International Credit Supply Shocks[☆]

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Abstract

Capital inflows are expansionary and associated with large swings in asset prices. House prices and exchange rates can potentially amplify the expansionary effects of capital inflows by inflating the value of collateral. We first set up a model of collateralized borrowing in domestic and foreign currency with international financial intermediation in which a change in capital requirements on these intermediaries leads to an international credit supply increase. In this environment, we illustrate how house price increases and exchange rates appreciations may contribute to fueling the boom by inflating the value of collateral. We then document empirically, in a Panel VAR for 50 advanced and emerging countries, that an increase in the leverage of US broker-dealers also lead to an increases in cross-border credit flows, an house price and consumption boom, a real exchange rate appreciation and a current account deterioration consistent with the transmission in the model. Finally, we study the sensitivity of the consumption and asset price response to such shock and show that country differences are associated with the level of the maximum loan-to-value ratio and the share of foreign currency denominated credit in total credit.

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1 Introduction

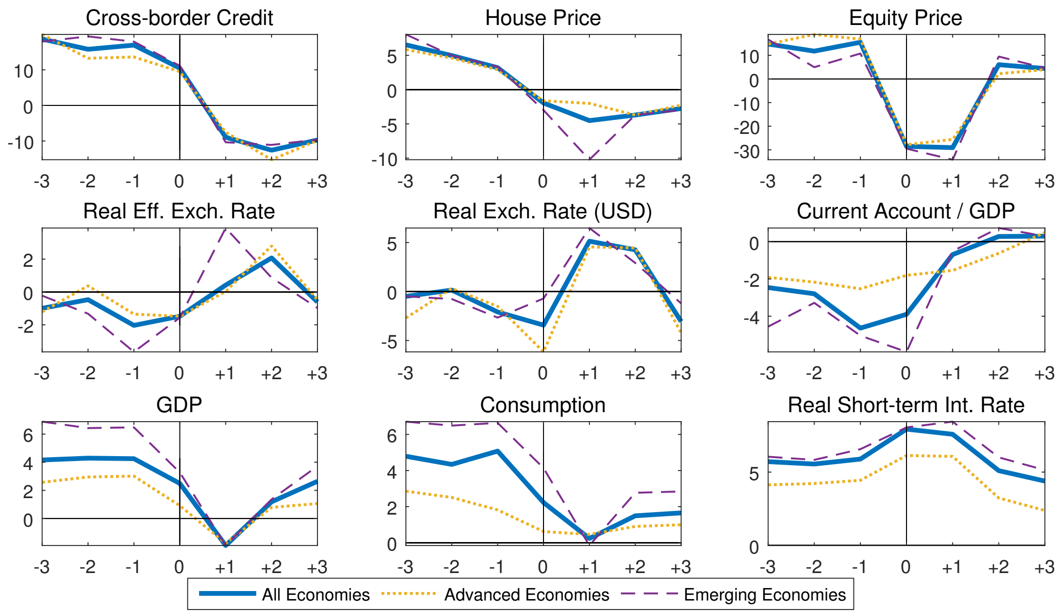
Contrary to the predictions of standard economic theory (Chari et al., 2005, Blanchard et al., 2015), capital inflows are expansionary and pose difficult challenges for policy makers—see, for instance, Rey (2013, 2016). Historically, however, some economies have been more sensitive than others to the volatility of capital inflows, with emerging market economies standing out as particularly vulnerable. What are the mechanisms through which capital inflows lead to macroeconomic booms? And what are the characteristics that account for the differences in sensitivity across countries? In this paper we explore the role of asset price inflation and credit market characteristics. Our main finding is that the currency denomination of credit flows and loan-to-value ratios are associated with the strength of the consumption response to international credit supply shocks.

Figure 1 shows that capital inflows are expansionary and associated with large swings in asset prices.[1] The Figure shows that during a boom in cross-border banking claims GDP and consumption growth rates are high, about 4-5 percent per year. The boom is accompanied by a sharp rise of house prices and equity prices, while the real interest rate starts to increase only the year before the peak. The real effective exchange rate is more stable during these episodes, but the real exchange rate vis-a-vis the US dollar appreciates during the last year of the boom phase. The current account balance deteriorates significantly before reverting during the last year of the expansion in about half of the episodes. During the bust phase, these dynamics are partially inverted. Both GDP and to a lesser extent consumption fall, and stabilize within a year. Equity prices drop sharply but are back to trend after two years. Conversely, both house prices and cross-border flows remain depressed for several years. The real exchange rate depreciates significantly, while the current account deficit closes quickly.

Not surprisingly, not all countries behave alike. For instance, Figure 1 also shows that emerging market countries experience much larger and more persistent boom-bust cycles

[1] See Appendix A and B for details on this event study and the underlying data.

Figure 1. Episodes of Boom-Bust In Cross-border Credit Flows



Note. The Figure plots the median pattern in whole cross section of countries in our sample, together with the median for advanced and emerging markets, respectively, across a set of boom-bust episodes in BIS cross-border claims, using a 6-year window that goes from three year before the peak to three years after the peak. In each panel, time 0 marks the peak of the boom-bust cycle in cross-border bank claims (i.e., the last period of a boom in which cross-border bank claims display a positive growth rate), which is also depicted with a vertical line. All variables are expressed in percentage changes, with the exception of the short-term interest rate and the current account over GDP which are expressed in percentage point changes. See Appendix A and B for more details on this event study and the data set we use in the paper.

than advanced economies (dashed and dotted lines, respectively). But this characterization of country heterogeneity is an over-simplification as countries cannot always be easily classified one way or the other. Several countries that are now member of the OECD, like South Korea or Mexico, have experienced some of the wildest gyrations in the recent past. At the same time, other more advanced economies like Ireland or Southern European countries encountered deeper or longer lasting financial crises than the typical emerging market economy. In this paper, therefore, we will attempt to study the heterogeneity at the country level based on specific characteristics as opposed to comparing country groupings formed from the outset, focusing on variables that have a counterpart in a fully specified model of international borrowing and lending.

Traditionally, the analysis of capital flows and their impact on the macroeconomy distinguished between "push" and "pull" factors (Calvo et al., 1996). The former are best thought as shocks that originate abroad and lead capital to flow in or out of individual countries. The latter are instead domestic shocks that attract foreign capital from the rest of the world. In this paper, we focus on one particular push shock—an international credit supply shock. Focusing on a specific shock facilitates isolating causal effects in the empirical analysis. It also allows us to explore both the transmission mechanism and the cross-country heterogeneity in more details from a theoretical point of view.

We proceed in three main steps. First, we set up a theoretical model of international financial intermediation and collateralized borrowing in domestic and foreign currency. Second, we identify an international credit supply shock in the data and document its transmission and relative importance. Third, we study the differential incidence of this shock across countries considering variables that can affect the shock transmission in the model.

Appreciating asset prices may amplify the expansionary effects of capital inflows by inflating the value of collateral and expanding the borrowing capacity of the economy. These channels of amplification may be more relevant the more developed the domestic credit market and the larger the foreign exchange exposure of the domestic economy balance sheet are. We assume that the main source of collateral is residential housing, and borrowing can be denominated in either foreign and domestic currency. We take the share of foreign currency denominated debt as given and study the implications of varying it exogenously. Housing is one of the largest asset classes in most countries, and the US dollar remains the dominant currency in the international financial system with relatively constant portfolio shares over time. Both house prices and the exchange rate can have an amplification effects, which differs depending on the characteristics of the national system of housing finance and currency denomination of credit.

The model we use embeds two blocks of with different characteristics. One block is small but financially integrated with the rest of the world. In this economy, households are relatively impatient and subject to a standard borrowing constraint like in (Kiyotaki and Moore, 1997). The other block is large and is the source of the global supply of credit. Households of the foreign economy own international financial intermediaries that operate globally and channel funds from savers to borrowers. These intermediaries are subject to an exogenous capital requirement as in Brunnermeier and Sannikov (2014) and He and Krishnamurthy (2013). A change in the leverage of international financial intermediaries leads to an increase in the international supply of credit as we will assume in our empirical analysis.[2]

In the model, the shift in the international credit supply leads to a consumption boom, an appreciation of the real exchange rate and house prices inflation (while the expected return on these assets falls), like we document in the data above. If the collateral constraint is binding, house prices always expand households' borrowing capacity. Similarly, when credit is denominated in foreign currency and the constraint is binding, a real exchange rate appreciation can also boost the borrowing capacity of the economy in foreign currency. Movements in the real exchange rate, however, affect the economy also through two other channels. In particular, the value of the domestic endowment increases, while the purchasing power of any new debt declines if this is denominated in foreign currency. While the collateral valuation effect of a house price increase is always expansionary, the net effect of the appreciation is an empirical/quantitative matter. In the model, we show that the housing and exchange rate collateral valuation effects are stronger the higher the LTV and the share of foreign currency liabilities.

Overall, the predictions of the model provide a solid theoretical foundation for our empirical analysis, even though we make a number of simplifying assumptions to keep the framework tractable and to highlight the key mechanisms at work. The model not only

[2]In practice, several factors, such as regulation, financial innovation, risk appetite, and monetary policy, can determine a change in the leverage constraint. We do not take a stand on the ultimate cause of this shift. Instead, we focus on its consequences for the international supply of credit and the transmission to foreign economies.

underpins the identification of our international credit supply shock in the data, but also highlights specific mechanism of transmission that is useful to interpret the evidence we report. The model also helps us select country characteristics that may be associated with a different sensitivity to such shock.

Next, we investigate empirically the transmission and the relative importance of our international credit supply shock, as well as the cross-country differences in its impact. We do so by specifying a Panel Vector Autoregression model (PVAR) for about 50 countries between 1985 and 2012. Following the insight of the theoretical model that we develop, we augment the PVAR model with the leverage of US Broker-Dealers, and then focus on a shock to this variable.

The VAR analysis shows that this leverage shock triggers a sharp and persistent increase in cross-border claims, house prices and consumption. The real exchange rate appreciates and the current account deteriorates. After about 5 years, these dynamics revert with some overshooting in line with the event study in Figure 1 and the transmission in the model. The evidence that we report shows that the shock explains about twice as much macroeconomic and asset price and consumption variance as a US monetary policy shock.

In the last step of the analysis, we study the sensitivity of the transmission to country characteristics. The individual country estimates reveal a significant degree of heterogeneity. Consistent with the predictions of the model, the impact of the shock is stronger in economies with a larger share of liabilities denominated in foreign currency and higher loan-to-value ratio. In the model, we show that both the tightness of the LTV and the share of domestic currency liability can potentially affect the impact of the international credit supply shock that we identify in the data, thus suggesting scope for macro-prudential policies to intervene on these margins.

Our paper relates to three strands of literature. A first set of contributions explore how US monetary or regulatory policy stance, innovations in the financial system, and risk taking behavior can affect leverage of international financial intermediaries and the global financial cycle, both from an empirical (Rey, 2013, 2016, Forbes et al., 2016) and theoretical (Bruno and Shin, 2015, Boz and Mendoza, 2014) perspective. We take this ideas one step further and investigate, both empirically and theoretically, possible mechanism of transmission to macroeconomic variables in individual countries. We investigate the next chain in the transmission of such shocks—from the leverage of US Broker-Dealers to macroeconomic dynamics in economies at the receiving end of capital inflows and also study the cross country distribution of these effects.

The second strand consists of papers that studied the role of international capital flows in fueling the US housing boom and subsequent crash–see, among others, Justiniano et al. (2015), and Favilukis et al. (2017).[3] In this paper, we explore the role of house prices and exchange rates for the transmission of capital flow shocks emanating at the center of the international financial system and potentially affecting the periphery.

Finally, this paper is also related to the literature on the sensitivity of consumption to house price and credit shocks. Berger et al. (2015) use US micro data to quantify the elasticity of consumption to changes in housing wealth. Kaplan et al. (2016) show that this elasticity depends on the source of the shock moving house prices. Calza et al. (2013) study how this elasticity depends on the mortgage market structure in advanced economies. We study this elasticity in an open-economy setting, focusing on how it is affected by the share of foreign currency liability and exchange rate dynamics. Almeida et al. (2006) document empirically how housing prices and mortgage demand respond more to income shocks in countries where households can achieve higher LTV ratios, consistent with the earlier evidence of Jappelli and Pagano (1989). Finally, Mian et al. (2016) document a cross-country association between household debt and consumption growth. We condition our analysis on a particular source of exogenous variation in consumption—an international credit supply shock—and document

[3] Aizenman and Jinjarak (2009) investigate empirically the impact of shocks to house prices for the current account. See Gete (2009) and Ferrero (2015) for models that rationalize this direction of causality.

an association between the share of foreign currency borrowing and the maximum level of the LTV and the consumption sensitivity to such a shock for the largest panel of countries studied to date for which quarterly data on house prices are available. The estimated implied elasticity is quantitatively sizable and estimated precisely.

The rest of the paper is organized as follows. Section 2 sets up the model that we use to illustrate the nature of the shock and support the VAR identification assumptions. Section 3 discusses the transmission mechanism. Section 4 presents the Panel VAR and reports the response of the typical economy in our cross section to the identified international credit supply shock. Section 5 investigates the cross-country sensitivity to LTV levels and the share of foreign currency liabilities. Finally, Section 6 concludes. The Appendix contains details of the event study above, data sources, model derivations, and results on the robustness of the PVAR analysis.

2 A Model of International Borrowing and Lending

This section presents a stylized model of international financial intermediation and collateralized borrowing. The model helps us to identify an international credit supply shock in the data, to interpret its transmission, as well as the sensitivity of its effect to country characteristics.

The world economy lasts for two periods, and consists of two blocks (countries), Home (H) and Foreign (F), of size $n \in (0,1)$ and $1-n$, respectively. In both periods, the representative Home and Foreign household receives a country-specific endowment of goods, and consumes a bundle of the two non-durable, tradable goods as well as non-tradable housing services, which are proportional to the stock of housing. For simplicity, we abstract from construction and assume that housing is in fixed supply, like land. The two blocks only differ in the degree of patience of their representative household. The Home household is relatively impatient and borrows to purchase housing services subject to a collateral constraint. The Foreign household saves via deposits and equity in a global financial intermediary that channels funds to the borrowers and is subject to a leverage constraint (or, equivalently, a capital requirement).

2.1 Goods Markets

The structure of the goods market is standard. The representative Home household consumes a Cobb-Douglas basket of Home and Foreign goods:

$$c = \frac{c_H^{\alpha} c_F^{1-\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}}, \tag{1}$$

where $\alpha \in (0,1)$ is the steady state share of consumption on Home goods. Following Sutherland (2005), we assume that the weight on imported goods in the Home consumption basket is a function of the relative size of the foreign economy $(1-n)$:

$$\alpha \equiv 1 - (1-n)\lambda,$$

where $\lambda \in (0,1)$ represents the degree of openness, equal for both countries. This assumption implies $\alpha \in (n,1]$ and generates home bias in consumption.[4]

Expenditure minimization implies that the demand for Home and Foreign goods by Home households is:

$$c_H = \alpha \left(\frac{P_H}{P}\right)^{-1} c \qquad \text{and} \qquad c_F = (1-\alpha)\left(\frac{P_F}{P}\right)^{-1} c, \tag{2}$$

where P_H and P_F are the Home currency prices of the Home and Foreign goods, respectively,

[4]The size of home bias decreases with the degree of openness and disappears when $\lambda = 1$. In the limit for $n \to 0$, the Home block becomes a small open economy. We will study this special case in details below.

and P is the overall price level. These price indexes are related to each other according to:

$$P = P_H^{\alpha} P_F^{1-\alpha}. \tag{3}$$

The representative household in the Foreign block has a symmetric consumption bundle, with $\alpha^* \equiv n\lambda$ representing the Foreign consumption share of imported goods. The demand for Home and Foreign goods by the Foreign representative household are symmetric to (2), with the only difference that an asterisk denotes Foreign variables.

2.2 Exchange Rates and Relative Prices

The nominal exchange rate $\mathcal{E}$ is defined as the number of units of Home currency required to buy one unit of Foreign currency, so that an increase of the nominal exchange rate corresponds to a depreciation of the Home currency. We assume that the law of one price (LOOP) holds for each good:

$$P_H = \mathcal{E} P_H^* \qquad \text{and} \qquad P_F = \mathcal{E} P_F^*, \tag{4}$$

where P_H^* and P_F^* are the Foreign currency prices of the Home and Foreign goods, respectively.

The terms of trade τ for the Home country represents the price of imports relative to the price of exports, where both prices are expressed in terms of the Home currency:

$$\tau = \frac{\mathcal{E} P_F^*}{P_H}. \tag{5}$$

An increase in the terms of trade corresponds to a rise in the price of imports relative to exports for the Home consumer in Home currency, so that Foreign imports become relatively more expensive. In this sense, an increase in τ represents a deterioration of the terms of trade for the Home country (i.e. a depreciation). All relative prices are a function of the terms of trade:

$$p_H = \tau^{\alpha-1} \qquad \text{and} \qquad p_F = \tau^{\alpha}, \tag{6}$$

where $p_k \equiv P_k/P$, for $k = \{H, F\}$. Similarly, for the Foreign country, we have:

$$p_H^* = \tau^{\alpha^*-1} \qquad \text{and} \qquad p_F^* = \tau^{\alpha^*}. \tag{7}$$

The real exchange rate s is the price of Foreign consumption in terms of Home consumption:

$$s \equiv \frac{\mathcal{E}P^*}{P}. \tag{8}$$

A higher s corresponds to an increase in the price of the Foreign consumption basket relative to the Home consumption basket in terms of the Home currency, and thus to a depreciation of the real exchange rate. In spite of the LOOP, purchasing power parity does not hold because of home bias, that is, the real exchange rate is generally different from one. However, the (log) real exchange rate is proportional to the (log) terms of trade:

$$s \equiv \frac{\mathcal{E}P^*}{P} = \frac{\mathcal{E}P_F^*}{P_H} \times \frac{p_H}{p_F^*} = \tau^{\alpha-\alpha^*}. \tag{9}$$

Therefore, we can characterize the equilibrium indifferently with respect to a single relative price.

2.3 Home Households

A continuum of measure $n \in [0, 1]$ of households populates the Home economy. All households are identical and relatively impatient. We denote by c_1 and c_2 their consumption in the two periods. In addition, in period 1, the household decides once and for all the amount of housing services to purchase, which we assume to be proportional to the housing stock

h_1. Lifetime utility therefore is:

$$\mathbb{U} = u(c_1) + \beta u(c_2) + v(h_1), \tag{10}$$

where $\beta \in (0, 1)$ is the individual discount factor. Preferences are risk-neutral with respect to consumption (i.e. $u'(\cdot) = \bar{c} > 0$), and are increasing and weakly concave with respect to housing (i.e. $v'(\cdot) > 0$ and $v''(\cdot) \leq 0$).

Households are endowed with y units of Home goods in each period and h_0 initial units of housing, and can obtain credit denominated in either Home (b) or Foreign (f) currency. Thus, the budget constraint in period 1 is:

$$c_1 + qh_1 - b - s_1 f = p_{H1} y + qh_0, \tag{11}$$

where q is the relative price of houses in terms of the consumption good, and we have assumed that the household starts with no credit to repay. In the second period, the household repays the debt contracted in the first period plus a gross interest rate, so that the budget constraint is:

$$c_2 = p_{H2} y - R^b b - s_2 R f, \tag{12}$$

where R^b and R are the gross interest rates on credit denominated in Home and Foreign currency, respectively.

While in principle households (and banks) do choose the currency denomination of their credit portfolio, in this paper, we abstract from this choice and treat the share of foreign currency denominated credit as given. In particular, we will characterize the equilibrium in terms of the ratio between credit in Home and Foreign currency:

$$\eta \equiv \frac{b}{s_1 f}, \tag{13}$$

so that $1/(1+\eta)$ represents the share of Foreign currency liabilities in total credit from the perspective of the Home country that can be measured in the data. If $\eta = 0$, the model corresponds to the limiting case in which all credit is denominated in Foreign currency. As f decreases, η increases, and in the limit the share of Foreign currency debt goes to zero.

Following Kiyotaki and Moore (1997), a collateral constraint limits total debt to a fraction $\theta \in [0,1]$ of the value of housing purchased in period 1:

$$b + s_1 f \leq \theta q h_1. \tag{14}$$

The parameter θ represents a limit that lenders impose on borrowers to mitigate issues related to asymmetric information. In practice, however, θ is also affected by policy as in many national housing finance systems regulation mandates the maximum loan-to-value (LTV) ratio that lenders can offer. Because borrowing is denominated in foreign-currency, both house prices and the exchange rate enter this constraint. Thus, equation (14) combines the typical specifications adopted in the housing and the open economy macroeconomics literatures.

The Home household maximizes (10) subject to (11), (12), and (14). Let $\mu\bar{c}$ be the Lagrange multiplier on the borrowing constraint, normalized by the marginal utility of consumption ($\bar{c}$). The first order conditions for the optimal demand of credit in period 1 in Home and Foreign currency are, respectively:

$$1 - \mu = \beta R^b \qquad \text{and} \qquad 1 - \mu = \beta R \frac{s_2}{s_1}, \tag{15}$$

with $\mu > 0$ when $b + s_1 f = \theta q h_1$. The two expressions in (15) are the consumption Euler equations under risk neutrality. Under these assumptions, when binding, a tighter borrowing constraint (i.e., a higher μ) reduces the cost of forgoing consumption today (or increases the benefits of saving today). No arbitrage requires Home households to be indifferent between credit denominated in Home and Foreign currencies:

$$R^b = R\frac{s_2}{s_1}, \tag{16}$$

This equation corresponds to the uncovered interest rate parity condition in real terms.

The Euler equation for the choice of housing services is:

$$(1 - \theta\mu)q = \frac{v'(h_1)}{\bar{c}}. \tag{17}$$

This equation shows that house prices are higher (i) the higher the maximum LTV ratio θ (ii) and the tighter the borrowing constraint μ.

All else equal, both the level of the LTV and the tightness of the borrowing constraint increase housing demand. A higher LTV directly allows for more borrowing in equation (15) and hence more consumption, including more housing services. Similarly, a tighter borrowing constraint (a higher value of the multiplier μ) increases house prices via higher demand for scarce collateral.[5] Conversely, when the collateral constraint is not binding ($\mu = 0$), housing demand is constant and house prices are equal to their fundamental value, that is the marginal utility of housing in units of marginal utility of consumption. Therefore, the housing market is insulated from exogenous shocks that instead affect other parts of the economy.

The unconditional evidence reported in the previous section suggests that both the real exchange rate and house prices increase during periods of capital inflows. In our model, both asset prices can amplify the effects of an international credit supply shock, but with different mechanisms.

When the collateral constraint binds, an increase in house prices boosts the (Home currency) value of the collateral and expands the households' borrowing capacity, thus support-

[5]This effect is particularly stark in our model because of the assumptions of risk neutrality and fixed hosing supply.

ing consumption of housing and non housing. This "collateral house price effect" is evident from equation (14) and mechanism corresponds to the standard amplification channel associated with house prices in the closed economy literature (e.g. Kiyotaki and Moore, 1997). As we will see below, the empirical evidence that we report suggests this mechanism may be an important transmission channel of international credit supply shocks.[6] When the collateral constraint is not binding, however, the feedback from house prices to the rest of the economy disappears because of our simplifying assumptions on preferences and housing technology.

In contrast, the exchange rate can amplify the effects of an international credit supply shock independently of whether the collateral constraint is binding or not. When total borrowing is constrained, equation (14) shows that an appreciation expands the borrowing capacity of the economy like house prices do, but in Foreign as opposed to Home currency—an effect that we label "collateral exchange rate valuation effect" or exchange rate collateral effect. Note here that this effect is stronger the higher the share of foreign currency liability (the ratio between f and b).

As we can see from the budget constraint (11), an appreciation also boosts the purchasing power of the Home endowment, but it reduces that of any given amount of foreign currency debt regardless of whether the constraint binds or not.[7] We call these two latter effects "endowment valuation effect", and "debt valuation effect", respectively. Note here again that the debt valuation effect is increasing in the share of foreign currency liabilities like the collateral valuation effect.

In summary, the exchange rate can amplify shocks in our models with or without a binding collateral constraint. The collateral valuation effect reinforces the endowment valuation effect, but could be offset by the debt valuation effect. The overall impact on the economy is a quantitative matter that depends on the total level of borrowing as well as its currency composition. In fact, both the debt and collateral valuation effects become less severe as the

[6] Of course, in the data, a richer sets of effects might be at play.

[7] In a fully dynamic setting, the latter effect would trade off the lower purchasing power of a given amount of debt contracted in the current period with the lower repayment on credit obtained in the past.

share of foreign currency declines (i.e., η gets bigger). We can see dependency of the debt valuation effect on the share of foreign currency credit by rewriting the budget constraint in terms of η as:

$$c_1 + qh_1 - (1+\eta)s_1 f = p_{H1}y + qh_0.$$

Similarly, rewriting the borrowing constraint at equality as a function of η, we can see that collateral valuation effect is also declining in η:

$$(1+\eta)s_1 f = \theta q h_1.$$

In both cases, a higher value of η dampens the effect of an appreciation of the real exchange rate (a fall in s_1) on the purchasing power of a given amount of credit in Foreign currency f.

On balance, therefore, an appreciation is more likely to be expansionary in our model at higher levels of debt, when the the borrowing constraint is more likely to bind and hence to activate the exchange rate collateral effect.

2.4 Foreign Households

The Foreign economy is populated by a continuum of identical households of measure $1-n$. Foreign households are relatively patient and derive utility solely from consumption (c^*). Their utility function is:

$$\mathbb{U}^* = u(c_1^*) + \beta^* u(c_2^*), \tag{18}$$

with $\beta^* \in (\beta, 1)$. Because of their relative patience, the borrowing constraint of the Foreign representative household never binds in equilibrium. Therefore, we abstract from Foreign purchases of housing services, as house prices in country F would be irrelevant for the equilibrium.[8]

[8] The only difference from explicitly incorporating foreign housing decisions would be to price housing in the lending country—something our empirical evidence has little to say about. The Foreign counterpart of equation (17) with $\mu^* = 0$ shows that we would obtain a solution for Foreign house prices of the form

Foreign households are endowed with y^* units of Foreign goods in each period, and can save via deposits (d) or equity holdings of financial intermediaries (e), which are subject to adjustments costs. The budget constraint in period 1 is:

$$c_1^* + d + e + \psi(e) = p_{F1}^* y^*, \tag{19}$$

where $\psi(\cdot)$ (with $\psi',\ \psi'' > 0$) represents a convex cost of changing the equity position.[9] As in Jermann and Quadrini (2012), the equity adjustment cost creates a "pecking order" of liabilities whereby intermediaries always prefer to issue debt relative to equity. The budget constraint in the second period is:

$$c_2^* = p_{F2}^* y^* + R^d d + R^e e + \Pi, \tag{20}$$

where R^d and R^e are the real gross returns on deposits and equity, respectively, and Π stands for the profits of the global financial intermediary that the Foreign representative household owns.

The problem for the foreign representative household is to maximize (18) subject to (19) and (20). The first order conditions for the optimal choice of deposits and equity are:

$$1 = \beta^* R^d, \tag{21}$$

and

$$1 + \psi'(e) = \beta^* R^e. \tag{22}$$

Combining these two first order conditions, we obtain:

$$R^e = R^d + \frac{\psi'(e)}{\beta^*}.$$

$q^* = v'(h_1^*)/\bar{c}^*$.

[9] For simplicity, we assume global financial intermediaries are set up in the first period, and normalize to zero initial deposits and equity.

Table 1. BALANCE SHEET OF A TYPICAL GLOBAL FINANCIAL INTERMEDIARY.

Assets		**Liabilities**	
Loans (Home currency):	b/s_1	Deposits:	d
Loans (Foreign currency):	f		
		Equity:	e

Because of the presence of adjustment costs, the return on equity pays a premium over the return on deposits, which is increasing in the degree of convexity of the portfolio cost of adjustment function.

2.5 Global Financial Intermediary

A representative financial intermediary (a global bank) operates in international credit markets and channels loans from patient foreign lenders to impatient domestic borrowers, funding its activity with a mix of equity and deposits raised in the Foreign country.

Table 1 summarizes the balance sheet of financial intermediaries in period 1. As discussed earlier, a given fraction η of their loan book is denominated in Home currency. Following Bräuning and Ivashina (2016), we assume that global financial intermediaries swap their exchange rate exposure by entering a contract with perfectly competitive specialized FX operators. These operators are endowed with a large amount of capital K and make zero profits. Using these swap contracts, banks can ensure that only the total asset size of their balance sheet, and not its currency composition, matters for their activity.

The profits of a generic financial intermediary at market value correspond to the the total return on loans, net of the payouts to depositors and equity holders, and of the costs of hedging:

$$\Pi = Rf + \frac{R^b b}{s_2} - R^d d - R^e e - \phi\left(\frac{b}{s_1}\right), \tag{23}$$

where $\phi(\cdot)$ (with $\phi'(\cdot),\ \phi''(\cdot) > 0$) represents the cost of swapping the total amount of credit denominated in Home currency issued by an intermediary.

Because equity is more expensive than deposits, financial intermediaries would like to leverage their balance sheet without bounds. We assume that a capital requirement limits leverage and the size of their balance sheet:

$$e \geq \chi \left(\frac{b}{s_1} + f \right), \tag{24}$$

with $\chi \in (0, \bar{\chi})$.[10]

The problem for the representative global financial intermediary is to maximize (23) subject to the leverage constraint (24) and the balance sheet constraint. Using the no arbitrage condition (16) and the definition of the share of credit denominated in Home currency (13) introduced earlier, we can rewrite the problem of the representative global bank as:

$$\max_{f} \ \Pi = (1+\eta)Rf - R^d d - R^e e - \phi(\eta f),$$

subject to the balance sheet constraint:

$$(1+\eta)f = d + e, \tag{25}$$

and the capital constraint:

$$e \geq \chi(1+\eta)f.$$

The main theoretical experiment that we focus on in the model is a one-time change in the capital constraint χ. We then map the results of this experiment into the identification of our international credit supply shock in the VAR analysis of the next section. For this purpose, we will focus on an equilibrium in which the capital constraint is binding. If the capital constraint were slack, financial intermediaries would become irrelevant, and a shock

[10] Gabaix and Maggiori (2014) obtain a similar constraint assuming financiers can divert part of the funds intermediated through their activity.

to χ would have no effect on macroeconomic variables and asset prices.

After substituting for deposits from the balance sheet constraint and for equity from the binding capital constraint, intermediaries profits become:

$$\Pi = \left[R - \chi R^e - (1-\chi)R^d\right](1+\eta)f - \phi(\eta f). \tag{26}$$

The first order condition for the optimal choice of lending is:

$$R = \chi R^e + (1-\chi)R^d + \frac{\eta}{1+\eta}\phi'(\eta f). \tag{27}$$

The lending rate is a weighted average of the funding costs, plus the cost of swapping the position denominated in Home currency. The capital constraint χ represents the weight on the return on equity: a tighter leverage constraint (a higher χ) implies a higher cost of equity, which is passed on to borrowers in the form of a higher loan rate. The last term on the right-hand side captures the cost of hedging: for given f, the loan rate is increasing in the share of credit issued in Home currency. Similarly, for given η, the loan rate is increasing in the amount of credit issued in Foreign currency because a larger balance sheet with a fixed share of Home currency credit corresponds to a larger amount of loans to hedge.

2.6 Equilibrium

We characterize the equilibrium in terms of the quantity of credit denominated in Foreign currency f, for a given share of credit denominated in Home currency η, which we treat as a parameter. In equilibrium, the demand for housing within each country must equal the available stock, which, without loss of generality, we normalize to one ($h_0 = h_1 = 1$). A competitive equilibrium for this economy is a collection of quantities and prices such that:

1. Domestic households maximize their utility subject to their budget and collateral constraints.

2. Foreign households maximize their utility subject to their budget constraints.

3. Financial intermediaries maximize their profits subject to their balance sheet and leverage constraint.

4. Goods market clear in every period.

The full list of equations that characterize the equilibrium of our model is reported in Appendix. Here we discuss the special case of a small open economy as we assume in our empirical analysis in section 4.

3 The Small Open Economy Case: An Example

In our empirical analysis, we will focus on the transmission of an international credit supply shock to individual countries. The key identifying assumption will be that each country in our sample is too small to influence the global supply of credit. This case can be analyzed in the model by taking the limit for n that goes to zero (a small open economy) and using our assumption about the degree of home bias that links country size, consumption shares, and degree of openness.

This small open economy assumption implies that Home demand does not affect the equilibrium in the market for Foreign goods, but Foreign demand remains relevant for the Home goods market equilibrium. In this case, we can solve for the real exchange as a function of the quantity of credit and the interest rate. The credit market then determines the entire equilibrium of the model.

3.1 The Exchange Rate and the Credit Market

The Appendix contains the derivations of the equilibrium relations below.

Exchange rate

Credit demand interacts with the goods market through the real exchange rate, which in period 1 and 2 is:

$$s_1 = \left[\frac{\lambda y}{\lambda y^* + (1-\lambda)(1+\eta)f}\right]^{1-\lambda}, \tag{28}$$

$$s_2 = \left[\frac{\lambda y}{\lambda y^* - (1-\lambda)R(1+\eta)f}\right]^{1-\lambda}. \tag{29}$$

Intuitively, higher borrowing in period 1 implies higher Home demand, and hence an appreciation of the terms of trade (and consequently of the real exchange rate). Conversely, higher debt or higher interest rates in period 1 imply lower resources (and therefore demand) in period 2, and therefore a depreciation.

Credit supply

The credit supply schedule is upward-sloping in the $\{f, R\}$ space:

$$R = \frac{1 + \chi\psi'[\chi(1+\eta)f]}{\beta^*} + \frac{\eta\phi'(\eta f)}{1+\eta}, \tag{30}$$

A larger balance sheet requires more equity to satisfy the capital constraint. Since equity is costly to raise, global financial intermediaries charge a higher lending rate to borrowers. In addition, as mentioned earlier, for a fixed share of Foreign (Home) currency credit in total credit, a larger balance sheet implies a higher hedging cost, which financial intermediaries pass on to borrowers. These two effects make credit supply increasing in the level of the interest rate.

The shock that we study originates from the balance sheet of global banks and is transmitted to individual countries through the international credit market. As equation (30) shows, an increase in the leverage of financial intermediaries (a reduction of the capital requirement parameter χ) shifts down the credit supply schedule. At any level of credit, the interest rate offered on loans issued to the Home country must fall. This mechanism is what underpins our identification assumptions in the VAR of section 4.

Credit Demand

The credit demand schedule differs depending on whether the collateral constraint binds or not. In particular, credit demand is a piecewise function with a kink at the level of credit where the borrowing constraint becomes binding:

$$R = \begin{cases} \frac{1}{\beta}\frac{s_1}{s_2} & \text{if } \ (1+\eta)s_1 f < \theta q \\ \frac{1}{\beta}\frac{s_1}{s_2}\left[\frac{\kappa}{(1+\eta)s_1 f} - \frac{1-\theta}{\theta}\right] & \text{if } \ (1+\eta)s_1 f = \theta q. \end{cases} \tag{31}$$

If the collateral constraint does not bind, the slope of the credit demand schedule is negative. In this region, the LTV level is irrelevant for the equilibrium. If the constraint binds, credit demand is downward-sloping for a sufficiently high level of the LTV ratio.[11]

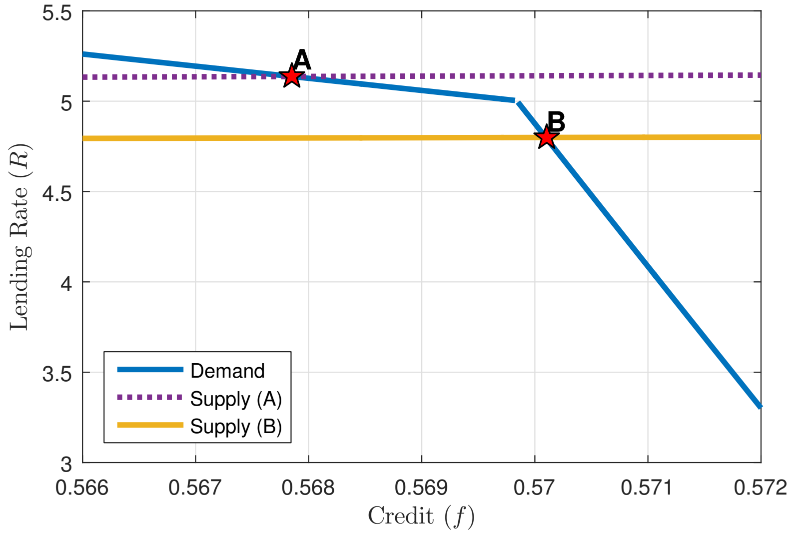
3.2 Equilibrium

Figure 2 plots the credit market equilibrium in the space $\{f, R\}$ for a reasonable choice of the parameters values. Starting with credit demand, which results from combining (28), (29), and (31), we normalize the endowment in both countries to $y = y^* = 1$ and fix the marginal utility of housing in units of marginal utility of consumption to $\kappa = 0.85$. We set a high value for $\theta = 0.9$, consistent with the observed (median) maximum LTV limit in our sample of countries, and $\eta = 0.43$ to match the median share of foreign currency liabilities from BIS data.[12] We pick a value for the openness parameter ($\lambda = 0.79$) slightly larger than

[11] See the Appendix for the formal derivations of the slope of the credit demand schedule in the two regions.

[12] For consistency with the VAR, we compute the share of foreign currency liabilities using a confidential version of the BIS dataset used for the empirical analysis that allows us to sort out different currencies. The share is computed as cross-border bank claims in foreign currency over total cross-border bank claims.

Figure 2. International Credit Market Equilibrium.



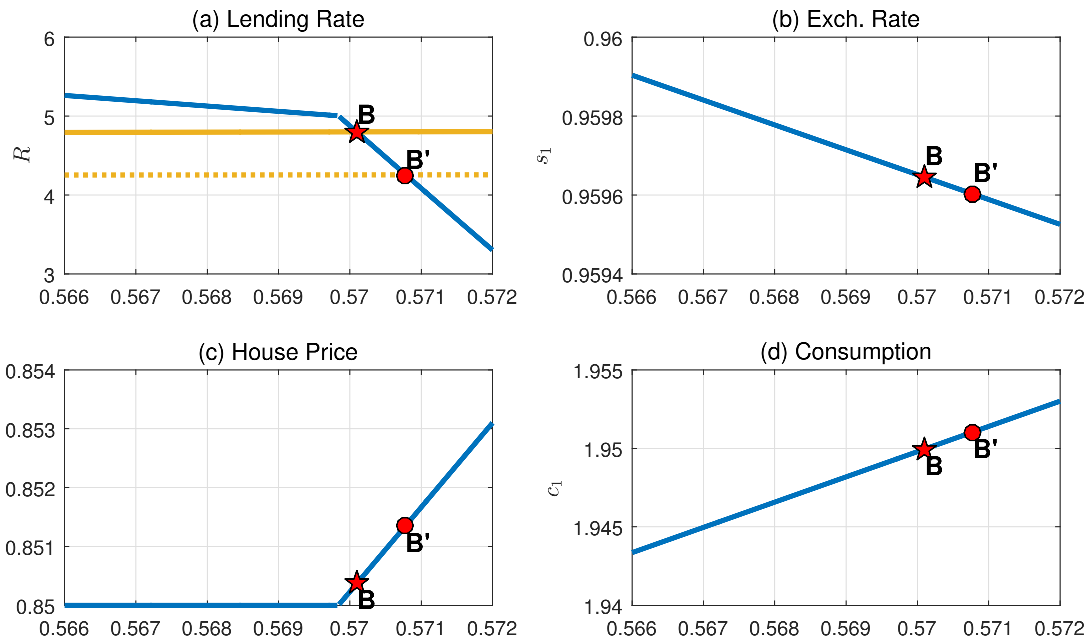
Note. Point A: Unconstrained equilibrium. Point B: Constrained Equilibrium.

in Gali and Monacelli (2005) but within the range discussed in the literature. Finally, we set the domestic discount factor to $\beta = 0.9$ to yield a reasonable value for the real interest rate in the credit market, whether the borrowing constraint is binding or not.

Focus next on credit supply (equation 30). The parameters that pin down its shape are the capital requirement, the discount factor of country F, and the the adjustment cost parameters. We choose a capital requirement of 10% ($\chi = 0.1$) to target a leverage ratio of 10—a value that is close to the average leverage of US commercial banks in the data. As common in the literature, we set $\beta^* = 0.99$ to obtain $R^d = 4.1\%$ in annualized terms. We assume that the adjustment cost functions for equity and hedging are both quadratic and treat the choice of their parameters residually. Given the rest of the calibration, their values determine whether the equilibrium is in the region where the borrowing constraint is binding or not, and the premium bank equity pays over deposits.

Figure 2 displays two types of credit market equilibrium that can arise in the model, depending on whether the constraint bind or not. For example, for a given cost of hedging, if the equity adjustment cost parameter is relatively high ($\zeta = 0.03$), financial intermediaries

Figure 3. International Credit Supply Shock with Binding Borrowing Constraint



Note. Change in χ from 0.1 to 0.025 (with leverage going from 10 to 40). Initial equilibrium: constraint is binding like in Point B in Figure 2; new equilibrium: Point B'. Credit volume on the horizontal axis.

pay a large premium over the return on deposits (about ten and a half percentage points). In this case, the equilibrium is in the unconstrained region (point A), with a relatively high interest rate on loans of 5.2%. Conversely, when the equity adjustment cost is relatively low ($\zeta = 0.02$), the equity premium is not as large (approximately seven percentage points), credit is abundant, and the interest rate on loans is lower at about 4.9%. In this case, given the LTV value, demand meets supply in the constrained region (point B).

3.3 The Transmission of a Leverage Shock

Figure 3 illustrates graphically the change in the credit market equilibrium (top-left panel), and the response of the real exchange rate (top-right panel), house prices (bottom-left panel), and consumption (bottom-right panel), to a reduction of χ from 0.1 to 0.02 in the region where the collateral constraint is binding. We start from the same constrained equilibrium of Figure 2 (point B) with low equity premium. The reduction in capital requirements of global banks increases the international supply of credit. The credit supply schedule shifts downward, and the new credit market equilibrium occurs in point B' (top-left panel of Figure 3), with higher credit and a lower interest rate. The higher availability of credit pushes up house prices (bottom-left panel). As demand rises in the Home country, the real exchange rate also appreciates (top-right panel) and consumption increases (bottom-right panel).

A similar adjustment would occur if the economy experienced the same shock starting from point A in Figure 2. The main difference is that, with a non-binding collateral constraint, house prices in the Home country would not be responsive to the increase supply of credit.[13]

While Figure 3 traces the impact of the shock for the particular set of parameter values discussed above, in Appendix B.4 we show that the sign of theses derivatives is preserved as long as the model solution is approximated around a steady state in which the constraint is binding.

4 An International Credit Supply Shock in the Data

In this section, we identify an international credit supply shock empirically and discuss its impact on macroeconomic variables and asset prices of receiving economies. We use a panel-vector autoregressive model (PVAR) that allows us to investigate both the behavior of the typical economy in response to the shock and the cross-countries differences in its transmission. As we shall see, most empirical findings are consistent with the predictions of our model.

[13] Starting from point A, with a large enough shock, the economy could also move from the unconstrained to the constrained equilibrium. The adjustment in this case would be similar to that depicted in Figure 3.

4.1 A PVAR Model

The PVAR model includes a small set of variables which have a direct counterpart in the theoretical model. We include the leverage ratio of US Broker-Dealers (described below) and cross-border bank claims to financial and non-financial sector, real private consumption, real house prices, the real exchange rate vis-a-vis the US Dollar, and the current account balance over GDP.[14]

The specification for each country i is:

$$x_{it} = a_i + b_i t + c_i t^2 + F_{1i} x_{i,t-1} + u_{it}, \tag{32}$$

where x_{it} is the vector of endogenous variables, a_i is a vector of constants, t and t^2 are vectors of deterministic trends, F_{1i} is a matrix of coefficients, and u_{it} is a vector of reduced form residuals with variance-covariance matrix Σ_{iu}. All variables considered enter in log-levels, except for the current account, which is expressed in percentage of GDP.[15] The empirical model is the same for all countries to avoid introducing differences in country responses due to different specifications, and because it would be difficult to find a perfectly data-congruent specification for all countries in the sample. In particular, somewhat arbitrarily, but mindful of the relatively short sample period for some of the emerging economies, we include one lag of each variable in every system. The full sample period is 1985:Q1-2012:Q4, but some country models are estimated with a later starting date, depending on data availability.

We estimate the model using the mean group estimator of Pesaran and Smith (1995) and Pesaran et al. (1996).[16] In the estimation, we drop all countries which have less than 40

[14]We do not include a price measure corresponding to the credit variable selected because data for interest rate on loans are not easily available for our large panel data. Nonetheless, below we use the model to link the response of house prices and the real exchange rate, which are observables, to the interest rate on loans. We include cross-border to both financial and non-financial firms as in the model the private sector consists of households only.

[15]We estimate the VAR systems in levels allowing for implicit cointegration among variables. Sims et al. (1990) show that, if cointegration among the variables exists, the system's dynamics can be consistently estimated in levels.

[16]Pooled estimators are inconsistent in a dynamic panel data model with slope coefficients varying across

observations or have unstable dynamics (i.e., with eigenvalues larger than 1). This selection leaves us with 51 out of the 57 countries originally in our event study.[17]

Finally, in the estimation of the country-specific VARs, we allow lagged domestic variables to affect the dynamics of leverage. Proceeding in this way we only loose efficiency, but not consistency, for the estimation of the leverage equation. Given that we do not use country-specific standard errors to construct the variance of the mean group estimator, the efficiency loss is not a major concern. The upshot is that our approach significantly simplifies the computations, as we can use OLS rather than maximum likelihood to estimate the reduced form of the country systems. For robustness, however, we also consider a restricted specification of the VAR where the dynamics of leverage are fully independent from the dynamics of the domestic variables (results are described in section 4.4 and reported in Appendix).

4.2 Identification

We want to identify a push shock to the international supply of credit as in the model presented in previous section. The model shows that changes in leverage of international financial intermediaries lead to an international credit supply expansion. In the PVAR model, we use innovations to US Broker-Dealers leverage as a source of exogenous changes in the international supply of credit to our collection of small open economies.[18] Leverage of US Broker-Dealers is readily available from the data (US Flow of Funds), and these institutions are a good proxy for the global financial intermediaries that we considered in the theoretical analysis.

Consistently with the model, our key assumption is that changes in the leverage of US

countries.

[17]Specifically, we drop from our original sample Brazil, Colombia, Greece, Indonesia because of unstable dynamics, and Morocco and Serbia because of the number of observations.

[18]Since the leverage of US Broker-Dealers is endogenous to the US, we do not include the US in the sample, leaving us with 50 countries.

Broker-Dealers lead to a shift in the international supply of credit, but leverage of US Broker-Dealers is not affected by conditions in individual countries outside the United States.[19]

Various factors can affect US Broker-Dealers' leverage, including US monetary policy, financial regulation, financial innovation, and shifts in risk appetite (see, for example, Bruno and Shin, 2015, Rey, 2013, Bekaert et al., 2013). For our purposes, we do not need to take a stand on the underlying structural sources of shifts in leverage. As long as country-specific, domestic pull factors do not affect leverage, we can treat changes in this variable as a proxy for an exogenous push shock to capital flows, or an international credit supply shock like in our model above. However, since a shock that is common to many small open economies could affect world GDP, and hence US broker-dealers leverage as well, to check the robustness of our results we experiment adding world GDP as a conditioning variables in the model.

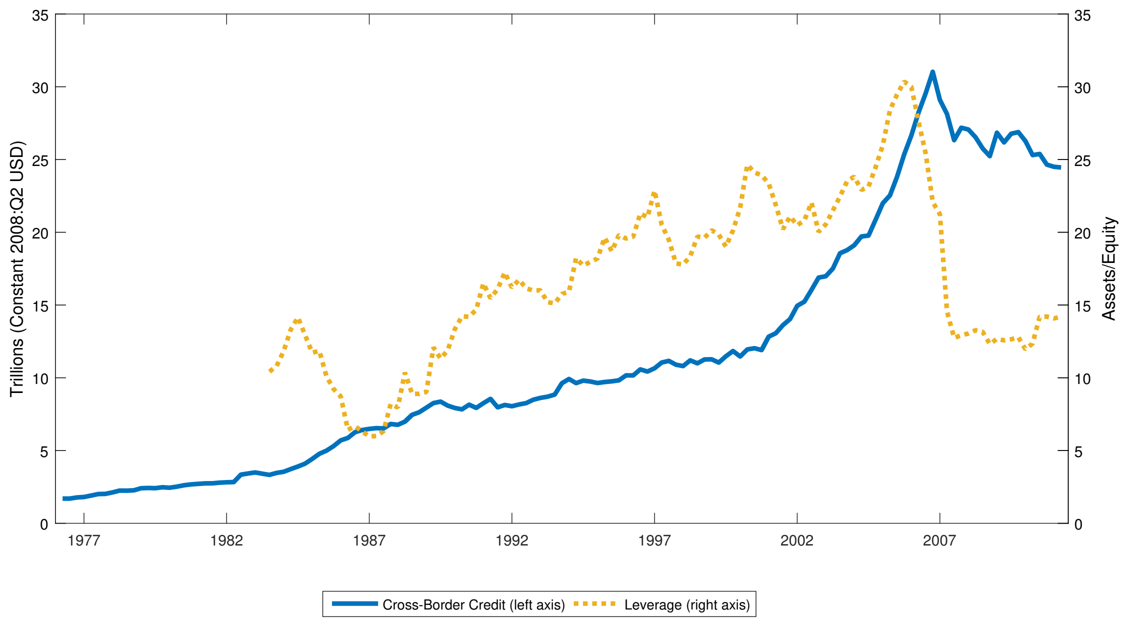
Figure 4 plots the sum cross-border bank claims over all countries in our sample (solid blue line) and the leverage of US Broker-Dealers (dashed yellow line). The two series share a secular upward trend as well as cyclical variations at relatively low frequency. Albeit to a different degree and with different timing, the two series increase sharply before the global financial crisis, and then collapse during the crisis. The correlation between the two series is 0.38 in levels, but only 0.04 in quarterly differences. As we shall see below, the response of the VAR system to our leverage shock is stationary. Thus, the shock that we identify is a persistent cyclical deviation of leverage from its long run trend value.

In practice, we obtain the impulse responses of all other variables in the system to a shock to US Broker-Dealers' leverage from the Cholesky decomposition of the variance-covariance matrix of the estimated reduced-form residuals of each country-specific VAR, with leverage ordered first in the system.[20]

[19] Bruno and Shin (2015) also show that changes in the leverage of US Broker-Dealers have a well defined theoretical and empirical linkage to changes in BIS cross-border claims.

[20] Note here that the order of the other endogenous variables in the VAR system does not matter for the transmission of the leverage shock.

Figure 4. Leverage of US Broker-Dealers and cross-border bank claims.



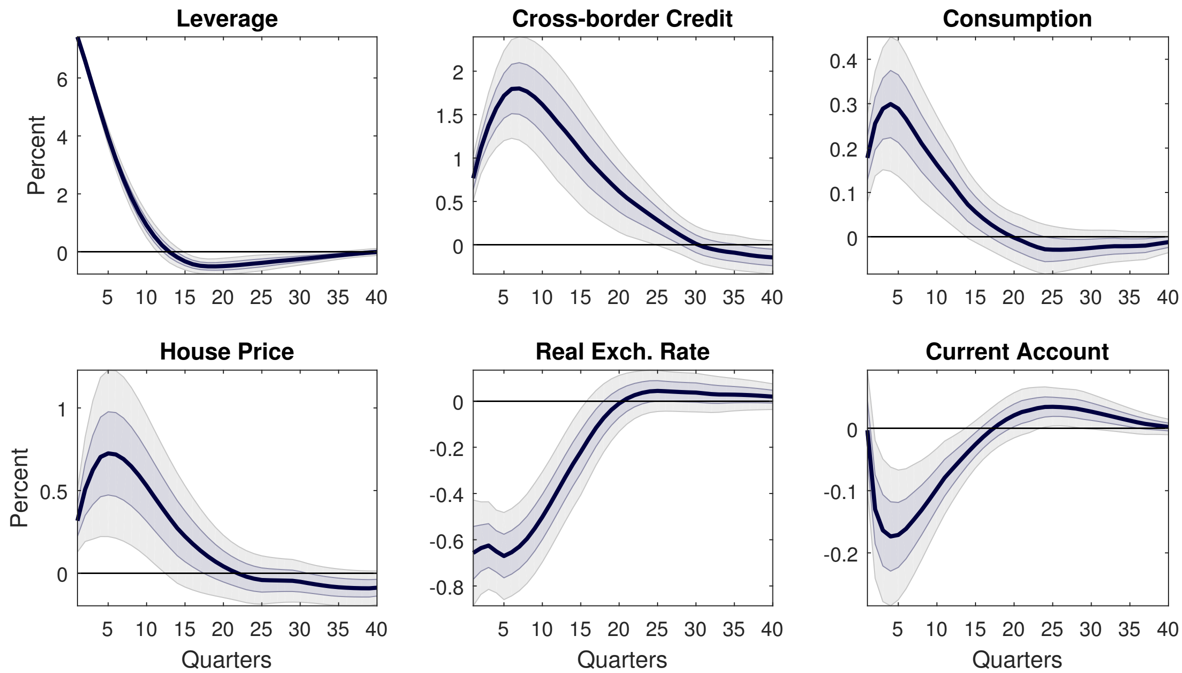
Note. International cross-border claims of BIS reporting banks to country i vis-a-vis all sectors (i.e., banks and non-banks), summed across all 57 countries in our sample. Trillions of constant (2008:Q2) US Dollars (left axis, solid line). The leverage of the US Brokers & Dealers sector (right axis, dotted line) is from the US Flow of Funds. Leverage is defined as the ratio between assets and equity.

4.3 The Typical Response of a Small Open Economy

Figure 5 reports the impulse response to the exogenous shift in the international supply of credit.[21] The size of the shock is set equal to the standard deviation of the residuals of the leverage equation, which (on average across all countries) is equal to 8%. We censor the responses included in the computation of the mean group estimator at the 10% level (5% each side) to eliminate the possible influence of any outliers on the cross-country average. The dark and light shaded areas represent the one- and two-standard deviation confidence intervals, respectively, computed based on the dispersion of the country responses across countries.

[21] We use a simple average of the country-specific estimates to construct the mean-group estimates. Results are robust to using a weighted average, which is not surprising given the large number of countries in the sample.

Figure 5. Impulse Responses to an International Credit Supply Shock



Note. Impulse responses to a one standard deviation (8%) increase in the leverage of US Broker-Dealers. The dark and light shaded areas are the one and two standard deviation confidence intervals, respectively.

The impulse responses to the US Broker-Dealers' leverage shock generates expansionary effects on consumption and asset prices that are consistent with the transmission in our theoretical model. In the typical small open economy represented here by the average response in the cross-section, our leverage shock leads to a statistically significant and persistent increase in cross-border claims, real consumption and house prices, real exchange rate appreciation, and a deterioration of the current account balance. Within the framework of our simple model, these responses are not inconsistent with the typical economy starting from a financially constrained position in which house prices respond to increased demand for collateral following the shock. The responses are also not inconsistent with the collateral and the endowment effects dominating the contractionary debt valuation effect of an appreciation. Both asset price responses, therefore, possibly amplify the initial effect of the shock.

Note also that, like in our simple two-period model, the exchange rate goes through a period of depreciation, in the medium term (about 4-5 years after the shock) before reverting completely. In the typical VAR model response, however, the bust-phase is much smaller than the boom-phase even though it has the same duration. In contrast, in the theoretical model (and the typical episode reported in Figure 1), the two phases have not only similar duration but also comparable magnitude.

Overall, the estimated US Broker-Dealers' leverage shock generates expansionary effects that are not only consistent with the transmission implied of our model but also quantitatively sizable. Cross-border bank claims display a hump-shaped response, with an impact response of slightly less than 1% percent and a peak response just below 2% percent, corresponding to an impact increase of about USD250 billions globally, relative to the post crisis global average of USD25 trillions (Figure 4). Consumption and real house prices increase by about 0.3% percent and 0.75% percent, respectively, above their long-run levels within a year. The real exchange rate vis-a-vis the US Dollar appreciates on impact by about 0.6% percent, arguably driven by the nominal exchange rate, strengthens some more, and then reverts very slowly to its equilibrium level. Finally, the current account turns into a deficit, with a trough of more than 0.15% percentage points of GDP. Ignoring the fact that the VAR model responses may not be accurate to evaluate such a large change in leverage, the estimated elasticities imply a consumption drop during the global financial crisis of about 4-5 percentage points in the typical economy, compared to the 7 percent registered in US data (during the NBER-dated phase of the great recession), with an associated 15-fold drop in leverage visible in Figure 4.

Data on interest rates on loans, either in domestic or foreign currency, are not easy to gather for a large and long panel data set like ours. The model, however, helps us connect the response of house prices to these interest rates. For simplicity, assume the LTV parameter θ is equal to one. The first order conditions for credit (15) and house prices (17) can be combined to give

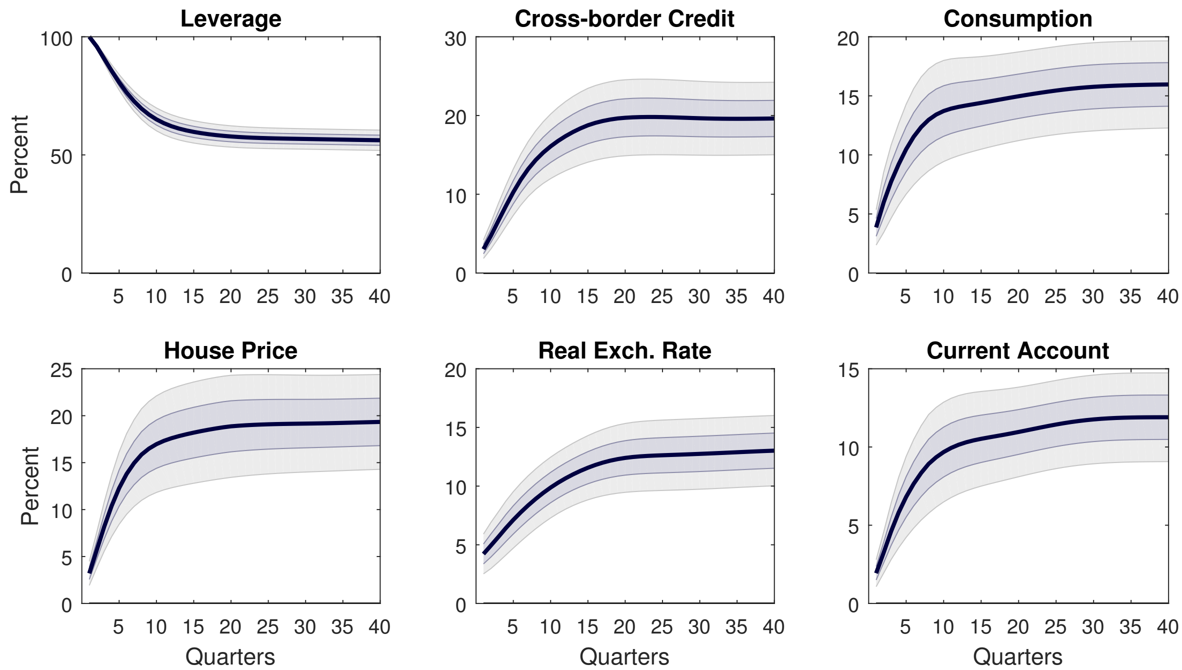
$$\beta R^b = \frac{\kappa}{q} \qquad \text{and} \qquad \beta R \frac{s_2}{s_1} = \frac{\kappa}{q}.$$

These two expressions equalize the cost of borrowing, in domestic and foreign currency, respectively, to the return on housing. Housing returns in domestic currency must fall in line with declining lending rates when the international supply of credit expands. Given that that the marginal utility of housing services is constant, this adjustment can happen only via increasing house prices that erode returns as the boom triggered by the shock propagates.

The model, therefore, predicts that returns on other "risky" assets fall in response to the international credit supply shock like in Blanchard et al. (2015). In our context, credit is the international asset while housing is the domestic non-financial asset. A positive international credit supply shock appreciates the real exchange rate and decreases the return on other domestic assets like housing via an asset price boom. In practice, in the data, the net effect of capital inflows will depend on the balance between the falling domestic asset price returns and the appreciating real exchange rate that make those lower returns more attractive to foreign investors. The fact that, in the typical case reported here, the current account swings into deficit in response to the shock means that cross-border claims co-move closely with total net capital inflows. This observation in turn suggests that the exchange rate component of the total return may be dominating the underlying return decline in domestic-currency from the perspective of foreign investors.

The leverage shock we focused on is important for the dynamics of the data as it explains a sizable portion of the variance of all variables in the VAR system. Figure 6 reports the mean group estimate of the variance share of our international credit supply shock. At the same time, US broker-dealer leverage is explained largely by shocks to itself within the first a year or so. Our leverage shock accounts for about fifteen to twenty percent of the long-run forecast error variance of cross-border credit, house prices, and consumption, and a slightly

Figure 6. Share of Variance Explained by International Credit Supply Shock



Note. Forecast error variance decomposition of the shock to US Broker-Dealers' leverage. The dark and light shaded areas are the one and two standard deviation confidence intervals.

smaller share (but still above 10%) for the real exchange rate and the current account. These magnitudes are economically meaningful and exceed the share of forecast error variance that is typically explained by monetary policy shocks.

4.4 VAR Robustness

In the panel VAR of the previous section we have identified a shock that is consistent with the one analyzed in the model. In theory, the small open economy assumption implies that the domestic economy cannot affect the leverage of global financial intermediaries. Consistent with that idea, in the empirical application we have assumed that fluctuations in US Broker-Dealers leverage cannot be contaminated by local demand ("pull") factors. A simple Cholesky decomposition of the covariance matrix of the VAR residuals delivers this restrictions: no domestic variable can affect US Broker-Dealer leverage contemporaneously.

In this section, we test the robustness of our results to two alternative specifications. First, we consider a specification where US Broker-Dealer leverage can be affected by neither contemporaneous nor lagged variables of the domestic economy. This specification is more in line with the theoretical model, but implies a tighter set of restrictions, whereby leverage is fully exogenous to developments in the domestic economy.

Second, we consider a specification where we control for the presence of synchronized country-specific shocks, something that would invalidate our identification assumption. Indeed, while the assumption that no single country can affect US Broker-Dealer leverage is reasonable in the face of country-specific pull shocks, this is less so in the case of globally synchronized pull shocks. To control for this, we augment our baseline specification with world GDP, which we order first in the vector of endogenous variables. As long as globally synchronized pull shocks affect world GDP, then the leverage shock can be recovered with a Cholesky decomposition of the covariance matrix of the VAR residuals, where the leverage residuals are now ordered second in the vector of endogenous.

The results from these two experiments (reported in Appendix in figures E.1 to E.4) show that our baseline results are particularly robust. Both the impulse responses and the forecast error variance decompositions display very similar dynamics to the baseline, with some quantitative differences (larger impact in the specification where leverage is treated as fully exogenous, smaller impact in the specification controlling for world GDP).

5 Understanding Cross-Country Differences

The error bands in Figure 5 of the responses of consumption, house price, and the real exchange rate are relatively wide, reflecting significant differences across countries. In this section, we investigate whether this heterogeneity follows specific patterns.

We conjecture that the observed cross-country differences may depend on the interaction between the amplification that asset prices generate in response to an international credit supply shock and certain features of the economies in our sample. In particular, our model suggests that the intensity of the country responses to the credit shocks may be affected by the share of foreign currency liabilities and the maximum LTV limit prevailing in that country.

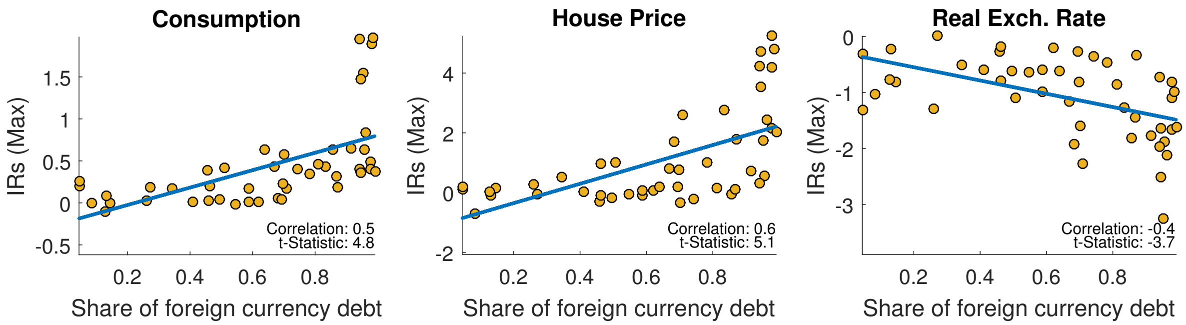
As the share of foreign currency debt increases, the collateral valuation channel associated with a binding borrowing constraint becomes stronger. Everything else equal, an appreciation of the real exchange rate relaxes the borrowing constraint more because effectively the foreign currency value of the collateral increases. A higher share of foreign currency debt, however, strengthens also the debt valuation effect that, all else equal, is contractionary. The endowment effect instead is not affected by this country characteristic in the model. Variations in the share of foreign currency liabilities produce two additional expansionary effects in the model. First, a higher share of foreign currency denominated debt decreases the interest rate burden of debt as global financial intermediaries transfer the cost of hedging onto domestic borrowers. Second, a higher share of foreign currency denominated debt increases the sensitivity of the real exchange rate to variations in the level of credit via the demand channel in equation (28).

Figure 7 provides evidence consistent with this hypothesis. The figure plots the cross-country peak responses of consumption (left panel), house prices (middle panel), and the real exchange rate (right panel) against the share of foreign currency liabilities computed using BIS banking data (horizontal axis).[22] The correlations are particularly strong for consumption and house prices (about 0.5 and 0.6, respectively). The correlation is slightly lower (-0.4) but nevertheless strongly statistically significant also for the real exchange rate.[23]

[22]For consistency with the VAR, we compute the share of foreign currency liabilities using a confidential version of the BIS dataset that allows us to sort out different currencies. The share is computed as cross-border bank claims in foreign currency over total cross-border bank claims.

[23]The results are robust to using the average response over the first 4 quarters or the share of variance of these variables explained by the credit supply shock during the first year.

Figure 7. Cross country differences in response to international credit supply shock: Share of foreign currency liabilities.

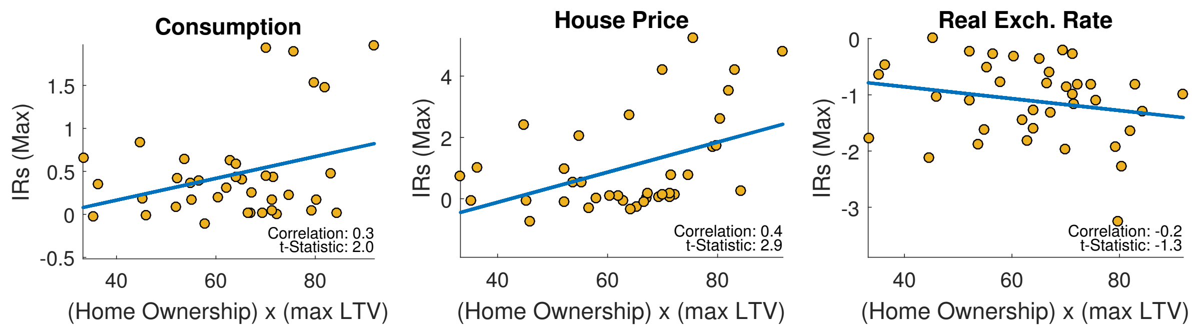


Note. The three panels plot the peak impulse response to the global liquidity shock (vertical axis, *IRs (max)*) of consumption (left panel), house prices (middle panel) and the real exchange rate (right panel) against the share of foreign currency liabilities computed using BIS banking data (horizontal axis). An exchange rate fall is an appreciation.

In general, it is not possible to characterize analytically the sign of the net effect associated with a higher share of foreign currency denominated debt in the model. However, in the numerical example discussed in Figure 3, the combination of these effects implies that consumption, house prices, and the real exchange rate are more sensitive to international credit supply shocks the higher the share of debt denominated in Foreign currency. Therefore, we interpret the empirical correlations as supporting evidence that the expansionary effects discussed in the model dominate. Of course, in the data, other channels absent from our model may be at work, including the traditional expenditure switching effect of exchange rate changes (which is muted in our model because of the absence of production) and the debt service effect we noted earlier. Nonetheless, the scatter plots in Figure 7 suggest that a higher share of foreign currency debt amplify the expansionary effect of the international credit supply shock.

A second candidate explanation to account for the heterogeneous sensitivity to the international credit supply shock is country variation in the LTV ratio. For given asset prices, if the borrowing constraint is binding, a higher LTV ratio allows for additional borrowing, which contributes to push up the price of housing further relaxing the borrowing constraint. The model predicts that, as long as the borrowing constraint is binding, higher LTV ratios

Figure 8. CROSS COUNTRY DIFFERENCES IN RESPONSE TO INTERNATIONAL CREDIT SUPPLY SHOCK: LTV RATIOS.



NOTE. The three panels plot the peak impulse response to the global liquidity shock (vertical axis, *IRs (max)*) of consumption (left panel), house prices (middle panel) and the real exchange rate (right panel) against the maximum LTV weighted by the homeownership ratio (horizontal axis, *Home Ownership* $\times$ *max LTV*).

typically increase consumption and house prices more, and lead to a larger appreciation of the real exchange rate. Obviously, if the borrowing constraint is not binding, a higher LTV ratio is irrelevant for the response of the economy to the credit supply shock, and we should find no association between the LTV ratio and the sensitivity of the economy to the shock.

Figure 8 plots the peak impulse responses of consumption (left panel), house prices (middle panel), and the real exchange rate (right panel) from the VAR (vertical axis) against the maximum LTV ratio interacted with the home-ownership rate (horizontal axis).[24] The LTV ratio is weighted with the home-ownership ratio to capture both leverage in the local financial system and the availability of housing collateral. Indeed, if high leverage is permitted, but home-ownership is low, like in the case of Germany and Switzerland for instance, the economy's sensitivity to a credit shock should be lower according to our model.

Figure 8 is also consistent with the mechanism stressed in our model.[25] The correlation is economically and statistically significant for house prices (about 0.4) and consumption (about 0.3) but weaker (about -0.2) and not statistically significant for the real exchange

[24]We obtain the data on maximum LTV ratios from Cerutti et al. (2015). Data on homeownership are from the Housing Finance Information Network (HOFINET).

[25]Like before, we obtain the same results by using the average response over the first 4 quarters or the share of the variance due to the credit supply shock.

rate. Interestingly, an upward sloping association between the LTV ratio and the house price response, in our model, implies that the marginal borrower is constrained in most of these economies, as we assumed in deriving the transmission of the shock.

In summary, the international credit supply shock that we identify has an expansionary effect on the receiving economies, consistent with both the patterns in the unconditional evidence presented earlier and the transmission implied by our model. The shocks explains a non-negligible share of the variance decomposition of macroeconomic variables and asset prices of individual countries. In the cross-country dimension, higher sensitivity to the shock is associated with higher share of foreign currency liabilities and higher access to leverage via housing collateral in a manner that is not inconsistent with the model.

6 Conclusions

In this paper, we have set up a model of collateralized borrowing in foreign currency with international financial intermediation. We have then identified a shock to the international supply of credit in an panel VAR consistent with this model.

We have found that the identified shock in the data has a transmission consistent with that implied by the model. Our international credit supply shock triggers a consumption boom, house price inflation, and real appreciation that are larger the higher the share of foreign currency liability and the maximum LTV in the domestic credit market. We also find that this shock explains about twice as much consumption variance as a US monetary shock.

Our findings have important policy implications and suggest areas for future research. As Rey (2013, 2016) noted, flexible exchange rates might not be insulating individual economies from capital flow shocks as much as traditional theory would predict, suggesting that a "dilemma" between capital controls and financial instability is more relevant than the traditional policy trilemma. At the same time, capital controls may be too costly to adopt or too difficult to implement (e.g., Fernandez et al., 2015). Our empirical findings suggest that domestic macro-prudential policies, such as lower LTV ratios in domestic credit markets and limits on the foreign currency exposure of borrowers, could be promising tools to help insulate economies from the expansionary impact of capital inflows.

Indeed, optimal macroeconomic stabilization policies may differ depending on which asset price is responsible for the amplification of foreign shocks via collateralized borrowing (Cespedes et al., 2017). If domestic asset prices like house prices are relaxing domestic borrowing constraints, macro-prudential tools, such as LTV requirements on individual borrowers or leverage caps on domestic financial intermediaries may be appropriate. However, if the source of amplification is the exchange rate, official reserve accumulation, sterilized intervention, or capital controls may be more effective in containing a boom. We leave the full exploration of these policy questions for future research.

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A Episodes of Boom-Bust in Cross-border Credit Flows

In this appendix we document the behavior of asset prices and the real economy associated with episodes of boom-bust in international capital flows in a large sample of advanced and emerging markets as reported in Figure 1 in the introduction. We focus on a specific component of capital flows, namely BIS reporting banks' cross-border claims to all sectors of the receiving economy (i.e. financial and non-financial) as this is the measure of international credit that we use in our empirical analysis in the paper.

For example, if $KF_{ij,t}$ is cross-border bank claims from country j to country i in period t, our capital flows variable for country i is defined as:

$$KF_{it} = \sum_{j=1}^{N} KF_{ij,t} \quad \forall j \neq i, \tag{A.1}$$

where $j = 1, ..., N$ indexes all BIS reporting countries.

We consider a wider set of variables than those studied in the theoretical and the VAR models. They include: GDP, private consumption, short-term interest rates, house prices and equity prices, the effective exchange rate, the exchange rate vis-a-vis the US Dollar, and the current account as a share of GDP. All variables are expressed in real terms. The sample period runs from 1970 to 2012 and the frequency is annual (while in our VAR analysis we use quarterly data). We use annual data to avoid seasonal and other noisy components in quarterly data. A description of the variables and their sources is reported in the Appendix.

We focus on the behavior of asset prices and the real economy around boom-bust episodes in cross-border claims. To identify boom-bust episodes we define a boom (bust) as a period longer than or equal to three years in which annual cross-border claim growth is positive (negative).[26] The peak (trough) is defined as the last period within the episode in which the annual rate of growth of cross-border credit is positive (negative). We then define "boom-bust" episodes as episodes of booms followed by a bust.

This procedure identifies 134 booms, 81 busts, and 50 boom-bust episodes. The summary statistics for these episodes (such as duration and amplitude) are reported in the Table below.

[26] This procedure is similar to the one commonly used in the literature (Gourinchas et al., 2001, Mendoza and Terrones, 2008, Cardarelli et al., 2010, Caballero, 2014, Benigno et al., 2015). The literature typically defines these episodes as periods in which credit (or capital inflows) rise more than one standard deviation above trend level. Our results are robust to using the traditional approach. The advantage of our approach is that we do not need to detrend the data, which introduces spurious variation over time in the analysis.

Figure 1 in the paper reports the results. **ADD Table here.**

B Data Sources

We consider 57 countries in our empirical analysis: 24 advanced economies (Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Malta, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, UK, and US) and 33 emerging economies (Argentina, Brazil, Bulgaria, Chile, China, Colombia, Croatia, Czech Republic, Estonia, Hong Kong, Hungary, India, Indonesia, Israel, Korea, Latvia, Lithuania, Malaysia, Mexico, Morocco, Peru, Philippines, Poland, Russia, Serbia, Singapore, Slovakia, Slovenia, South Africa, Taiwan, Thailand, Ukraine, and Uruguay).

We collect data over the 1970:Q1 – 2012:Q4 (subject to availability) for the following variables:

Total cross-border bank lending. Foreign claims (all instruments, in all currencies) of all BIS reporting banks vis-à-vis all sectors deflated by US consumer price inflation. Source: BIS.

Cross-border bank credit. Foreign claims (loans and deposits, in all currencies) of all BIS reporting banks vis-à-vis the banking sector deflated by US consumer price inflation. Source: BIS.

House prices. Nominal house prices deflated by consumer price inflation. Source: OECD house price database, BIS Residential property price statistics, Dallas FED International House Price Database, National Central Banks, National Statistical Offices, academic and policy publications. More details on the definitions and the sources are reported in Table B.1.

Equity prices. Equity price index deflated by consumer price inflation. Source: OECD, IMF IFS, Bloomberg.

Nominal exchange rate vis-à-vis US dollar. US dollars per unit of domestic currency (a decline is a depreciation). Source: Datastream. Real bilateral exchange rate obtained by adjusting with CPI indexes.

Real effective exchange rate. Index such that a decline is a depreciation. Source: IMF IFS, BIS, Bloomberg.

GDP. Real index. Source: OECD, IMF IFS, Bloomberg.

Consumption. Real private final consumption index. Source: OECD, IMF, IFS, Bloomberg.

Consumer prices. Consumer price index. Source: OECD, IMF IFS, Bloomberg.

Short-term interest rates. Short-term nominal market rates. A real ex-post interest rate is obtained by subtracting consumer price inflation. Source: OECD, IMF, IFS, Bloomberg.

Current account to GDP ratio. Current account balance divided by nominal GDP. Source: OECD, IMF IFS, Bloomberg.

Home-ownership. HOFINET.

Maximum LTV ratios. Cerutti et al. (2015).

FX Shares. Authors' calculations based on confidential BIS data.

Table B.1. House Price Data: Definitions and Sources

Country	Definition	Source
Argentina	House Apartments in Buenos Aires City, average price per sqm (USD).	Arklems
Australia	House Price Indexes: Eight Capital Cities.	OECD
Austria	Residential property prices, new and existing dwellings.	OECD
Belgium	Residential property prices, existing dwellings, whole country.	OECD
Brazil	Residential Real Estate Collateral Value Index.	Central Bank
Bulgaria	Residential property price, existing flats (big cities), per sqm.	BIS
Canada	Average existing home prices.	OECD
Chile	HPI general, houses and apartments.	Central Bank
China	House price index.	OECD
Colombia	House Price Index.	Central Bank
Croatia	House price index	Dallas FED
Czech Rep.	Residential property prices, existing dwellings, whole country.	OECD
Denmark	Price index for sales of property.	OECD
Estonia	Residential property prices, all dwellings, per sqm.	BIS
Finland	Prices of dwellings.	OECD
France	Indice trimestriel des prix des logements anciens.	OECD
Germany	Residential property prices in Germany.	OECD
Greece	Prices of dwellings.	OECD
Hong Kong	Residential property price, all dwellings, per sqm.	BIS
Hungary	Residential property price, all dwellings, per sqm.	BIS
Iceland	Residential property price, all dwellings (Reykjavk), per sqm.	BIS
India	Residex.	National Housing Bank
Indonesia	Residential property prices, new houses (big cities), per dwelling.	BIS
Ireland	Residential property price index.	OECD
Israel	Prices of dwellings.	OECD
Italy	Residential property prices, existing dwellings, whole country.	OECD
Japan	Urban Land Price Index.	OECD
Korea	House price index.	Dallas FED
Latvia	Residential property prices, new and existing flats, whole country.	ECB
Lithuania	Residential property price, all dwellings, per sqm.	BIS
Luxembourg	House price index.	Dallas FED
Malaysia	Residential property prices, all dwellings, per sqm.	BIS
Malta	Property Prices Index (based on advertised prices).	Central Bank
Mexico	Residential property prices, all dwellings, per dwelling.	BIS
Morocco	Residential property prices, existing dwellings, per sqm.	BIS
Netherlands	House Price Index for existing own homes.	OECD
New Zealand	House price index.	OECD
Norway	House price index.	OECD
Peru	Residential property prices, per sqm.	BIS
Philippines	Residential and commercial property prices, flats (Makati), per sqm.	BIS
Poland	Residential property prices, (big cities), per sqm.	BIS
Portugal	Residential property prices, new and existing dwellings.	BIS
Russia	Residential property prices, existing dwellings, per sqm.	BIS
Serbia	Average prices of dwellings in new construction, per sqm.	National Stat. Office
Singapore	Average prices of dwellings in new construction, per sqm.	BIS
Slovak Rep.	Residential property prices, existing dwellings.	OECD
Slovenia	House price index.	OECD
South Africa	Residential property price.	BIS
Spain	Precio medio del m2 de la vivienda libre (> 2 anos de antiguedad).	OECD
Sweden	Real estate price index for one and two dwelling buildings for permanent living.	OECD
Switzerland	Real estate price indices.	OECD
Taiwan	National House Price Index.	Synyi
Thailand	Residential property prices, average of all detached houses, per sqm.	BIS
Ukraine	Average Price of Apartments, Kiev, per sqm (USD).	Blagovest
UK	Mix-adjusted house price index.	OECD
US	Purchase and all-transactions indices.	OECD
Uruguay	Precio promedio del metro cuadrado de compraventas, Montevideo (USD).	National Stat. Office

Note. See Cesa-Bianchi, Cespedes, and Rebucci (2015) for more details and the sources of house price series extended with historical data.

C Model Derivations

This appendix report the derivations of the results discussed in the paper. The first section characterizes the equilibrium of the model. The second and third sections derive expressions for the terms of trade and the credit market equilibrium in the case of a small open economy.

C.1 Equilibrium

A competitive equilibrium for our economy is a collection of quantities $\{c_1, c_2, c_1^*, c_2^*, d, e, f\}$ and prices $\{q, \mu, R^b, R^d, R^e, \tau_1, \tau_2, s_1, s_2\}$ such that:

1. Domestic households maximize their utility subject to their budget and collateral constraint:

$$
\begin{aligned}
1-\mu &= \beta R^b, \\
1-\mu &= \beta R \frac{s_2}{s_1}, \\
(1-\mu\theta)q &= \kappa, \\
(1+\eta)s_1 f &\leq \theta q, \\
c_1 &= \tau_1^{\alpha-1} y + (1+\eta)s_1 f, \\
c_2 &= \tau_2^{\alpha-1} y - (1+\eta)s_2 R f,
\end{aligned}
$$

   with $\mu \geq 0$, and where $\kappa \equiv v'(1)/\bar{c} > 0$ is the marginal utility of housing in units of marginal utility of consumption.

2. Foreign households maximize their utility subject to their budget constraint:

$$
\begin{aligned}
1 &= \beta^* R^d, \\
1+\psi'(e) &= \beta^* R^e, \\
c_1^* &= \tau_1^{\alpha^*} y^* - [d + e + \psi(e)], \\
c_2^* &= \tau_2^{\alpha^*} y^* + R^d d + R^e e
\end{aligned}
$$

3. Financial intermediaries maximize their profits subject to their balance sheet and lever-

age constraints:

$$
\begin{aligned}
R &= \chi R^e + (1-\chi)R^d + \phi'(\eta f), \\
(1+\eta)f &= d + e, \\
e &= \chi(1+\eta)f.
\end{aligned}
$$

4. Goods market clear in every period:

$$
\begin{aligned}
ny &= n\alpha\tau_1^{1-\alpha}c_1 + (1-n)\alpha^*\tau_1^{1-\alpha^*}c_1^*, \\
ny &= n\alpha\tau_2^{1-\alpha}c_2 + (1-n)\alpha^*\tau_2^{1-\alpha^*}c_2^*, \\
(1-n)y^* &= n\left(1-\alpha\right)\tau_1^{-\alpha}c_1 + (1-n)\left(1-\alpha^*\right)\tau_1^{-\alpha^*}c_1^*, \\
(1-n)y^* &= n\left(1-\alpha\right)\tau_2^{-\alpha}c_2 + (1-n)\left(1-\alpha^*\right)\tau_2^{-\alpha^*}c_2^*.
\end{aligned}
$$

5. The real exchange rate is related to the terms of trade in every period according to:

$$
s_1 = \tau_1^{\alpha-\alpha^*} \qquad\qquad s_2 = \tau_2^{\alpha-\alpha^*}.
$$

There are 18 equations for 16 variables. Two goods market equilibrium conditions (one in each period) are redundant by Walras's Law.

C.2 Small Open Economy Case

We now take the limit for $n \to 0$ so that the Home country becomes a small open economy, consistent with our identification assumption in the VAR analysis.

C.2.1 Goods Market and the Terms of Trade

We start from the goods market equilibrium:

$$
ny = n\alpha\tau^{1-\alpha}c + (1-n)\alpha^*\tau^{1-\alpha^*}c^*, \tag{C.1}
$$

$$
(1-n)y^* = n\left(1-\alpha\right)\tau^{-\alpha}c + (1-n)\left(1-\alpha^*\right)\tau^{-\alpha^*}c^*, \tag{C.2}
$$

where we dropped the time subscript as these expressions are static and have the same form in both periods. Rewrite these conditions as

$$y = \alpha\tau^{1-\alpha}c + \frac{1-n}{n}\alpha^{*}\tau^{1-\alpha^{*}}c^{*}, \tag{C.3}$$

$$y^{*} = \frac{n}{1-n}(1-\alpha)\tau^{-\alpha}c + (1-n)(1-\alpha^{*})\tau^{-\alpha^{*}}c^{*}. \tag{C.4}$$

Next, use the relationship between the consumption shares, the country size, and the degree of openness ($\alpha = 1-(1-n)\lambda$ and $\alpha^{*} = n\lambda$) to obtain

$$y = [1-(1-n)\lambda]\tau^{(1-n)\lambda}c + \frac{1-n}{n}n\lambda\tau^{1-n\lambda}c^{*}, \tag{C.5}$$

$$y^{*} = \frac{n}{1-n}(1-n)\lambda\tau^{(1-n)\lambda-1}c + (1-n\lambda)\tau^{-n\lambda}c^{*}. \tag{C.6}$$

Simplifying and taking the limit for n that goes to zero, the previous expressions yield

$$y = (1-\lambda)\tau^{\lambda}c + \lambda\tau c^{*}, \tag{C.7}$$

$$y^{*} = c^{*}, \tag{C.8}$$

which imply that Home demand does not affect the equilibrium in the market for Foreign goods and that Foreign consumption is exogenous.

As housing is in fixed supply, in equilibrium, the Home household budget constraint in the first period becomes

$$c_1 = \tau_1^{1-\lambda}(1+\eta)f + \tau_1^{-\lambda}y, \tag{C.9}$$

where we have used the relation above between the real exchange rate and the terms of trade. Now replace this expression in the Home goods market equilibrium and solve for the terms of trade to obtain a relation between the terms of trade and credit

$$\tau_1 = \frac{\lambda y}{\lambda y^{*} + (1-\lambda)(1+\eta)f},$$

and thus

$$s_1 = \left[\frac{\lambda y}{\lambda y^{*} + (1-\lambda)(1+\eta)f}\right]^{1-\lambda}. \tag{C.10}$$

Intuitively, higher foreign debt implies higher Home demand, and hence an appreciation of the terms of trade (and consequently of the real exchange rate).

In period 2, the budget constraint of the Home representative household is

$$c_2 = \tau_2^{-\lambda}y - \tau_2^{1-\lambda}(1+\eta)Rf.$$

Substitute again into the goods market equilibrium to obtain the terms of trade

$$\tau_2 = \frac{\lambda y}{\lambda y^* - (1-\lambda)(1+\eta)Rf}, \tag{C.11}$$

and and hence the real exchange rate

$$s_2 = \left[\frac{\lambda y}{\lambda y^* - (1-\lambda)(1+\eta)Rf}\right]^{1-\lambda}. \tag{C.12}$$

The terms of trade in period 2 depend on both debt and the lending rate. Intuitively, high foreign debt or lending interest rates in period 1 imply lower resources (and therefore demand) in period 2, and therefore a depreciation.

C.2.2 Credit Market

Next, we can characterize the equilibrium in the credit market.

Credit Supply. We start with credit supply. Substituting the expressions for the return on deposit and the return on equity in the zero profit condition for financial intermediaries, together with the binding capital constraint, yields an expression for credit supply

$$R = \frac{1 + \chi\psi'\left[\chi(1+\eta)f\right]}{\beta^*} + \frac{\eta\phi'(\eta f)}{1+\eta}.$$

This expression is independent of country size and thus holds also in the limit for $n \to 0$.

Credit Demand. Next, we move on to credit demand. We start from the optimal choice of housing services. If the borrowing constraint is not binding ($\mu = 0$), the equilibrium conditions for domestic households boil down to $q = \kappa$ (first order condition for housing services), $(1+\eta)s_1 f < \theta q$ (non-binding collateral constraint), and the consumption Euler equation

$$R = \frac{1}{\beta}\frac{s_1}{s_2}.$$

Now, consider the equilibrium with binding borrowing constraint ($\mu > 0$). In this case, we can solve for the Lagrange multiplier from the Euler equation to yield

$$\mu = 1 - \beta R \frac{s_2}{s_1}. \tag{C.13}$$

Substituting this expression into the housing pricing equation we have

$$\left(1-\theta+\theta\beta R\frac{s_2}{s_1}\right)q=\kappa. \tag{C.14}$$

And solving for q and substituting into the borrowing constraint with equality yields

$$(1+\eta)s_1 f=\frac{\theta\kappa}{1-\theta+\theta\beta R s_2/s_1}, \tag{C.15}$$

which can be solved to obtain

$$R=\frac{1}{\beta}\frac{s_1}{s_2}\left[\frac{\kappa}{(1+\eta)s_1 f}-\frac{1-\theta}{\theta}\right].$$

C.3 Slope of Credit Demand

In this section, we need to study the slope of the credit demand function because debt valuation effects associated with the real exchange rate may generate portions of the credit demand function that are not downward sloping.

We start from the region in which the collateral constraint is not binding. Substituting the expressions of the real exchange rate gives

$$R=\frac{1}{\beta}\left[\frac{\lambda y^*-(1-\lambda)(1+\eta)Rf}{\lambda y^*+(1-\lambda)(1+\eta)f}\right]^{1-\lambda}.$$

Now define the function

$$G_1(f,R)\equiv\frac{1}{\beta}\left[\frac{\lambda y^*-(1-\lambda)(1+\eta)Rf}{\lambda y^*+(1-\lambda)(1+\eta)f}\right]^{1-\lambda}-R,$$

so that we can apply the implicit function theorem. In particular, we have that

$$\frac{\partial R}{\partial f}=-\frac{\partial G_1/\partial f}{\partial G_1/\partial R}. \tag{C.16}$$

The derivative at the numerator is

$$\frac{\partial G_1}{\partial f}=-\frac{1}{\beta}\left(\frac{s_1}{s_2}\right)^{\lambda}\frac{\lambda y^*(1+\eta)(R+1)}{[\lambda y^*+(1-\lambda)(1+\eta)f]^2}<0.$$

The derivative at the denominator is

$$\frac{\partial G_1}{\partial R} = -\left[1 + \frac{1}{\beta}\left(\frac{s_1}{s_2}\right)^{\lambda}\frac{(1+\eta)f}{\lambda y^* + (1-\lambda)(1+\eta)f}\right] < 0.$$

As both numerator and denominator of (C.16) are negative, in the region where the collateral constraint does not bind, the credit demand function will be negatively sloped.

Next, we move to the region where the collateral constraint is binding. To simplify the analysis, start from the limiting case of $\theta = 1$. In this simpler case, substituting for the real exchange rate at time 2, we can construct the function

$$G_2(f, R) \equiv \frac{\kappa}{\beta(1+\eta)f}\left[\frac{\lambda y^* - (1-\lambda)(1+\eta)Rf}{\lambda y}\right]^{1-\lambda} - R$$

The slope of credit demand if the collateral constraint binds is

$$\frac{\partial R}{\partial f} = -\frac{\partial G_2/\partial f}{\partial G_2/\partial R}. \tag{C.17}$$

And the derivative at the numerator is

$$\frac{\partial G_2}{\partial f} = -\frac{\kappa}{\beta(1+\eta)s_2 f}\left[\frac{1}{f} + \frac{(1+\eta)s_2^{1-\lambda}R}{\lambda y}\right] < 0,$$

while the derivative at the denominator is

$$\frac{\partial G_2}{\partial R} = -\left(1 + \frac{\kappa s_2^{1-\lambda}}{\beta\lambda y}\right) < 0.$$

So in the limiting case of 100 percent LTV credit demand continues unequivocally to be downward sloping. A simple continuity argument suggests that the result carries through for high enough values of θ. Indeed, in our numerical example in which we set θ to the high value of 92% (close to the average maximum LTV in our country sample of about 90%), credit demand is downward sloping when the collateral constraint binds.

Note here that the slope of the credit demand when the constraint bind depends on the sensitivity of the house price to the tightness of the collateral demand, captured by μ in equation .

C.4 Transmission of an international credit supply shock

Here we derive responses of the economy to a change in χ. We will then study the sensitivity of those responses to change in the characteristics of the economy. We focus on the region in which the collateral constraint binds. For small enough shocks in χ, a log-linear approximation provides an accurate description of the impact of the credit supply shock.[27]

Starting from the expression (C.10) for the real exchange rate in period 1, we can rewrite it as

$$s_1 = \left[\frac{y^*}{y} + \frac{1-\lambda}{\lambda}\frac{(1+\eta)f}{y}\right]^{\lambda-1}.$$

The linear approximation around a steady state with binding constraint is

$$s_1 = \bar{s}_1 - (1-\lambda)\left[\frac{y^*}{y} + \frac{1-\lambda}{\lambda}\frac{(1+\eta)\bar{f}}{y}\right]^{\lambda-2}\frac{1-\lambda}{\lambda}\frac{1+\eta}{y}\left(f-\bar{f}\right).$$

Using the expression for s_1, we can write the last expression as

$$s_1 - \bar{s}_1 = -\frac{(1-\lambda)^2(1+\eta)}{\lambda y}\bar{s}_1^{1+\frac{1}{1-\lambda}}\left(f-\bar{f}\right).$$

Dividing by $\bar{s}_1$ and $\bar{f}$ we get

$$\hat{s}_1 = -\frac{(1-\lambda)^2}{\lambda y}\bar{s}_1^{\frac{1}{1-\lambda}}(1+\eta)\bar{f}\hat{f}. \tag{C.18}$$

Now consider period 2 and rewrite s_2 as

$$s_2 = \left[\frac{y^*}{y} + \frac{1-\lambda}{\lambda}\frac{(1+\eta)Rf}{y}\right]^{\lambda-1}.$$

The linear approximation around the steady state is

$$s_2 = \bar{s}_2 + (1-\lambda)\left[\frac{y^*}{y} + \frac{1-\lambda}{\lambda}\frac{(1+\eta)\bar{R}\bar{f}}{y}\right]^{\lambda-2}\frac{1-\lambda}{\lambda}\frac{1+\eta}{y}\left[\bar{R}\left(f-\bar{f}\right)+\bar{f}\left(R-\bar{R}\right)\right].$$

Using the expression for s_2, we can write the last expression as

$$s_2 - \bar{s}_2 = \frac{(1-\lambda)^2(1+\eta)}{\lambda y}\bar{s}_2^{1+\frac{1}{1-\lambda}}\left[\bar{R}\left(f-\bar{f}\right)+\bar{f}\left(R-\bar{R}\right)\right].$$

[27] We denote the steady state value of a generic variable x with $\bar{x}$ and the log-deviation from steady state as $\hat{x} \equiv (x-\bar{x})/\bar{x}$.

Dividing by $\bar{s}_2$, $\bar{f}$, and $\bar{R}$ we get

$$\hat{s}_2 = \frac{(1-\lambda)^2}{\lambda y} \bar{s}_2^{\frac{1}{1-\lambda}} (1+\eta)\bar{R}\bar{f}\left(\hat{R}+\hat{f}\right). \tag{C.19}$$

The credit demand schedule can be rewritten as

$$R = \frac{1}{\beta}\left[\frac{\kappa}{(1+\eta)s_2 f} - \frac{s_1}{s_2}\frac{1-\theta}{\theta}\right]$$

And its linear approximation is

$$R = \bar{R} - \frac{1}{\beta}\frac{\kappa}{(1+\eta)\bar{s}_2\bar{f}^2}\left(f_1-\bar{f}\right) - \frac{1}{\beta}\frac{\kappa}{(1+\eta)\bar{s}_2^2\bar{f}}\left(s_2-\bar{s}_2\right) - \frac{1-\theta}{\beta\theta}\frac{1}{\bar{s}_2}\left(s_1-\bar{s}_1\right) + \frac{1-\theta}{\beta\theta}\frac{\bar{s}_1}{\bar{s}_2^2}\left(s_2-\bar{s}_2\right).$$

Dividing by $\bar{R}$, we get

$$\hat{R} = -\frac{1}{\beta\bar{R}}\left[\frac{\kappa}{(1+\eta)\bar{s}_2\bar{f}}\left(\hat{s}_2+\hat{f}\right) + \frac{1-\theta}{\theta}\frac{\bar{s}_1}{\bar{s}_2}\left(\hat{s}_1-\hat{s}_2\right)\right]. \tag{C.20}$$

Finally, the expression for credit supply is

$$R = \frac{1}{\beta^*} + \frac{\chi\psi'[\chi(1+\eta)f]}{\beta^*} + \frac{\eta\phi'(\eta f)}{1+\eta},$$

and its linear approximation is

$$R - \bar{R} = \left[\frac{\psi'}{\beta^*} + \frac{\bar{\chi}(1+\eta)\bar{f}\psi''}{\beta^*}\right](\chi-\bar{\chi}) + \frac{\bar{\chi}^2\psi''(1+\eta)}{\beta^*}(f-\bar{f}) + \frac{\eta^2\phi''}{1+\eta}(f-\bar{f}),$$

where ψ' and ψ'' represent the first and second derivatives of the equity adjustment cost function, respectively, evaluated at steady state. Dividing through by the steady state real interest rate and expressing variables in percentage deviations from steady state, we obtain

$$\hat{R} = \frac{\bar{\chi}}{\beta^*\bar{R}}[\psi' + \bar{\chi}(1+\eta)\psi''\bar{f}]\hat{\chi} + \frac{\bar{f}}{\beta^*\bar{R}}\left[\bar{\chi}^2\psi''(1+\eta) + \frac{\eta^2\phi''}{1+\eta}\right]\hat{f}. \tag{C.21}$$

Expressions (C.18)-(C.21) constitute a linear system of four equations in four unknowns $\{\hat{s}_1, \hat{s}_2, \hat{R}, \hat{f}\}$ that also depend on $\hat{\chi}$. Thus, we can write the solution as

$$\hat{z} = \Gamma\hat{\chi},$$

where

$$z' \equiv \begin{bmatrix} \hat{s}_1 & \hat{s}_2 & \hat{R} & \hat{f} \end{bmatrix}$$

and $\Gamma \equiv A^{-1}B$, with

$$A \equiv \begin{bmatrix} 1 & 0 & 0 & a_{14} \\ 0 & 1 & a_{23} & a_{24} \\ a_{31} & 1 & 1 & a_{34} \\ 0 & 0 & 1 & a_{44} \end{bmatrix},$$

and

$$B' \equiv \begin{bmatrix} 0 & 0 & 0 & b_{41} \end{bmatrix}.$$

The coefficients of the matrix A are

$$\begin{aligned}
a_{14} &\equiv \frac{(1-\lambda)^2}{\lambda y} \bar{s}_1^{\frac{1}{1-\lambda}} (1+\eta)\bar{f} > 0 \\
a_{23} = a_{24} &\equiv -\frac{(1-\lambda)^2}{\lambda y} \bar{s}_2^{\frac{1}{1-\lambda}} (1+\eta)\bar{R}\bar{f} < 0 \\
a_{31} &\equiv \frac{1}{\beta \bar{R}} \frac{1-\theta}{\theta} \frac{\bar{s}_1}{\bar{s}_2} > 0 \\
a_{34} &\equiv \frac{\kappa}{\beta \bar{R} \bar{s}_2 (1+\eta)\bar{f}} > 0 \\
a_{44} &\equiv -\frac{\bar{f}}{\beta^* \bar{R}} \left[\bar{\chi}^2 \psi''(1+\eta) + \frac{\eta^2 \phi''}{1+\eta} \right] < 0
\end{aligned}$$

and the non-zero coefficient of the vector B is

$$b_{41} \equiv \frac{\bar{\chi}}{\beta^* \bar{R}} [\psi' + \bar{\chi}(1+\eta)\psi'' \bar{f}] > 0.$$

After inverting the matrix A, we can write the solution as

$$\begin{aligned}
\hat{s}_1 &\equiv \frac{a_{14} b_{41} (a_{23} - 1)}{d} \hat{\chi} \\
\hat{s}_2 &\equiv -\frac{b_{41} a_{23} (1 - a_{24} + a_{14} a_{31})}{d} \hat{\chi} \\
\hat{R} &\equiv \frac{b_{41} (a_{23} - a_{34} + a_{14} a_{31})}{d} \hat{\chi} \\
\hat{f} &\equiv -\frac{b_{41} (a_{23} - 1)}{d} \hat{\chi},
\end{aligned}$$

where

$$d \equiv a_{44} - a_{34} + a_{14} a_{31} + a_{23}(1 - a_{44}).$$

In the limit, for $\theta \to 1$, we have that $a_{31} = 0$ and hence $d < 0$. In this case it is easy to see that

$$\frac{\partial \hat{s}_1}{\partial \hat{\chi}} > 0 \qquad \frac{\partial \hat{R}}{\partial \hat{\chi}} > 0 \qquad \frac{\partial \hat{f}}{\partial \hat{\chi}} < 0.$$

Therefore, in response to a positive international credit supply shock (a fall in χ), the real exchange rate appreciates, the real lending rate falls, and the amount of credit extended to the Home economy increases.

Given that we are in the region in which the collateral constraint binds, the approximated response of house prices is

$$\hat{q} = \hat{s}_1 + \hat{f} \Rightarrow \frac{\partial \hat{q}}{\partial \hat{\chi}} = \frac{\partial \hat{s}_1}{\partial \hat{\chi}} + \frac{\partial \hat{f}}{\partial \hat{\chi}}.$$

Substituting the values of the partial derivatives above gives

$$\frac{\partial \hat{q}}{\partial \hat{\chi}} = \frac{b_{41}(a_{23} - 1)(a_{14} - 1)}{d},$$

which is positive as long as $a_{14} > 1$; a condition that is always satisfied for large enough levels of credit over GDP.

Finally, the response of consumption to the credit shock is

$$\frac{\partial c_1}{\partial \chi} = (1 + \eta)\bar{s}_1 \frac{\partial f}{\partial \chi} + \left[(1 + \eta)\bar{f} - \frac{\lambda}{1 - \lambda} \bar{s}_1^{-\left(1 + \frac{\lambda}{1-\lambda}\right)} y \right] \frac{\partial s_1}{\partial \chi}$$

A positive international credit supply shock increases consumption, both directly (the first term in the expression above) and indirectly because the real exchange rate appreciation makes the domestic endowment more valuable (the second term in square brackets). The appreciation of the real exchange rate, however, also reduces the purchasing power of credit denominated in foreign currency (the first term in square brackets). The overall effect is ambiguous, although our numerical simulations suggest consumption increases in response to a positive shocks for reasonable values of the parameters.

D Sensitivity to Credit Market Characteristics

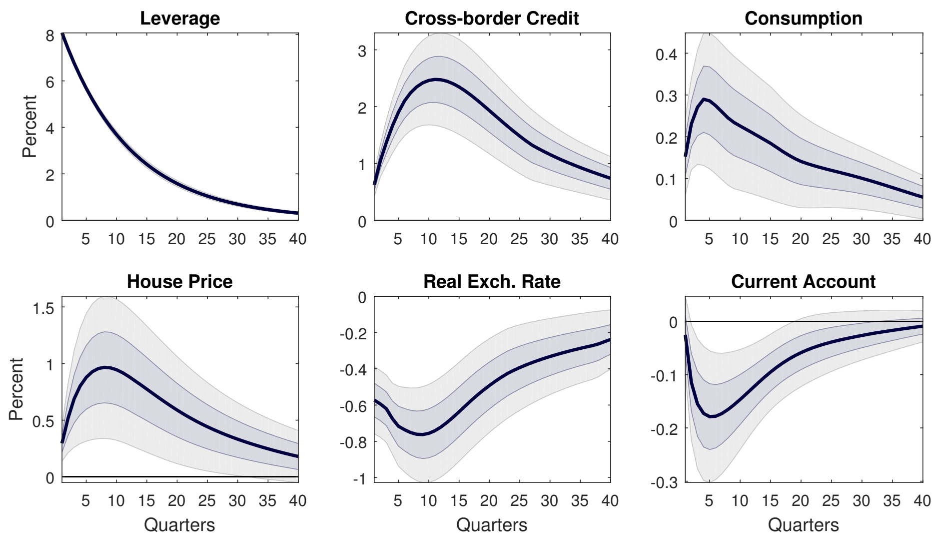
In this section we study the sensitivity of the economy's response to the international credit supply shock to variations in the share of foreign currency liabilities $(1 + \eta)^{-1}$ and in the

LTV ratio θ.

TBC.

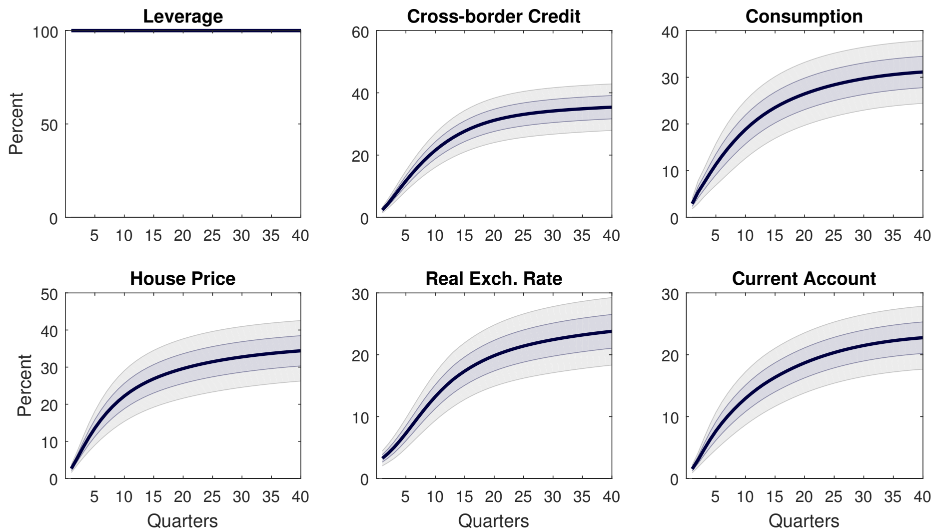
E VAR Robustness

Figure E.1. Impulse Responses to an International Credit Supply Shock: Restricted Model



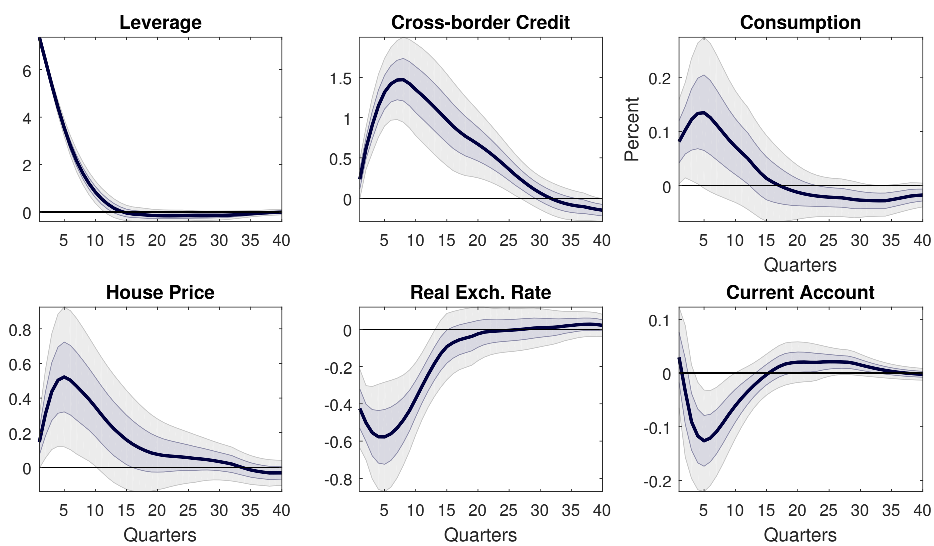
Note. Impulse responses to a one standard deviation (8%) increase in the leverage of US Broker-Dealers. The dark and light shaded areas are the one and two standard deviation confidence intervals, respectively.

Figure E.2. Share of Variance Explained by International Credit Supply Shock: Restricted Model



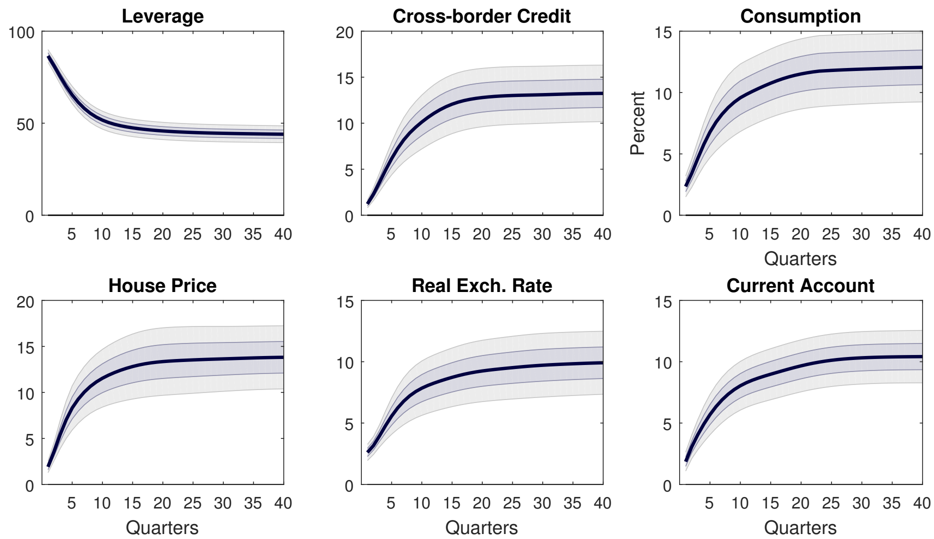
Note. Forecast error variance decomposition of the shock to US Broker-Dealers' leverage. The dark and light shaded areas are the one and two standard deviation confidence intervals.

Figure E.3. Impulse Responses to an International Credit Supply Shock: Controlling for World GDP



Note. Impulse responses to a one standard deviation (8%) increase in the leverage of US Broker-Dealers. The dark and light shaded areas are the one and two standard deviation confidence intervals, respectively.

Figure E.4. Share of Variance Explained by International Credit Supply Shock: Controlling for World GDP



Note. Forecast error variance decomposition of the shock to US Broker-Dealers' leverage. The dark and light shaded areas are the one and two standard deviation confidence intervals.