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Abstract

Understanding gross capital flows is increasingly viewed as crucial for both macroeconomic and financial stability policies, but theory is lagging behind many key policy debates. We fill this gap by developing a 2-country DSGE model that tracks domestic and cross-border gross positions between banks and households, with explicit settlement of all transactions through banks. We formalize the conceptual distinction between cross-border saving and financing, which often move in opposite directions in response to shocks. This matters for at least four policy debates. First, current accounts are poor indicators of financial vulnerability, because in a crisis creditors stop financing debt rather than current accounts, and because following a crisis current accounts are not the primary channel through which balance sheets adjust. Second, we re-interpret the global saving glut hypothesis by submitting that US households do not finance current account deficits with foreigners' physical saving, but with digital purchasing power, created by banks that are more likely to be domestic than foreign. Third, Triffin's current account dilemma is not in fact a dilemma, because the creation of additional US dollars requires dollar credit creation by domestic or foreign banks rather than US current account deficits. Finally, we show that the observed high correlation of gross capital inflows and outflows is overwhelmingly an automatic consequence of double entry bookkeeping, rather than the result of two separate and synchronized sets of economic decisions.

JEL Classification: E44, E51, F41, F44

Keywords: bank lending, International Capital Flows, Gross capital flows, current account, money creation, Sudden stops, global saving glut, Triffin's dilemma

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1. Introduction

The open economy macroeconomics literature has for some time been emphasizing the importance of gross capital flows, and of gross asset and liability positions, for both financial and macroeconomic stability (Obstfeld (2010, 2012, 2013), Shin (2012)). On the empirical front, better data have allowed for an increasingly detailed study of cross-border (and domestic) gross flows and gross positions.[1] However, on the theoretical front the vast majority of the literature continues to rely on net capital flow models that were first developed much earlier.[2] These models record exchanges of current physical goods or resources[3] against present or future physical resources, in contemporaneous or intertemporal barter exchanges. The latter, in an open economy setting, represent *net* capital flows, and the deferred payment claims on physical resources are typically referred to as international bonds.

There are several reasons why such models are not sufficiently detailed to represent *gross* capital flows and stocks. First, they lack a separate monetary-financial dimension whereby final settlement for any purchase of physical resources must use a financial (non-physical) medium of exchange, whose creation, circulation and destruction is separate from the creation, circulation and consumption of physical resources. In modern economies this medium of exchange function is almost exclusively performed by banks' gross liabilities, which we will refer to as deposits or deposit money. Second, this medium of exchange is also required for trades in gross financial assets, which are far larger than physical resource trades in modern economies. Third, an economy's banking system has the capacity not merely to facilitate the transfer of but also to create (and destroy) this medium of exchange, mostly through the granting of new loans but also through the purchase of existing assets. There are therefore generally very large differences between the sizes, and the changes in size over time, of physical resource stocks and of financial sector balance sheets. Fourth, any cross-border purchases require settlement, which in most cases takes place through the interbank accounts of domestic and foreign banks, and which necessarily affects banking sector and household sector balance sheets. A model without a banking sector that provides the medium of exchange and final settlement can therefore not fully represent either the size or the mechanics of gross capital flows and stocks.[4] Finally, as shown by Borio and Disyatat (2011), empirically cross-border bank loans and bank deposits account for a very large share of major economies' overall cross-border gross positions, and should therefore be part of a complete model.

Our paper addresses these issues by building a 2-country New Keynesian DSGE model that fully integrates endogenously determined gross financial flows and stocks between domestic and foreign banks and households, where the latter include both households and manufacturing firms, into a framework with the usual physical resource flows. Domestic banks extend domestic currency household loans to both domestic and foreign households, against the collateral of domestic or foreign land, and maintain interbank settlement accounts in both domestic and foreign currencies. Domestic and foreign currency bank loans create domestic and foreign currency bank deposits for a representative household that needs a composite of the two currencies to lower the cost of purchasing consumption goods.

[1] See Avdjiev et al. (2017) and Davis et al. (2019) for examples.

[2] See Obstfeld and Rogoff (1995, 1996). More recent examples include Caballero et al. (2008), Ueda (2012), Dedola et al. (2013), Justiniano et al. (2014) and Banerjee et al. (2016).

[3] Physical goods/resources include services. The latter, as in the national accounts under the heading of FISIM (financial intermediation services, indirectly measured), include cross-border net interest payments.

[4] See Appendix A for a more extensive discussion and some illustrative examples.

In this model, the granting of new loans represents the outcome of the simultaneous solution of banks' and households' optimization problems over gross financial asset and liability positions rather than, as in typical net flow models, their preferences over net physical flows such as consumption and labor supply. Similar to the closed-economy gross flow DSGE model of Jakab and Kumhof (2020), banks can therefore instantaneously increase loans in response to changes in preferences over gross positions, and this can be completely disconnected from the underlying physical resource flows and stocks of the economy.[5] Borio and Disyatat (2011) refer to this much greater elasticity of preferences over gross positions as the "excess elasticity" of the financial system. We use this model to show that net and gross foreign liabilities can send very different signals for a country's vulnerability to financial shocks, and that net foreign financing and foreign saving are entirely different concepts that for many shocks move in opposite directions. We then show that this has major implications for several key policy debates in open economy macroeconomics.

We emphasize that when we refer to banks, bank loans and bank deposits, we are referring to the institutions, assets and liabilities of the entire financial system, which includes both banks and non-bank financial institutions (NBFIs). As shown in Pozsar (2014), banks are the central actors in the financial system, because their ability to create new deposit money implies that the system as a whole has the ability to create new deposit money, even if other institutions such as NBFIs only have the ability to intermediate but not to create such money. Furthermore, when we refer to bank deposits, we are referring to all bank liabilities except equity as having monetary functions, and therefore as representing a very broad (interest-paying) monetary aggregate with diminishing marginal liquidity services.[6,7] With this interpretation, we assume that the deposit liabilities of domestic and foreign banks exhibit high but finite (imperfect) liquidity-driven substitutability, leading to systematic deviations from uncovered interest parity (UIP). As a result, our model implies that the real exchange rate is jointly determined by both excess demands for goods and for currencies, so that the latter have real effects.

Bond portfolio holdings are an increasingly important part of observed gross financial positions, as international debt securities issuance has risen strongly in the aftermath of the 2008 Great Financial Crisis (Aldasoro and Ehlers (2018)). Our model goes some way towards capturing the financial and real effects of additional bond issuance by non-banks. If the bonds are held by banks, they are equivalent to bank loans in their effect on financial positions and on real activity. If the bonds are held by other non-banks, they are netted out of financial positions but nevertheless stimulate real activity. This is because any bond issuance results in a transfer of existing bank deposits from the purchaser to the issuer, who generally then spends the deposits, thereby increasing the velocity of bank deposits. Shocks to velocity can be readily studied in our model, and result in a combination of higher output and smaller bank balance sheets.

[5] Jakab and Kumhof (2020) show that, empirically, variations in credit are by far the most important mechanism whereby an economy's aggregate financial system grows or shrinks its gross positions, which include cross-border gross positions. By contrast, bond (or equity) transactions between the banking system and non-banks play a negligible role.

[6] As discussed in the literature on divisia indices of money (Barnett et al. (1984), Anderson et al. (2018)), the moneyness of different bank liabilities is a continuum, ranging from low interest checking accounts with high liquidity to higher interest term deposits or bank bonds with lower liquidity. A recent literature has also stressed the liquidity features of safe bonds, see Krishnamurthy and Vissing-Jorgensen (2012) for the seminal contribution.

[7] This offers a different perspective on Schularick and Taylor (2012), who have argued that a weaker empirical relationship between credit and the comparatively narrow monetary aggregates produced by statistical agencies reduces the reliability of traditional monetary models of credit growth. The correlation between our model's very broad monetary aggregate and credit is very close to one by construction.

The role of the banking system in the modern money creation process has recently been emphasized in many central bank publications, including the Bank of England (McLeay et al. (2014a,b)), the BIS (Borio and Disyatat (2011, 2015)), Bundesbank (2017) and the Reserve Bank of Australia (Doherty et al. (2018)).[8] It has been formalized in closed economy settings by Goodfriend and McCallum (2007), Jakab and Kumhof (2020), Kumhof and Wang (2019), and Rungcharoenkitkul et al. (2019), and in the open economy by Cesa-Bianchi et al. (2019). Such models can directly incorporate the many advances that the DSGE literature has recently made in the modelling of banks. This is because their critical feature is not banks' optimization problem, nor the labelling of bank liabilities as money, but the budget constraints of banks' customers. Our model is closely related to Cesa-Bianchi et al. (2019), but our focus is on capital flows rather than exchange rate determination, and we therefore allow for a richer set of cross-border gross positions. We briefly discuss the implications of our model for exchange rate determination in Appendix B.

Several recent papers have started to allow for cross-border gross positions between different asset classes. These include bonds issued in one currency to the foreign economy in order to acquire bonds issued in a different currency by the foreign economy (Devereux and Saito (2006), Devereux et al. (2018), Gabaix and Maggiori (2015)), bonds issued to the foreign economy in order to acquire equities issued by the foreign economy (Fostel et al. (2015), Gourinchas et al. (2017)), or equities issued to the foreign economy in order to acquire equities issued by the foreign economy (McGrattan and Prescott (2010), Caballero and Simsek (2019)). These analyses have yielded many insights, but they abstract from the role of the banking system, an inseparable component of all cross-border financial flows and stocks. They therefore cannot fully account for some key features of gross capital flows. Most importantly, any gross financial inflow must be matched by an inseparable gross outflow as a result of settlement mechanics and double-entry bookkeeping, rather than of an economic mechanism that synchronizes separate decisions by domestic and foreign investors. The omission of settlement through the banking system also overlooks perhaps the most important gross flows of all, namely *financing* flows, which create new aggregate purchasing power by simultaneously creating new gross bank assets and bank liabilities in the same currency. As observed by Lane and McQuade (2013), "open-economy models that seek to capture the macroeconomic impact of capital-flow cycles should incorporate their impact on domestic credit conditions".

Because a clear distinction between cross-border payments for physical resources and cross-border payments for financial assets is at the heart of our analysis and its applications, we adopt a terminology that reflects this. Consistent with the treatment in the balance of payments[9], when we refer to physical resources or to financial assets as being transferred cross-border, this refers to the border between domestic and foreign residents rather than the physical border between economies. Crossing the border therefore includes the delivery of goods from a foreign to a domestic resident within the physical border of the foreign economy, and also the delivery of a deposit held at a foreign bank from a domestic to a foreign resident who deposits it at the same foreign bank.

We denote as a cross-border **net payment flow** the cross-border transfer of a medium of exchange for settlement, from the buyer to the seller, whose inseparable counterpart is a flow of physical resources that crosses the border in the opposite direction. In the balance of payments, one leg of such a transaction, the physical resource flow, is recorded in the current account, while its matching counterpart, the net payment flow, is recorded in the financial account. Net payment flows are therefore the exact mirror image of the current account. The existing net flows literature

[8] See also the recent exposition of the credit mechanics approach in Decker and Goodhart (2018).
[9] See International Monetary Fund (1993).

exclusively refers to these types of flows as capital flows and omits all other flows. But our model differs from this literature even for net flows because of its explicit modeling of net payment flows through the banking system, and their effects on gross as well as net positions.[10]

We denote as a cross-border **financial flow** the transfer of a medium of exchange, from the buyer to the seller, whose inseparable counterpart is a flow of other gross financial assets that crosses the border in the opposite direction, without any role for physical resource flows.[11] In the balance of payments, both legs of such a transaction are therefore recorded in the financial account.

Net payment flows and financial flows are therefore almost completely unrelated concepts. As emphasized by Borio (2016), payment flows mainly reflect the global pattern of goods production and goods trade networks, while financial flows reflect the global pattern of liquidity production and financing networks. Because financial flows and stocks are generally far larger than net payment flows and net foreign asset positions[12], their omission is the main reason why net flow models cannot adequately represent gross capital flows and stocks.

We also fix the terminology for interbank accounts, which are used by banks to settle and clear retail payments across borders, by reference to banking practice. A deposit held by a domestic bank in a foreign bank is a **nostro account**, while a loan obtained by a domestic bank from a foreign bank is a **vostro account**. Banks typically maintain a pair of nostro and vostro accounts in the currency of a foreign economy with correspondent banks located in that economy. For any currency, the net balance between all global nostro and vostro accounts represents the amount of central bank reserves in that currency. For simplicity, central bank reserves will be in zero net supply in our model.

Our model provides a coherent framework for the analysis of key characteristics of international capital flows that can present conceptual difficulties within net-flow models. To illustrate this we study impulse responses for a range of financial and real shocks. We begin with a quintessential capital inflow shock, a **financial inflow shock**, modelled as an exogenous increase in foreigners' demand for domestic currency deposits. The shock triggers a gross financial flow into domestic banks away from foreign banks, and illustrates why any financial inflow is necessarily a gross inflow that is accompanied by an equal and offsetting gross outflow. Specifically, in this case the inflow is an increase in foreigners' deposits in domestic banks, after they deposit foreign payment instruments ("checks") that are drawn on their foreign bank accounts. The corresponding outflow is an increase in domestic banks' interbank nostro or vostro net claims on foreign banks, as domestic banks submit the foreign payment instruments for collection and settlement. Foreign banks settle by transferring foreign currency reserves equal to the value of the payment instruments to domestic banks. The two gross flows sum to zero on impact, and therefore have zero effects on net flows, in other words on the current account.

If domestic and foreign banks are required, by regulation or their own risk management frameworks, to eliminate the currency mismatches that arise from the settlement of gross inflows, there can be general equilibrium changes in real exchange rates and real interest rates that also affect real variables and the current account. For the financial inflow shock, the increase in demand for

[10] Gross goods flows, and therefore gross payment flows, are absent from our model.

[11] For example, when the foreign buyer of a domestic bond pays using a foreign bank deposit, the gross inflow is his increase in holdings of domestic bonds, while the gross outflow is the bond seller's increase in holdings of foreign bank deposits.

[12] See Borio and Disyatat (2015).

domestic currency increases its relative convenience yield and thereby reduces its relative financial yield. This triggers three effects that satisfy the demand of foreign households for greater relative holdings of domestic currency. First, it causes domestic households to substitute away from domestic currency. Second, it causes domestic banks to increase their loans to create more domestic currency. And third, it causes foreign banks to decrease their loans to create less foreign currency. The credit creation flows are domestic gross financial flows, in that they simultaneously create (or destroy) domestic currency assets and liabilities, which are again inseparably linked. Domestic households' switch to foreign currency is a gross outflow that matches the gross inflow due to the shock to foreign households' preferences. Domestic and foreign banks end up with zero net exposures to each other. Their respective currency mismatches can then be eliminated by swapping gross exposures in their interbank accounts.

We also consider a number of quantitative exercises to shed light on important policy debates, including the use of current accounts as indicators of financial vulnerability, the global saving glut hypothesis, Triffin's current account dilemma and interpretations of the high observed correlation of gross capital inflows and outflows.

The global saving glut hypothesis (Bernanke, 2005), put forward to explain the persistent US current account deficits during the late 1990s-early 2000s, is one instance where the model provides a new perspective with potentially very different policy implications. We first study a standard **physical saving shock** to foreign preferences, which increases foreign physical saving and triggers a US current account deficit in general equilibrium. Such shocks, along with technology shocks, have been frequently used in net flow models to study the global saving glut. But in our framework they cannot reproduce a key feature of the saving glut episode: gross domestic and cross-border balance sheet positions increased by far more than GDP, and were much more volatile, than implied by such shocks. Furthermore, we show that for these shocks the current account contains no information about the direction of foreign financing flows, which in fact *decline*.

Meanwhile a **domestic credit supply shock**, an increase in US credit to US households that stimulates US demand, provides a very plausible alternative explanation of the saving glut phenomenon. This shock gives rise to a US current account deficit, but in this case accompanied by a US credit glut, with changes in balance sheet positions that are an order of magnitude larger than changes in GDP, congruent with the data. This shock emphasizes financing, the access to existing or newly created purchasing power, rather than foreign saving, as the factor that allows domestic households to pay for additional imports. But that financing can be obtained domestically as well as abroad. This shock suggests very different remedies to the saving glut phenomenon, because it identifies US credit rather than non-US physical saving as its trigger.

A "sudden stop" (Calvo (1998)) is a **foreign credit shock** that results in a sharp drop in foreign bank financing to domestic households. This shock reduces domestic purchasing power, and thereby real activity and imports. The current account improves, so that by definition foreign saving decreases by the same amount. But foreign financing immediately drops by approximately 10 times more than foreign saving. This represents a large and instantaneous stock demand for loan repayments that cannot be met by current account flow adjustments. Instead, households repay loans by drawing on their existing deposits, and by approaching domestic banks to obtain additional loans to finance repayment of foreign loans. Financial vulnerability therefore depends mostly on the size, and the susceptibility to sudden stops, of an economy's different classes of gross liabilities. The current account is not informative, as it is merely the by-product of the reversal in gross flows, and plays virtually no role in satisfying the demands of foreign creditors.

The rest of the paper is organized as follows. Section 2 discusses four key policy debates for which a more complete modelling of gross capital flows is critical. Section 3 presents the model and its calibration. Section 4 studies the model's impulse responses and their relation to the policy debates discussed in Section 2. Section 5 concludes.

2. Gross Capital Flows and Open Economy Policy Debates

As argued in Borio (2016), the key problem in many policy debates is the conflation of two distinct concepts, saving and financing. Saving is a goods market concept, it denotes output not consumed. Financing is a money market concept, it represents the creation of purchasing power in an accepted settlement medium. In practice this is largely commercial bank money that is created, save for the role of collateral, independently of physical resources. This ability of the banking system to create money is behind the Borio and Disyatat (2011) "excess elasticity" of the financial system, which implies that the magnitudes of physical resource flows and stocks and of non-physical financing flows and stocks are disconnected.

However, the notion in many policy debates that "saving finances investment", or in open economies that "saving finances the current account" (Krugman (2007), Blanchard and Milesi-Ferretti (2009, 2011)), treats saving and financing as identical. Borio (2016) explains that this is because the underlying modeling frameworks do not separately track monetary financing flows, and therefore implicitly represent goods themselves as the medium of exchange. Borio (2016) calls this "real economies disguised as monetary economies".[13]

We now illustrate the importance of distinguishing between saving and financing in the context of four key policy debates. These are the use of current accounts as indicators of financial vulnerability, the global saving glut hypothesis, Triffin's current account dilemma, and interpretations of the high correlation of gross capital inflows and outflows. In each case, we highlight the analytical pitfalls of conflating saving with financing, and why this can have a major effect on policy conclusions.

2.1. Current Accounts as Indicators of Financial Vulnerability

The distinction between saving and financing matters for this debate because in a financial crisis, creditors do not stop financing current accounts, they stop financing debt.

An economy's balance sheet vulnerability to foreign shocks is determined primarily by the amount and composition of its gross rather than its net foreign debt. An economy with very low net foreign liabilities can nevertheless be highly vulnerable if its gross foreign liabilities are very large. And in response to large financial shocks that require the immediate repayment of a sizeable volume of debt, changes in the current account cannot make any contribution on impact, and only a small contribution over time. Instead, they mostly reflect the macroeconomic adjustments that follow such shocks. At the same time, gross capital flows have zero immediate impact on current accounts, and in some cases even zero longer-run effects, while potentially completely changing the magnitude and risk profile of gross debt burdens.

[13] Some net flow models incorporate physical cash, but cash is almost everywhere negligible in terms of the overall value of transactions, especially for cross-border trade.

An important caveat is that an economy that runs large current account deficits over many years must eventually acquire not only large net but also gross foreign liabilities. We therefore do not argue that the current account is necessarily irrelevant for an economy's financial vulnerability. Rather we argue that gross liabilities are far more important, that they can change very quickly and for reasons that are completely unrelated to the current account, and that they are often the driver of the current account rather than the reverse.

The net-flow perspective is limited in its ability to study balance sheet vulnerability, because it does not distinguish between foreign financing and foreign saving. Instead, it interprets the current account, a goods market concept, as an indicator of the availability of foreign financing.[14] As a result, current account deficits and net foreign liabilities have long been interpreted as sufficient statistics for an economy's financial vulnerability and risks of "sudden stops" in external funding (Calvo (1998)). Similarly, global imbalances are often treated as synonymous with current account imbalances (Group of 20 (2011)), and financial crises are deemed to require current account adjustments (International Monetary Fund (2014)). This viewpoint is increasingly being challenged. Obstfeld (2013), Borio and Disyatat (2011, 2015) and others argue that the current account and net flows are generally a symptom of financial developments and of gross flows rather than their cause.

This can be illustrated by way of examples. A financial inflow shock has no immediate bearing on the current account. Instead, it is the shift in the balance sheet composition – more reliance on foreign retail deposit funding and less reliance on foreign interbank funding – that has implications for financial vulnerability. A foreign credit or sudden stop shock has no immediate bearing on the current account either. But it exposes pre-existing financial vulnerabilities if reliance on foreign loans was high, and it reduces remaining financial vulnerabilities once repayments have been made. The shock does entail a reduction in domestic demand and a current account surplus, but this is far smaller than the reduction in foreign credit, and is the consequence, rather than the cause, of the adjustments.

Empirical evidence highlights the important and distinct role of gross flows before and during crises. Borio and Disyatat (2011) document the increasingly important role of gross capital flows in the run-up to the GFC. They show that global gross flows rose from around 10% of world GDP in the late 1990s to over 30% in 2007, and that these flows mostly took place between developed economies. The GFC itself is a prime example for why gross rather than net capital flows and stocks indicate the source of financial vulnerabilities. In the crisis year 2008, global current account imbalances (net flows) narrowed only slightly, and by only $20 billion in the case of the US, while global gross capital inflows and outflows collapsed, by $1600 billion in the case of the US.

A large empirical literature documents that gross financial flows, including cross-border flows but also domestic credit creation flows, trigger economic booms and busts, while current accounts are the consequence rather than the cause of such events. Borio and Lowe (2002), Gourinchas and Obstfeld (2012), and Jorda et al. (2011a) show that credit booms are the best leading indicator of financial crises, and the information content of current accounts tends to vanish once these booms are controlled for. McCauley et al. (2015) argue that external sources of credit expansion tend to

[14] Examples include Prasad et al. (2006), who claim that the current account is a "measure of total external capital financing available for investment in a country", Gourinchas and Rey (2013), who state that "the United States has been a net capital importer since 1982 and has been increasingly financed by fast growing emerging economies", or Bernanke (2005), who states that "... the large current account deficit of the United States, in particular, requires substantial flows of foreign financing".

outpace domestic ones in the later stages of credit booms, and that the eventual bust in financing is what causes real activity to come to a halt. Chinn et al. (2014) find that faster growth in household leverage, due to credit booms, is associated with weaker current accounts. Unger (2015) finds, in the euro area, that increases in domestic gross credit flows, by creating purchasing power, trigger increases in real demand that result in increases in current account deficits.

Lane and McQuade (2013) find, for European countries over the period 1993-2008, that domestic credit growth is strongly positively correlated with current account deficits, which in turn is closely correlated with net debt inflows (but not with net equity inflows). Lane and Milesi-Ferretti (2008) and Caballero et al. (2008) find a strong positive relation between domestic financial liberalization and the size of domestic financial systems on the one hand and the scale of cross-border financial positions on the other. Jorda et al. (2011b) find that the correlation between credit growth and the current account became significant after 1975. Mendoza and Terrones (2012) find that credit booms are typically associated with net capital inflows. Finally, Acharya and Schnabl (2009) argue that the current account balance is not a good guide to the direction of bank-related capital flows: they find that prior to the GFC the US shadow banking system was mainly financed by Europe, which ran a balanced current account, rather than by the main current account surplus countries.

Several studies have documented the critical role of banks in cross-border capital flows and stocks. For flows, Milesi-Ferretti and Tille (2011) document that in the run-up to the GFC bank capital flows increased more rapidly than other types of capital flows, and that the share of banks in total developed-country outflows and inflows reached around one third. For stocks, McCauley et al. (2010) report that in 2007 the cross-border positions of banks accounted for 40%-60% of the external liabilities of Belgium, Switzerland and the UK, and for 25% or more in the cases of France, Italy and the Netherlands. Both flows and stocks include both cross-border lending and deposit-taking and cross-border interbank positions. Rey (2018) and Bruno and Shin (2015) provide further evidence on the importance of banking flows in cross-border flows.

2.2. The Global Saving Glut

The distinction between saving and financing matters for this debate because domestic households do not finance current account deficits with physical saving provided by foreign households, but with digital purchasing power provided by banks, which are more likely to be domestic than foreign.

The global saving glut hypothesis, first advanced by Bernanke (2005), argues that over-abundant foreign saving has been financing US current account deficits and has thus contributed to widening them. Bernanke (2005) and the subsequent literature take for granted the equivalence between saving and financing, and focus on reasons why the true returns to *physical* capital in less developed countries may not be as high as their low capital to labor ratios suggest. Such explanations include weak institutions (Alfaro et al. (2008)), costly physical capital (Hsieh and Klenow (2007), Caselli and Feyrer (2007)), default risk (Reinhart and Rogoff (2004)), the absence of sufficiently attractive store-of-value assets in less developed countries (Caballero et al. (2008)), precautionary saving (Mendoza et al. (2009)) and greater risk tolerance in developed economies (Gourinchas et al. (2017)).

To study the role of saving, we note that foreign saving cannot play a direct role in financing domestic imports. Foreign saving is a goods market concept and a national accounts residual, it *is* the current account deficit by definition (ignoring investment for simplicity). What is required to pay for a current account deficit is not physical resources set aside by foreigners. Instead it is purchasing power created by banks.[15]

This suggests a reinterpretation of the saving glut hypothesis. To study the role of financing, consider several ways in which higher US goods imports could be paid for. US households can transfer existing domestic or foreign bank balances to foreigners, which involves no financing at all. Or they can borrow from domestic banks and then transfer the newly created deposits to foreign households, which involves domestic financing but no foreign financing. Finally, they can borrow from foreign banks and then transfer the newly created deposits to foreign households. This last option does involve foreign financing, but in practice this is the least likely options for the majority of domestic residents.

Our framework is able to distinguish between current account deficits triggered by changes in foreign saving, foreign loan financing, domestic loan financing, the use of existing foreign deposits, or the use of existing domestic deposits. These five possibilities have very different policy implications. In most of the net flows literature by contrast, the role of gross financial variables, which is critical for all but the first possibility, is disregarded. This has critical implications for the debate about how to correct perceived global imbalances. The global saving glut hypothesis puts the onus of adjustment on surplus countries, by encouraging them to boost aggregate demand and reduce their "excessive saving". But in reality this might exacerbate existing domestic vulnerabilities, including the triggering of credit booms that increase financial vulnerability in surplus countries. Examples include not only China recently (Chen and Kang (2018)), but also Japan in the 1980s (Shiratsuka (2003)). Furthermore, it diverts attention from the possibility that the onus of adjustment should be on deficit countries, if their "excessive credit" is the main culprit behind their large current account deficits. Under this changed perspective, foreigners are no longer seen as investors of physical resources into the domestic economy, but as recipients of payments from that economy.

Similar arguments apply to the 'Lucas paradox' that poor countries tend to run current account surpluses while rich ones run deficits. Given the distinction between saving and financing, this pattern says nothing about the direction of financing flows, which is determined by the location of financing banks rather than by the location of goods-producing non-banks. As clearly documented in Borio and Disyatat (2015), net bilateral financial flows generally do not correspond to net bilateral trade flows. If the binding constraint on capital accumulation in poor countries is less about access to physical resources than access to financing, the source for the paradox might be insufficient *domestic* credit, which is not constrained by saving.

2.3. Triffin's Current Account Dilemma

The distinction between saving and financing matters for this debate because the creation of US dollars requires US dollar credit creation, not foreign saving and thus not US current account deficits. Furthermore, US dollar credit creation can be performed by both US and non-US banks.

[15] Of course this purchasing power is only acceptable to foreigners if it embodies a credible promise of convertibility into goods at a later time. However, bank deposits will only lose that credibility under conditions of severe financial and fiscal distress, which did not prevail during the pre-GFC saving glut period.

The current account version of Triffin's dilemma posits that a growing world economy requires an increasing quantity of the global reserve currency to facilitate private sector goods and asset trades. This is taken to imply that the economy issuing the reserve currency must run persistent current account deficits if it is to provide the rest of the world with sufficient amounts of its currency. By doing so, the country eventually becomes increasingly indebted to foreigners, until the currency ceases to be risk-free. For examples of this view, see Zhou (2009), Camdessus and Icard (2011), Paul Volcker's statements in Feldstein (2013) and Prasad (2013). In the late 1990s, this mechanism was also held to be a risk for the forthcoming EMU (see Bergsten (1997) and Alagoskoufis and Portes (1997)). A sizeable empirical literature is also based on this hypothesis: for example, Chinn et al. (2014) perform a panel analysis of current accounts, and interpret the pattern of wider-than-predicted observed US current account deficits as reflecting the US dollar's reserve role. Bayoumi et al. (2015) and Bergsten and Gagnon (2017) report related results.

But as Bordo and McCauley (2017), McCauley (2019), and Obstfeld (2013) point out, this version of Triffin's dilemma is flawed in both fact and logic. In fact, the US ran persistent current account *surpluses* during the post-war period, and with brief interruptions until 1980, while global dollar reserves grew. And in logic, it treats as equivalent changes in the quantity of physical resource flows, which are recorded in current accounts and *net* foreign liabilities, and in the quantity of currencies, which are recorded within financial accounts and in the stocks of public or private sector liquid *gross* liabilities. The creation of dollars for the purpose of efficient international trade only requires digital credit creation by US banks or the US government, and is independent of physical trade deficits incurred by households and firms. Furthermore, dollar credit can also be created by non-US banks, as long as they have adequate access to correspondent banking arrangements or central bank swap lines with the reserve currency economy. There is therefore no dilemma.

A closely related notion to Triffin's current account dilemma is the idea that current account surpluses "fund" the accumulation of foreign exchange reserves (Bernanke (2005), Bernanke et al. (2011), Gros (2009)). This view is based on the accounting identity whereby the current account equals official reserve accumulation plus other gross outflows minus gross inflows. But the accumulation of foreign exchange reserves (a gross financial outflow) is a purely financial transaction, and must therefore automatically generate an offsetting reduction in private sector gross outflows or an increase in private sector gross inflows, without requiring any changes to the current account. For example, consider the increase in reserve assets associated with a central bank foreign exchange purchase financed by the sale of domestic government securities off its balance sheet. This gross outflow is offset either by a reduction in private-sector gross outflows if the counterparty of the central bank is a domestic seller of foreign exchange, or an increase in gross inflows if the counterparty is a nonresident seller of foreign exchange.

The fiscal version of Triffin's dilemma is narrower, in that on the demand side it focuses on central bank demand for high-quality reserve assets, while on the supply side it focuses on fiscal deficits in reserve currency countries as a source of such assets. In other words, the focus is on fiscal deficits rather than current account deficits (see Caballero and Krishnamurthy (2009), Farhi et al. (2011), Obstfeld (2013), Jeanne (2012), Gourinchas and Jeanne (2012), Caballero and Farhi (2016) and Caballero et al. (2017)). However, Bordo and McCauley (2017), argue that even this version posits an implausibly inflexible demand for and supply of safe assets.

2.4. The High Correlation of Gross Capital Inflows and Outflows

The distinction between saving and financing matters for this debate because all financial flows necessarily consist of a pair of gross inflow and outflow components that are inseparable as a matter of accounting, and that are therefore necessarily perfectly correlated. Because financial flows are far larger than net payment flows, this implies a very high overall correlation.

Gross capital inflows and outflows of individual national economies are very highly correlated (Broner et al. (2013)). From the perspective of net flow models, the two legs of such gross flows must necessarily result from two separate sets of cross-border investment decisions. In a typical narrative, foreign investors are the recipients of domestic outflows and "send the capital back", with a build-up of gross positions as the end result. To that literature, this synchronization presents a puzzle that requires a theoretical explanation.

But in fact, the high aggregate correlation is not the outcome of any economic mechanism that requires a theoretical explanation. Instead it is simply an automatic result of the balance of payment's double-entry bookkeeping. All financial flows involve two inseparable gross financial flows into and out of the economy. They involve one single investment decision by a single investor, with a zero net change and no flow of physical resources. The correlation of these financial outflows and inflows is one by construction. The only two reasons why overall gross capital inflows and outflows may exhibit a lower correlation are measurement errors ("errors and omissions") and a significant role for net payment flows, where only one of the flows is financial while the other is physical.[16]

In the empirical literature, Broner et al. (2013) is perhaps the most prominent example of the net flows perspective. Their interpretation of the evidence is that "when foreigners invest in a country, domestic agents invest abroad, and vice versa." As we have discussed, for financial flows at the aggregate level this must automatically be true. This also partly accounts for the predominantly positive correlations between gross capital flows at the sectorial level documented by Rey (2018), but of course the detailed sectorial correlations are not exclusively determined by the mechanics of aggregate financial flows.

In the theoretical literature, Caballero and Simsek (2019) is a prominent recent example of the net flows perspective. In their model, fickleness and retrenchment represent two separate sets of decisions about physical resource flows by separate sets of domestic and foreign investors that end up being synchronized because of the model's economic mechanism. By contrast, if the settlement flows through the banking system were present, it would become clear that fickleness alone (or retrenchment alone) would give rise to perfectly correlated gross capital inflows and outflows. In this context, the observation by Avdjiev et al. (2017) that global banks are largely responsible for the fickleness and retrenchment patterns seen in the data acquires added significance.

[16] Net payment flows accounted for a larger share of global capital flows during the age of capital controls. Broner et al. (2013) find that the correlation between gross inflows and outflows became stronger between the 1970s and the 2000s. Today net payment flows are very small relative to financial flows.

3. The Model

3.1. Overview

The world economy consists of two countries, Home and Foreign, with respective shares in the world population of n and $1-n$. Each country is populated by households, manufacturers, unions, banks and a government. In our baseline calibration $n = 0.5$ and the two countries are fully symmetric in economic structure and in the calibration of all parameters. Figure 1 illustrates the model's domestic and cross-border financial flows together with its trade flows.

Households in each country own the domestic stock of land, which both serves as an input into the production function of domestic value added and as collateral for borrowing from banks.[17] Output is produced using labor in addition to land. Household income consists of land rents, wages and lump-sum profit distributions from manufacturers, unions and banks. Households, both domestic and foreign, are the only retail borrowers from and retail depositors at banks. They consume a CES composite of domestic and foreign goods, and they purchase these goods using a CES composite of domestic and foreign[18] currency deposits, which are created for them by banks through loans. Manufacturers and unions have pricing power, and set prices and wages subject to nominal rigidities. Monetary policy targets inflation by setting the risk-free interest rate following an inflation forecast based rule. We abstract from all fiscal policy considerations.

The banking sector has three functions. The first is wholesale lending and wholesale deposit issuance, with an optimal choice of the overall balance sheet size in order to maximize net worth. The second and third are retail lending and retail deposit issuance, with an optimal choice of the terms of loan and deposit contracts. One key feature of the banking sectors is that their non-equity liabilities, all of which we will generically refer to as deposits, are the only generally accepted medium of exchange. The specification of the medium of exchange function of bank liabilities in the model is based on the Schmitt-Grohé and Uribe (2004) transactions cost technology.[19] The specification of the money-creating function of bank assets in the model is based on the costly state verification model of Bernanke et al. (1999), but modified to allow for non-contingent lending rates and therefore ex-post bank losses, and also to allow for time-varying shares of collateral that banks take into account when assessing the creditworthiness of potential borrowers.

In the real world, the perceived safety that underpins the unique role of bank liabilities as a medium of exchange is due partly to asset diversification on the part of banks, but mainly to the extensive regulatory and support mechanism put in place by governments, central banks and regulatory authorities. The formalization of the regulatory support mechanism in the model is necessarily stylized, but nevertheless aims to capture its salient elements. Specifically, banks' net worth maximization is subject to minimum capital adequacy regulation (MCAR), which imposes penalties on banks whose capital drops below a specified minimum percentage of total assets[20], foreign currency

[17] We abstract from capital accumulation for analytical simplicity.

[18] Recall that the household sector includes firms, who use foreign currency deposits to pay for imports and to receive export revenues.

[19] As shown in Kumhof and Wang (2019), this is a shortcut for a more decentralized representation where banks serve as intermediaries between different spenders of bank deposits in circulation. The model merges these multiple spenders into a single representative household in the spirit of Lucas (1990) and Schmitt-Grohé and Uribe (2004).

[20] MCAR ensure a zero default risk for banks (capital dropping below 0% of assets). Banks optimally limit their leverage to minimize the non-zero risk of regulatory penalties for MCAR violations (capital dropping below 8.5% of assets), thereby limiting the amount of credit and money creation.

monetary transactions costs (MONFX), which requires banks to maintain correspondent accounts with foreign banks in order to compensate for the absence of a lender of last resort in foreign currency, and foreign exchange mismatch rules (FXMR), which describe either prudential rules or banks' policies regarding the matching of balance sheet exposures to foreign account holders.[21]

Home banks issue loans exclusively in Home currency in order to create deposits in Home currency, and Foreign banks only issue loans in Foreign currency to create deposits in Foreign currency.[22] Because households require positive quantities of both currencies issued by banks in both countries, they must bank with banks in both countries, and thus their loan and deposit exposures to banks in the foreign country represent a part of the economy's gross and net foreign asset positions, with the remainder accounted for by interbank loan and deposit exposures.

A key implication of this set-up is that relative supplies of, and demands for, currencies become a further determinant of exchange rates, alongside relative goods demands/supplies and standard interest parity conditions. This aspect is treated in much greater detail by Cesa-Bianchi et al. (2019), but because some of their analysis is useful in order to understand our own results, we briefly re-derive their key insights on the monetary aspects of exchange rate determination later in this section, with a more detailed treatment in Appendix B.

3.2. Conventions and Assumptions

Except where specifically mentioned, our model description limits itself to the Home economy. Where interactions with Foreign are described, superscript asterisks * indicate Foreign variables. We observe the convention that a real normalized variable is the nominal variable divided by the price level P_t and the level of global productivity T_t. The exogenous and constant growth rate of global productivity is $x = T_t/T_{t-1}$, while the endogenous and time-varying growth rate of the price level is $\pi_t^p = P_t/P_{t-1}$. The nominal exchange rate E_t is the price, expressed in domestic currency, of a unit of foreign currency (so that an increase indicates a depreciation of the domestic currency), and its depreciation rate is defined as $\varepsilon_t = E_t/E_{t-1}$. The real exchange rate is defined as the ratio of the two countries' CPI price levels expressed in a common currency, $e_t = (E_t P_t^*)/P_t$. Nominal variables are denoted by upper case letters, real variables are denoted by the corresponding lower case letters (for loans, the symbols are L and ℓ), and real normalized variables are denoted by the symbol for the corresponding real variable with an inverse hat symbol above the variable. The real value of Home/Foreign currency assets is always expressed in terms of Home/Foreign goods, irrespective of whether the holder is located in Home or Foreign. Home and Foreign goods production and consumption and Home and Foreign currency balance sheet positions are indicated by the subscripts H and F. Superscripts h, f and b indicate balance sheet positions of Home households, Foreign households and banks. For the example of the domestic real value of domestic and foreign currency deposits held by Home households we therefore have $\check{d}^h_{H,t} = d^h_{H,t}/T_t = D^h_{H,t}/(T_t P_t)$ and $e_t \check{d}^h_{F,t} = e_t d^h_{F,t}/T_t = ((E_t P_t^*)/P_t)\left(D^h_{F,t}/(T_t P_t^*)\right)$. All interest rates are in gross terms, and a subscript t on a nominal interest rate denotes an interest rate paid

[21] In empirical work, the fact that banks generally hedge their foreign exchange exposure has been exploited to infer their derivative positions from apparent mismatches on their balance sheets. See Borio et al. (2017) for an example.

[22] Cesa-Bianchi et al. (2019) consider the case where banks in each country issue loans in both currencies, but exclusively to households in their respective countries. Their setup only gives rise to cross-border financial positions between banks, and is therefore well-suited to study monetary aspects of exchange rate determination, but not many of the capital flow questions addressed in the present paper.

on an asset held from period t to period $t+1$. The real interest rate on a generic domestic currency balance sheet item Z in Home is given by $r_{zHt} = i_{zHt-1}/\pi_t^p$, while the real interest rate on a generic foreign currency balance sheet item Z is given by $r_{zF,t} = (i_{zF,t-1}\varepsilon_t)/\pi_t^p$. We generally describe original optimization problems in nominal and agent-specific form, while optimality conditions are shown in real, normalized and aggregate form.

3.3. Banking Sector

The three functions of the banking sector are wholesale lending and wholesale deposit issuance, retail lending, and retail deposit issuance. For analytical convenience, we split banks' optimization problem into these three components, and assign them to different sectors within the banking system. In their interactions with households, domestic banks exclusively extend loans and create deposits in domestic currency.

3.3.1. Wholesale Banks

Wholesale banks have unit mass and are indexed by j, where individual banks differ by the size of their net worth. Wholesale banks issue wholesale loans in domestic currency $L^h_{H,t}(j)$ and $L^f_{H,t}(j)$ to two domestic retail lending banking sectors that in turn lend to domestic and foreign households. Wholesale banks also issue interbank loans in domestic currency $L^b_{H,t}(j)$ to foreign wholesale banks, and hold interbank deposits in foreign currency $D^b_{F,t}(j)$ at foreign retail deposit banks. Their principal source of financing consists of wholesale deposits in domestic currency $D_t(j)$ issued to domestic retail deposit banks, who in turn issue deposits to domestic and foreign households and to foreign wholesale banks. The remainder of wholesale banks' financing consists of interbank loans from foreign wholesale banks in foreign currency $L^b_{F,t}(j)$ and net worth held by domestic households $N^b_t(j)$. An individual wholesale bank's balance sheet is given by

$$L^h_{H,t}(j) + L^f_{H,t}(j) + L^b_{H,t}(j) + E_t D^b_{F,t}(j) = D_t(j) + E_t L^b_{F,t}(j) + N^b_t(j) \; . \tag{1}$$

We can derive an expression for the banking sector's aggregate balance sheet by using the results of subsections 2.3.2 and 2.3.3 on retail deposit and retail lending banks to consolidate the wholesale and retail sectors. Specifically, we set $D_t(j) = D^h_{H,t}(j) + D^f_{H,t}(j) + D^b_{H,t}(j)$, where $D^h_{H,t}(j)$, $D^f_{H,t}(j)$ and $D^b_{H,t}(j)$ are retail deposits from domestic households, foreign households and foreign wholesale banks. The symbols for wholesale and retail loans are identical. After aggregating over individual banks we obtain

$$L^h_{H,t} + L^f_{H,t} + L^b_{H,t} + E_t D^b_{F,t} = D^h_{H,t} + D^f_{H,t} + D^b_{H,t} + E_t L^b_{F,t} + N^b_t \; . \tag{2}$$

MCAR limits wholesale banks' ability to create credit and money. Bank j faces a future penalty of $\chi \frac{P_{t+1}}{P_t} \left[L^h_{H,t}(j) + L^f_{H,t}(j) + L^b_{H,t}(j) + E_t D^b_{F,t}(j) \right]$ if net worth in the next period falls short of γ times risk-weighted assets in the next period, where the regulatory risk weight on loans to households equals one while the regulatory risk-weight on interbank positions equals $\zeta < 1$.

The penalty is therefore payable if

$$\left[i^h_{\ell H,t}L^h_{H,t}(j)+i^f_{\ell H,t}L^f_{H,t}(j)+i^b_{\ell H,t}L^b_{H,t}(j)+E_{t+1}i^b_{dF,t}D^b_{F,t}(j)\right]\omega^b_{t+1} \tag{3}$$
$$-i_{w,t}D_t(j)-E_{t+1}i^b_{\ell F,t}L^b_{F,t}(j)-s^b_t(j)\,L^f_{H,t}(j)+P_{t+1}\left(\Pi^R_{t+1}(j)-\Lambda^b_{t+1}(j)\right)$$
$$<\gamma\left[i^h_{\ell H,t}L^h_{H,t}(j)+i^f_{\ell H,t}L^f_{H,t}(j)+\zeta\left(i^b_{\ell H,t}L^b_{H,t}(j)+E_{t+1}i^b_{dF,t}D^b_{F,t}(j)\right)\right]\omega^b_{t+1}\ ,$$

where $i_{w,t}$ is the nominal interest rate on wholesale deposits, $\Pi^R_{t+1}(j)-\Lambda^b_{t+1}(j)$ represent the prorated share (by share of total bank net worth) in net profits of domestic retail deposits banks minus net losses of domestic retail lending banks[23], and $s^b_t(j)\,L^f_{H,t}(j)$ represents monetary transactions costs MONFX (see below). The variable ω^b_{t+1} is a log-normally distributed idiosyncratic shock to the loan return with mean 1 and variance $\left(\sigma^b\right)^2$. It can reflect a number of individual bank characteristics, such as differing success at raising non-interest income and minimizing non-interest expenses, where the sum of the two equals zero over all banks. We denote the pdf and cdf of the idiosyncratic shock by $f^b\left(\omega^b_{t+1}\right)$ and $F^b\left(\omega^b_{t+1}\right)$. The lagged condition (3) implicitly defines a cutoff loan return shock $\bar{\omega}^b_t$ below which regulations are breached and the penalty has to be paid, and we define $f^b_{t+1}\equiv f^b\left(\bar{\omega}^b_{t+1}\right)$, $F^b_{t+1}\equiv F^b\left(\bar{\omega}^b_{t+1}\right)$. The closed-form expression for $\bar{\omega}^b_t$ is omitted to conserve space.

MONFX reflects the fact that banks' exposures to foreign households are costlier to maintain than exposures to domestic households. The reason is that the absence of a lender of last resort in foreign currency requires that banks self-insure, by maintaining readily accessible foreign currency funds in nostro correspondent accounts at foreign banks, to facilitate conversions between foreign and domestic currencies when domestic currency loans to foreigners are made or repaid. This is modelled as a monetary transactions cost that is increasing in loans to foreign households $L^f_{H,t}(j)$ and decreasing in interbank foreign currency liquidity $D^b_{F,t}(j)$. We choose the functional form $s^b_t(j)L^f_{H,t}(j)$, where

$$s^b_t(j)=\frac{\varphi_b}{\vartheta_b}\left(e_t\check{d}^b_{F,t}(j)\right)^{-\vartheta_b}\ . \tag{4}$$

FXMR describe banks' management of exposures to foreign residents. There is a continuum of different options for each country, parameterized by the parameter $\phi_{fxmr}\in[0,1]$:

$$D^b_{F,t}(j)-L^b_{F,t}(j)=\phi_{fxmr}\left(D^f_{H,t}(j)-L^f_{H,t}(j)\right)\ . \tag{5}$$

We will distinguish three cases.

FXMR1, or accommodating FXMR, sets $\phi_{fxmr}=1$ for both countries, so that banks take on exchange rate risk. One way to interpret this case is as the algebraic representation of the instantaneous bookkeeping entries that occur automatically when foreign households' cross-border transfer is settled through the debiting and crediting of nostro and vostro interbank accounts, which does not require an additional decision by banks or their customers (except for the currency of settlement, on which see below). Under this assumption, responses to cross-border transfers that are inherently not instantaneous, such as in lending and in domestic household deposit holdings, are

[23] Note that the net losses of domestic retail lending banks are experienced vis-a-vis both domestic and foreign households. We therefore also need to keep track of a second bank loss variable, the loss rebates received, from both domestic and foreign banks, by domestic households. We denote this variable, in aggregate terms, by $\check{\Lambda}^h_t$.

insignificant. Another way to interpret FXMR1 is as the intentional exposure to exchange rate risk by domestic banks as part of their longer-term strategy. In practice, commercial banks rarely leave open foreign exchange positions for any meaningful period, but as discussed above banks in our model also represent NBFIs, who in many cases actively manage foreign exchange positions. However, we do not model this case beyond the assumption of $\phi_{fxmr} = 1$.

A switch by foreign households from foreign currency to domestic currency deposits implies a change in the currency exposures of banks. This is inevitable, because households in either country are[24] unwilling to take the other side in a currency swap to eliminate this new exposure, so that any partial equilibrium ability to hedge by an individual bank cannot carry over to the aggregate financial system. The only question is which of the two banking systems is exposed to the foreign exchange risk, and we assume that it is the recipient rather than the originating bank. We need to choose one of these two polar assumptions, because the model does not contain sufficient frictions to allow for an endogenous determination of the currency of interbank reserve positions. In the real world both scenarios can occur. The initiative is not with the bank but with the customer, whose instructions determine where conversion to foreign currency takes place. Finally, we observe that if FXMR1 holds symmetrically in both countries, it implies that the net foreign asset position cannot change, and therefore that the current account must remain zero at all times.

FXMR2, or strict FXMR, sets $\phi_{fxmr} = 0$ for both countries. This implies the elimination of all interbank currency mismatches, and in our view describes the most plausible longer-term response of the financial system, particularly for commercial banks, to changes in foreign households' exposures to domestic currency. It implies that any inflow of retail deposits from foreign households must be balanced by other bank positions vis-à-vis domestic or foreign households. As mentioned above, because this requires changes in retail credit and in domestic households' deposit holdings, rather than only in interbank positions, it takes more time. In practice, banks can eliminate foreign exchange exposures more quickly by using derivatives such as foreign exchange swaps, which are economically equivalent to lending in one currency and borrowing in another. A combination of swap contracts between domestic banks and domestic households, and between domestic and foreign banks, is therefore equivalent to the changes in our model of retail credit, of domestic households' deposit holdings, and of interbank positions, accompanied by market clearing prices that make these changes optimal.

FXMR3, or asymmetric FXMR, sets $\phi_{fxmr} = 1$ and $\phi^*_{fxmr} = 0$. We will use this version to study the small open economy case, where we will think of Foreign as including the US, and of its currency as the dollar. The rule for Foreign rules out bank exposures of Foreign to the Home currency, while the rule for Home allows for bank exposures of Home to the dollar. Interbank position mismatches in dollars can therefore open up. This is a natural assumption, as the dollar is the world's reserve currency, and in small economies exposures to it cannot always be eliminated at the aggregate level.

Net worth maximization involves taking first-order conditions with respect to all four asset side items. Banks internalize the risk of breaching the MCAR, so that expected net worth includes the penalty payable if a breach occurs, weighted by the probability of a breach. The objective function for net worth maximization of an individual bank j anticipates the result that for retail deposit banks wholesale deposits in domestic currency and domestic government bonds are perfect substitutes, so that the equilibrium nominal interest rate for domestic currency wholesale deposits $i_{w,t}$ equals the policy rate i_t.

[24] The shock changes the desired currency holdings of foreign households, with no shock to domestic households.

We have the following optimization problem:

$$\max_{\left\{\begin{array}{c} L_{H,t}^{h}(j),\ L_{H,t}^{f}(j), \\ L_{H,t}^{b}(j),\ D_{F,t}^{b}(j) \end{array}\right\}} \mathbb{E}_t \left[\begin{array}{c} \left[i_{\ell H,t}^{h} L_{H,t}^{h}(j) + i_{\ell H,t}^{f} L_{H,t}^{f}(j) + i_{\ell H,t}^{b} L_{H,t}^{b}(j) + E_{t+1} i_{dF,t}^{b} D_{F,t}^{b}(j)\right] \omega_{t+1}^{b} \\ -i_t D_t(j) - E_{t+1} i_{\ell F,t}^{b} L_{F,t}^{b}(j) \\ -s_t^{b}(j) L_{H,t}^{f}(j) + P_{t+1}\left(\Pi_{t+1}^{R}(j) - \Lambda_{t+1}^{b}(j)\right) \\ -P_{t+1}\int_0^{\bar{\omega}_{t+1}^{b}(j)} \frac{\chi}{P_t}\left(L_{H,t}^{h}(j) + L_{H,t}^{f}(j) + L_{H,t}^{b}(j) + E_t D_{F,t}^{b}(j)\right) f^{b}\left(\omega_{t+1}^{b}\right) d\omega_{t+1}^{b} \end{array} \right] . \tag{6}$$

The deposit terms must be replaced using a combination of the balance sheet identity (1) and the FXMR rule (5). We arrive at post-dividend net worth by deducting dividends that equal a fixed fraction of net worth, and that are paid out to households in a lump-sum fashion, a specification that can be obtained by applying the "extended family" approach of Gertler and Karadi (2011). The law of motion for net worth is not shown to conserve space.

Optimization yields first-order conditions that we show in full, because they reveal important details concerning the structure of interest rate spreads. We can drop individual indices because in equilibrium the ratios to net worth of loans, deposits, retail deposit profits and retail lending losses are identical across banks. We therefore show the conditions in real normalized form. We adopt the shorthand notation $\check{\ell}_t^{\ell} = \check{\ell}_{H,t}^{h} + \check{\ell}_{H,t}^{f} + \check{\ell}_{H,t}^{b} + e_t \check{d}_{F,t}^{b}$ for aggregate total assets, which is the basis to which the MCAR penalty parameter χ is applied. The expressions $\check{\Omega}_{yX,t}^{x}$ are the derivatives $\partial\bar{\omega}_{t+1}^{b}/\partial\check{y}_{X,t}^{x}$, with $X \in \{H, F\}$, $x \in \{h, f, b\}$ and $y \in \{\ell, d\}$. We note that $\check{\Omega}_{yX,t}^{x}$ are always positive, that they are very similar in size between the two types of wholesale loans and separately between the two types of interbank positions, and finally that they are smaller for interbank positions than for wholesale loans, due to the lower regulatory risk weight on interbank positions.

For domestic currency loans to domestic households $\check{\ell}_{H,t}^{h}$ we have

$$\mathbb{E}_t\left\{r_{\ell H,t+1}^{h} - r_{t+1} - \chi\left[F_{t+1}^{b} + f_{t+1}^{b}\check{\Omega}_{\ell H,t}^{h}\check{\ell}_t^{\ell}\right]\right\} = 0 . \tag{7}$$

This condition shows that there is a *regulatory spread* $\chi[F_{t+1}^{b} + f_{t+1}^{b}\check{\Omega}_{\ell H,t}^{h}\check{\ell}_t^{\ell}]$ between the wholesale lending rate and the policy rate. Specifically, the wholesale lending rate compensates wholesale banks for the fact that that at the margin an additional loan increases the penalty payable in case of a breach of MCAR. The size of this spread depends on a combination of the size of the MCAR, γ (this enters $\check{\Omega}_{\ell H,t}^{h}$), the penalty payable in case of a breach of MCAR, χ (this also enters $\check{\Omega}_{\ell H,t}^{h}$), and the likelihood of a breach given the riskiness of individual banks, F_{t+1}^{b} and f_{t+1}^{b}. This condition is identical across all versions of FXMR.

For domestic currency loans to foreign households $\check{\ell}_{H,t}^{f}$, we have the following general condition as a function of ϕ_{fxmr}:

$$\mathbb{E}_t\left\{r_{\ell H,t+1}^{f} - \phi_{fxmr} r_{\ell F,t+1}^{b} - \left(1-\phi_{fxmr}\right) r_{t+1} - \frac{s_t^{b}}{\pi_{t+1}^{p}} - \chi\left[F_{t+1}^{b} + f_{t+1}^{b}\check{\Omega}_{\ell H,t}^{f}\check{\ell}_t^{\ell}\right]\right\} = 0 . \tag{8}$$

While the regulatory spread $\chi[F_{t+1}^{b} + f_{t+1}^{b}\check{\Omega}_{\ell H,t}^{f}\check{\ell}_t^{\ell}]$ is virtually identical in size to that for loans to domestic households, this condition contains two additional spreads. First, except for the polar case of $\phi_{fxmr} = 0$, the spread is partly or wholly relative to the interest rate on foreign currency wholesale interbank loans $r_{\ell F,t+1}^{b}$ rather than the policy rate r_{t+1}, with the difference between these two rates representing an additional *interbank borrowing spread* $(r_{\ell F,t+1}^{b} - r_{t+1})$. The reason for this spread is that with $\phi_{fxmr} > 0$ foreign currency interbank loans are partly or wholly the marginal source of refinancing additional wholesale loans to foreigners, and foreign banks charge a regulatory spread on these loans (this will be discussed from the point of view of domestic banks below, see (9)). Second, there is an additional *interbank monetary spread* $\left(s_t^b/\pi_{t+1}^p\right)$, which arises because an increase in exposures to foreign households must be matched with a costly increase in foreign currency interbank liquidity.

For domestic currency loans to foreign banks $\check{\ell}_{H,t}^b$ we have

$$\mathbb{E}_t \left\{ r_{\ell H,t+1}^b - r_{t+1} - \chi \left[F_{t+1}^b + f_{t+1}^b \check{\Omega}_{\ell H,t}^b \check{\ell}_t^\ell \right] \right\} = 0 \ . \tag{9}$$

The difference to the condition for wholesale loans is that the regulatory spread for interbank loans $\chi[F_{t+1}^b + f_{t+1}^b \check{\Omega}_{\ell H,t}^b \check{\ell}_t^\ell]$ is significantly smaller, due to a much lower Basel risk weight ζ (this enters $\check{\Omega}_{\ell H,t}^b$). As discussed in connection with (8), for foreign banks the interest rate $r_{\ell H,t+1}^b$ partly determines the marginal cost of refinancing foreign currency wholesale loans to domestic households, and also the marginal cost of refinancing domestic currency interbank deposits at domestic banks (see (10) below). This condition is identical across all versions of FXMR.

For foreign currency deposits at foreign banks $\check{d}_{F,t}^b$ we have

$$\mathbb{E}_t \left\{ \left(r_{dF,t+1}^b - r_{t+1} \right) - \left(r_{\ell F,t+1}^b - r_{t+1} \right) - s_t^{b\prime} \frac{\check{\ell}_{H,t}^f}{\pi_{t+1}^p} - \chi \left[F_{t+1}^b + f_{t+1}^b \check{\Omega}_{dF,t}^b \left(\check{\ell}_t + \check{\ell}_{H,t}^b + e_t \check{d}_{F,t}^b \right) \right] \right\} = 0 \ . \tag{10}$$

The *interbank borrowing spread* $(r_{\ell F,t+1}^b - r_{t+1})$ is due to FXMR, but unlike for domestic currency loans to foreign households it is not conditional on the value of ϕ_{fxmr}. The reason is that foreign currency interbank loans are the marginal source of refinancing foreign currency interbank deposits under any specification of the FXMR rule. The *regulatory spread* $\chi[F_{t+1}^b + f_{t+1}^b \check{\Omega}_{dF,t}^b \check{\ell}_t^\ell]$ is virtually identical in size to that of domestic currency interbank loans. In equilibrium the sum of these spreads is however more than offset by the *interbank monetary discount* $s_t^{b\prime}(\check{\ell}_{H,t}^f/\pi_{t+1}^p) < 0$. The reason for this discount is that holdings of foreign currency interbank deposits reduce the cost of exposures to foreign households. This condition is identical across all versions of FXMR.

3.3.2. Retail Deposit Banks

Retail deposit banks have unit mass and are indexed by j, where individual banks differ by the deposit variety they offer. The function of retail deposit banks is to set the terms of retail deposit contracts. Retail deposit banks issue retail deposit varieties $D_{H,t}^h(j)$ and $D_{H,t}^f(j)$ to domestic and foreign households and interbank deposit varieties $D_{H,t}^b(j)$ to foreign wholesale banks. Retail deposits finance purchases of wholesale deposits $D_t(j)$ and government bonds $B_t(j)$, where the latter are in zero supply at the aggregate level. The balance sheet of an individual retail bank is therefore given by

$$D_t(j) + B_t(j) = D_{H,t}^h(j) + D_{H,t}^f(j) + D_{H,t}^b(j) \ , \tag{11}$$

with $B_t(j) = 0$ in a symmetric equilibrium. As explained above, arbitrage between wholesale deposits and government bonds implies that $i_{w,t} = i_t$.

Retail deposit banks behave as monopolistic competitors, and depositors demand a CES composite of all deposit varieties. This implies the pricing rules for deposits

$$i^h_{dH,t} = \mu^h_{dH} i_t \ , \quad (12)$$
$$i^f_{dH,t} = \mu^f_{dH} i_t \ ,$$
$$i^b_{dH,t} = \mu^b_{dH} i_t \ ,$$

where the markdown terms μ^x_{dH} are smaller than one. Retail deposit banks are fully owned by wholesale banks, and their aggregate real profits $\check{\Pi}^R_t$ are transferred lump-sum to the latter.

3.3.3. Retail Lending Banks

There are two retail lending bank sectors, one each for loans to domestic and foreign households. These two groups of borrowers each have unit mass and are indexed by j, where individual borrowers may differ by the size of their internal funds and therefore their borrowing capacity. Retail lending banks themselves are homogenous, and each bank lends the same amount to borrower j. The function of retail lending banks is to set the terms of loan contracts, in a formally very similar fashion to Bernanke et al. (1999), henceforth BGG, whose set-up we follow and extend.

The collateral for a loan contract between retail lending banks and borrower j is the value of land $Q_t k_t(j)$, where Q_t is the nominal price of land and $k_t(j)$ is the stock of land owned by j, with the aggregate stock of land k_t constant in aggregate. While in most frameworks that use the BGG model the available collateral is assumed to consist of 100% of the total market value of collateral at all times, in our framework that fraction does not necessarily equal 100% in steady state, is subject to stochastic shocks, and is split into two parts, one to collateralize domestic currency loans from domestic banks and another to collateralize foreign currency loans from foreign banks. Specifically, domestic and foreign households j are able to pledge time-varying (and not necessarily equal to 100%) shares $\kappa^h_{H,t}$ and $\kappa^{f^*}_{H,t}$ of land to collateralize loans $L^h_{H,t}(j)$ and $L^f_{H,t}(j)$. There are two ways to think about shocks to these shares. The first is as regulatory changes that affect permissible loan-to-value ratios. The second is as a reduced-form representation of changes in banks' own willingness to lend against a given stock of collateral. We adopt the second interpretation, and refer to shocks to $\kappa^h_{H,t}$ and $\kappa^f_{H,t}$, which follow first-order autoregressive processes, as willingness-to-lend shocks.

Land yields a nominal return $Ret_{k,t} = \left(Q_t + R^k_t\right)/Q_{t-1}$ that includes both appreciation Q_t/Q_{t-1} and rent R^k_t/Q_{t-1}, with the real return equal to $ret_{k,t} = Ret_{k,t}/\left(x\pi^p_t\right)$. Domestic and foreign borrowers are subject to idiosyncratic productivity shocks $\omega^x_{H,t+1}$, $x \in \{h, f\}$, that are log-normally distributed with mean 1 and variance $(\sigma^x_H)^2$. We denote the pdf and cdf of these shocks by $f^x(\omega^x_{H,t+1})$ and $F^x(\omega^x_{H,t+1})$ and the cutoff productivity shocks below which bankruptcy occurs ex-post by $\bar{\omega}^x_{H,t}$, and we define $f^x_{H,t} = f^x(\bar{\omega}^x_{H,t})$ and $F^x_{H,t} = F^x(\bar{\omega}^x_{H,t})$.

Loan contracts stipulate non-contingent retail lending rates $i^x_{rH,t}$ on loans $L^x_{H,t}(j)$ that must be paid in full if the realization of the shock is sufficiently high to avoid bankruptcy. Borrowers decide to declare bankruptcy if their individual productivity shock remains below $\bar{\omega}^x_{H,t}$. In that case handing over the entire value of their project over to the bank becomes preferable to realizing the project and repaying the loan. We omit the closed form expression for $\bar{\omega}^x_{H,t}$ to conserve space. In case of bankruptcy, because of monitoring costs, the bank can only recover a fraction $1 - \xi^x_H$ of the project value, where ξ^x_H is the loss-given-default percentage. The cost of funding for retail lending banks is given by wholesale lending rates $i^x_{\ell H,t}$, which can be thought of as the lending rates that would apply to notionally riskless borrowers, which are not present in the model. The participation constrains for retail loans are[25]

$$i^h_{\ell H,t} L^h_{H,t}(j) = \mathbb{E}_t \left[\begin{array}{c} \left(1 - F^h\left(\bar{\omega}^h_{H,t+1}(j)\right)\right) i^h_{rH,t} L^h_{H,t}(j) + \\ \left(1-\xi^h_H\right) \int_0^{\bar{\omega}^h_{H,t+1}(j)} \kappa^h_{H,t} Q_t k_t(j)\, Ret_{k,t+1} \omega^h_{H,t+1}(j)\, f^h\left(\omega^h_{H,t+1}(j)\right) d\omega^h_{H,t+1}(j) \end{array} \right],$$

$$i^f_{\ell H,t} L^f_{H,t}(j) = \mathbb{E}_t \left[\begin{array}{c} \left(1 - F^f\left(\bar{\omega}^f_{H,t+1}(j)\right)\right) i^f_{rH,t} L^f_{H,t}(j) + \\ \left(1-\xi^f_H\right) \int_0^{\bar{\omega}^f_{H,t+1}(j)} \kappa^f_{H,t} E_{t+1} Q^*_t k^*_t(j)\, \frac{1-n}{n} Ret^*_{k,t+1} \omega^f_{H,t+1}(j)\, f^f\left(\omega^f_{H,t+1}(j)\right) d\omega^f_{H,t+1}(j) \end{array} \right].$$

These conditions state that the wholesale return on a loan $L^x_{H,t}(j)$ must equal the sum of two terms. The first is gross interest on fully repaid loans weighted by the probability of a sufficiently high realization of the idiosyncratic productivity shock. The second is the value of pledged collateral (note the parameter $\kappa^x_{H,t}$) net of monitoring costs (note the parameter ξ^x_H) recoverable in case of default. These constraints can be rewritten as

$$\begin{aligned} \mathbb{E}_t\left[\kappa^h_{H,t} Ret_{k,t+1} Q_t k_t(j)\left(\Gamma^h_{H,t+1}(j) - \xi^h_H G^h_{H,t+1}(j)\right) - i^h_{\ell H,t} L^h_{H,t}(j)\right] &= 0\,, \quad (13) \\ \mathbb{E}_t\left[\kappa^f_{H,t} E_{t+1} Ret^*_{k,t+1} Q^*_t k^*_t(j)\left(\Gamma^f_{H,t+1}(j) - \xi^f_H G^f_{H,t+1}(j)\right) - i^f_{\ell H,t} L^{f^*}_{H,t}(j)\right] &= 0\,, \end{aligned}$$

where $\Gamma^x_{H,t+1}(j)$ denotes lenders' gross share in pledged earnings of land, and $\xi^x_H G^x_{H,t+1}(j)$ denotes lenders' monitoring costs share in pledged earnings of land. This states that ex-ante net loan losses must equal zero. Ex-post net loan losses can be different from zero because lending rates are non-contingent. Retail lending banks are fully owned by wholesale banks, and their net aggregate loan losses $\check{\Lambda}^b_t$ are transferred to the latter in a lump-sum fashion. The participation constraints enter into households' optimization problems, and affect their decision rules for land and loans.

3.3.4. Cross-Border Financial Markets

Domestic and foreign households and banks are linked through balance sheet positions and in terms of interest rates. For Home, the nominal interest rates on foreign currency loans and deposits are identical to those prevailing in Foreign, $i^x_{\ell F,t} = i^{x*}_{\ell F,t}$ and $i^x_{dF,t} = i^{x*}_{dF,t}$, where $x \in \{h, b\}$. The corresponding cross-border balance sheet positions are $\check{\ell}^x_{F,t} = \check{\ell}^{x*}_{F,t} \frac{1-n}{n}$ and $\check{d}^x_{F,t} = \check{d}^{x*}_{F,t} \frac{1-n}{n}$. Analogous relationships hold for Home currency exposures in Foreign.

3.4. Households

3.4.1. Lifetime Utility and Constraints

Households have unit mass and are indexed by j. Households maximize lifetime utility subject to sequences of intertemporal budget constraints and bank participation constraints, by choosing

[25] In the second condition, $L^f_{H,t}(j)$ is in Home per capita terms while $E_{t+1} Q^*_t k^*_t(j)$ is in Foreign per capita terms. This explains the factor $(1-n)/n$ muliplying $E_{t+1} Q^*_t k^*_t(j)$. For future reference, we will use the notation $L^{f^*}_{H,t}(j) = L^f_{H,t}(j) \frac{n}{1-n}$ (and similarly for other quantities) to convert nominal per capita quantities.

plans for consumption $c_t(j)$, hours worked $h_t(j)$, loans in both currencies $L^h_{X,t}(j)$, deposits in both currencies $D^h_{X,t}(j)$, and land holdings $k_t(j)$. Their consumption bundle is a CES physical aggregate that includes both domestic and foreign goods $c_{H,t}(j)$ and $c_{F,t}(j)$. They face monetary transaction costs for purchases of the consumption bundle that are decreasing in a CES deposits aggregate that includes the purchasing power of both domestic and foreign currency deposits $D^h_{H,t}(j)$ and $E_t D^h_{F,t}(j)$. The objective function for domestic household j is

$$\max \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_{0,t} \left\{ \left(1 - \frac{\nu}{x}\right) S^c_t \log\left(c_t(j) - \nu c_{t-1}\right) - \psi \frac{h_t(j)^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}} \right\} , \tag{14}$$

where ν parameterizes external habit persistence, η is the elasticity of labour supply, ψ is a labour supply scale parameter, S^c_t is a first-order autoregressive stochastic process for consumption preferences, $\beta_{0,t} = \Pi^{t-1}_{\tau=0} \beta_{\tau,\tau+1}$ for $t > 0$ (with $\beta_{-1,0} = 1$), and $\beta_{t,t+1}$ is a first-order autoregressive stochastic process for the stochastic discount factor between times t and $t+1$. Shocks to S^c_t and $\beta_{t,t+1}$ are the main real aggregate demand shocks in the model. The CES consumption bundle, with consumption home-bias parameter b^c and elasticity of substitution θ_c, is given by

$$c_t(j) = \left[(b^c)^{1/\theta_c} \left(c_{H,t}(j)\right)^{\frac{\theta_c - 1}{\theta_c}} + (1-b^c)^{1/\theta_c} \left(c_{F,t}(j)\right)^{\frac{\theta_c - 1}{\theta_c}} \right]^{\frac{\theta_c}{\theta_c - 1}} , \tag{15}$$

with corresponding utility-based price index P_t. The Home and Foreign goods sub-aggregates are in turn given by CES bundles over a continuum of goods, with elasticities of substitution θ_p. We make the conventional assumption that $\theta_p > \theta_c$.

Households demand a deposits aggregate that consists of the purchasing power of domestic and foreign currency deposits, and that reduces the monetary transactions costs of purchasing the bundle of consumption goods. The functional form for liquidity demand is a simplified version of the one used in Schmitt-Grohé and Uribe (2004),

$$s^c_t(j) = A^c S^{md}_t \left(v^c_t(j)\right)^{\varpi} \quad , \quad v^c_t = \frac{P_t c_t(j)}{D_{liq,t}(j)} , \tag{16}$$

where A^c is a parameter that determines steady state velocity, and thereby the size of overall money demand and the size of banks' balance sheet, $v^c_t(j)$ is the endogenous velocity of circulation of money, ϖ determines the elasticity of monetary transactions costs with respect to velocity variations, and S^{md}_t is a first-order autoregressive stochastic shock to liquidity preference. We will think of shocks to the latter as "flight to safety" shocks, because an increase in S^{md}_t can be thought of as an increase in the demand for the safety of money, in either currency, at a given level of real activity. The nominal CES deposits aggregate, with "financial home bias" parameter $b^d S^{mm}_t$ and elasticity of substitution θ_d, is given by

$$D_{liq,t}(j) = \left[\left(b^d S^{mm}_t\right)^{1/\theta_d} \left(D^h_{H,t}(j)\right)^{\frac{\theta_d - 1}{\theta_d}} + \left(1 - b^d S^{mm}_t\right)^{1/\theta_d} \left(E_t D^h_{F,t}(j)\right)^{\frac{\theta_d - 1}{\theta_d}} \right]^{\frac{\theta_d}{\theta_d - 1}} , \tag{17}$$

where S^{mm}_t is a first-order autoregressive stochastic process for the demand for foreign versus domestic currency. We will think of shocks to $S^{mm^*}_t$ as "flight to the dollar" shocks, because a decrease in $S^{mm^*}_t$ can be thought of representing an increase in Foreign households' demand for Home currency ("dollars") relative to Foreign currency, at a given level of real activity. In equilibrium the main effect of this shock will be a depreciation of the domestic currency, with the size of the depreciation depending on the substitutability θ_d between domestic and foreign currency. For future reference, the derivatives of real liquidity $d_{liq,t}(j)$ with respect to its two arguments are denoted by $d^{H'}_{liq,t}(j)$ and $d^{F'}_{liq,t}(j)$. The representative household's nominal flow budget constraint can be shown to be

$$\begin{aligned} & D^h_{H,t}(j) + E_t D^h_{F,t}(j) + Q_t k_t(j) - L^h_{H,t}(j) - E_t L^h_{F,t}(j) \\ = \; & i^h_{dH,t-1} D^h_{H,t-1}(j) + E_t i^h_{dF,t-1} D^h_{F,t-1}(j) \\ & + Ret_{k,t} Q_{t-1} k_{t-1}(j) \left(1 - \kappa^h_{H,t-1} \Gamma^h_{H,t}(j) - \kappa^{h^*}_{F,t-1} \Gamma^{h^*}_{F,t}(j)\right) \\ & - P_t (1 + s^c_t(j)) c_t(j) + W^{hh}_t h_t(j) + P_t \Upsilon_t(j) \end{aligned}$$

This states that households' net assets (deposits plus land minus loans) at time t must equal the gross return on net assets held in the previous period (on deposits and on the shares of land returns that do not go to banks to repay loans) minus consumption (including transaction costs $s^c_t P_t c_t(j)$) plus labour income $W^{hh}_t h_t(j)$ and lump-sum net income $P_t \Upsilon_t(j)$. The latter equals the sum of profits and dividends of manufacturers, unions and banks, price and wage adjustment costs, costs of monitoring manufacturers, penalty costs paid by banks, and monetary transactions costs related to retail and interbank deposits. All adjustment and transactions costs are therefore assumed to represent payments to households rather than resource costs, which means that they do not appear in the aggregate resource constraint. The real normalized Lagrange multiplier of the budget constraint is denoted by $\check{\lambda}_t$. Households also face the participation constraints (13) for taking out loans in domestic and foreign currency. The real multipliers on these participation constraints are denoted by $\check{\lambda}_t \tilde{\lambda}^h_{H,t+1}$ and $\check{\lambda}_t \tilde{\lambda}^{h^*}_{F,t+1}$, where the latter multiplies one of the participation constraints of foreign banks, because these are the source of foreign currency credit.

3.4.2. Optimality Conditions

We assume that each household holds identical initial stocks of all physical and financial assets and liabilities, and receives identical lump-sum dividends from banks, manufacturers and unions. Because households face identical market prices, this implies that they make identical decisions, and remain symmetric at all times. The index j can therefore be dropped when stating the optimality conditions, which are presented in real normalized form. The first-order conditions for domestic and foreign consumption goods, hours worked, and the bankruptcy cutoff conditions, are standard for models in this class, and are omitted to conserve space.

The first-order condition for consumption is

$$\frac{S^c_t \left(1 - \frac{\nu}{x}\right)}{\check{c}_t - \frac{\nu}{x}\check{c}_{t-1}} = \check{\lambda}_t \left(1 + s^c_t + s^{c'}_t v^c_t\right) \ . \tag{18}$$

This states that the marginal utility of consumption equals the marginal utility of wealth multiplied by the effective purchase price of consumption goods p^c_t, an important variable for the transmission mechanism of our model:

$$p^c_t = 1 + s^c_t + s^{c'}_t v^c_t \ . \tag{19}$$

We note that, due to monetary transactions costs, p^c_t exceeds unity but is decreasing in the quantity of deposits.

The first-order condition for land is

$$
\begin{aligned}
1 \;=\; & \beta_{t,t+1}\mathbb{E}_t\frac{\check{\lambda}_{t+1}}{\check{\lambda}_t}\check{ret}_{k,t+1}\left[\left(1-\kappa^h_{H,t}\Gamma^h_{H,t+1}-\kappa^{h^*}_{F,t}\Gamma^{h^*}_{F,t+1}\right)\right. \\
& \left. +\tilde{\lambda}^h_{H,t+1}\kappa^h_{H,t}\left(\Gamma^h_{H,t+1}-\xi^h_H G^h_{H,t+1}\right)+\tilde{\lambda}^{h^*}_{F,t+1}\kappa^{h^*}_{F,t}\left(\Gamma^{h^*}_{F,t+1}-\xi^{h^*}_F G^{h^*}_{F,t+1}\right)\right] \;,
\end{aligned} \tag{20}
$$

which reflects that some shares of land returns are paid out to banks to repay loans, and that the availability of land as collateral relaxes banks' participation constraints.

The first-order conditions for domestic and foreign currency deposits are

$$
\begin{aligned}
1-s^{c'}_t\left(v^c_t\right)^2 d^{H'}_{liq,t} &= \frac{\beta_{t,t+1}}{x}\mathbb{E}_t\frac{\check{\lambda}_{t+1}}{\check{\lambda}_t}r^h_{dH,t+1}\;, \\
1-s^{c'}_t\left(v^c_t\right)^2 d^{F'}_{liq,t} &= \frac{\beta_{t,t+1}}{x}\mathbb{E}_t\frac{\check{\lambda}_{t+1}}{\check{\lambda}_t}r^h_{dF,t+1}\;.
\end{aligned} \tag{21}
$$

This states that the product of the intertemporal marginal rate of substitution and the deposit interest rate is less than one, due to monetary transactions costs that are inversely related to the quantity of deposits.

The first-order conditions for Home and Foreign currency loans are

$$
\begin{aligned}
1 &= \frac{\beta_{t,t+1}}{x}\mathbb{E}_t\frac{\check{\lambda}_{t+1}}{\check{\lambda}_t}\tilde{\lambda}^h_{H,t+1}r^h_{\ell H,t+1}\;, \\
1 &= \frac{\beta_{t,t+1}}{x}\mathbb{E}_t\frac{\check{\lambda}_{t+1}}{\check{\lambda}_t}\tilde{\lambda}^{h^*}_{F,t+1}r^h_{\ell F,t+1}\;.
\end{aligned} \tag{22}
$$

3.4.3. The Monetary UIP Condition (MUIP)

Derivation An important theoretical prediction of our model is that relative supplies and demands of domestic and foreign currency deposits are key drivers of the exchange rate and of relative returns to the two currencies. To show this analytically, we derive a MUIP condition that combines the two household first-order conditions for domestic and foreign currency deposits (21) with the optimal pricing conditions of retail deposit banks (12), and noting that in our calibration we will have $\mu^{h^*}_{dF}=\mu^h_{dH}$. After log-approximation we obtain expressions for the excess return of domestic over foreign currency assets xsr_t and the MUIP spread u_t:[26]

$$
xsr_t=\mathbb{E}_t\left(\ln i_t-\ln i^*_t-\ln\varepsilon_{t+1}\right)\cong\mathbb{E}_t\left(\ln r_{t+1}-\ln r^*_{t+1}-\ln\varepsilon^{\text{real}}_{t+1}\right)=\mathbb{E}_t u_t\;, \tag{23}
$$

$$
u_t=\mathbb{E}_t\Xi_{t+1}\left(\left(\frac{1-b^d S^{mm}_t}{b^d S^{mm}_t}\frac{\check{d}^h_{H,t}}{e_t\check{d}^h_{F,t}}\right)^{\frac{1}{\theta_d}}-1\right)\;. \tag{24}
$$

The MUIP spread enters due to imperfect substitutability between deposits in domestic and foreign currencies. Because the two policy rates and exchange rate depreciation are common across countries, the two countries' MUIP spreads must be arbitraged internationally:

$$
u_t+u^*_t=0\;. \tag{25}
$$

[26] We use the notation $\varepsilon^{\text{real}}_{t+1}=e_{t+1}/e_t$. See Appendix B for the full expression for $\Xi_{t+1}>0$. In steady state, $\bar{u}=0$.

In terms of terminology, when discussing our results we will refer to changes in the the exchange rate caused by interest rate changes or by changes in the MUIP spread as **UIP effects** or **MUIP effects**, respectively. UIP effects occur in all modern open economy models, while MUIP effects are specific to our model.

We can derive an expression for the real exchange rate as a function of future real interest rate differentials and MUIP spreads. Anticipating our calibration of the steady state real exchange rate at 1, we obtain

$$\ln\left(e_t\right) = \mathbb{E}_t \Sigma_{j=0}^{\infty} \left(\ln\left(r^*_{t+j+1}\right) - \ln\left(r_{t+j+1}\right) + u_{t+j}\right) \ . \tag{26}$$

Increases in the domestic real policy rate or decreases in the MUIP spread represent a greater attractiveness of the domestic currency in terms of its financial or non-financial return, and therefore appreciate the real exchange rate.

Finally, we can use the two household first-order conditions for deposits (21) to derive an expression for the steady state interest spread elasticity of the relative demand for domestic currency $\epsilon^{int} = d\log(\check{d}^h_H/(e\check{d}^h_F))/d\log(r^h_{dH}/r^h_{dF})$. We can also use the two household first-order conditions for domestic currency deposits (21) and loans (22) to derive an expression for the steady state opportunity cost elasticity of the demand for domestic currency $\epsilon^{opp} = d\log(\check{d}^h_H)/d\log((r^h_{\ell H}\tilde{\lambda}^h_H)/r^h_{dH})$. Closed form expressions for these two elasticities are used to calibrate parameters of the monetary transactions costs technology.

Interpretation The key concept in the interpretation of the MUIP condition (23) is the MUIP spread (24). It represents the relative convenience yield, or the relative marginal value of the monetary services (reductions in transactions costs) that this currency provides to its users. As one currency becomes more abundant, the non-pecuniary services of its marginal unit become less valuable and its relative convenience yield declines. This means that, ceteris paribus, its financial return, which includes expected exchange rate depreciation, must increase. In other words, the market-clearing relative financial return on a currency is increasing in the relative quantity of that currency. We note that in (24) the MUIP spread is the relative convenience yield of *Foreign* currency. Appendix B provides further details.

3.5. Manufacturers, Unions and Goods Market Clearing

Manufacturers have unit mass and are indexed by j, where individual manufacturers differ by the goods variety that they produce and sell. Manufacturers optimally combine labour $h_t\left(j\right)$ and land $K_t\left(j\right)$ to produce and price varieties of the domestic good $y_t\left(j\right)$. They set the price of their output variety $P_t(j)$ subject to monopolistic competition and Rotemberg (1982) quadratic price adjustment costs, with buyers demanding a composite of output varieties with elasticity of substitution θ_p. The production function for manufacturer j is given by

$$y_t\left(j\right) = T_t\left(S^a_t h_t\left(j\right)\right)^{1-\alpha}\left(K_t\left(j\right)\right)^{\alpha} \ , \tag{27}$$

where S^a_t is a first-order autoregressive stochastic process for labour-augmenting technology. Shocks to the latter are the main aggregate supply shock in the model. The technology (27) implies standard conditions for real marginal cost and for factor demands. We assume that manufacturers adopt local currency pricing in both domestic and foreign markets. Maximization of discounted nominal profits with respect to $P_{H,t}(j)$ and $P^*_{H,t}(j)$ yields a pair of standard New Keynesian Phillips curves. Because of symmetry, and because land is in fixed supply, we have $K_t(j) = K_t = k_{t-1} = \bar{k}$, where $\bar{k}$ is an exogenous constant. Manufacturers are fully owned by households, and their profits are transferred to the latter in a lump-sum fashion.

Unions have unit mass and are indexed by j, where individual unions differ by the labour variety they sell. Unions buy labor from households at a nominal household wage rate W_t^{hh} set in a competitive labor market. They set the price of their labor variety $W_t^{pr}(j)$ subject to monopolistic competition and quadratic wage adjustment costs, with manufacturers demanding a composite of labor varieties with elasticity of substitution θ_w. Maximization of discounted nominal profits with respect to $W_t^{pr}(j)$ yields a standard wage Phillips curve. Unions are fully owned by households, and their profits are transferred to the latter in a lump-sum fashion.

The model features no investment and government spending, and all adjustment costs are rebated to households in a lump-sum fashion. The goods market clearing condition, in real normalized terms, is therefore given by

$$\check{y}_t = \check{c}_{H,t} + \check{c}^*_{H,t}\frac{1-n}{n} \ . \tag{28}$$

Nominal GDP deflated by the CPI price index is given by

$$\check{gdp}_t = \check{c}_t + \check{x}_t - \check{m}_t \ , \tag{29}$$

where real exports are $\check{x}_t = e_t p^*_{H,t} c^*_{H,t} \frac{1-n}{n}$ and real imports are $\check{m}_t = p_{F,t}\check{c}_{F,t}$. In our simulations the concept of GDP in (29) is only used to compute ratios to GDP of other CPI-deflated variables, such as balance sheet ratios. The variable "real GDP" in our charts is based on a Fisher index.

3.6. Monetary Policy

Monetary policy is assumed to follow an inflation-forecast-based interest rate rule

$$i_t = (i_{t-1})^{m_i} \left(\bar{r}\bar{\pi}^p\right)^{1-m_i} \left(\frac{\pi_{4,t+3}}{\bar{\pi}^p}\right)^{(1-m_i)m_\pi} \ , \tag{30}$$

where $\bar{\pi}^p$ is the quarterly inflation target and $\pi_{4,t} = (\pi_t \pi_{t-1} \pi_{t-2} \pi_{t-3})^{0.25}$. The expression for the steady state real interest rate $\bar{r}$ is obtained by combining the first-order conditions for domestic-currency deposits of households and retail deposit banks. The result, $\bar{r} = \left(x/\bar{\beta}\mu^h_{dH}\right)(1 - \bar{s}^{c'} (\bar{v}^c)^2 \bar{d}^{H'}_{liq})$, reveals that steady state real interest rates in this model depend not only on the traditional determinants of the natural real interest rate, but in addition on aspects of the financial system, including the market power of banks, steady state velocity of deposits, and the elasticity of monetary transactions costs with respect to that velocity. As for fiscal policy, the initial stock of government debt is assumed to equal zero, and both government spending and taxation are zero at all times, so that government debt remains zero at all times.

3.7. Balance of Payments

There are two links between Home and Foreign. First, households in both countries trade in Home and Foreign goods. Second, households and banks in each country maintain balance sheet positions with each other and with foreign banks in both Home and Foreign currencies.

The current account equation, in real normalized terms, is therefore given by

$$\begin{aligned}
&\left(\check{\ell}^f_{H,t} + \check{\ell}^b_{H,t}\right) + e_t\left(\check{d}^h_{F,t} + \check{d}^b_{F,t}\right) - \left(\check{d}^f_{H,t} + \check{d}^b_{H,t}\right) - e_t\left(\check{\ell}^h_{F,t} + \check{\ell}^b_{F,t}\right) \\
&= \frac{1}{x}\left(r^f_{\ell H,t}\check{\ell}^f_{H,t-1} + r^b_{\ell H,t}\check{\ell}^b_{H,t-1} + r^h_{dF,t}e_{t-1}\check{d}^h_{F,t-1} + r^b_{dF,t}e_{t-1}\check{d}^b_{F,t-1}\right) \\
&- \frac{1}{x}\left(r^f_{dH,t}\check{d}^f_{H,t-1} + r^b_{dH,t}\check{d}^b_{H,t-1} + r^h_{\ell F,t}e_{t-1}\check{\ell}^h_{F,t-1} + r^b_{\ell F,t}e_{t-1}\check{\ell}^b_{F,t-1}\right) \\
&+ \check{\Lambda}^h_t - \check{\Lambda}^b_t + e_t p^*_{H,t}\check{c}^*_{H,t}\frac{1-n}{n} - p_{F,t}\check{c}_{F,t} \ ,
\end{aligned} \tag{31}$$

where the first line is the net foreign asset position, which consists of eight gross positions. This is the minimum needed to tell the full story of gross cross-border positions, which requires both loans and deposits gross positions, positions vis-a-vis both foreign households and foreign banks, and positions in both domestic and foreign currencies. The change in the net foreign asset position equals the sum of net interest payments on the eight gross positions plus the trade balance.

3.8. Calibration

The baseline calibration is for a symmetric 2-country model. We use a combination of US and international data, together with established parameter values from the literature, to calibrate the model. The US is a frequently used benchmark and has good data availability. However, it is atypical in one important respect - its currency lies at the centre of international trade in goods and assets, so that it relies less than most countries on foreign currencies. Therefore, for certain parameters, especially those relating to the use of foreign currencies, we use non-US values to calibrate the model.

3.8.1. Real Sector Parameters

World trend productivity growth x is calibrated at 2% in annual terms, while the equilibrium real interest rate $\bar{r}$ and the CPI inflation target $\bar{\pi}^p$ are calibrated at 3% and 2% in annualized terms, respectively, the former by adjusting the steady state discount factor $\bar{\beta}$. Our parameterization of the monetary policy rule is taken from the estimates of Christiano et al. (2014), with interest rate smoothing and inflation feedback parameters of $m_i = 0.85$ and $m_\pi = 2.4$.

For preferences, we normalize the steady state labour supply to 1 by adjusting the preference weight ψ. We set the steady state share of foreign goods in the domestic consumption basket to 15.3% by adjusting the goods market home bias parameter b^c. The 15.3% value matches the average ratio of imports to total final expenditure in the US over the period 2000-2016. The elasticity of substitution θ_c between domestic and foreign goods is set to 1.5, a common value in the open economy macro literature. We set the elasticity of labour supply η to 1. The habit parameter ν is calibrated at 0.74, based on the estimation results of Christiano et al. (2014).

For technology, we set the land share of income to 20% by adjusting the share parameter α. Land accounts for approximately half of the income attributed to capital in the national accounts, and capital in turn accounts for 41% in the most recent data. This means that the labour share in our model effectively represents the income shares of labour and physical capital. We adjust the endowment of land $\bar{k}$ in order to normalize the steady state real price of land $\bar{q}$ to 1. We set both price and wage gross markups, μ_p and μ_w, to 1.1. For price and wage stickiness, we use the estimation results in Christiano et al. (2014), which are based on a Calvo (1983) setup, to compute the equivalent Rotemberg (1982) parameters as $\phi_p = 105$ and $\phi_w = 212$.[27]

3.8.2. Financial Sector Parameters

The first subset of financial sector calibration targets relates to prudential regulation and the riskiness of banks and their borrowers. The capital adequacy ratio γ is set to 10.5% which is the sum of the 8.0% Basel III total capital ratio and the 2.5% capital conservation buffer (see Basel Committee on Banking Supervision (2017)). We omit the countercyclical and GSIB buffers, and the additional supervisory requirements, as these do not apply to all banks and/or at all times. In our setup banks will end up holding considerable capital above the regulatory minimum to self-insure against the risk of violating the MCAR. We therefore set the actual steady state capital adequacy ratio to 15.5%, based on recent data[28], by adjusting banks' dividend payout parameter δ^b. The cumulative share of banks that violate the Basel minimum in any quarter is F^b_{t+1}. We set it to 2.5% in steady state, close to the approximate historical frequency of systemic banking crises in Jorda et al. (2011a), by adjusting the bank riskiness parameter σ^b. Bankruptcy rates of domestic and foreign bank borrowers, $F_{H,t+1}$ and $F_{F,t+1}$, respectively, are set at 1.5% in steady state by adjusting the loss-given-default parameters ξ_H and ξ_F. This matches the findings of Ueda and Brooks (2011) for non-financial listed US companies, and also approximately matches the historical average of per-capita default rates reported in Albanesi et al. (2017).

The second subset of financial sector calibration targets relates to steady-state interest-rate spreads in the banking system. We first discuss banks' asset-side rates, and then turn to liability-side rates. To facilitate the exposition, Figure 2 provides a graphical representation of steady state interest rates in our model. We set the parameter ζ, the Basel risk weight on interbank claims, to zero. This risk weight was given a value of 20 percent in the Basel I rules, but subsequent versions of the Basel rules made this parameter model-based or risk-sensitive, and hence non-unique (see Basel Committee on Banking Supervision (2017)). A zero risk weight implies spreads between interbank lending rates and the short-term policy rate of 25 basis points, both for Home currency loans to Foreign banks and for Foreign currency loans to Home banks (*Interbank Lending Rate* in Figure 2). This is close to the 16 basis points average spread between the 1-month LIBOR and the effective Federal Funds rate over the period 2000-2016. To exactly match that spread would have required setting ζ to a slightly negative value. The interest rate on wholesale deposits equals the domestic policy rate (*Wholesale Deposit Rate* in Figure 2).

To calibrate the remaining lending spreads, we use a data set, constructed by Anderson and Cesa-Bianchi (2020), of "maturity-adjusted credit spreads" (MACS) for all listed non-financial firms in the US. These are spreads between the cost of borrowing for a given firm and an equal-maturity risk-free interest rate. We recall that in the model the wholesale lending rate corresponds to the interest rate that would be charged to a notional zero-risk corporate borrower. A model-consistent calibration for wholesale lending spreads is therefore the spread between the average commercial paper rate paid by the very best blue-chip (AAA) non-bank corporates and the policy rate at matching maturities of 3 months. Over the sample period 2000-2016 we compute this as 66 basis

[27] Christiano et al. (2014) also allow for indexation to past inflation. However, at least for price stickiness, their weight on indexation is close to zero.

[28] See Federal Reserve Bank of New York (2018).

points, and calibrate the wholesale lending spread charged to domestic households to this value, by adjusting the MCAR parameter χ (*Domestic Household Wholesale Lending Rate* in Figure 2). The wholesale lending spread charged to foreign households also contains a regulatory spread of 66 basis points, but in this case there are additional spread components. The first component, which applies under all FXMR rules, is a small MONFX spread. We calibrate this at 10 basis points, by adjusting the steady state willingness-to-lend parameter for loans to foreign households $\bar{\kappa}_H^f$. The second component, which only applies if $\phi_{fxmr} > 0$, is due to the fact that the marginal cost of funds for loans to foreign households partly or wholly depends on the foreign currency interbank lending rate, which as mentioned above is 25 basis points higher than the domestic policy rate. The total foreign household wholesale spread therefore equals between 76 and 101 basis points, the latter for FXMR1 (*Foreign Household Wholesale Lending Rate* in Figure 2).

External finance premia or retail lending spreads, which are the spreads between the retail and wholesale lending rates, are calibrated by adjusting the borrower riskiness parameters σ_H^h and σ_H^f. Their data counterpart is the difference between the MACS of all firms and the MACS of AAA-rated firms only, again at matching maturities of 3 months. In our data set this difference is equal to 167 basis points[29], which we use to calibrate the spread on domestic household retail loans. This yields a domestic household retail lending rate of 5.33% (*Domestic Household Retail Lending Rate* in Figure 2). The spread on foreign household retail loans is calibrated at 132 basis points, so that the foreign household retail lending rate under FXMR1 also equals 5.33% (*Foreign Household Retail Lending Rate* in Figure 2), while it equals 5.08% under FXMR2. The lower retail spread for foreign relative to domestic household loans is justified by the fact that foreign loans are taken out by larger corporates that are more creditworthy than the average domestic currency borrower.

Turning to liability-side rates, the steady state spread between the domestic policy rate and the domestic currency interbank deposit rate is calibrated at -10 basis points by adjusting the spread parameter μ_{dH}^b. This calibration is based on interpreting the interbank deposit rate as LIBID, and noting that the historic spread between US LIBID and the Fed Funds rate was around -10 basis points over the period 1990Q3-2008Q3, prior to the effective zero lower bound period. The steady state spreads between the policy rate and retail deposit rates are calibrated by adjusting the spread parameters μ_{dH}^h and μ_{dH}^f. The average spread between the US policy rate and the effective interest rate on household checking accounts (obtained from FDIC data) over the period 1998Q3-2008Q3 equalled around -300 basis points.[30] However, in our model deposits include a much wider range of bank liabilities, including wholesale deposits which attract rates much closer to the policy rate. To approximate the average convenience yield of total financial sector liabilities to non-banks, we therefore calibrate this spread at -150 basis points. This is very similar to Ashcraft and Steindel (2008), who compute, for the single year 2006, a spread of -134 basis points between the average rate of US commercial banks' portfolio of treasury and agency securities on the one hand and the average rate on their complete portfolio of liabilities on the other hand.

The third subset of parameters determines the size and composition of balance sheets. Figure 3 provides a graphical representation of Home and Foreign steady state balance sheet positions, in % of GDP, with steady state GDP equal across countries. L and D represent bank loans and bank deposits, HO and FO represent Home and Foreign balance sheet positions, H and F represent Home and Foreign currency positions, h and f represent Home and Foreign households, and b

[29] As a cross-check, the average BAA-AAA spread from Moody's over the same period equals 108 basis points. The discrepancy is due to the fact that the average firm has a worse rating than BAA.

[30] This spread has been significantly compressed during the ZLB period, but we exclude this period because we do not consider it representative of normal conditions in the banking sector.

represents interbank positions. Figure 4 shows data, drawn from BIS locational banking statistics, that motivate several aspects of this calibration.

Loans to domestic non-banks are calibrated at 100% of GDP by adjusting the money demand parameter A^c. This is slightly larger than the ratio of loans of the US commercial banking sector to GDP prior to the GFC, but as shown in Figure 4 slightly smaller than recent values for Germany and France, and much smaller than for the UK.[31] We calibrate the ratio of the value of land to GDP, which can be shown, based on Fed and NIPA data, to equal around 250% of GDP, by adjusting the steady-state willingness-to-lend parameter for domestic currency loans $\bar{\kappa}_H^h$. The ratio to GDP of Foreign currency household deposits in Home is set to 20% by adjusting the Home deposits home bias parameter b^d. Figure 4 shows that the 20% value is considerably larger than cross-border bank-to-nonbank positions for the US, slightly larger for Japan, but considerably smaller for Germany and especially for the UK. We set the ratio of cross-border gross interbank positions to GDP to 20%, and for symmetry we assume that this is equally split between domestic and foreign currency positions on both the asset and liability sides. We calibrate these ratios by adjusting the parameters φ_b and ϑ_b of the interbank money demand functions. This calibration implies that FXMR2 holds in steady state, and Figure 4 shows that foreign currency interbank positions are generally closely matched for the countries shown. FXMR2 is therefore a good approximation except for the short-run response of the banking system. Figure 4 shows that the 20% interbank asset and liabilities ratios are slightly higher than the historical average for the US, slightly lower for France and Germany, and considerably lower for the UK.[32] The equal currency split is roughly representative of European banking systems, while the US banking system's interbank balances are almost exclusively in terms of US dollars.

The elasticity of substitution between domestic and foreign currency deposits θ_d is calibrated at a baseline value of 1.5. There is to our knowledge no established literature on this parameter, and we will conduct sensitivity analysis to explore the sensitivity of our results to θ_d. With $\theta_d = 1.5$ the implied elasticity of the relative demand for domestic currency with respect to the interest differential equals a high $\epsilon^{int} = 22.5$. For the alternative of $\theta_d = 0.5$ we have $\epsilon^{int} = 7.5$, while for the UIP alternative, which we proxy by $\theta_d = 2500$, we have $\epsilon^{int} = 37500$.

The elasticity of monetary transactions costs with respect to velocity variations ϖ is calibrated to yield a steady state elasticity of the demand for domestic currency with respect to its opportunity cost of $\epsilon^{opp} = 3$, which yields a value of ϖ slightly below 4. Within a broad range of values around $\epsilon^{opp} = 3$ the properties of the model are not highly sensitive to ϖ. The literature on the interest semi-elasticity of money demand is of limited help in calibrating ϵ^{opp}, because the domestic-foreign interest rate spread is only one component of the opportunity cost of money creation, with the other, the multiplier of banks' participation constraint, being far more volatile for many key shocks.[33]

[31] We do not have reliable data for pre-2012 Europe.

[32] Figure 7 in Lane and Milesi-Ferretti (2018) shows that 20% corresponds approximately to the global average across BIS-reporting banks.

[33] The empirical literature on the interest semi-elasticity of money demand has found values ranging from 3 to 11 (Burnside (2011)).

4. Simulation Results

In this section we study the model economy's properties by way of impulse responses. The black solid line in all figures shows strict FXMR, the red dashed line in Figure 5 shows accommodating FXMR, the green dashed line in Figure 6 shows asymmetric FXMR, and the blue dashed and red dotted lines in Figure 7 show alternatives to the baseline calibration of $\theta_d = 1.5$. Figures 7-10 only show strict FXMR, because we consider this to be the relevant case over the medium and long run.

Our discussion of the MUIP condition will be in terms of real yields and real exchange rate changes. The MUIP spread is expressed in per cent per annum to make it comparable to interest rates. For ease of comparison all Foreign balance sheet items are converted to Home currency and Home per capita terms and then scaled by Home per capita GDP. Home's foreign saving to GDP ratio is the negative of the current account to GDP ratio. Home's net foreign financing to GDP ratio equals the ratio to GDP of the difference between Foreign bank loans to Home households $L^h_{F,t}$ and Home bank loans to Foreign households $L^f_{H,t}$. The fourth row of each figure decomposes Home liabilities to Foreign (a similar decomposition of Home assets is omitted to conserve space). NFL (net foreign liabilities) represents the sum of eight gross items as shown in equation (31). In the remaining three items RoW stands for rest of the world, or Foreign. Home households' loan liabilities to Foreign banks are $E_t L^h_{F,t}$, Home banks' deposit liabilities to Foreign households are $D^f_{H,t}$, and Home banks' interbank liabilities to Foreign banks are $D^b_{H,t} + E_t L^b_{F,t}$. The bottom half of each figure shows the financial sector balance sheets of Home (left two columns) and of Foreign (right two columns), except for net worth.[34]

The impulse responses are normalized to facilitate interpretation of the magnitudes. The financial gross capital inflow into Home currency equals 10% of Home GDP under accommodating FXMR in Figures 5-7, the Home current account deficit equals 1% of Home GDP in Figures 8-9, and the Home current account surplus equals 1% of Home GDP in Figure 10.

4.1. Financial Inflow Shock

Figures 5-7 study a shock that increases Foreign households' demand for Home currency deposits. The shock consists of a large and persistent ($\rho^*_{mm} = 0.95$) decline in the home bias parameter $S^{mm^*}_t$ in the Foreign liquidity aggregate $D^*_{liq,t}$. From the perspective of Foreign, this represents a sudden shift in domestic investor preferences that could be interpreted as capital flight to the safety of the US dollar. From the perspective of Home, this is the most natural representation of a "capital inflow shock". However, such a financial inflow is automatically a gross flow with zero net value, because it must have as its instantaneous counterpart a matching financial outflow. In other words, the current account and net foreign asset effects of such a shock must equal zero on impact, and they could remain zero over time, depending on the subsequent banking sector response, which depends on FXMR.

[34] Because in Figures 7-10 interbank positions show no major changes, the figures omit these positions. Compared to Figures 5 and 6 they therefore miss the final two rows.

4.1.1. Accommodating FXMR

Responses under accommodating FXMR are shown as red dashed lines in Figure 5. This necessarily represents the instantaneous response of the financial system to an increase in the demand for domestic deposits, because it accurately represents the settlement of the incoming payment instrument. The shock to $S_t^{mm^*}$ represents a reduction in Foreign households' demand for Foreign currency deposits $D_{F,t}^{f^*}$ and an increase in their demand for Home currency deposits $D_{H,t}^{f}$. The magnitude of the shock is calibrated to result in an increase of Foreign households' Home currency deposit holdings equal to exactly 10% of Home GDP on impact.

It is useful to study the sequence of events whereby a Foreign household acts on this type of preference shock in a modern financial system. It must start by issuing a financial instrument, which we can generically refer to as a "check", that is drawn on its existing Foreign currency account in a Foreign bank, and it must then pay this check into an existing or new Home currency account in a Home bank. This check only has value because the deposit account on which it is drawn already exists and has a positive balance. This means that the check's receipt by the Home bank does not represent net new savings, or a new deposit, for the global financial system. Furthermore, when the Home bank receives the deposit, this does not give it any additional funds to lend. Instead it automatically lends the funds in the instant it receives them, because by double-entry bookkeeping the counterpart of crediting the check to their customer's account (a debit and liability of the Home bank) is the acquisition of an accounts receivable claim, for settlement of the underlying check, on the Foreign bank (a credit and asset of the Home bank). In our model, without loss of generality, settlement of such check deposits is performed in the currency of the checks, in this case in Foreign currency.[35] Under accommodating FXMR this could take the form of either an increase in Home banks' Foreign currency nostro accounts $D_{F,t}^{b}$ or a decrease in Home banks' Foreign currency vostro accounts $L_{F,t}^{b}$. In our model the nostro accounts are fairly closely tied down by the interbank money demand function, leaving most of the adjustment to be made through a decrease in the vostro accounts, which decrease by just under 10% of Home GDP, virtually the same amount as the increase in Foreign households' deposits $D_{H,t}^{f}$.

Foreign banks' balance sheet therefore shrinks by the amount of the deposit transfer, while the size of Home banks' balance sheet remains unchanged, with a change in the liability composition away from interbank liabilities and towards Foreign household deposits. Other than some very small general equilibrium effects on lending, no further significant balance sheet adjustments occur.

The movements in $D_{F,t}^{f^*}$ and $D_{H,t}^{f^*}$ under accommodating FXMR, facilitated by the movements in Home banks' vostro accounts, are so large that they nearly completely match the movement in the home bias parameter $S_t^{mm} b^{d^*}$, with the MUIP spread staying nearly constant. There are therefore almost no MUIP effects on the exchange rate. Furthermore, the shock itself, being purely financial, has no direct effect on GDP, inflation and real policy rates, so that UIP effects on the exchange rate are also very small. As a result, the shock has negligible real effects. Accommodating FXMR therefore insulates the macroeconomy from even very large currency demand shocks. However, it does so at the cost of increasing financial stability risks among banks, because the change in Home banks' vostro accounts implies that the Home financial system is now significantly long Foreign currency. As we will now see, these financial stability risks must be undone by banks under strict FXMR, but this can only be done by creating significant additional macroeconomic volatility. There is therefore a clear trade-off between financial stability and macroeconomic stability.

[35] The settlement currency determines which bank ends up with a currency mismatch as a result of the shock.

4.1.2. Strict FXMR

Responses under strict FXMR are shown as black solid lines in Figure 5. This rule prohibits a change in the net balance between both Home and Foreign banks' foreign currency nostro and vostro accounts, and provides a plausible representation of banks' medium and long run behavior. In this case, all adjustments to the gross deposit inflow have to be made through changes in household loans or exchanges of household deposits that undo any currency mismatch. Price adjustments play a critical role in these adjustments. First, prices need to change to make it optimal for Home banks to offer additional Home currency credit, albeit not at the level demanded at pre-existing prices and interest rates. Second, they need to change to make it optimal for Foreign banks to reduce Foreign currency credit. Third, they need to change to make it optimal for Home households to reduce their desired holdings of Home currency deposits so that they are willing to exchange them against Foreign currency deposits with Foreign households. Home households can offer Foreign households either some of their existing Home currency deposits, or Home currency deposits that they obtain by themselves obtaining new Home currency credit from Home banks. Fourth, they need to change to make it optimal for Foreign households to reduce the desired increase in their Home currency deposits to the point where their demand can be satisfied by either Home banks or Home households.

There are several reasons why the ability of Home banks to satisfy the additional Foreign demand for Home currency deposits through additional loans is limited. First, the steady state Foreign collateral share $\bar{\kappa}_H^f$ that is available to secure such loans is far too small to collateralize a large increase in loans. Second, for banks additional lending has not only a regulatory cost but also a cost due to a tightening of their participation constraint (see (22)). The latter is affected by changes in the value of land, which decreases in Foreign in Foreign currency. The reason is that a relative decrease in demand for loans in Foreign currency, which are disproportionately collateralized by Foreign land, decreases demand for that land, and therefore, given fixed supply, decreases its price. Third, the value of Foreign collateral in Home currency drops due to the real exchange rate appreciation, which will be discussed below.

In quantitative terms, and focusing on the impact period, Home banks increase Home currency loans by 1.3% of Home GDP, divided into increases in loans to Home households, by 1.1% of GDP, and to Foreign households, by 0.2% of GDP. Foreign banks decrease Foreign currency loans by 2.4% of Home GDP, divided into decreases in loans to Foreign households, by 1.9% of Home GDP, and to Home households, by 0.5% of Home GDP. The decreases in Foreign positions are made larger by the real appreciation. It can also be shown that Home banks' Basel capital adequacy ratio drops by 0.1 percentage point on impact while Foreign banks' ratio increases by a similar amount. The reason is that Home banks lever up while Foreign banks deleverage. Because the responses of Home and Foreign loan supplies are limited by the lending technology and the availability of collateral, they create and destroy deposits in the desired currencies, but not in sufficient quantities, and not for the households who require them. A further reallocation of deposits across countries and households is therefore necessary.

To study this reallocation we turn to the MUIP condition. The ceteris paribus effect of the decrease in Foreign households' preference parameter $S_t^{mm^*}$ is an increase in their MUIP spread. Furthermore, by (25) MUIP spreads need to be arbitraged worldwide, so that the increase in the Foreign MUIP spread must be matched by a decrease in the Home MUIP spread, which is the spread shown in Figure 5. This represents an increase in the relative convenience yield of Home currency, and therefore a decrease in the required financial yield of Home currency. In the case of Foreign households this is a direct result of their increase in preferences for Home currency. Home households do not experience this preference-driven change in convenience yields. Instead they respond only to the change in relative financial yields in favor of Foreign currency deposits. They do so by increasing their relative holdings of Foreign currency deposits at the expense of Home currency deposits, through an exchange with Foreign households. This brings their relative convenience yield into line with that of Foreign households. The exchange of deposits satisfies a major portion of Foreign households' increased demand for Home currency, and this is why loans do not need to change one-for-one to accommodate the change in currency preferences.

Because policy rates are set with inertia by policymakers, changes in policy rates accomplish only a small part of the required relative changes in financial yields, with the major part accomplished by a large expected rate of real exchange rate depreciation of the Home currency. Given an unchanged steady state real exchange rate, on impact the Home real exchange rate therefore appreciates by more than 1.5%. This is an intuitive result - an increase in demand for Home currency leads to its appreciation. The appreciation is expansionary and inflationary for the Foreign economy and contractionary and disinflationary for the Home economy. This calls for a persistent decrease in the Home policy rate and a persistent increase in the Foreign policy rate, following initial movements of real rates in the opposite direction because of interest rate smoothing. This explains why policy rates move in the right direction to contribute to the decrease in the Home MUIP spread.

In quantitative terms, and again focusing on the impact period, for Foreign households the increase in the relative financial return on Foreign currency serves to moderate the increase in their demand for Home currency deposits, which under strict FXMR is only 4.1% of Home GDP compared to 10% under accommodating FXMR, and the decrease in their demand for Foreign currency deposits, which is only 5.5% of Home GDP. For Home households the same change in relative financial returns leads them to increase their holdings of Foreign currency deposits by 3.3% of Home GDP, and to decrease their holdings of Home currency deposits by 2.9% of Home GDP. Therefore, of Foreign households' 4.1% of Home GDP increase in demand for Home currency deposits, only 0.2% of GDP is satisfied by additional Home currency loans to Foreign households, with the remainder coming from an approximately 4.0% of GDP exchange of Home currency deposits against Foreign currency deposits with Home households, who obtain additional Home currency loans of 1.1% of GDP but end up holding a stock of Home currency deposits that is lower by 2.9% of GDP. For Home banks, who experience a 4.1% of GDP increase in demand for Home currency deposits by Foreign households, a combination of a 1.3% of GDP increase in Home currency loans and a 2.9% of GDP decrease in Home currency deposits by Home households allows Home banks to match their Home currency books, and thus also their Foreign currency books. For Foreign banks, who experience a 5.5% of GDP decrease in demand for Foreign currency deposits by Foreign households, a combination of a roughly 2.4% of GDP decrease in Foreign currency loans and a 3.3% of GDP increase in Foreign currency deposits by Home households allows Foreign banks to match their Foreign currency books, and thus also their Home currency books.[36]

For interbank reserves, the large transfer of Home household deposits in Home banks to deposits in Foreign banks leads to reserve losses for Home banks that cancel out the reserve gains that came with the original deposits by Foreign households. In aggregate, because mismatched interbank positions in either currency are ruled out, the quantity of domestic currency lending, which is not

[36] Note that there are small rounding differences when adding up balance sheet items. These are partly explained by positive and negative changes in the net worth of Home and Foreign banks.

infinitely elastic, directly determines the quantity of domestic currency deposits. In other words, there is a less than 10% of Home GDP supply response to the increase in the relative demand for Home currency deposits, because returns adjust in order to moderate the increase in demand for Home currency deposits by Foreign households, and by decreasing the demand for Home currency deposits by Home households.

Turning to the real economy, the cut in the policy rate and the wealth effect of the appreciating real exchange rate stimulate Home consumption. This deteriorates the current account and thereby leads to a 0.2% decrease in Home GDP and a 0.2% increase in Foreign GDP. This is therefore an important example of a purely financial shock that, through the real exchange rate, has sizeable effects on the real economy. The size of this effect depends on the details of the calibration of the nonfinancial side of the economy. For example, in a comparable calibration but with sticky inflation rather than sticky prices the Home GDP contraction can exceed 1%.

4.1.3. Open Economy Policy Debates

Figure 5 can also illuminate aspects of the policy debates discussed in Section 2. We begin with the use of **current accounts as indicators of financial vulnerability**, and recall that *creditors do not stop financing current accounts, they stop financing debt.* We begin with the pre-shock steady state of this economy, where net foreign liabilities equal zero. Absent other information this might indicate low vulnerability. However, as shown in Figure 3, gross liabilities are very large, and are therefore highly vulnerable to changes in creditor sentiment. Furthermore, given the relative sizes of the different categories of gross liabilities, they are most vulnerable not to foreign but to domestic creditors. Turning now to the changes induced by the inflow shock, the fourth row of Figure 5 shows that there are very large differences between changes in net and gross foreign liabilities. Under accommodating FXMR, we observe an increase in gross deposit liabilities of 10% of GDP matched by an approximately equal decrease in gross interbank liabilities. This will have positive financial stability effects if deposit liabilities are a more stable source of funding than interbank loans, while the unchanged net foreign liabilities position fails to convey this information. Under strict FXMR, Home's net interbank liabilities never change, while there is a sharp increase in gross deposits owed to foreign households. Net foreign liabilities increase far less and far more slowly. Again, the key question for financial stability is whether foreign household deposits are a stable source of funding, not whether net foreign liabilities increase.

We now turn now to the **global saving glut**, and recall that *domestic households do not finance current account deficits with physical saving provided by foreign households, but with digital purchasing power provided by banks, which are more likely to be domestic than foreign.* We can think of Home as the US and Foreign as the rest of the world. Foreign saving and net Foreign financing are shown next to each other in two panels on the third row of Figure 5. Under accommodating FXMR, we observe a very large gross capital inflow equal to 10% of GDP, but no change at all in foreign saving and minimal changes in net foreign financing. There is therefore no necessary connection between, on the one hand, the large capital inflows that are observable in financial markets and that are often interpreted as saving or financing inflows in policy debates, and on the other hand, a global saving glut. Under strict FXMR, Foreign saving does increase, but this is merely a by-product of that regime's real exchange rate changes, which affect physical production and consumption decisions. Net Foreign financing behaves completely differently, as Foreign banks, in response to a drop in demand for Foreign currency, sharply cut back credit to all borrowers, including Home households. Home households can nevertheless pay for their increased imports, using a combination of existing deposits and deposits newly created for them by Home banks. Financial inflows, changes in net Foreign financing, and the saving inflows of the global saving glut hypothesis, are therefore fundamentally different concepts. The reason is that the "wall of saving" (Borio and Disyatat (2011)) in models of international net capital flows is a physical concept that has no counterpart in observable financial variables.

Next we discuss the **current account version of Triffin's dilemma**, and recall that *the creation of US dollars requires US dollar credit creation, not foreign saving and thus not US current account deficits, and that furthermore US dollar credit creation can be performed by both US and non-US banks.* We can think of Home as the US and Foreign as the rest of the world, and of the shock as an increase in demand for the global reserve currency. Figure 5 shows that US banks can satisfy this demand through changes in US dollar loans, either interbank loans to foreign banks or retails loans to domestic or foreign households, and that US households can satisfy it by trading their US dollar deposits against Foreign currencies. Current account deficits are merely a side effect of this shift in currency demand, and they are far smaller, even after several years, than the increase in foreigners' demand for US dollar assets.

Finally, we study the **high correlation between gross capital inflows and outflows**, and recall that *all financial flows necessarily consist of a pair of gross inflow and outflow components that are inseparable as a matter of accounting, and that are therefore necessarily perfectly correlated.* In Figure 5, we can see this most clearly under accommodating FXMR, where the "capital inflow", of deposits held by Foreign households, instantaneously gives rise to a "capital outflow", in interbank settlement vostro accounts. There could of course be simultaneous financial outflows whereby Home households deposit their checks in Foreign banks, but this would again be transactions that consist of two separate gross flows. Under strict FXMR, the additional credit creation flows, whether domestic or cross-border, also consist of two matching gross flows. For this shock, net payment flows play a negligible role relative to financial flows, and this is clearly visible in Figure 5.

4.1.4. Exchange Rate Related Empirical Puzzles

Figure 5 shows why the financial inflow shock can account for the **UIP puzzle**. The primary and direct effect of the shock is a strong decrease in the MUIP spread, and therefore a strong decrease in the excess financial return on Home currency. Because this leads to a Home exchange rate appreciation, it also decreases relative Home GDP and inflation, and therefore leads to a negative policy rate differential. But these UIP effects are much weaker than the MUIP effects, so that the increase in expected exchange rate depreciation, and the decrease in the excess return, are far larger than the decrease in the interest differential. In other words, in the presence of financial inflow shocks low-interest currencies tend to depreciate over time. As a result, as found empirically by Fama (1984), in a regression of the rate of exchange rate depreciation on the interest rate differential the regression coefficient is negative and large.

Figure 5 also shows why the financial inflow shock can account for the **exchange rate disconnect puzzle**. The shock triggers large exchange rate changes, with only indirect and small effects on real variables. As a result, as found empirically by Meese and Rogoff (1983), changes in the nominal exchange rate are close to white noise, and changes in nominal and real exchange rates are highly correlated.

4.1.5. Asymmetric Country Sizes and FXMR

Figure 5 may give the impression that it is only for the very restrictive case of accommodating FXMR for both banking systems that financial inflow (and outflow) shocks have small effects on the real economy. Figure 6 shows that this impression is misleading, because accommodating FXMR for a small open economy combined with strict FXMR for the rest of the world yields very similar results for the small open economy. This assumption may not be unrealistic for some small open economies that are unable to find, at the level of the global financial system, private non-bank counterparties to hedge large exposures denominated in the US dollar.

Figure 6 studies the same shock as in Figure 5 but for the case of a small open economy, with Home equal to 3.25% of the world economy, which roughly corresponds to the share of the UK economy in global GDP. In the calibration this requires appropriate changes in goods and deposits home bias parameters, while all key steady state variables and ratios except goods and asset shares remain extremely close to the symmetric baseline. The figure compares the case of strict FXMR in both economies (solid black lines), and of asymmetric FXMR (dashed green lines). Under asymmetric FXMR, Foreign (96.75% of the world economy) follows strict FXMR with respect to Home currency deposits ("pounds"), allowing no mismatches, while Home follows accommodating FXMR with respect to Foreign currency deposits ("dollars"), allowing mismatches. The shock is calibrated such that under asymmetric FXMR there is an increase in Home currency deposits held by Foreign households equal to 10% of Home GDP, as in Figure 5.

Under strict FXMR, we observe very similar results to Figure 5, including the effects on Home banks' balance sheets and Home real variables. The only differences are the very large drops of Foreign households' Foreign currency loans and deposits relative to Home GDP. The reason is that Home is a very small economy, so that it is much easier for Foreign households to reduce their Foreign currency deposits than to obtain additional Home currency deposits. When scaled by Foreign GDP, the changes in Foreign currency loans and deposits only amount to around 0.1%.

By contrast, under asymmetric FXMR we observe very similar results to the case of accommodating FXMR in Figure 5. In Home, the 10% increase in Home currency deposits held by Foreign households is matched almost exactly by a decline in Foreign currency interbank vostro accounts, with very little movement elsewhere on the Home balance sheet. In Foreign, households reduce their holdings of Foreign currency deposits, matched on their banks' asset side by roughly equal-sized contractions in Foreign currency nostro account lending to Home banks and Foreign currency lending to Foreign households. On the real side, the accommodating stance of Home banks with respect to currency mismatches ensures that the shock has minimal effects on the MUIP spread, the real exchange rate, the current account, consumption and GDP. It can be shown that this property of asymmetric FXMR carries over to all other shocks studied below. Finally, under asymmetric FXMR, as under accommodating FXMR, we observe a very large gross capital inflow equal to 10% of GDP, but almost no change at all in foreign saving and net foreign financing.

4.1.6. The Role of Deposit Substitutability

Figure 7 shows the sensitivity of the results in Figure 5 to different elasticities of substitution between Home and Foreign currencies, θ_d and θ_d^*. The solid black lines are identical to the strict FXMR case in Figure 5, and represent the baseline case with $\theta_d = \theta_d^* = 1.5$, the blue dashed lines represent the case of very low substitutability with $\theta_d = \theta_d^* = 0.5$, and the pink dotted lines represent the case of UIP, which we proxy by setting $\theta_d = \theta_d^* = 2500$.

The reallocation of Foreign household deposits to Home currency deposits has the same basic pattern in all three scenarios, but with differences in the sources from whom they obtain their deposits. Under UIP all deposits come from Home households, without any lending response by Home or Foreign banks. Under low substitutability the required deposits come increasingly, and in the limit completely, from the lending response of banks.

Under UIP, the shock leads to a simple reallocation of Home and Foreign currency deposits between Home and Foreign households, with no change in interest rates, the real exchange rate, the current account, and output. The shock elicits no lending response at all because a minimal, and in the limit zero, change in the MUIP spread is sufficient to reallocate highly substitutable deposits between Home and Foreign households. Just like for the case of accommodating FXMR in Figure 5, gross capital inflows into Home currency deposits have zero effects on Home banks' lending, and are matched by an equal and exactly offsetting gross capital outflow that implies no change in any real variables. The difference is that in Figure 5 the matching gross outflow is an increase in Home banks' interbank claims on Foreign banks, while in Figure 7 it is an increase in Home households' retail deposit claims on Foreign banks.

Under very low substitutability, we observe much larger effects on the MUIP spread, because the shock has a larger effect on the relative convenience yield of the two currencies. A larger MUIP spread in turn implies larger changes in the real exchange rate, in real policy rates, and in real variables. Home households are far less willing to supply the Home currency desired by Foreign households out of their existing holdings, so that a greater share of the balance sheet adjustments must come through lending responses. Home households still supply a large share of the required deposits, but in this case by obtaining additional bank loans that create additional Home currency deposits, which they then exchange with Foreign households against Foreign currency deposits.

4.2. Global Saving Glut: Physical Glut or Credit Glut?

Financial shocks to gross asset demands or to gross credit supplies are a very common feature of modern economies. Yet they can only be studied in models of gross capital flows. The open economy literature has predominantly been using models of net capital flows and therefore of physical resource flows. As a result, it has attempted to explain the global saving glut based on shocks to preferences or technologies. We will now show that financial shocks can equally give rise to global saving glut dynamics, but with more realistic implications for the relative evolution of real and financial variables. Furthermore, while the global saving glut hypothesis argues that foreign saving *financed* the US current account deficit, our results clearly highlight the entirely distinct behavior of foreign saving and foreign financing.

4.2.1. Foreign Physical Saving Glut

Figure 8 studies a persistent ($\rho^{\beta} = 0.975$) shock that increases the Foreign discount factor $\beta^{*}_{t,t+1}$. The shock is calibrated to generate a Home current account deficit that peaks at 1% of GDP.

The immediate effect of the shock is a drop of the Foreign real policy rate of more than 180 basis points. Because the Foreign rate of time preference drops by even more, Foreign households increase their saving. They do so through a combination of lower Foreign consumption, which drops by around 0.20% over the first year, and higher Foreign labor supply, which increases Foreign GDP by around 1.1%. The Home policy rate also drops, but only by around 35 basis points. Because of the interest rate gap between Foreign and Home rates, the Home real exchange rate appreciates by more than 4%, with Home consumption increasing by around 0.85% due to a combination of lower policy rates and the wealth effects of an appreciated real exchange rate. The appreciation triggers a drop in Home GDP and inflation.

Foreign saving increases by 1% of Home GDP. But this has virtually no connection with net Foreign financing, which drops by 0.7% of Home GDP on impact. This is mainly due to the fact that Home lending to Foreign households increases, due to a sharp drop in the opportunity cost of Home credit creation for Foreign households. This in turn is due to a massive 14% increase in the Home value of Foreign collateral, triggered by the very low interest rates in Foreign, which far outweigh the negative effects of the real appreciation. The opportunity cost of Foreign credit creation for Foreign households drops for the same reason, with the Foreign value of Foreign collateral rising by around 18%. Foreign households therefore demand additional credit across the board. Values of collateral and credit also increase in Home, but given the smaller drop in Home interest rates they increase by considerably less than in Foreign. The general picture is one of global expansion of gross asset and liability positions on impact due to low interest rates, while of course net foreign liabilities do not change at all on impact. However, the changes in gross positions are merely of a similar magnitude as changes in real variables, while during typical capital inflow episodes financial sector balance sheets tend to grow by far more than real variables.

The subsequent evolution of loan and deposit balances reflects the accumulation of Home net foreign liabilities. Home households' deposits decrease while their loans keep increasing, whereas Foreign households' deposits increase while their loans are nearly flat or decreasing. But these changes are very slow and much smaller than the impact changes in gross positions. In other words, net payment flows are very small relative to financial flows even for real shocks.

The MUIP spread initially changes by less than 10 basis points following this shock, and subsequently increases gradually. The reason is that the accumulation of trade surpluses by Foreign households, whose demand is overwhelmingly for Foreign currency deposits, and vice versa for Home households, increases the demand for Foreign currency relative to Home currency, and therefore increases the relative convenience yield of Foreign currency. But this plays only a minor role in exchange rate determination, which is dominated by the very strong UIP effects caused by the domestic-foreign interest rate differential.

Under accommodating FXMR, which is not shown in Figure 8, there are almost no changes in the real exchange rate, the current account, and output. Because very low interest rates raise the value of their collateral, Foreign households demand large quantities of additional credit, including from Home banks. In other words, with accommodating FXMR there is no general equilibrium increase in Foreign saving at all even for this shock to saving preferences, while there is a very large increase in Home financing of the Foreign economy rather than the reverse.

We note that during the saving glut episode of the 1990s and 2000s, US credit expanded far more strongly than in Figure 8. Thus, an account of this period based on shocks to Foreign saving preferences implies counterfactual predictions for many important variables. We now turn to financial explanations of the saving glut episode to study whether they exhibit the same shortcoming.

4.2.2. US Credit Glut

Figure 9 studies an expansionary shock to Home bank credit extended to Home households, specifically a persistent ($\rho^{\kappa_H^h} = 0.95$) willingness-to-lend shock that increases the coefficient $\kappa_{H,t}^h$. The shock is again calibrated to yield a Home current account deficit that peaks at 1% of GDP. Because our subject is the global saving glut, we think of Home as the US.

The shock causes 12.1% and 10.3% of GDP expansions in Home households' Home currency loans and deposits. This large increase in available purchasing power, which lowers the Home effective price of consumption by 2.3% on impact, is the proximate cause of a 2.9% increase in Home consumption, a 1.7% increase in Home GDP, a 230 basis points increase in Home inflation, and an eventual 150 basis points increase in the Home real policy rate. The difference between Home GDP and Home consumption represents dissaving and a Home current account deficit. The increase in global demand implies that Foreign GDP also increases, but by far less, at around 0.4%, while Foreign consumption decreases by 0.9%.

The MUIP spread, or Home currency financial excess return, increases by around 40 basis points on impact. The reason is that the very large relative expansion in Home credit increases the abundance and thus reduces the relative convenience yield of Home currency. Foreign households, due to the excess financial return, demand relatively more Home currency, and obtain it by exchanging some of their Foreign currency deposits against Home currency deposits with Home households. As for loans, all households reduce their borrowing in sectors where banks have not adopted more generous lending policies. Foreign households therefore borrow less from all banks, while Home households borrow less from Foreign banks.

The increase in the Home MUIP spread would ceteris paribus depreciate the Home exchange rate on impact, but we observe that it in fact appreciates by around 1.6%. The reason is that this shock has strong effects on Home aggregate demand, inflation and real interest rates because it increases the amount of purchasing power available to households. UIP effects therefore give rise to a nominal interest differential in favor of Home currency of around 100 basis points at the maximum. This is large enough to more than offset the exchange rate effects of the MUIP spread.

Turning to the saving glut, there is a Home current account deficit, but this is financed by US banks' additional credit, not by Foreign households "lending" additional physical resources. While Foreign physical saving increases, net Foreign financing decreases, mainly because Home households demand less credit from Foreign banks when Home banks offer more generous credit. Home households do over time increase their net foreign liabilities position, but this is mostly reflected in very small and gradual changes to their domestic and foreign currency deposit balances as they make payments.

A key aspect of the saving glut was the "Greenspan bond conundrum" (Greenspan (2005)), the observation that US long-term bond yields declined during the height of the saving glut episode in

2004-2005 despite continuous policy interest rate increases. The saving glut hypothesis appeals to foreign physical saving as an explanation for such a divergence. However, at least in our impulse response in Figure 8 the opposite occurs following a physical saving shock - a drop in output and inflation leads to a drop in the real policy rate, while the lending spread does not change by much, and in fact increases by around 10 basis points. The latter is consistent with the fact that foreign financing, unlike foreign saving, decreases. The credit glut view instead appeals to domestic credit and creation of purchasing power as the driving force of the divergence, and the impulse response in Figure 9 is at least qualitatively consistent with the divergence - output and inflation increase and lead to an increase in the real policy rate, while the lending spread decreases very significantly. In fact the lending spread shown in Figure 9 is the net effect of an increase in the regulatory spread of around 60 basis points (due to higher bank leverage) and a decrease in the retail lending spread of around 120 basis points (due to lower perceived household credit risk).

Figure 9 shows that credit supply shocks imply changes in gross positions that are an order of magnitude larger than changes in GDP. Given that the saving glut episode was, if not triggered by, then at least accompanied by, large expansions in US financial sector balance sheets, this points to an important role for financial shocks in explaining the joint evolution of real and financial variables. If US credit was indeed the dominant driving force of the saving glut, this would favor the policy conclusion that the onus of adjustment for global imbalances ought be on the deficit rather than the surplus countries, because the former's excessive credit was the main culprit behind their large current account deficits.

We have also studied a contractionary shock to Foreign bank credit extended to Foreign households. This shock can be motivated by the comparatively weak expansion in the domestic credit of major current account surplus economies, including Germany and China, during the saving glut episode. While the effects of this shock on the quantity of global credit are of course the opposite of those in Figure 9, their effects on relative credit conditions, and therefore on MUIP spreads, interest rate differentials and real exchange rates, are very similar. In each case, a relative shortage of Foreign relative to Home credit is the underlying driver. The key insight is that in each case Home households can finance their current account deficit because they have access to more abundant Home purchasing power, not to more abundant Foreign physical resources.

4.3. Current Accounts and Financial Vulnerability: Sudden Stops

Figure 10 studies a "sudden stop" shock to Foreign bank credit extended to Home households, specifically a persistent ($\rho^{\kappa_F^{h^*}} = 0.95$) Foreign willingness-to-lend shock that reduces the coefficient $\kappa_{F,t}^{h^*}$. The shock is calibrated to produce a Home current account surplus that peaks at 1% of GDP.

Avdjiev et al. (2012) provide evidence that such "sudden stop" shocks to cross-border credit have played an important role in emerging market crises. They show that during such events domestic bank credit only contracts little, while cross-border credit, meaning foreign bank lending to either domestic non-banks or domestic banks, contracts sharply. They also show that during boom phases cross-border credit is an important enabler of domestic credit booms. Given this background, we interpret Home in Figure 10 as the emerging markets group of economies.

The shock represents a scenario where Foreign banks suddenly demand repayment of a large share of their loans to Home households. This is reflected in a nearly 100 basis points increase in the lending spread on, and a 10.8% of GDP contraction of, Foreign currency loans to Home households.

The latter make part of the required immediate loan repayments by using their existing Foreign currency deposits, which drop by 3.9% of GDP. In order the obtain the remaining repayment funds of 6.9% of GDP, Home households approach Home banks, whose willingness to lend has not changed, for additional Home currency loans of 5.5% of GDP. Home households then exchange the Home currency deposits thereby created, plus some of their existing Home currency deposits, with Foreign households, to obtain the Foreign currency needed to repay the remainder of their Foreign currency loans. Because Home currency deposits drop by 1.4% of GDP, the total repayment made out of these deposits therefore equals exactly the required 6.9% of GDP.

Foreign households have a financial incentive to invest in these additional Home currency deposits and to reduce their investment in Foreign currency deposits. The reason is that the shortage of Foreign currency deposits triggered by Foreign banks' repayment demand increases the convenience yield of Foreign currency, and therefore increases the excess financial return of Home currency. We can see this in a sharp increase in the MUIP spread of almost 120 basis points. As a result, Foreign households obtain substantial additional Foreign currency loans, equal to 5.7% of Home GDP, to obtain additional Foreign currency deposits. They then exchange these new and some of their existing Foreign currency deposits with Home households, against Home currency deposits.

In the real economy, Home households' shortage of liquidity triggers a 1.6% increase in the effective price of consumption, and as a result a 1.5% drop in consumption and a 0.7% drop in GDP. For this shock the evolution of the real exchange rate is dominated by the very large increase in the MUIP spread in response to the shortage of Foreign currency. This causes a 2.6% real depreciation of the Home currency and a 1% of GDP current account surplus.

However, and this is crucial for the subject of financial vulnerability, this current account surplus does not make a significant contribution to the required repayment of Foreign loans. This is because the repayment requires an instantaneous stock adjustment in financial variables, while current accounts are flows that equal zero on impact. Thereafter, current accounts require years to produce significant changes in net foreign liabilities, and even those changes are far smaller than the required loan repayment. We can see this in the third row of Figure 10, where even over the first full quarter the required immediate adjustment in net foreign financing is 40 times larger, at more than 10% of annual Home GDP, than the current account improvement and reduction in net foreign liabilities. When studying the changes in financial vulnerability as a result of sudden stops, the key variables are therefore not the current account or net foreign liabilities, but rather gross foreign liabilities. This includes not only its absolute size but also its composition and thus its susceptibility to reversals. We observe that, while Home households' Foreign currency retail loans decrease by 10.8% of GDP, Foreign households' Home currency retail deposits in Home banks increase by 6.2%, and Home banks' Foreign currency interbank loans decrease by 1.2%. If deposits are a more stable type of Foreign liability, this shift in Home's dependence away from Foreign loan liabilities and towards Foreign deposit liabilities will contribute far more, and far more quickly, to future reductions in financial vulnerability than current account surpluses.

The same focus on gross foreign liabilities is necessary when studying the initial vulnerability to sudden stops. In our initial steady state the net foreign liabilities position equals zero, which might suggest no vulnerability, and its subsequent changes are small and gradual, which might suggest very slow changes in vulnerability. But before the sudden stop, the gross foreign liabilities position equals 50% of GDP (20% Home households' Foreign currency bank loans, 10% Home banks' Foreign currency interbank loans, 20% Foreign households' Home currency retail deposits in Home banks), and could be highly vulnerable to changes in sentiment by Foreign households or banks.

The main message is therefore that, compared to gross balance sheet positions, current accounts and net foreign liabilities contain very little and in some cases highly misleading information about vulnerability to foreign financing shocks. The reason is, again, that in a financial crisis lenders do not stop financing current accounts, they stop financing debt. In fact, especially in the short run, current accounts are largely a symptom of the required adjustment of the real economy to these shocks, rather than representing a quantitatively important adjustment in their own right. Specifically, while a sudden stop does trigger a current account improvement, it does not do so by reducing any supply of Foreign physical saving to Home, but by creating an excess demand for Foreign currency that depreciates the Home exchange rate and thereby increases the demand for Home goods.

4.4. Other Business Cycle Shocks

For completeness, we very briefly comment on monetary policy shocks and technology shocks. We limit ourselves to studying whether our model's behavior differs from that of a standard UIP-based open economy model. We therefore compare the baseline MUIP model with $\theta_d = 1.5$ with the UIP model with $\theta_d = 2500$. Impulse responses are omitted to conserve space.[37]

For a contractionary monetary policy shock S_t^{int}, the policy rate does not mainly work through financial channels that affect the demand-supply balance of currencies, but rather through real channels such as changes in the intertemporal marginal rate of substitution that affect the demand-supply balance of physical resources. Higher real policy rates in Home therefore reduce Home physical consumption. While this does reduce credit and money demand in Home, this is only as a by-product of the physical changes and therefore roughly of the same order of magnitude as changes in real variables, and furthermore these credit reductions do not distinguish between Home and Foreign currencies. The behavior of real variables in the MUIP model is therefore virtually identical to that of the UIP model, and thus standard for models in this class. For a contractionary Home technology shock S_t^a, the results are again standard for the business cycle literature, for very similar reasons.

5. Conclusions

We have developed a model of gross capital flows that allows us to reexamine the relationship between saving and financing, and the relationship between gross and net positions on balance sheets. We use this analytical framework to revisit several well-known policy debates in open economy macroeconomics. At the heart of the analysis is a sharp distinction between cross-border net payment flows, which are the exact financial account mirror image of the physical resource flows of the current account and which are the only type of capital flow in net capital flow models, and cross-border financial flows, which consist of two matching and inseparable gross capital inflows and outflows, both of which are recorded in the financial account. The key features of the model are creation of the domestic currency by each economy's banking system on the basis of risky collateralized loans, settlement of cross-border net payment and financial flows through interbank nostro and vostro accounts, and imperfect substitutability, in their use as a medium of exchange, between commercial bank deposits denominated in different currencies. In this model, the real

[37] Cesa-Bianchi et al. (2019) cover these shocks in much greater detail.

exchange rate is determined by excess demands for both currencies and goods. This framework introduces novel financial shocks, including currency demand and credit supply shocks, that play a key role in the analysis of gross capital flows.

The vast majority of the open economy literature is based on net capital flow models. As explained by Borio (2016), these modeling frameworks do not separately track physical resource flows and monetary financing flows, and therefore implicitly represent physical resources themselves as the medium of exchange. This leads directly to statements such as "foreign saving finances the current account", which treat two distinct concepts, saving and financing, as identical. Saving is a goods market concept, it denotes output not consumed. Financing is a money market concept, it represents newly created purchasing power in an accepted settlement medium, which in modern economies almost exclusively takes the form of commercial bank money. Financing is required not only for goods trades but also for asset trades, which are a quantitatively far more important component of gross flows. As a result, the magnitudes of net resource flows and stocks and of gross financial flows and stocks are disconnected, a phenomenon that has been labelled the "excess elasticity" of the financial system by Borio and Disyatat (2011).

The model shows that currency mismatch rules play a key role not only for financial but also for real outcomes. This is because at the aggregate level banks can only eliminate currency mismatches through changes in credit, which have real effects through their effects on both aggregate purchasing power and relative financial returns. The model is able to track the full set of gross cross-border financial inflows and outflows, including domestic and cross-border credit creation flows. It demonstrates that net foreign financing (net foreign loans) and foreign saving (domestic current account deficits) are entirely different concepts, and that for many shocks they move in opposite directions. The model also shows how net and gross foreign liabilities can send opposite signals for a country's vulnerability to financial shocks, and that the contribution of current accounts to restoring sustainability in response to contractionary financial shocks must be zero on impact, and is negligible over the longer run.

This analytical framework allows us to shed new light on four important policy debates that are associated with international capital flows. The first debate concerns the pervasive use of current accounts as indicators of financial vulnerability. The issue with this practice is that in a financial crisis lenders, who can be domestic as well as foreign, do not stop financing current accounts, they stop financing debt. Even with a zero current account and net foreign liabilities position, an economy can exhibit very large gross debt positions that are vulnerable to reversals. Furthermore, there are many different categories of debt. Some of these categories could be far more vulnerable to reversals than others pre-crisis, and post-crisis the effects of reversals on vulnerability depend on their differential effects on different categories of debt. Interpreting the current account as the principal indicator of financial vulnerability therefore misses almost all relevant information.

The second debate is the global saving glut hypothesis. Here the issue is similar, in that US non-banks do not finance imports and current account deficits using physical saving provided by foreign non-banks. Instead, current account deficits are financed using digital purchasing power, provided by banks that are more likely to be domestic than foreign. In the latter case, a US credit glut becomes a plausible alternative explanation for the saving glut to traditional foreign saving or technology shocks. To help distinguish between these alternatives, we show that foreign saving shocks imply changes in financial sector balance sheets that are about as large as the simultaneous changes in GDP, while credit supply shocks imply far larger changes to financial than to real variables. As has been amply documented in the literature, the latter did characterize the saving glut episode. The fact that the financing bank can be located in the domestic as well as the foreign economy emphasizes that the current account or foreign physical saving contain no information about the source and direction of the financing flows that allow domestic residents to finance current account deficits. This matters for policy recommendations, because the global saving glut hypothesis puts the onus of adjustment on surplus countries, while the US credit glut hypothesis does the opposite.

The third debate is Triffin's current account dilemma. The issue here is that the creation of dollars as an international medium of exchange requires financing, or credit creation, denominated in dollars, by US or foreign banks. It does not require the setting aside, or saving, of foreign physical resources by foreign non-banks. In other words, the creation of a sufficient quantity of US dollars is completely independent of US current account deficits. There is therefore no dilemma.

The fourth debate concerns interpretations of the high correlation of gross capital inflows and outflows. The issue here is that all financial flows necessarily consist of a pair of gross inflows and gross outflows that are inseparable as a matter of accounting, and that are therefore necessarily perfectly correlated. Correlated flows therefore do not represent, as in many interpretations, the result of synchronized economic decision-making by domestic and foreign investors. The only two ways in which the correlation between inflows and outflows could be lower than one is "errors and omissions", whereby some gross financial flows are not captured in the balance of payments statistics, and a significant role for net payment flows, where only one of the flows is financial while the other is physical.

There are several other topics in international macroeconomics that would likely benefit from a reexamination using this model. Some of them are the subject of ongoing research by the authors.

Appendix A Cross-Border Banking and Bookkeeping

General Discussion

Any economic transaction, including both physical and financial trades, consists of two inseparably linked components or "legs", the second of which always involves the transfer of a retail or interbank monetary settlement medium. Our model is novel, and distinct from existing models of gross capital flows, in that it always explicitly contains this second leg, and describes its implications.

The presence of two inseparable components in economic transactions is true even for physical resource trades, although it is rarely discussed in those terms. Consider the example of a cross-border goods purchase by a firm. The purchase results in a credit to the firm's goods inventory account and a debit to its bank account, both of which are gross positions. The debit to the bank account is the final settlement component of the transaction, which in this case, because it takes place between two non-banks, uses commercial bank money. Net flow models generally do not make final settlement explicit. Instead they record a debit to a deferred settlement net position referred to as a bond, whose real-world counterpart is the net balance of multiple gross financial positions. This simplification is unproblematic when the work in question concentrates on physical shocks and physical variables, where the bond merely tallies the cumulated net effects of physical decisions. But it can become problematic when the work concentrates on financial questions, and starts to treat the bond as an actual financial decision variable, when in fact all financial decisions concern gross positions. And it is particularly problematic, as we will explain, to discuss changes in the net foreign liabilities position as representing cross-border financing decisions.

Financial trades similarly entail two inseparable components. We will discuss three examples, cross-border investment, cross-border financing, and domestic financing. Consider a cross-border investment into a foreign bank deposit. The domestic investor uses a payment instrument drawn on his domestic bank. For the receiving foreign bank, the deposit results in a debit to the bank's gross stock of deposits, and a credit either to its interbank deposit account held at the bank issuing the payment instrument (nostro account), or to its interbank loan account from the bank issuing the payment instrument (vostro account). The credit to the interbank account is the final settlement component of the transaction, which in this case uses interbank money, or reserves, because the settlement leg of the transaction takes place between two banks. The credit to reserves, a form of money that is not accessible to non-banks, represents the receiving bank's claim to receive value for the payment instrument that it has credited to the investor's account. This purely financial cross-border transaction therefore necessarily records a gross outflow whose inseparable counterpart must be a gross inflow. This is true for all cross-border financial trades, which therefore cannot directly give rise to any changes in net claims, meaning in the current account and in net foreign assets.

Next consider cross-border financing, specifically a cross-border loan by a foreign bank to a domestic household. From the point of view of the domestic household, the loan results in a debit to his loan account at the foreign bank, and a credit to his deposit account at the foreign bank. From the point of view of the foreign bank, the loan is a credit and represents its right to receive future installments on the loan, while the deposit is a debit and represents its obligation to deliver current funds. Banks are unique in that their liability to deliver current funds can immediately be used *as* current funds, as money. The reason is the extensive public support mechanisms for the banking system, through central banks and regulatory agencies, which ensure that bank deposits are credible as a universal medium of exchange. The credit to the deposit account is the final settlement component of this transaction, which in this case uses commercial bank money, because settlement takes place between banks and non-banks. Cross-border flows for this financing transaction are again exactly matched, with a zero direct effect on net foreign liabilities. Furthermore, in this case no interbank settlement is involved, because the entire financing operation takes place at the foreign bank. The subsequent use of the newly created cross-border deposits may involve either a purchase of physical resources or further financial transactions. But neither necessarily affects net foreign liabilities. To see this, consider the example of a domestic household who uses his new foreign bank balances to purchase goods from another domestic household who also maintains a foreign bank account.

Finally, consider a domestic financing operation, where the foreign bank in the previous example is replaced with a domestic bank. This again creates two matching positions, but in this case both of them are domestic. The credit to the deposit account is again the final settlement component of this transaction. It is essential to include such domestic gross flows in the model, for two reasons. First, domestic credit booms and busts can become a major source of cross-border gross and net flows (see for example Cesa-Bianchi et al. (2019)), as shown in one of our impulse responses for the global saving glut. And second, changes in domestic credit are a key component of banks' adjustment to currency mismatches on their balance sheet.

Two Illustrative Examples

Gross flow models that omit the banking and settlement system make strong simplifications that omit many possible constellations of gross capital flows, and ignore the real-world constraints that the banking system imposes on the ability of non-banks to realize their desired gross positions. The following two examples illustrate the critical role of banks in facilitating the settlement of cross-border flows.

Assume first that Home households issue additional bonds in Foreign currency, and Foreign households issue additional bonds in Home currency. Assume also that the ultimate objective of each bond issuance is to take a long position in domestic currency through the bond market. In practice these positions cannot be reached without the involvement of banks. Instead, three separate steps are necessary. First, Home households issue Foreign currency bonds to and collect Foreign currency deposits from Foreign households. Second, Foreign households issue Home currency bonds to and collect Home currency deposits from Home households. After this step different currency bonds have been issued, but all households are exactly matched in terms of currencies. If the objective had been to use the foreign currencies for acquisitions of goods or other assets, these two steps would be sufficient, and the bonds would have simply reallocated existing purchasing power among households. Third, in order to bring about the desired pure exchange of bonds, Home and Foreign households must exchange their newly collected deposits against each other.

While this final outcome describes one possibility for gross capital flows, it leaves out many others that cannot be studied in a framework that only allows for gross nominal bond positions. This is because all of the foregoing steps can occur by themselves rather than jointly, and the banks that issue the Home and Foreign currency deposits can be located in either jurisdiction. This creates myriad possibilities of different domestic and cross-border gross capital flow scenarios, all of them with potentially very different policy implications.

Furthermore, this scenario ultimately relies on the willingness of a foreign household to take a matching position in general equilibrium, when this is not really required because domestic or foreign banks could take the matching position. And in fact, for the majority of households and firms that do not have access to bond markets, the desired reallocation of gross currency positions can only be achieved through their banking system. But banks are subject to very different constraints from foreign households, as we will now discuss.

Assume that both domestic and foreign households start off with domestic and foreign currency loans and deposits, with foreign currency positions initially matched one for one. Home households wish to short Foreign currency by paying their Foreign currency deposits, held at Foreign banks, into Home currency deposits, held at Home banks. Given that their Foreign currency loans continue to be on the books of Foreign banks, they are now short Foreign currency and long Home currency, as desired. Banks have to settle these incoming and outgoing deposits, in our example by crediting Home banks' Foreign currency interbank settlement or reserve accounts. The end result is that Home banks are now short Home currency (additional deposit liabilities) and long Foreign currency (additional reserves), while Foreign banks exhibit no currency mismatches. If Home banks are willing to live with these mismatches, Home households have achieved their desired goal of shorting Foreign currency and going long in Home currency, without any need for Foreign households to be involved.

However, in practice banks are subject to currency mismatch regulations that tend to be strictly observed. Home banks will therefore have to eliminate their new mismatches. Currency swaps are ruled out, because neither domestic nor foreign households in aggregate are willing counterparties, and foreign banks face their own mismatch regulations. Instead, in response to return differentials, Foreign households switch to Foreign currency, while banks make or call in loans that create or destroy deposits in the desired currencies. This changes the ability of Home households to achieve their originally desired currency positions, for very different reasons from interactions with Foreign households in a bonds-only model.

Appendix B The Monetary UIP Condition (MUIP)

The subject of exchange rate determination is treated much more extensively in Cesa-Bianchi et al. (2019), who also review the related literature about systematic deviations from UIP. However, because that paper's cross-border banking setup is different from ours, and also because of the key role that the MUIP spread u_t plays in the transmission of shocks in our model, we revisit their key insights within our own framework. The key equations and mechanism are presented and briefly discussed in the text and will not be repeated here. Instead we expand on their economic interpretation, and on their ability to address exchange rate related empirical puzzles.

Interpretation of the Key Equations

We expand on the discussion in the text by way of three examples.

Consider the effects of an increase in the supply of domestic currency due to an increase in domestic banks' willingness to lend in domestic currency, reflected in equation (24) in higher $\check{d}^h_{H,t}$. This implies, ceteris paribus, that $u_t > 0$. The reason is that domestic currency becomes more abundant, so that the relative convenience yield of domestic currency declines. As a result, domestic currency pays a financial premium relative to foreign currency. But this premium will not mainly take the form of a higher domestic nominal policy interest rate, which is set with inertia by the policymaker. Rather, the response will also involve expected exchange rate appreciation. Appreciation over time implies an upward jump, or a depreciation, of the exchange rate on impact. To summarize, an increase in the supply of domestic currency leads to an exchange rate depreciation on impact.

Consider next the effects of an increase in the demand for domestic currency, reflected in equation (24) in higher S^{mm}_t. This implies, ceteris paribus, that $u_t < 0$. The reason is that the relative convenience yield of domestic currency increases. As a result, domestic currency pays a financial discount relative to foreign currency, mainly through expected exchange rate depreciation. As a result, the exchange rate appreciates on impact. To summarize, an increase in the demand for domestic currency leads to an exchange rate appreciation on impact.

Finally, consider the effects, for a given increase in the demand for domestic currency, of different elasticities of substitution. On the one hand, as $\theta_d \to \infty$, or as the two types of deposits become perfect substitutes, the term in brackets in equation (24) approaches zero regardless of the relative demands for the two currencies, and the MUIP spread is eliminated. The limiting case is the standard UIP model of exchange rate determination. On the other hand, as domestic and foreign currency assets become increasingly imperfect substitutes, changes in the MUIP spread become larger, because the relative convenience yield, and therefore the required relative financial return on domestic currency assets, becomes more sensitive to the relative amounts of currency demanded.

UIP Effects versus MUIP Effects on the Exchange Rate

UIP effects on the exchange rate are caused by interest rate changes. These are either due to exogenous monetary policy shocks, or to systematic responses to Taylor rule fundamentals such as inflation gaps and output gaps. Changes in the nominal interest rates of the two economies in turn lead to changes in the exchange rate to ensure that the arbitrage condition holds. UIP effects therefore occur in all modern open economy models, and are also present in our model.

MUIP effects on the exchange rate are caused by changes in the MUIP spread. In this case economic shocks trigger the same UIP effects as in standard models, but in addition they trigger changes in the MUIP spread that lead to exchange rate changes independently of and in addition to UIP effects. Because in general such exchange rate changes affect the real economy, they also trigger second-round UIP effects, through the systematic component of monetary policy. MUIP effects are specific to our model.

The relative importance of UIP and MUIP effects depends on both the strength of the respective transmission channels and the nature of economic shocks. When MUIP spreads are not very responsive to changes in relative currency supplies and demands, such as when the elasticity of substitution between currencies is very high, this decreases the relative importance of MUIP effects. The same is true when economic shocks are primarily to relative supplies and demands of physical resources. But when the elasticity of substitution between currencies is lower, and/or when economic shocks are primarily to relative supplies (of loans) and demands (for deposits) of currencies, this increases the relative importance of MUIP effects.

Ability to Address Empirical Puzzles

Our theory is able to shed light on two key puzzles in open economy macroeconomics, the Fama (1984) UIP puzzle and the Meese and Rogoff (1983) exchange rate disconnect puzzle. Table 1 is based on Table 2 in Itskhoki and Mukhin (2017), and the data column is taken directly from that paper. We use a version of our model that adjusts the country size of Home to be equal to the share of the US in the world economy while leaving other aspects of our calibration unchanged. We generate Table 1 by running, for each shock separately, 1000 stochastic simulations of 1100 quarters each. For each simulation we discard the first 100 observations and then compute the relevant statistics. The values reported in Table 1 are the means over all 1000 simulations of each statistic, with standard errors reported in brackets.

The Fama (1984) UIP puzzle is that according to the UIP relationship an increase in the interest differential between a country's nominal interest rate and the corresponding foreign nominal rate should predict a nominal depreciation of the country's currency. However, in a regression of exchange rate changes on interest differentials the coefficient on interest differentials is found to be negative, which means that an increase in the domestic interest rate is associated with an expected appreciation rather than an expected depreciation. Furthermore, this regression generally has a very low R^2. An alternative version of this puzzle is due to Engel (2016), who regresses currency excess returns on interest differentials. He finds that the coefficient on interest differentials is positive and greater than one, which means that an increase in the domestic interest rate is associated with a positive excess return on domestic currency. Finally, the ratio of standard errors of the interest differential and the rate of depreciation is generally very close to zero.

The Meese and Rogoff (1983) exchange rate disconnect puzzle is that the best empirical predictor of the future nominal exchange rate is the current nominal exchange rate, while macroeconomic fundamentals do not robustly contribute to explaining future exchange rate changes. Specifically, the first-order autocorrelation coefficient of the rate of nominal exchange rate depreciation is close to zero, the correlation coefficient between changes in nominal and real exchange rates is close to one, and the ratio of standard errors of changes in nominal and real exchange rates is close to one.

For the UIP puzzle, the top half of Table 1 presents the regression coefficient of the interest differential β_{Fama}, as well as the R^2, of the Fama (1984) regression, the regression coefficient of the interest differential β_{Engel} of the Engel (2016) regression, and the ratio of standard errors of the interest differential and the rate of exchange rate depreciation $\sigma\left(i_t - i_t^*\right)/\sigma\left(\varepsilon_t\right)$. We find that the model's real business cycle shocks, including the technology shock S_t^a, consumption demand shock S_t^c, and monetary policy shock S_t^{int}, are not consistent with the UIP puzzle, with β_{Fama} of 0.85 or above, R^2 of at least 0.14, and a ratio of standard errors of at least 0.38. The intertemporal discount factor shock $\beta_{t,t+1}$ shows the greatest deviations from the empirically observed values of β_{Fama} and β_{Engel}. The domestic credit supply shock $\kappa_{H,t}^h$ and the domestic liquidity preference shock S_t^{md} exhibit behavior quite similar to that of the real shocks and are therefore also not consistent with the UIP puzzle. This is because expansionary realizations of these shocks support an increase in consumption demand, either through increased liquidity provision on the part of banks or through increased utilization of existing liquidity on the part of households. On the other hand, both cross-border relative currency demand shocks $S_t^{mm^*}$ and cross-border relative currency supply shocks $\kappa_{H,t}^f$ are highly consistent with the UIP puzzle, with a highly negative β_{Fama}, a very low R^2 and a very low ratio of standard errors. The reason is that these shocks directly change the relative demands or supplies of the two currencies while having much smaller effects on real variables, thereby affecting currency excess returns in a way that is consistent with the UIP puzzle. We explain the details in our discussion of the impulse responses.

For the exchange rate disconnect puzzle, the bottom half of Table 1 presents the autocorrelation coefficient of the rate of nominal exchange rate depreciation $\rho(\varepsilon_t)$, the correlation coefficient between changes in nominal and real exchange rates $corr\left(\varepsilon_t^{\text{real}}, \varepsilon_t\right)$, and the ratio of standard errors of changes in nominal and real exchange rates $\sigma\left(\varepsilon_t^{\text{real}}\right)/\sigma\left(\varepsilon_t\right)$. We find that the model's real business cycle shocks are mostly unable account for this puzzle, with significantly positive autocorrelation of nominal exchange rate depreciation and a correlation between nominal and real exchange rate depreciation of well below 1. The exception is the intertemporal discount factor shock, whose main shortcoming is therefore its marked lack of consistency with the UIP puzzle. The domestic credit supply shock and the domestic liquidity preference shock again exhibit behavior quite similar to that of the real shocks and are therefore also not consistent with the exchange rate disconnect puzzle. But the cross-border relative currency demand and currency supply shocks are highly consistent with this puzzle, with a significantly negative (but not too large in absolute value) autocorrelation of nominal exchange rate depreciation of around -0.13, a correlation between nominal and real exchange rate depreciation of 1, and a ratio of standard errors of nominal and real exchange rate depreciation of very close to 1. These shocks are therefore very promising candidates to make open economy models consistent with these key puzzles.

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Table 1
Shocks and Puzzles

	Data	$S_t^{mm^*}$	$\kappa_{H,t}^f$	$\kappa_{H,t}^h$	S_t^{md}	S_t^c	$\beta_{t,t+1}$	S_t^{int}	S_t^a
β_{Fama}	$\lesssim 0$	-4.39 (0.60)	-4.22 (0.93)	0.52 (0.04)	0.93 (0.01)	0.85 (0.03)	2.12 (0.82)	0.98 (0.08)	0.96 (0.05)
β_{Engel}	$\gtrsim 1$	5.39 (0.60)	5.22 (0.93)	0.48 (0.04)	0.92 (0.01)	0.15 (0.03)	-1.12 (0.82)	0.02 (0.08)	0.04 (0.05)
R^2_{Fama}	0.02	0.06 (0.01)	0.02 (0.01)	0.14 (0.03)	0.07 (0.01)	0.37 (0.04)	0.01 (0.01)	0.14 (0.04)	0.30 (0.01)
$\sigma\left(i_t - i_t^*\right)/\sigma\left(\varepsilon_t\right)$	0.06	0.06 (0.00)	0.04 (0.00)	0.71 (0.03)	1.04 (0.01)	0.72 (0.02)	0.04 (0.01)	0.38 (0.03)	0.57 (0.04)

UIP Puzzle (standard errors in parentheses)

	Data	$S_t^{mm^*}$	$\kappa_{H,t}^f$	$\kappa_{H,t}^h$	S_t^{md}	S_t^c	$\beta_{t,t+1}$	S_t^{int}	S_t^a
$\rho(\varepsilon_t)$	0.00	-0.14 (0.03)	-0.12 (0.03)	0.08 (0.05)	0.95 (0.01)	0.48 (0.05)	0.01 (0.04)	0.17 (0.05)	0.19 (0.03)
$corr\left(\varepsilon_t^{\text{real}}, \varepsilon_t\right)$	0.98	1.00 (0.00)	1.00 (0.00)	0.66 (0.02)	0.25 (0.02)	0.55 (0.03)	0.96 (0.01)	0.81 (0.03)	0.89 (0.01)
$\sigma\left(\varepsilon_t^{\text{real}}\right)/\sigma\left(\varepsilon_t\right)$	0.99	0.97 (0.00)	0.98 (0.00)	0.79 (0.02)	0.86 (0.04)	0.58 (0.01)	0.92 (0.01)	0.75 (0.02)	1.45 (0.02)

Meese-Rogoff Puzzle (standard errors in parentheses)

$\sigma(\cdot)$ = standard error, $\rho(\cdot)$ = first-order autocorrelation, $corr(\cdot,\cdot)$ = correlation coefficient

Figure 1
Domestic and Cross-Border Gross Financial Flows

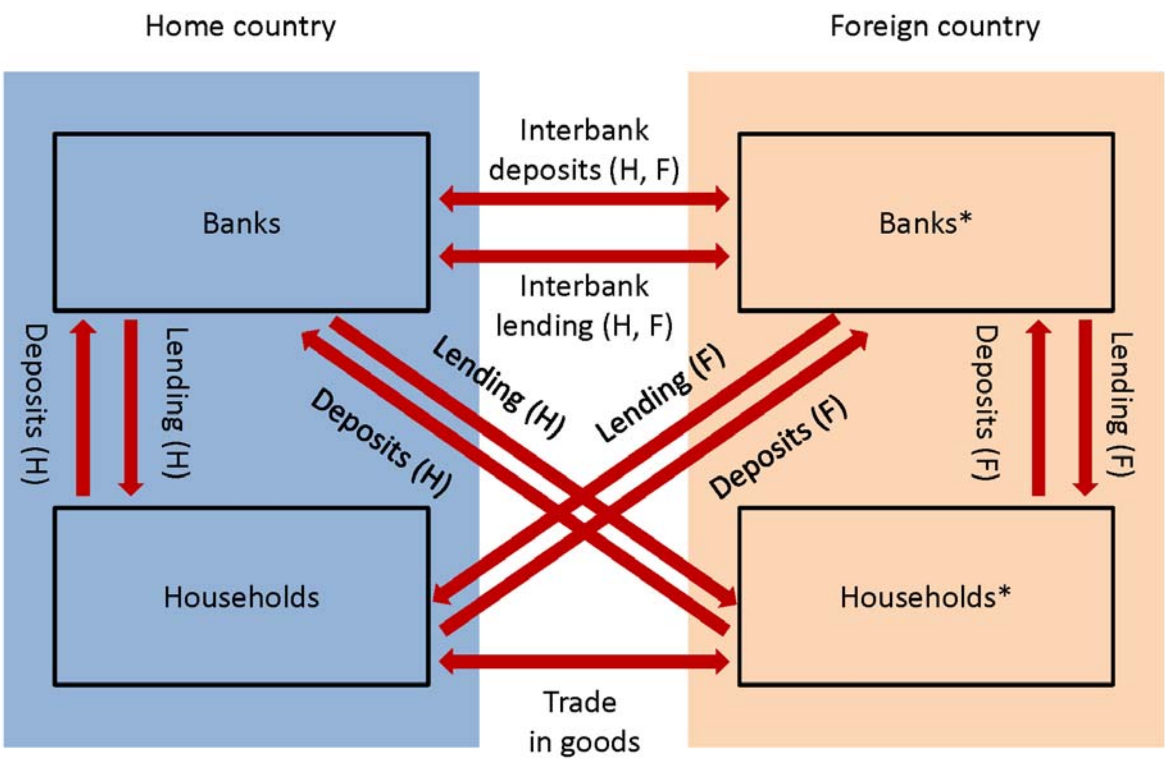


Figure 2
Steady State Interest Rate Spreads

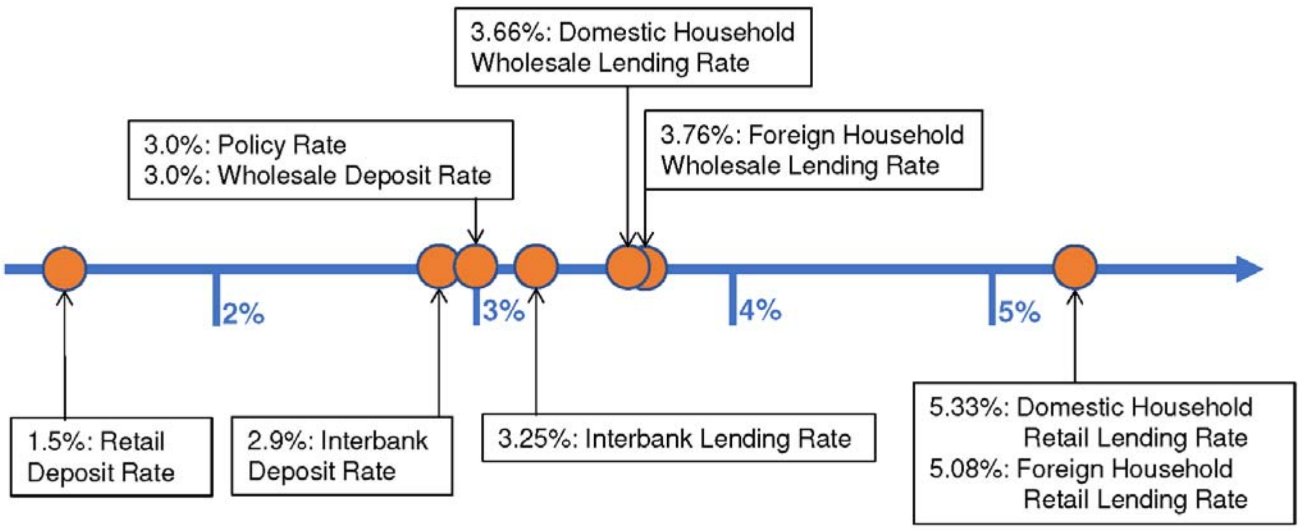


Figure 3
Steady State Bank Balance Sheets

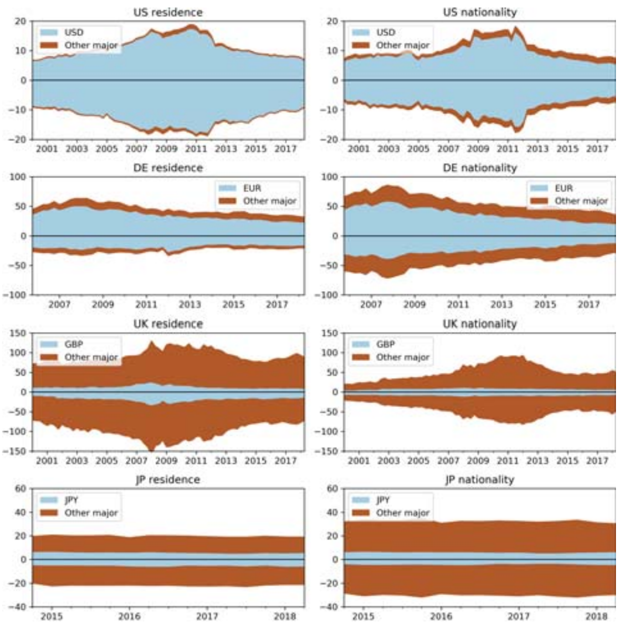
Home Banks

L_H_h_HO	100	NW_B_HO	19
		D_H_h_HO	81
L_H_f_HO	20	D_H_f_HO	20
L_H_b_HO	10	D_H_b_HO	10
D_F_b_HO	10	L_F_b_HO	10

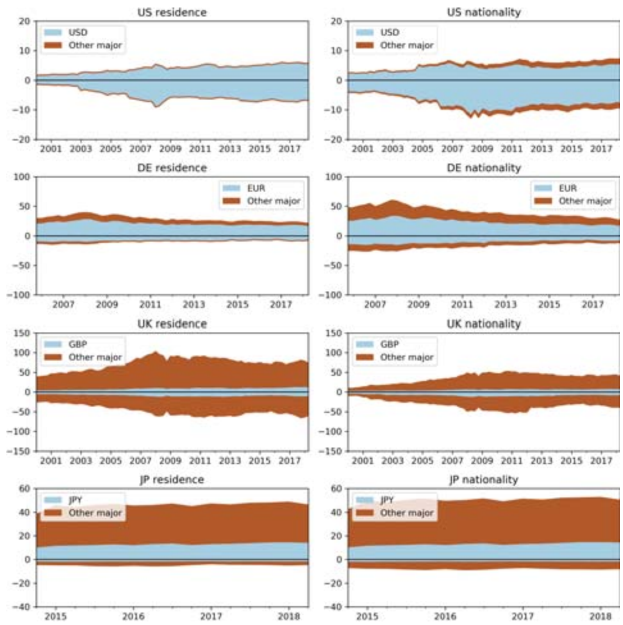
Foreign Banks

L_F_f_FO	100	NW_B_FO	19
		D_F_f_FO	81
L_F_h_FO	20	D_F_h_FO	20
L_F_b_FO	10	D_F_b_FO	10
D_H_b_FO	10	L_H_b_FO	10

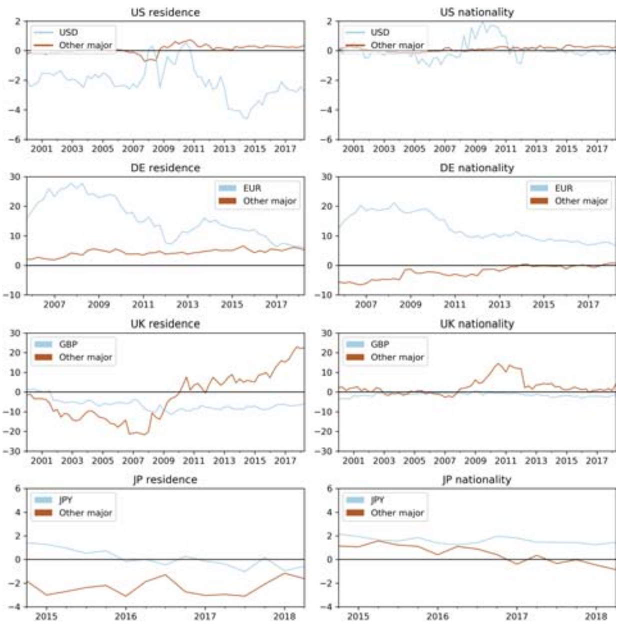
Figure 4
Balance Sheet Stylized Facts



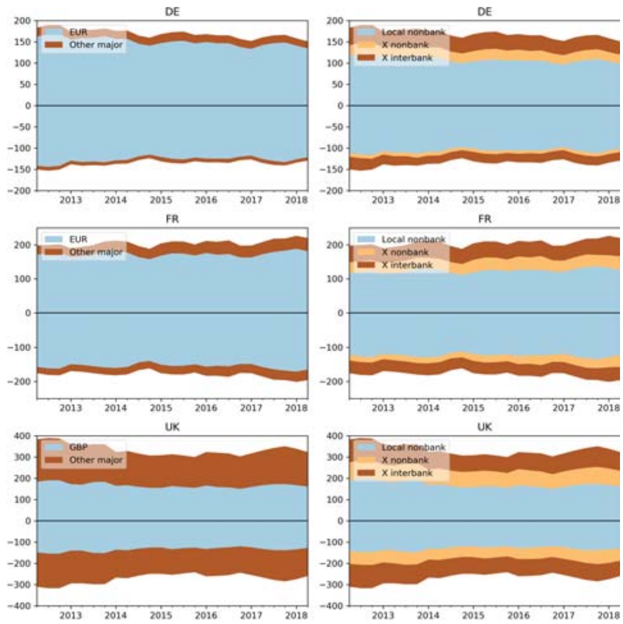
Gross Interbank Cross-Border Positions



Gross Bank-to-Nonbank Cross-Border Positions



Net Interbank Cross-Border Positions

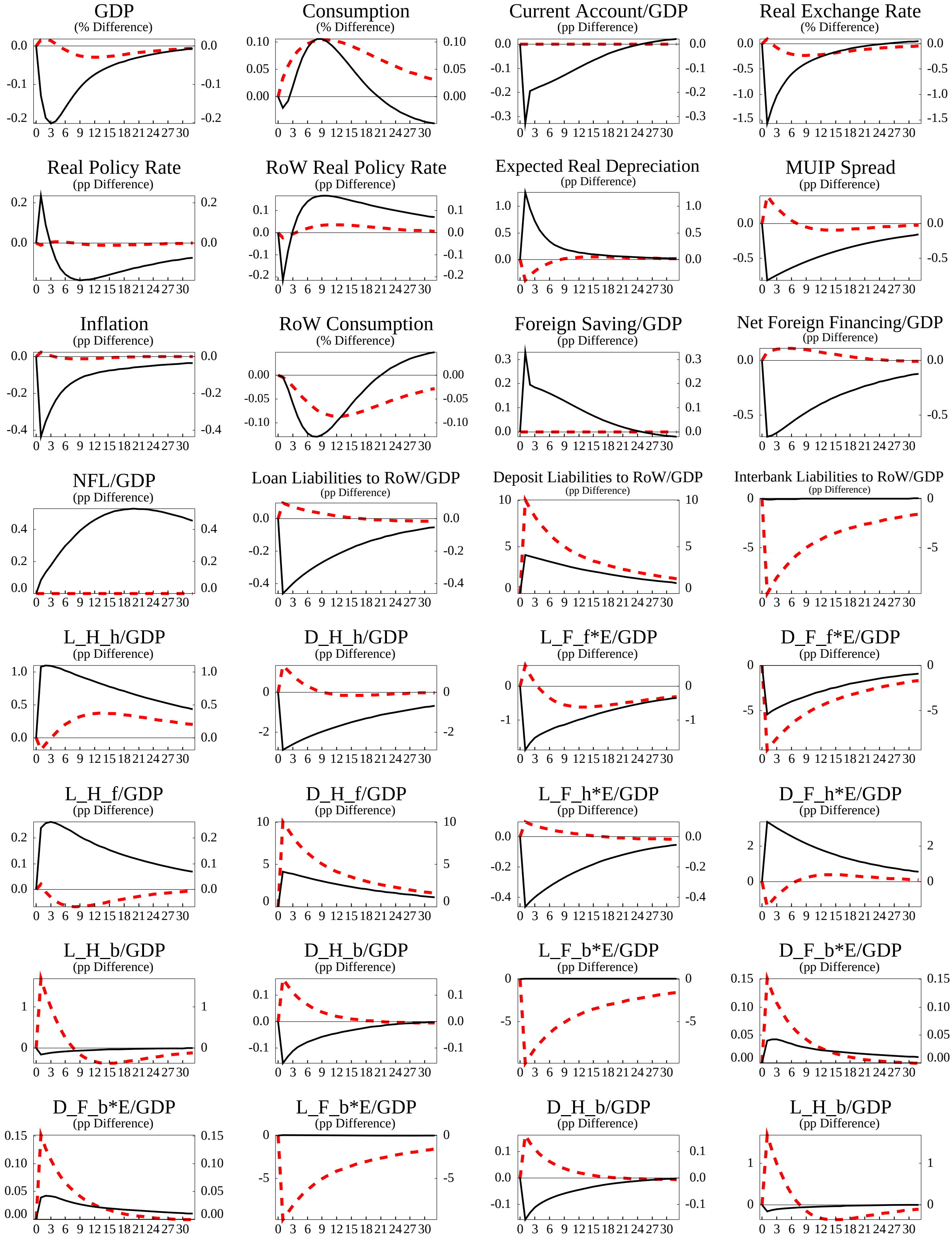


Gross Local and Cross-Border Positions[38]

[38] Data shown are on residential basis.

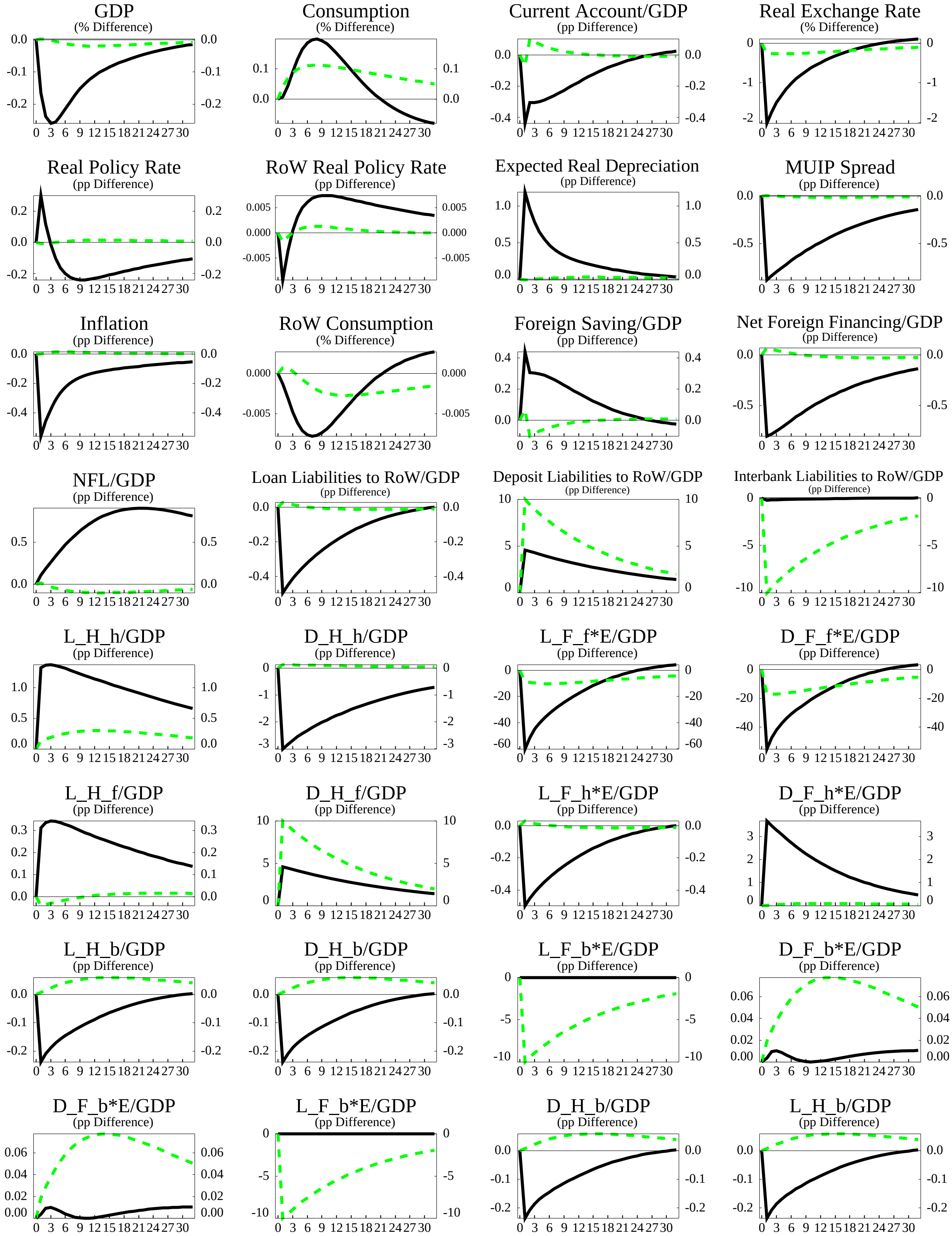
Figure 5

Financial Inflow Shock: Accommodating and Strict FXMR



(dashed red = accommodating FXMR, solid black = strict FXMR)

Figure 6
Financial Inflow Shock: Asymmetric Country Sizes and FXMR



(solid black = strict FXMR, dashed green = asymmetric FXMR)

Figure 7
Financial Inflow Shock: The Role of Deposit Substitutability

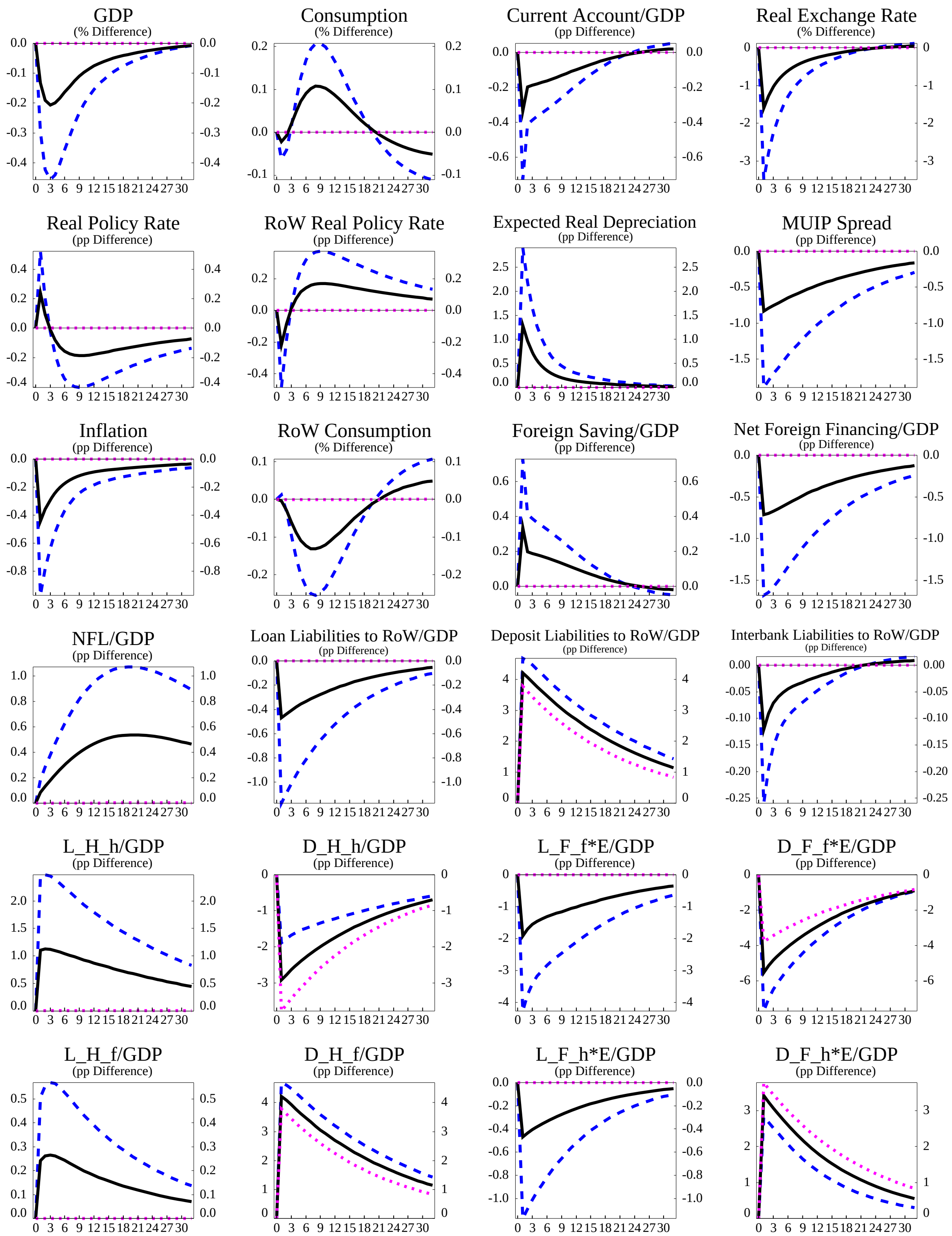


Figure 8
Global Saving Glut: Foreign Physical Saving Glut

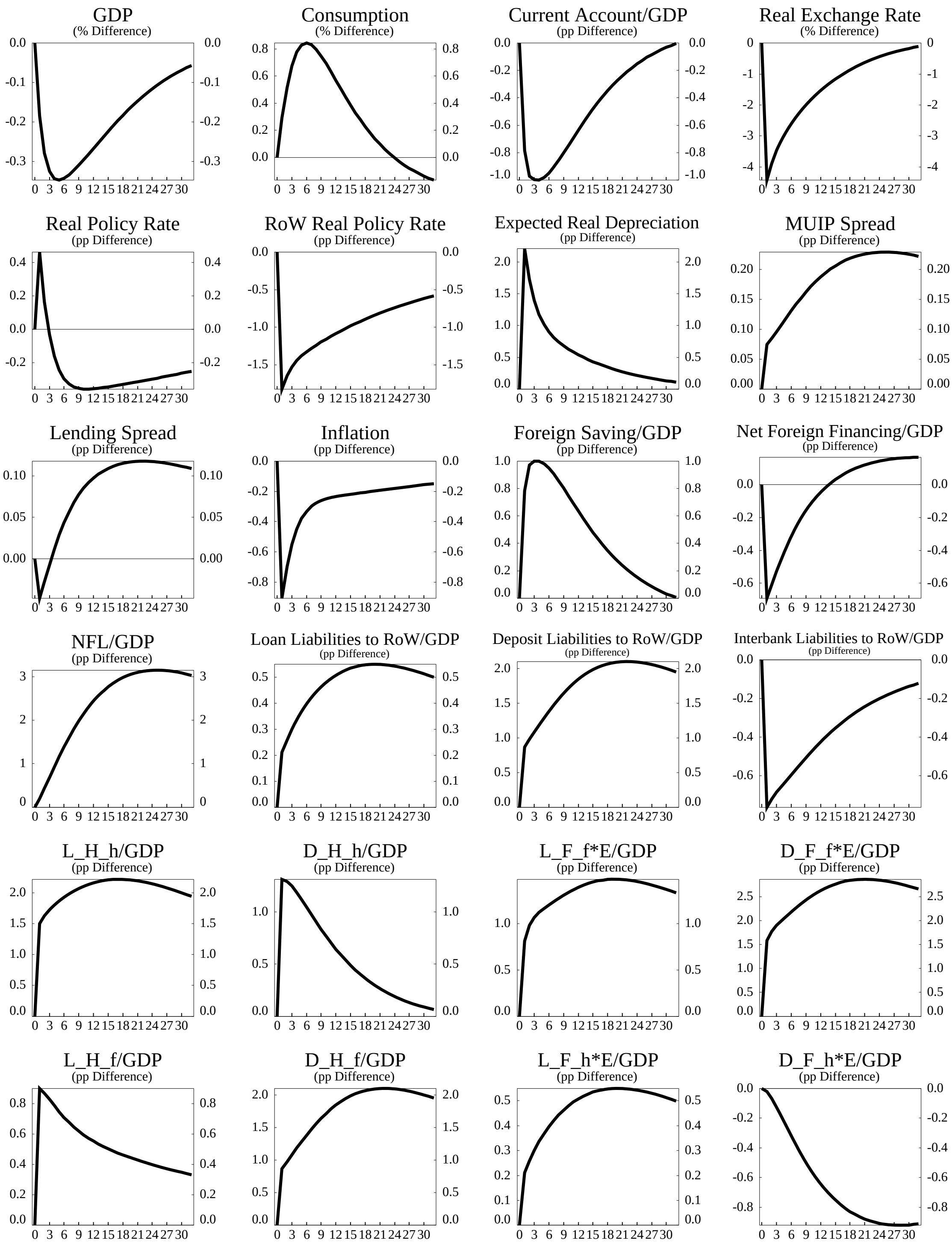


Figure 9
Global Saving Glut: US Credit Glut

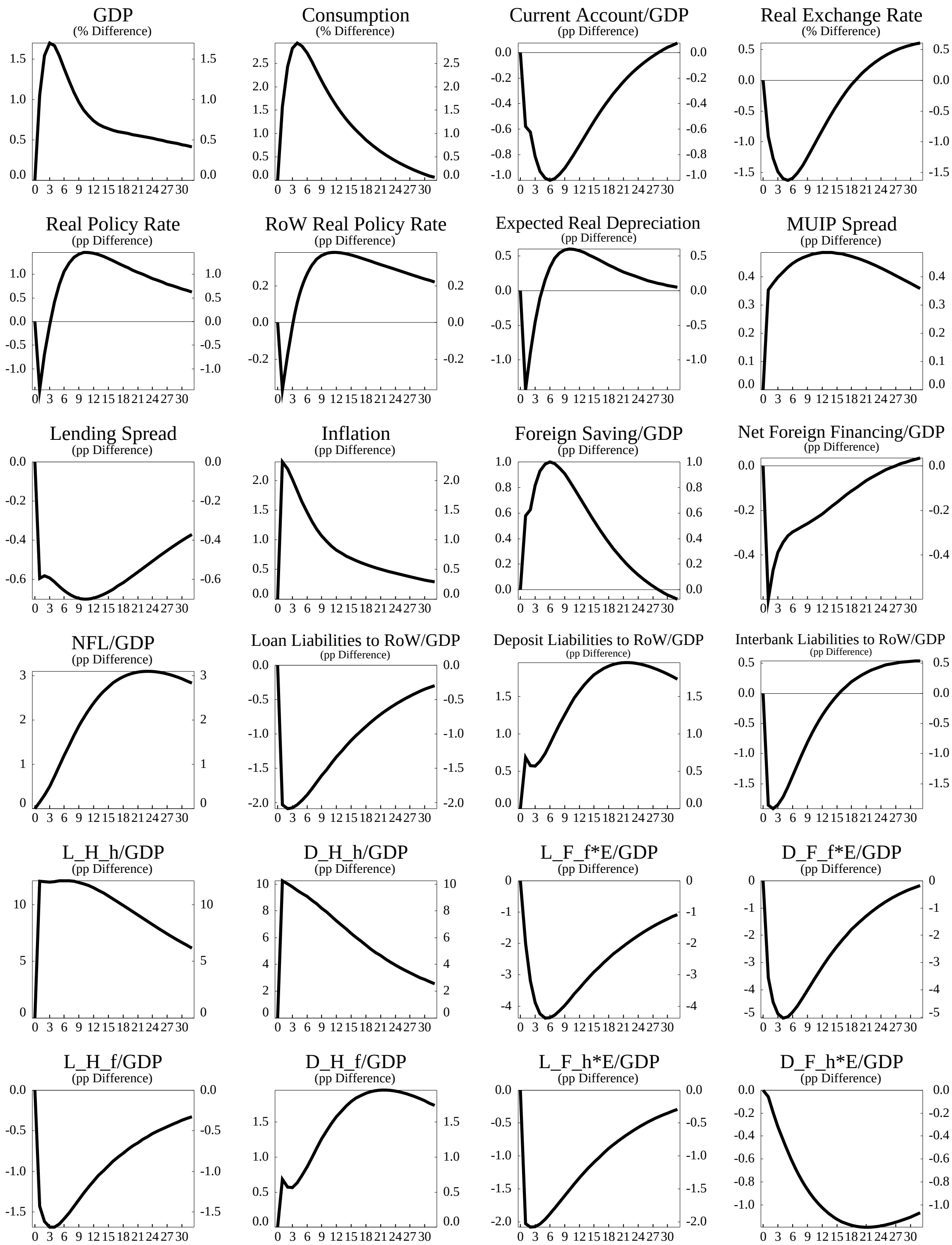


Figure 10
Current Accounts and Financial Vulnerability: Sudden Stops