P(1,\mathscr{S})}\right)^{-\mu} (C + \delta K) + \frac{(1-n)}{n}(1-\omega^*) \left(\frac{1}{P^*(1,\mathscr{S})}\right)^{-\mu} (C^* + \delta K^*) \tag{97}$$

Foreign good:

$$Y_f + Y_f^* = \frac{n}{1-n}(1-\omega)\left(\frac{\mathscr{S}}{P(1,\mathscr{S})}\right)^{-\mu}(C+\delta K) + \omega^*\left(\frac{\mathscr{S}}{P^*(1,\mathscr{S})}\right)^{-\mu}(C^*+\delta K) \tag{98}$$

Home Bank:

$$\tilde{\Lambda}(\tilde{r}_k - r) = \lambda(\kappa_{Kh1} + \kappa_{Kh2}K_h) \tag{99}$$

$$\tilde{\Lambda}(\tilde{r}_k^* - r) = \lambda(\kappa_{Kf1} + \kappa_{Kf2}K_f) \tag{100}$$

$$\tilde{\Lambda}(r_h - r) = \lambda(\kappa_{h1} + \kappa_{h2}d_h) \tag{101}$$

$$\tilde{\Lambda}\left(r_f - r\right) = \lambda(\kappa_{f1} + \kappa_{f2}d_f) \tag{102}$$

$$\tilde{\Lambda} = \beta((1-\theta) + \theta\upsilon) \tag{103}$$

$$\tilde{r}_K = r_K + (1-\delta) \tag{104}$$

Home envelope condition:

$$\upsilon = \frac{((1-\theta)+\theta\upsilon)}{1-\eta} \tag{105}$$

Home participation constraint:

$$\begin{aligned} \upsilon n \;=\; & ((\kappa_{Kh1} + \kappa_{Kh2}K_h)K_h + (\kappa_{Kf1} + \kappa_{Kf2}RERK_f)RERq^*K_f \\ & +(\kappa_{h1} + \kappa_{h2}d_h)d_h + (\kappa_{f1} + \kappa_{f2}RER_t d_f)RER_t d_f) \end{aligned} \tag{106}$$

Home net worth dynamics:

$$\begin{aligned} n = \; & \theta((\tilde{r}_k - r)K + (r_h - r)d_h + (r_f - r)\mathscr{Q}d_f + rn) \\ & +\varphi\left(K + d_h + \mathscr{Q}d_f\right) \end{aligned} \tag{107}$$

Foreign Bank:

$$\tilde{\Lambda}^*(\tilde{r}_k - r^*) = \lambda^*(\kappa_{Kh1}^* + \kappa_{Kh1}^*K_h^*) \tag{108}$$

$$\tilde{\Lambda}^*(\tilde{r}_k^* - r^*) = \lambda^*(\kappa_{Kf1}^* + \kappa_{Kf1}^*K_f^*) \tag{109}$$

$$\tilde{\Lambda}^*(r_h - r^*) = \lambda^*(\kappa_{h1}^* + \kappa_{h2}^*d_h^*) \tag{110}$$

$$\tilde{\Lambda}^*\left(r_f - r^*\right) = \lambda^*(\kappa_{f1}^* + \kappa_{f2}^*d_f^*) \tag{111}$$

$$\tilde{\Lambda}^* = \beta((1-\theta) + \theta\upsilon^*) \tag{112}$$

$$\tilde{r}_K^* = r_K^* + (1-\delta) \tag{113}$$

Foreign envelope condition:

$$\upsilon^* = \frac{((1-\theta)+\theta\upsilon^*)}{1-\eta^*} \tag{114}$$

Foreign participation constraint:

$$\begin{aligned}\upsilon^* n^* &= ((\kappa^*_{Kf1} + \kappa^*_{Kf2} K^*_f) K^*_f + (\kappa^*_{Kh1} + \kappa^*_{Kh2} \frac{1}{RER} K^*_h) \frac{1}{RER} K^*_h \\ &\quad + (\kappa^*_{h1} + \kappa^*_{h2} \frac{1}{RER} d^*_{h,t}) \frac{1}{RER} d^*_h + (\kappa^*_{f1} + \kappa^*_{f2} d^*_f) d^*_f)\end{aligned} \tag{115}$$

Foreign net worth dynamics:

$$\begin{aligned}n^* = \;& \theta((\tilde{r}^*_k - r^*) K^* + (r_h - r^*) \frac{d^*_h}{RER} + (r_f - r^*) d^*_f + r^* n^*) \\ & + \varphi \left(K^* + \frac{d^*_h}{RER} + d^*_f \right)\end{aligned} \tag{116}$$

Home monetary policy

$$r_h = r_{h,ss} \tag{117}$$

Foreign monetary policy

$$r_f = r_{f,ss} \tag{118}$$

Take mc, r, q, I, $\tilde{\Lambda}$ as given (and same for Foreign). Then we have (82), (86), (87), (90),(92), (93), (96), (97), (98), (99), (101), (102), (105), (106), (107), (109), (110), (111), (114), (115), (116). Solve for C, C^*, K, K^*, L, L^*, Y, Y^* $\mathscr{S}$, d_h, d_f, n, n^*, υ, υ^* η, η^*, r_k, r^*_k, r_h, r_f

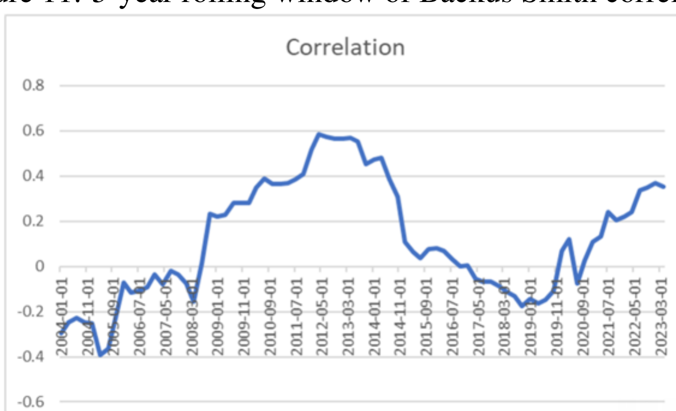
C Data source

We refer to the data in Section 2, 4 and 6. The table below provide the data source and sample period for computing those moments. The data sources are reported in Table 10.

D Additional analysis

D.1 Backus-Smith correlation

Figure 11: 5-year rolling window of Backus Smith correlation



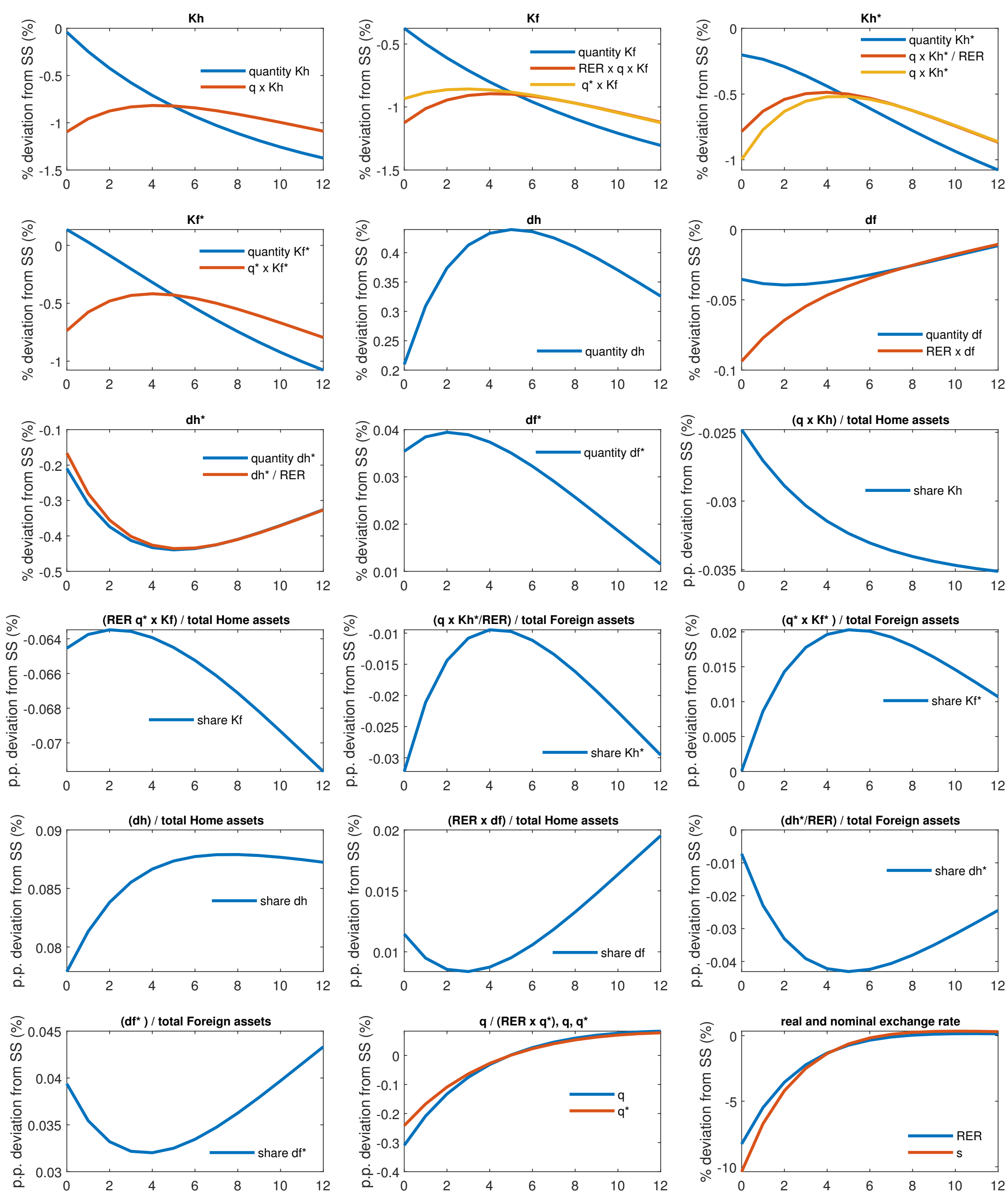
Notes: The figure plots the five-year samples rolling correlation of the log of the U.S. relative to Euro area consumption, and the log of the real U.S./Euro area real exchange rate. The horizontal axis plots the ending of each sample.

Table 10: Data source data

	Data source & Sample	Note
Empirical facts		
Exchange rate	FRED Jan 1999 - Mar 2021	
Liquidity yield	Du et al. (2018) Jan 1999 - Mar 2021	
Government interest rates	Du et al. (2018) Jan 1999 - Mar 2021	
Treasury Flow	Chaudhary et al. (2024) Q1 2003- Q1 2021	
Net foreign asset position	Atkeson et al. (2022) Q1 1999 - Q1 2023	
Trade balance	FRED Q1 1999 - Q1 2023	BOPGSTB, NGDPSAXDCUSQ
Capital inflow and outflow	Bluedorn et al. (2013)	
Targeted moments		
Equity premium	Bansal and Coleman (1996)	
Home bias of equity	Hnatkovska (2019)	
Deposit rate	FDIC Q1 1999 - Q4 2023	
3m government interest rate	FRED Q1 1999 - Q4 2023	DGS3MO
(CA-TB)/GDP	Worldbank WDI 1982-2022 annual	CA/GDP - TB/GDP
Debt to GDP	FRED, ECB 1999-2023	US: FYGFGDQ188S (60%) Eurozone: FRED GCDODTOTLGDZSEMU ECB data portal for share of debt held by ECB GFS.A.N.I9.W2.S13.S121.C.L.LE.GD.T._Z.XDC_R_GD._T.F.V.N._T (70%)
Foreign holding of US debt	FRED Q1 1999 - Q4 2023	Federal Debt Held by Foreign: FDHBFIN, Federal Debt: GFDEBTN
Non-targeted moments (Table 3, 4, 5)		
Exchange rate	FRED Jan 1999 - Mar 2021	
Liquidity yield	Du et al. (2018) Jan 1999 - Mar 2021	
Government interest rates	Du et al. (2018) Jan 1999 - Mar 2021	
Treasury Flow	Chaudhary et al. (2024) Q1 2003- Q1 2021	
Capital inflow and outflow	Bluedorn et al. (2013) and BEA	
US bank earnings announcements	Ottonello and Song (2022) January 1, 1999, to March 9, 2021	
GDP	FRED Q1 1999 - Q1 2023	GDPC1, CLVMNACSCAB1GQEA19
Consumption	FRED Q1 1999 - Q1 2023	PCEC96, NAEXKP02EZQ189S
Interest rate	FRED Q1 1999 - Q1 2023	DGS3MO, IR3TIB01EZM156N
Trade balance	FRED Q1 1999 - Q1 2023	BOPGSTB, NGDPSAXDCUSQ
Investment	FRED Q1 1999 - Q1 2023	GPDIC1, NAEXKP02EZQ189S

D.2 Baseline global financial shock portfolio dynamics

Figure 12: Portfolio dynamics under baseline case with 4% global capital quality shock (ϑ, ϑ^*)

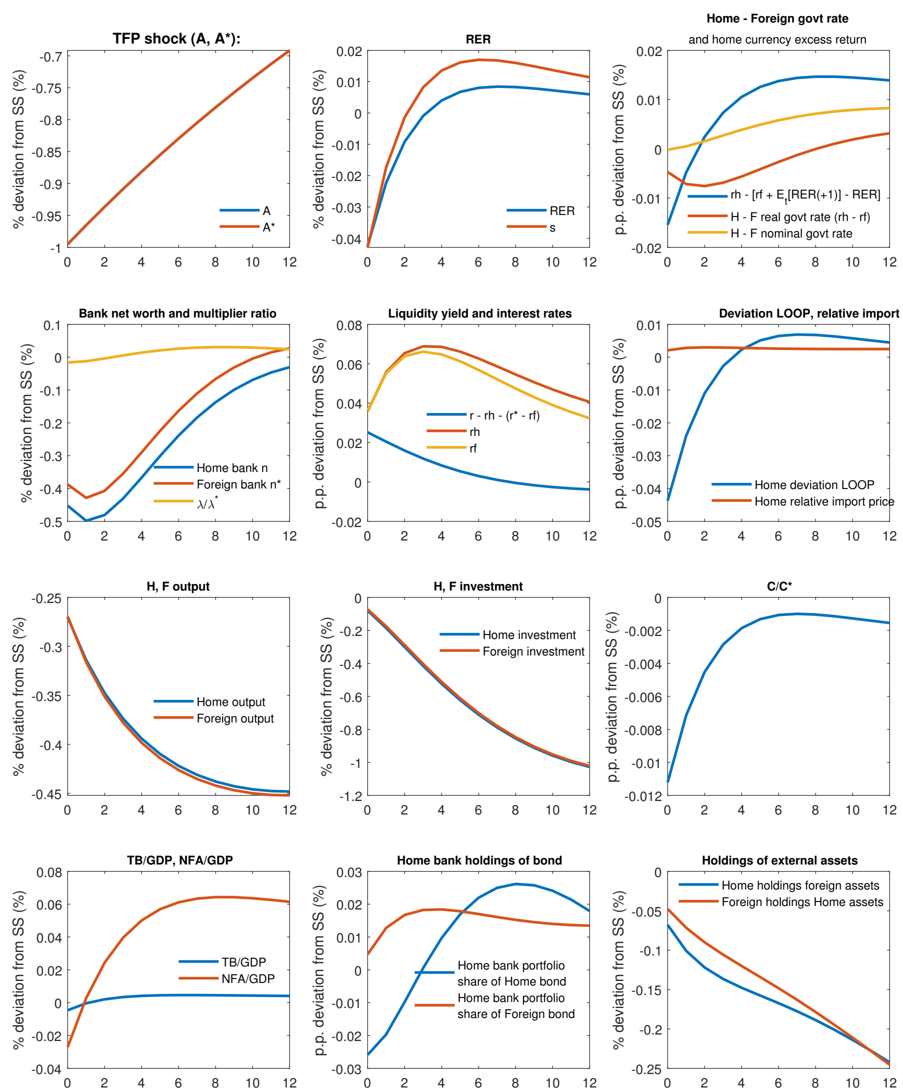


Notes: The figure shows IRF of a 4% global capital quality shock.

D.3 *Global Productivity Shock*

Figure 13 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.

Figure 13: 1% TFP shock (A, A^*) with baseline calibration

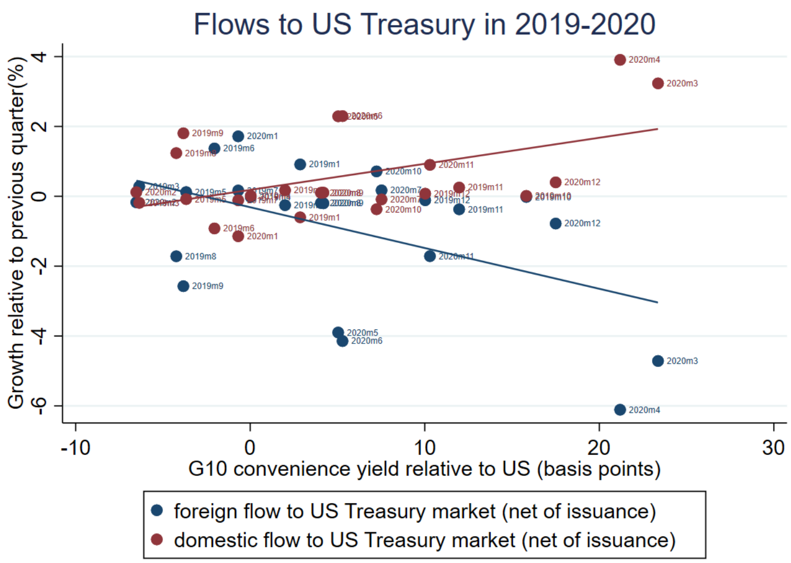


Notes: The figure shows IRF of a 1% global productivity shock.

E Robustness

E.1 Motivational figure during COVID-19 episode

Figure 14: Flow to US Treasury during 2019-2020



Notes: Flow data are from Chaudhary et al. (2024).

E.2 Instrumental variable regressions

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.[28]

The regression estimates are reported in column 3 of Table 11. 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

[28] 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). .

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.

Table 11: Model implied regression and the empirical counterpart

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

	Panal daily IV regression of G10 currencies		
	(1)		
$\Delta\eta_{j,t}$	-9.07**	$\eta_{j,t-1}$	-0.002
	(4.53)		(0.002)
$\Delta(i-i^*)_{j,t}$	-8.58**	$(i-i^*)_{j,t-1}$	-0.040
	(3.86)		(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.

E.3 Unconditional moments with different assumptions

In this section, we report the unconditional moments in Table 7 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 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 12, we assume there is no collateral advantage for the U.S. Treasury. We assume $\kappa_{h1} = \kappa^*_{h1} = \kappa_{f1} = \kappa^*_{f1} = 0.040$ 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.

In Table 13, 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.

In Table 14, we assume there are PCP and no collateral advantage for the U.S. Treasury. That is, we assume $\kappa_{h1} = \kappa^*_{h1} = \kappa_{f1} = \kappa^*_{f1} = 0.04$ 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 12: Long-run moments without 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				
$\sigma(\Delta s)/\sigma(\Delta GDP)$	2.63	0.44	0.33	0.19
$\sigma(\Delta s)/\sigma(\Delta c)$	2.61	0.95	0.41	0.25
$\sigma(i-i^*)/\sigma(\Delta s)$	0.16	0.40	0.40	0.39
Fama β	-1.12	0.32	0.32	0.32
$\rho(\Delta q, \Delta c - \Delta c^*)$	0.30	-0.98	-0.98	-0.98
$\sigma(\Delta q)/\sigma(\Delta s)$	0.82	1.37	1.37	1.36
$\rho(\Delta s)$ (NER)	-0.16	0.43	0.43	0.41
$\rho(q)$ (RER)	0.97	0.99	0.99	0.99
$\rho(i-i^*)$	0.98	0.98	0.98	0.98
$\rho(i)$	0.99	0.99	0.99	0.99
$corr(\Delta nx, \Delta q)$	0.28	0.72	0.48	0.06
$\sigma(\Delta nx)/\sigma(\Delta q)$	0.22	2.06	2.65	4.57
$\sigma(\Delta c)/\sigma(\Delta GDP)$	1.01	0.87	0.81	0.77
$\rho(\Delta c, \Delta GDP)$	0.61	0.40	0.53	0.66
$\rho(\Delta I, \Delta GDP)$	0.63	0.61	0.71	0.77
$\rho(\Delta GDP, \Delta GDP^*)$	0.61	0.45	0.69	0.90
$\rho(\Delta c, \Delta c^*)$	0.62	0.53	0.70	0.90
$\rho(\Delta I, \Delta I^*)$	0.97	0.97	0.99	0.99

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.

Table 13: Long-run moments with PCP

	Original model moments unconditional	Model moments low volatility state	Model moments unconditional	Model moments high volatility state
	(1)	(2)	(3)	(4)
Exchange rates				
$\sigma(\Delta s)/\sigma(\Delta GDP)$	2.63	1.20	1.26	1.30
$\sigma(\Delta s)/\sigma(\Delta c)$	2.61	2.60	3.48	4.30
$\sigma(i-i^{*})/\sigma(\Delta s)$	0.16	0.22	0.17	0.13
Fama β	-1.12	-1.14	-2.04	-3.07
$\rho(\Delta q, \Delta c-\Delta c^{*})$	0.30	-0.38	-0.14	0.20
$\sigma(\Delta q)/\sigma(\Delta s)$	0.82	0.33	0.31	0.29
$\rho(\Delta s)$ (NER)	-0.16	-0.4	-0.40	-0.41
$\rho(q)$ (RER)	0.97	0.99	0.98	0.97
$\rho(i-i^{*})$	0.98	0.93	0.89	0.83
$\rho(i)$	0.99	0.99	0.99	0.99
$corr(\Delta nx, \Delta q)$	0.28	0.87	0.91	0.97
$\sigma(\Delta nx)/\sigma(\Delta q)$	0.22	0.53	0.46	0.43
$\sigma(\Delta c)/\sigma(\Delta GDP)$	1.01	0.46	0.36	0.30
$\rho(\Delta c, \Delta GDP)$	0.61	0.43	0.60	0.75
$\rho(\Delta I, \Delta GDP)$	0.63	0.40	0.41	0.42
$\rho(\Delta GDP, \Delta GDP^{*})$	0.61	-0.53	-0.75	-0.82
$\rho(\Delta c, \Delta c^{*})$	0.62	0.47	0.64	0.85
$\rho(\Delta I, \Delta I^{*})$	0.97	0.96	0.98	0.99

Table 14: Long-run moments with PCP and without convenience yield

	Original model moments unconditional	Model moments low volatility state	Model moments unconditional	Model moments high volatility state
	(1)	(2)	(3)	(4)
Exchange rates				
$\sigma(\Delta s)/\sigma(\Delta GDP)$	2.63	0.34	0.26	0.16
$\sigma(\Delta s)/\sigma(\Delta c)$	2.61	0.42	0.34	0.21
$\sigma(i-i^{*})/\sigma(\Delta s)$	0.16	0.44	0.44	0.43
Fama β	-1.12	0.4	0.4	0.39
$\rho(\Delta q, \Delta c-\Delta c^{*})$	0.30	-0.97	-0.97	-0.96
$\sigma(\Delta q)/\sigma(\Delta s)$	0.82	1.11	1.10	1.08
$\rho(\Delta s)$ (NER)	-0.16	0.15	0.15	0.12
$\rho(q)$ (RER)	0.97	0.99	0.99	0.99
$\rho(i-i^{*})$	0.98	0.99	0.99	0.99
$\rho(i)$	0.99	0.99	0.99	0.99
$corr(\Delta nx, \Delta q)$	0.28	0.76	0.53	0.09
$\sigma(\Delta nx)/\sigma(\Delta q)$	0.22	2.66	3.31	5.41
$\sigma(\Delta c)/\sigma(\Delta GDP)$	1.01	0.81	0.77	0.74
$\rho(\Delta c, \Delta GDP)$	0.61	0.28	0.45	0.64
$\rho(\Delta I, \Delta GDP)$	0.63	0.56	0.67	0.76
$\rho(\Delta GDP, \Delta GDP^{*})$	0.61	0.25	0.44	0.85
$\rho(\Delta c, \Delta c^{*})$	0.62	0.49	0.67	0.88
$\rho(\Delta I, \Delta I^{*})$	0.97	0.97	0.98	0.99

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.

F Risky steady state

We solve the model around the "risky steady state" as in Coeurdacier et al. (2011) and Gertler et al. (2012). The risky steady state postulates the agents to understand the risk structure at the steady state and allocate portfolio accordingly but there is no shocks realized. To be specific, in the bank first order conditions, the covariance between stochastic discount factor of the banks and the risky returns are considered.

$$E_t\Lambda_{i,t+1}E_t\frac{S_{t+1}}{S_t}R_{f,t+1}+cov_t(\Lambda_{i,t+1},\frac{S_{t+1}}{S_t}R_{f,t+1})-E_t\Lambda_{i,t+1}R_{t+1}=\lambda_{i,t}(\kappa_{f1}+\kappa_{f2}S_t\tilde{D}_{f,t}) \tag{119}$$

$$E_t\Lambda_{i,t+1}E_t\tilde{R}_{k,t+1}\vartheta_{t+1}+cov_t(\Lambda_{i,t+1},\tilde{R}_{k,t+1}\vartheta_{t+1})-E_t\Lambda_{i,t+1}R_{t+1}=\lambda_{i,t}(\kappa_{Kh1}+\kappa_{Kh2}Q_t\tilde{K}_{h,t+1}) \tag{120}$$

$$E_t\Lambda_{i,t+1}E_t\frac{S_{t+1}}{S_t}\tilde{R}^*_{k,t+1}\vartheta^*_{t+1}+cov_t(\Lambda_{i,t+1},\frac{S_{t+1}}{S_t}\tilde{R}^*_{k,t+1}\vartheta^*_{t+1})-E_t\Lambda_{i,t+1}R_{t+1}=\lambda_{i,t}(\kappa_{Kf1}+\kappa_{Kf2}S_tQ^*_t\tilde{K}_{f,t+1}) \tag{121}$$

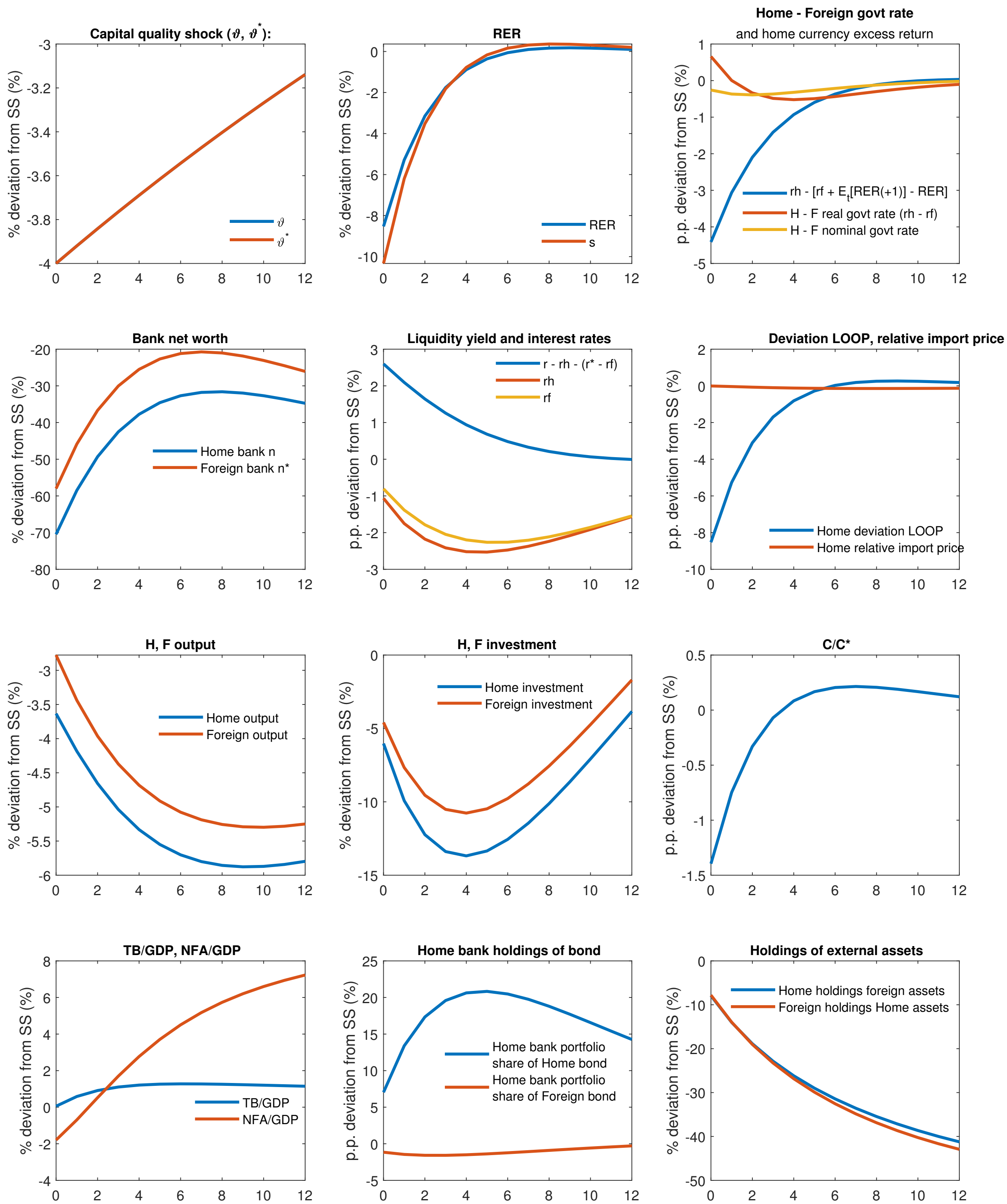
$$E_t\Lambda^*_{i,t+1}E_t\frac{S_t}{S_{t+1}}R_{h,t+1}+cov_t(\Lambda_{i,t+1},\frac{S_t}{S_{t+1}}R_{h,t+1})-E_t\Lambda_{i,t+1}R_{t+1}=\lambda_{i,t}(\kappa_{f1}+\kappa_{f2}\tilde{D}^*_{h,t}/S_t) \tag{122}$$

$$E_t\Lambda^*_{i,t+1}E_t\tilde{R}^*_{k,t+1}\vartheta_{t+1}+cov_t(\Lambda^*_{i,t+1},\tilde{R}^*_{k,t+1}\vartheta_{t+1})-E_t\Lambda^*_{i,t+1}R_{t+1}=\lambda_{i,t}(\kappa^*_{Kf1}+\kappa^*_{Kf2}Q_t\tilde{K}_{h,t+1}) \tag{123}$$

$$E_t\Lambda^*_{i,t+1}E_t\frac{S_t}{S_{t+1}}\tilde{R}_{k,t+1}\vartheta_{t+1}+cov_t(\Lambda^*_{i,t+1},\frac{S_t}{S_{t+1}}\tilde{R}_{k,t+1}\vartheta_{t+1})-E_t\Lambda^*_{i,t+1}R_{t+1}=\lambda_{i,t}(\kappa_{Kf1}+\kappa_{Kf2}Q_t\tilde{K}_{f,t+1}/S_t) \tag{124}$$

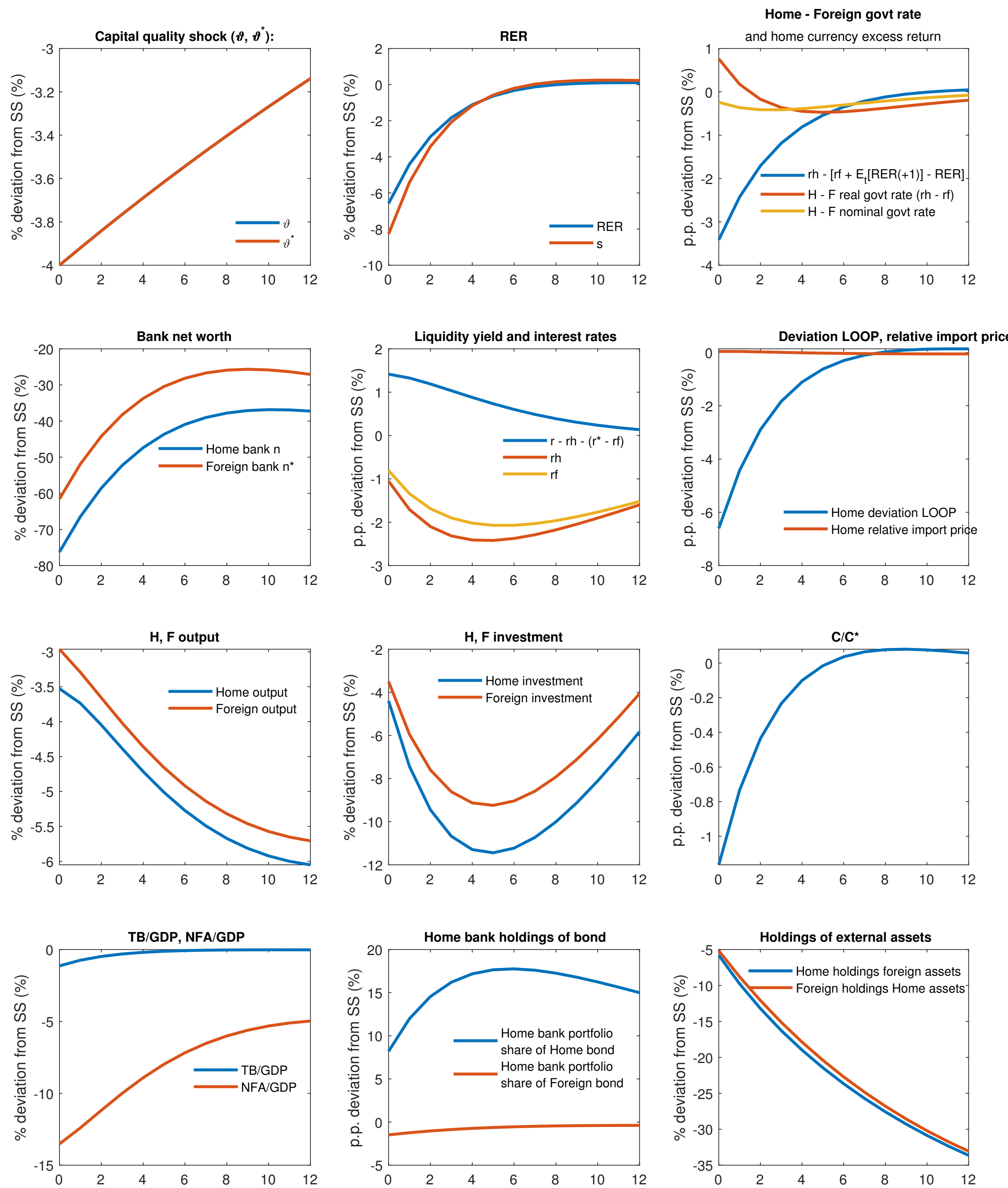
We follow the procedures suggested by Gertler et al. (2012) to compute the risky steady state. In brief, we start with an initial guess of each of the six covariance terms and solve the model. And then we simulate the model to compute the model implied covariance. We iterate this until the covariance terms converges. The model's κ parameters are recalibrated such that it targets the four moments as in the main text. The values are $\{\kappa_{h1},\ \kappa_{f1},\ \kappa^*_{h1},\ \kappa^*_{f1}\}$={0.045, 0.436, 0.1229, 0.368}. From Figure 15 to Figure 17 and Table 15 to Table 17, we present the figures and tables that correspond to Figure 4 to Figure 10 and Table 5 to Table 9 in the main text, but calibrated using the risky steady state concept. All results are quantitatively similar to those under the non-stochastic steady state calibration reported in the main text. In Figure 18 we solve the model at the risky steady state using a second-order approximation, thus incorporating risk considerations both at the steady state and in the dynamic responses.

Figure 15: Risky steady state: Baseline with 4% global financial shock (ϑ, ϑ^*)



Notes: The figure shows IRF of a 4% global financial shock.

Figure 16: Risky steady state: Baseline with 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 4% global financial shock.

Table 15: Risky steady state: 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 regression of G10 currenices (quarterly)	Model implied regression (quarterly)	Rigobon regression (daily)	Rigobon regression with fitted $\hat{\eta}$ (daily)	Model implied regression (capital quality shocks)
	(1)	(2)	(3)	(4)	(5)
$\Delta\eta_{j,t}$	-1.65**	-1.29	-0.97***	-2.2***	-0.73
	(0.76)		(0.17)	(0.53)	
$\Delta(i-i^*)_{j,t}$	-2.61***	-2.80	-1.63***	-0.89***	–1.07
	(0.97)		(0.17)	(0.17)	
$\eta_{j,t-1}$	-2.08**	0.03	-0.02	-0.01	-0.03
	(0.87)		(0.02)	(0.02)	
$(i-i^*)_{j,t-1}$	-0.44**	0.02	-0.006***	-0.001	-0.04
	(0.22)		(0.002)	(0.005)	
s_{t-1}	-0.06**	-0.006	-0.001***	-0.0012***	-0.03
	(0.02)		(0.0002)	(0.004)	
Observations	739	14,900	37209	37209	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.

Table 16: Risky steady state: Model implied regression and the empirical counterpart

	Quarterly empirical regression of US holding of US Treasury	Model regression of US holding of UST	Quarterly empirical regression of Foreign holding of US Treasury	Model regression of Foreign holding of UST
	(1)	(2)	(3)	(4)
$\eta_{j,t}$	0.74***	0.82	-1.39***	-1.79
	(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. Data regression sample is 2003Q1 to 2021Q1. Model implied regression is performed with 15,000-quarter observations and burning the first 100 quarters.

Table 17: Risky steady state: 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	1.95	2.41	2.85
$\sigma(\Delta s)/\sigma(\Delta c)$	3.3	1.97	2.42	2.85
$\sigma(i-i^*)/\sigma(\Delta s)$	0.07	0.23	0.16	0.11
Fama β	-0.18	-0.50	-1.00	-2.22
$\rho(\Delta q, \Delta c - \Delta c^*)$	0.05	-0.01	0.23	0.59
$\sigma(\Delta q)/\sigma(\Delta s)$	0.99	0.85	0.83	0.82
Persistence				
$\rho(\Delta s)$ (NER)	-0.03	-0.15	-0.16	-0.18
$\rho(q)$ (RER)	0.93	0.98	0.96	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	0.35	0.29	0.26
$\sigma(\Delta nx)/\sigma(\Delta q)$	0.07	0.42	0.28	0.16
Business cycle				
$\sigma(\Delta c)/\sigma(\Delta GDP)$	1.1	0.99	0.99	1.0
$\rho(\Delta c, \Delta GDP)$	0.94	0.51	0.61	0.74
$\rho(\Delta I, \Delta GDP)$	0.81	0.56	0.62	0.67
$\rho(\Delta GDP, \Delta GDP^*)$	0.88	0.46	0.63	0.85
$\rho(\Delta c, \Delta c^*)$	0.90	0.55	0.66	0.82
$\rho(\Delta I, \Delta I^*)$	0.55	0.96	0.97	0.99

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.

Figure 17: Risky steady state: Simulation from 1999Q1-2023Q1

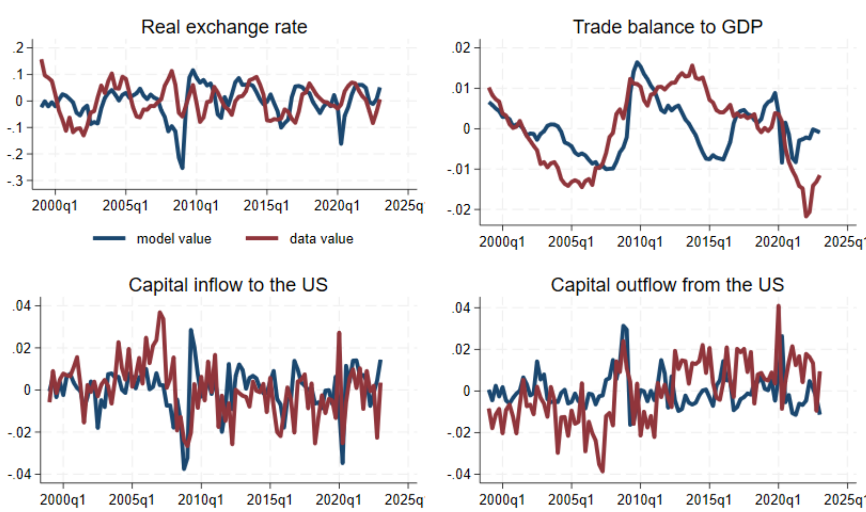


Table 18: Risky steady state: Model implied regression from 1999Q1 to 2023Q1

	Panel regression of G10 currenices (quarterly)	Model implied exchange rate regression
	(1)	(2)
$\Delta\eta_t$	-1.65**	-1.20
	(0.76)	
$\Delta(i-i^*)_t$	-2.61***	-3.72
	(0.97)	
η_{t-1}	-2.08**	0.16
	(0.87)	
$(i-i^*)_{t-1}$	-0.44**	0.09
	(0.22)	
s_{t-1}	-0.06**	-0.07
	(0.02)	
Observations	739	96

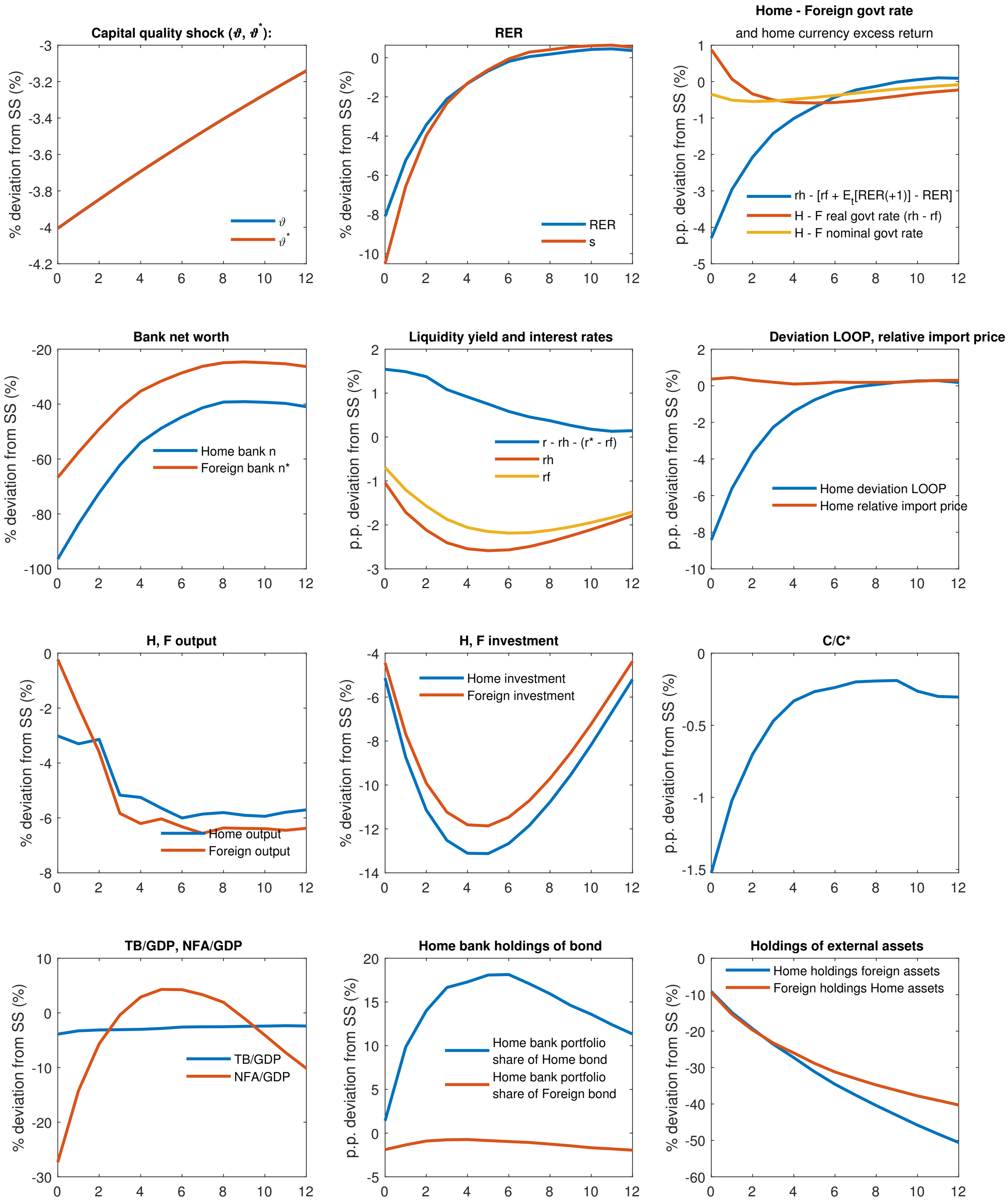
Notes: Model implied regression is performed with 96-quarter observations along the simulated path mimicking the 1999Q1-2023Q1 period.

Table 19: Risky steady state: Model implied regression from 1999Q1 to 2023Q1

	Quarterly empirical regression of US holding of US Treasury	Model regression of US holding of UST	Quarterly empirical regression of Foreign holding of US Treasury	Model regression of Foreign holding of UST
	(1)	(2)	(3)	(4)
$\eta_{j,t}$	1.05***	0.73	-1.39***	-1.75
	(0.36)		(0.51)	
Observations	71	96	71	96

Notes: Model implied regression is performed with 96-quarter observations along the simulated path mimicking the 1999Q1-2023Q1 period. Data regression sample is 2003Q1 to 2021Q1.

Figure 18: Risky steady state and second order approximation: Baseline with 4% global financial shock (ϑ, ϑ^*)



Notes: The figure shows IRF of a 4% global financial shock.

G 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:

$$E_t \sum_{t=s}^{\infty} (\beta_t)^t \left[\frac{(C_t)^{1-\sigma} - 1}{1-\sigma} + v_h(D_{h,t}) + v_f(S_t D_{f,t}) - \frac{\chi}{1+\psi} (H_t)^{1+\psi} \right] \tag{125}$$

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:

$$\begin{aligned} P_t C_t + B_t + D_{h,i,t} + S_{t+1} D_{f,i,t} + Q_t K_{h,t+1} + Q_t^* K_{f,t+1} = \\ W_t H_t + R_t B_{t-1} + R_{h,t+1} D_{h,t-1} + S_{t+1} R_{f,t+1} D_{f,t-1} + (\tilde{R}_{k,t} \vartheta_t) Q_t K_t + (S_t \tilde{R}_{k,t}^* \vartheta_t^*) Q_t^* K_{f,t} + \Pi_t + TR_t - T_{s,t} \end{aligned} \tag{126}$$

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

$$E_t \Lambda_{i,t+1} \left(R_{h,t+1} - R_{t+1} \right) = \kappa_{h2} D_{h,t} - \kappa_{h1} \tag{127}$$

$$E_t \Lambda_{i,t+1} \left(\frac{S_{t+1}}{S_t} R_{f,t+1} - R_{t+1} \right) = \kappa_{f2} \frac{S_{t+1}}{S_t} D_{f,t} - \kappa_{f1} \tag{128}$$

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

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

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

Figure 19 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).

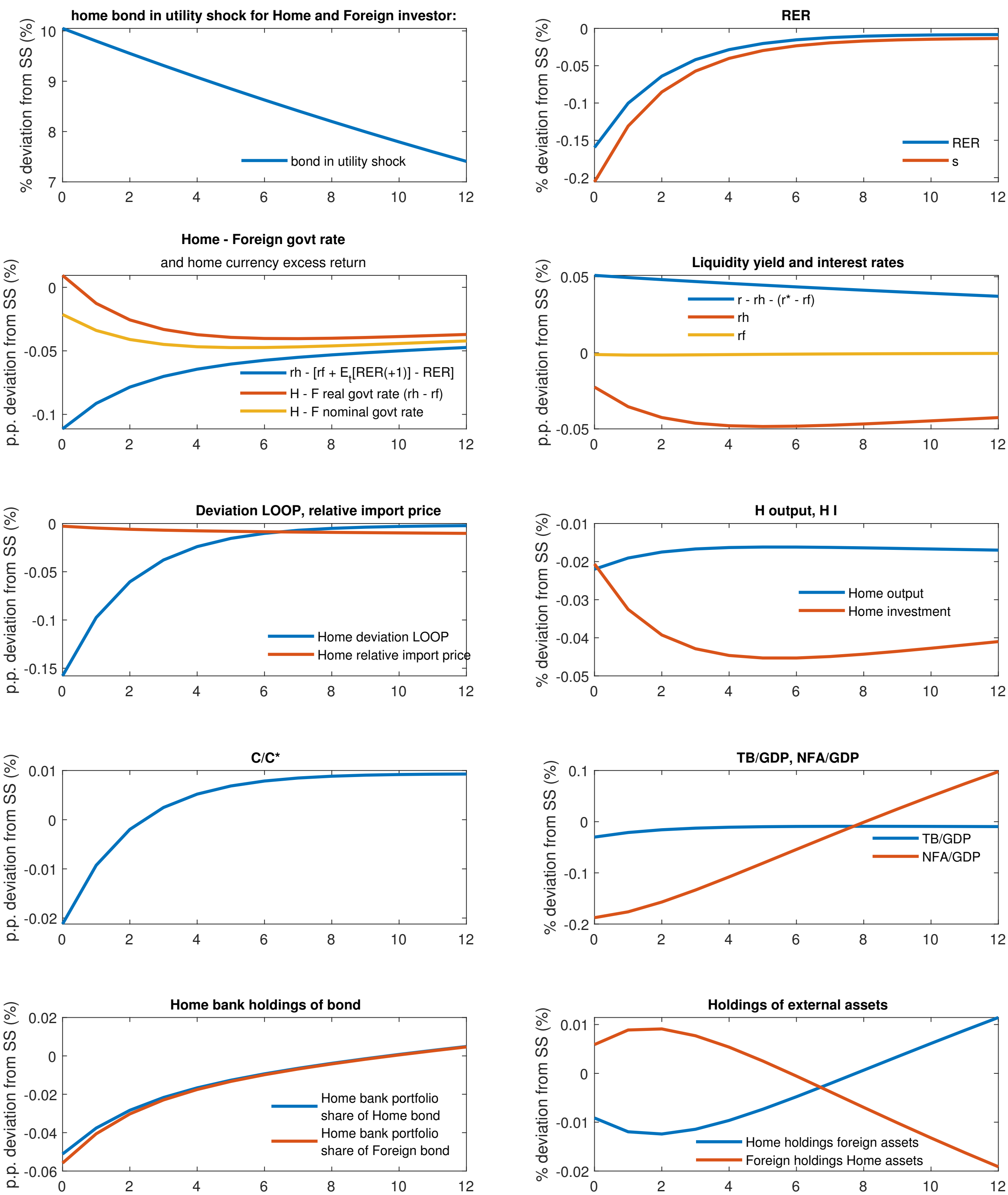
On the goods market side, the dollar appreciation results in a minor change in relative prices but leads to a significant deviation from LOOP (row 3, column 1). Regarding output, the dollar appreciation is linked to a decline in Home output (row 3, column 2), as well as reductions in Home investment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

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 (sd) 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 sd of TFP shock is set at 0.0107, the sd of discount rate shock is set at 0.001 and the sd of bond preference shock (ω_t^h and ω_t^f) is set at 0.15.

Figure 19: Bond in utility: 10% increase of Home and Foreign investors utility to home bond $(\omega_t^h, \omega_t^{h*})$



In Table 20, we report the regression tables as in 5. 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 20: Bond in utility: Model implied regression and the empirical counterpart

	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**	-1.41	-2.00
	(0.76)		
$\Delta(i-i^*)_{j,t}$	-2.61***	-3.07	-2.16
	(0.97)		
$\eta_{j,t-1}$	-2.08**	0.03	-0.05
	(0.87)		
$(i-i^*)_{j,t-1}$	-0.44**	0.02	-0.03
	(0.22)		
s_{t-1}	-0.06**	-0.005	-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.

Table 21: Bond in utility: 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.

However, Table 21 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 22 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 22: Bond in utility: Long-run moments

	Data moments of Eurozone vs US	Model moments low volatility state	Model moments unconditional	Model moments 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
$\rho(\Delta s)$ (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
$corr(\Delta nx, \Delta q)$	-0.06	0.55	0.45	0.18
$\sigma(\Delta nx)/\sigma(\Delta q)$	0.07	0.69	0.62	0.43
$\sigma(\Delta c)/\sigma(\Delta GDP)$	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.

H Simple version of the model for analytical results

The full model described above has many moving parts and cannot be easily summarized in analytical form. Here we take a greatly stripped-down version of the model to show the intuition behind the key results. Here we assume a) banks last for just one period, so $\theta = 0$, b) no capital adjustment costs, so $\psi = 0$, c) no quadratic terms in the pledgeable collateral values, d) equal values of the pledgeability parameters for both Home and Foreign banks, e) one step ahead nominal price setting and (as in the main text) LCP in goods pricing, and f) Home banks hold all the equity in the home capital stock. None of these assumptions is necessary for the main results of the paper, but collectively they help illustrate some of the essential features of the model.

In this case, we may write the excess return expressions for the Home Bank's investment in Home and Foreign bonds, in real terms as:

$$E_t \tilde{\Omega}_{i,t+1} r_{h,t+1} = 1 + \lambda_t \kappa_{h1}, \; E_t \tilde{\Omega}_{i,t+1} r_{f,t+1} \frac{RER_{t+1}}{RER_t} = 1 + \lambda_t \kappa_{f1} \tag{129}$$

The unit term of the right hand side comes from the fact that the banks and households have equivalent stochastic discount factors when banks operate for just one period. Then, taking logs of both sides of these conditions noting that $\log(1+\lambda_{i,t}\kappa_{h1}) \approx \lambda\kappa_{h1}$, and taking the difference we have the approximation:

$$\log r_{h,t+1} - \log r_{f,t+1} - (E_t \log RER_{t+1} - \log RER_t) = \lambda_t(\kappa_{h1} - \kappa_{f1}) \tag{130}$$

A similar approximation applies for the Foreign bank. Since the approximations are identical this must imply that the tightness of the collateral constraints are identical, so $\lambda = \lambda_t^*$, up to a first order.

A global decline in capital quality leads to a tightening of the collateral constraints for both banks so λ_t increases after the shock. If there were no 'collateral advantage', then this would have no consequences for the left hand side of (3), and UIP would hold up to first order, despite the presence of financial intermediaries in the model. But when $\kappa_{h,1} - \kappa_{f,1} < 0$, given the monetary policy rule for Home and Foreign lending rates, this leads to an immediate real appreciation of the dollar, and a rise in the measured convenience yield on US dollar bonds.

In addition to condition (129), in the set of assumptions described above, we have the condition for the Foreign country

$$E_t \tilde{\Omega}^*_{i,t+1} r_{h,t+1} \frac{RER_t}{RER_{t+1}} = 1 + \lambda_t \kappa_{h1} \tag{131}$$

Using the same approximations as above, and taking the difference between the approximations to (129), we can establish the condition

$$\sigma E_t(\Delta c_{t+1} - \Delta c_t) = E_t \log RER_{t+1} - \log RER_t \tag{132}$$

where $\Delta c_t = \log C_t - \log C_t^*$ is the log difference in consumption. For this special case the model has the same properties as the standard incomplete markets economy without balance sheet constraints. The expected real depreciation of the US dollar leads to a rise in the expected Home consumption growth relative to Foreign consumption growth. Iterating forward on (132) gives

$$\Delta c_t = E_t \sum_{j=0}^{\infty} (\log RER_{t+1+j} - \log RER_{t+j}) + E_t \lim_{s=\infty} \Delta c_{t+s} \tag{133}$$

A property of our model (see Figure 2 in the text) is that the real exchange rate converges monotonically, and that Δc is stationary. This implies that $\Delta c_t < 0$, so the immediate impact of a capital quality shock is that Home consumption falls relative to Foreign consumption.

Based on the assumptions made above, the optimal equity decisions for Home and Foreign firms are described as

$$E_t \Omega_{i,t+1} \tilde{r}_{k,t+1} = 1 + \lambda_t \kappa_{Kh1}, \; E_t \Omega^*_{i,t+1} \tilde{r}^*_{k,t+1} = 1 + \lambda_t^* \kappa_{Kh1} \tag{134}$$

Using the same approximations, and taking the difference between the Home and Foreign approximations, again noting that up to a first order $\lambda_t = \lambda_t^*$, we get:

$$\log \tilde{r}_{k,t+1} - \log \tilde{r}^*_{k,t+1} = \sigma E_t (\Delta c_{t+1} - \Delta c_t) \tag{135}$$

This indicates that the home country's marginal product of capital must rise relative to that of the foreign country following a capital quality shock. Thus, Home investment falls relative to Foreign investment, as illustrated in Figure 2 of the text.

Finally, from the market clearing conditions from the home and foreign country in this special case model we have $\Delta y = (2\omega - 1)(\Delta c_t + \Delta I_t)$. Where $\Delta y_t = \log Y_t - \log Y_t^*$, and $\Delta I_t = \log I_t - \log I_t^*$. Since relative home consumption and relative home investment both fall in response to a negative capital quality shock, relative home output must also fall. In this case, with predetermined nominal prices and LCP, there is no contemporaneous expenditure switching effect on relative demand, despite the real appreciation of the home currency.

H.1 A simple exposition of retrenchment

A robust feature of our results is that a financial crisis gives rise to portfolio retrenchment. One key underlying force behind retrenchment is the real appreciation of the US dollar. In contrast to the popular narrative that an increase in foreign demand for safe US assets leads to a real dollar appreciation, and consistent with the empirical evidence, our model implies that foreign banks substitute away from US dollar assets towards domestic assets during the crisis. To see this force in our simplified model, note that under our suite of assumptions described above, the binding collateral constraints on the home and foreign banks are written

$$V_t = \kappa_{Kh1} K_{t+1} + \kappa_{h1} d_{h,t+1} + \kappa_{f1} RER_t d_{f,t}, \; V_t^* = \kappa_{Kh1} K^*_{t+1} + \kappa_{h1} \frac{d^*_{h,t+1}}{RER_t} + \kappa_{f1} d^*_{f,t}$$

In response to the fall in net worth, the left hand side of both these constraints fall, requiring the banks to either reduce their total balance sheet size, or rearrange their portfolios (or both) to reduce the balance sheet cost of borrowing. Since the home asset is the least collateral costly, a reduction in the balance sheet cost can partly be achieved by a substitution from costly foreign assets to less costly home assets. But since the real appreciation increases the value of US assets for the foreign bank, and in equilibrium all US dollar bonds must be purchased by the banking system, there is a reallocation of US assets towards the US bank. A analogous argument holds for the holdings of foreign assets by the foreign bank.

I Simple version of the model for relationship of collateral quality and settlement uncertainity

Take a very simple two period partial equilibrium model where there is a large number of households who make deposits in banks. All depositors are identical, and make savings choices so that their deposit schedule can be written as

$$R_D(D)$$

where $R_D^{'}(D) > 0$. R_D is the deposit rate, and D is the total amount of deposits. This represents a supply curve of bank deposits.

Banks start the first period with a given net worth N, and accept deposits from households, investing these deposits in government bonds, so that

$$N + D = B_T + B_E$$

Banks can invest in two types of bonds; dollar bonds (treasury bills), or euro bonds (e.g. bunds). Unlike the text, we don't distinguish between home and foreign banks, since this is not our main interest here, and for the same reason we abstract from differences in currencies.

Assume also that banks are the only holders of bonds, so that higher bank demand for bonds drives up the price of these bonds, or drives down the rate of return. Thus, there is an implicit price schedule $R_T(B_T)$, and $R_E(B_E)$, with $R_T^{'}(B_T) < 0$ and $R_E^{'}(B_E) < 0$.

We assume that bonds are settled in different settlement systems. In particular, U.S. Treasuries are held on the Fedwire Securities platform, while Bunds are settled through the Eurozone's TARGET2 system. As discussed in the main text, banks hold US Treasuries directly on the Fedwire platform, and this ensures that they can be returned for cash at face value with a high degree of certainty. For non US bonds, there is more heterogeneity in the value that can recovered in the event that a debtor defaults. This difference translates into a difference in the fraction of the asset that can be recovered in the event that a bank chooses to divert the assets and not repay depositors. In particular, if we assume that $1-\theta_T$ is the recoverable share of the value of Treasuries, and $1-\theta_E$ the equivalent for Bunds, then we can assume that $1-\theta_T > 1-\theta_E$,or equivalently $\theta_E > \theta_T$. As a result, if the bank attempts to divert the assets and not repay depositors, it can obtain at most a fraction θ_T of the value of Treasuries, and θ_E of the value of Bunds. Thus, if the bank abscond with the funds, it could obtain at most

$$\theta_T R_T B_T + \theta_E R_E B_E$$

Given this incentive to divert funds, depositors will only lend to banks whose profits while staying in business are at least as great as the payoff they would get from diverting funds. Banks profits are denoted as

$$R_T B_T + R_E B_E - R_D D$$

Thus, banks must operate subject to the constraint:

$$\underbrace{R_T B_T + R_E B_E - R_D D}_{\textbf{bank profit if running the business regularly}} \geq \underbrace{\theta_T R_T B_T + \theta_E R_E B_E}_{\textbf{bank profit if running away from the business}}$$

As discussed at length in the main text, this makes US Treasuries superior collateral in the sense that they place less constraint on the bank's balance sheet.

Banks therefore choose bonds B_T and B_E to maximize profits subject to the above constraint, as well that the balance sheet identity:

$$N + D = B_T + B_E$$

The first order conditions imply that

$$R_T - R_D = \frac{\lambda}{1+\lambda}\theta_T R_T$$
$$R_E - R_D = \frac{\lambda}{1+\lambda}\theta_E R_E$$

where λ is the Lagrange multiplier on the minimum profit constraint.

In equilibrium the profit constraint will be binding so that:

$$(R_T(1-\theta_T) - R_D)B_T + (R_E(1-\theta_E) - R_D)B_E + R_D N = 0$$

Given the pricing schedules of the bonds $R_T(B_T)$ $R_E(B_E)$ and the supply function of deposits $R_D(D)$ along with the balance sheet constraint, $D = B_T + B_E - N$, these three equations determine bond holdings B_T and B_E, as well as the Lagrange multiplier λ.

Result 1

The fact that $\theta_E > \theta_T$ ensures that the return on treasuries is less than that on bunds.

$$R_E > R_T$$

In addition, the return on both treasuries and bunds must exceed the deposit rate if the profit constraint is binding.

$$R_E > R_D, \;\; R_E > R_D$$

Result 2

The binding profit constraint also must imply that

$$(R_T(1-\theta_T)-R_D)B_T+(R_E(1-\theta_E)-R_D)B_E<0$$

, or

$$R_D>\frac{R_T(1-\theta_T)B_T+R_E(1-\theta_E)B_E}{(B_T+B_E)}$$

This says that the return on deposits must exceed the amount that depositors would obtain if they had to recover the bonds in the event that the banks absconded with the funds, relative to the total quantity of bonds. Equivalently, this implies that on average, the return on deposits must exceed the potential recovery value of the assets that depositors would receive in the event of default.

Result 3

A fall in bank net worth raises the excess return on bunds. To see this note from the bank's first order conditions we have that

$$\frac{R_E}{R_T}=\frac{\left(1-\frac{\lambda}{1+\lambda}\theta_T\right)}{\left(1-\frac{\lambda}{1+\lambda}\theta_E\right)}$$

A fall in bank net worth N will tighten the constraint on bank profits, leading to a rise in $\frac{\lambda}{1+\lambda}$. Given that $\theta_E>\theta_T$, this must raise the right hand side of the above expression. Thus $\frac{R_E}{R_T}$ must increase.