# International Credit Supply Shocks☆

Ambrogio Cesa-Bianchi† Andrea Ferrero‡ Alessandro Rebucci§

February 23, 2017

**Abstract**

House prices and exchange rates can potentially amplify the expansionary effects of capital inflows by inflating the value of collateral. We first document that, during a boom in capital inflows, real exchange rates, house prices and equity prices appreciate; the current account deteriorates; and consumption and GDP expand; while in a bust these dynamics reverse sharply. Next set up an open-economy model of housing consumption with domestic and international financial intermediation in which a shock to the international supply of credit is expansionary. In this model environment, we illustrate how the evidence uncovered may be interpreted in terms of relative importance of exchange rate and house price appreciations in emerging and advanced economies. We finally show that an identified change to the international supply of credit in a Panel VAR for 50 advanced and emerging countries displays a similar transmission. The intensity of the consumption response to such a shock, however, differs significantly across countries and it is associated with country characteristics of both the housing finance system and the monetary policy framework.

**Keywords**: Capital Flows, Credit Supply Shock, Leverage, Global Liquidity, Exchange Rates, and Balance Sheet Effects, House Prices.
**JEL codes**: C32, E44, F44.

☆We would like to thank our discussants Alice Fabre and John Rogers. We have also benefited from comments by participants at the Sils Macro Workshop, EMG-ECB Workshop on Global Liquidity, 2016 EEA Meetings, HKCU-HKMA Conference on Real Estate and Financial Stability, 4th Workshop in Macro Banking and Finance, SF Fed-HKCU Conference on International Finance, 2015 NYU Alumni Conference, and at seminars at the BIS Asia Office, the University of Durham and the University of York. Alessandro Rebucci thanks the Black & Decker Research Fund for partial financial support for this paper. The views expressed in this paper are solely those of the authors and should not be taken to represent those of the Bank of England.

†Bank of England and CfM. Email: ambrogio.cesa-bianchi@bankofengland.co.uk.
‡University of Oxford. Email: andrea.ferrero@economics.ox.ac.uk.
§Johns Hopkins University Carey Business School and NBER. Email: arebucci@jhu.edu.

## 1 Introduction

Contrary to the predictions of standard economic theory, sudden increases in capital inflows are expansionary (Chari et al., 2005, Blanchard et al., 2015) and pose difficult challenges for policy makers—see for instance, Rey (2013, 2016). Historically, however, some economies appeared to be more vulnerable than others. So what are the specific mechanisms through which capital inflows lead to macroeconomic booms in the receiving economies? And what are the country characteristics that are associated with these country differences in vulnerability?

In this paper we explore the role of asset price inflation, mortgage market characteristics, and the currency denomination of foreign financing. 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. And these these channels of amplification may be more relevant, the more developed the domestic credit market and the higher the share of foreign currency denominated liabilities in the domestic economy.

Traditionally, the analysis of capital flows and their impact on the macroeconomy distinguished between "push" and '"pull" factors. 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 type of "push" shock—an international credit supply shock. We identify such shock empirically by looking at changes in leverage of international financial intermediaries. We also build a model in which a change in the leverage of an international financial intermediary leads to an increase in the international supply of credit as we assumed in our empirical analysis. The model allows us to explore also cross country properties of the trasmission of such shock, as we do in the data.

We proceed in three main steps. First, we document that episodes of large swings in cross-border bank claims are expansionary. Domestic variables, such as consumption and GDP, increase, the current account deteriorates, while all asset prices (the real exchange rate, house prices, and equity prices) appreciate. These dynamics reverse sharply when international bank claims revert.

Next, we set up a simple theoretical model of international financial intermediation and collateralized borrowing in foreign currency. In the model, a global financial intermediary is subject to a leverage constraint that, when relaxed, expands the international supply of credit as assumed in the VAR. Domestic households use housing as collateral for borrowing in foreign currency. So both house prices and the exchange rate can have an amplification role, which differs depending on whether domestic borrowing constraints bind or not. In this set up, both the tightness of this borrowing constraint (the LTV) and the share of foreign currency liability can potentially affect the trasmission of the international credit supply shock.

Finally, we investigate the trasmission and the relative importance of a shock to the international supply of credit. We do so specifying a panel vector autoregression model augmented with the leverage of US Broker-Dealers, consistent with a simple theoretical model of international financial intermediation and collateralized borrowing in foreign currency that we set up.

The VAR analysis show that this shock increases international claims of global banks, generates responses of macroeconomic variables (GDP, consumption, and the current account) and asset prices (house prices, the real exchange rates, and the real short-term interest rate) in line with the unconditional evidence. The evidence we report shows that the shock explain about twice as much macroeconomic and asset price variability as a US monetary policy shock.

The VAR analysis, also, reveals a significant degree of heterogeneity in the transmission mechanism across countries. The the impact of the shock is much stronger in economies with larger share of liabilities denominated in foreign currency and high LTV limits also potentially consistent with the model we set up.

We present the unconditional evidence following the methodology adopted by Mendoza and Terrones (2008) to describe booms and busts in capital flows. We construct an event study by identifying boom-bust episodes in cross-border bank claims, and focus on the behavior of the economy around the peak of those boom-bust cycles.

The theoretical apparatus in this paper consists of an open economy model with two blocks of different characteristics. One block is 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 (Kiyotaki and Moore, 1997). The other block is large and is the source of the global supply of savings. Households of the foreign economy own financial intermediaries that operate globally and channel funds to the borrowing country. Financial intermediaries are subject to an exogenous leverage constraint as in Brunnermeier and Sannikov (2014) and He and Krishnamurthy

(2013). 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 stance 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.

We make a number of simplifying assumptions to keep the model analytically tractable and to highlight the key transmission mechanisms of shocks to the leverage of global banks. As housing is one of the largest asset classes in most countries and the US dollar remains the dominant currency in the international financial system, the framework we develop in the paper captures two amplification channels of high empirical relevance. A relaxation of the leverage constraint on global financial intermediaries increases the international supply of credit, drives a domestic boom, and leads to an appreciation of the real exchange rate. House prices can expand households' borrowing capacity only if the collateral constraint is binding. In this regime, when credit is denominated in foreign currency, the real exchange rate plays a similar role to house prices. Movements in the real exchange rate, however, imply valuation effects also when the borrowing constraint is not binding. In particular, the value of the domestic endowment increases while the value of borrowing decreases if credit is denominated in foreign currency. Overall, the model supports a clear direction for the effects of a leverage shock of global banks and nuanced view of the amplification role played by different asset prices. The predictions of the model provide a theoretical foundation for our empirical exercise.

We study the response of macroeconomic variables and asset prices to an identified shock to the international supply of credit (a global liquidity shock) in 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 focus on a shock to the leverage of US Broker-Dealers. The effects of this shock are consistent with the unconditional evidence from the event study. However, the intensity of the transmission differs and depend on cross-country differences in the share of foreign currency liabilities and LTV limits.

Our paper relates to three main strands of literature. A first set of contributions explored 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, the 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).[1] 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 to 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. Almeida et al. (2006) illustrate 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 to a particular source of exogenous variation in consumption—an international credit supply shock—and document an association between the share of foreign currency borrowing and the maximum level of the LTV and the consumption sensitivity to such shock.

The rest of the paper is organized as follows. Section 2 describes the event study. Section 3 sets up a simple equilibrium model that we use to illustrate the nature of the shock, clarify the transmission mechanism, and support the VAR identification assumptions. Section 4 reports our Panel VAR analysis. Section 5 concludes. A number of appendices report derivations, additional details, data sources and robustness analysis.

[1] 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.

## 2 Capital Flows, Asset Prices, and Economic Activity

In this Section 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. 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. finacial and non-financial). 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:

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

where $j = 1, ..., N$ indexes all BIS reporting countries. We consider the following variables: 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. 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).[2] 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 use annual data to avoid seasonal and other noisy components in quarterly data. We then define "boom-bust" episodes as episodes of booms followed by a bust.

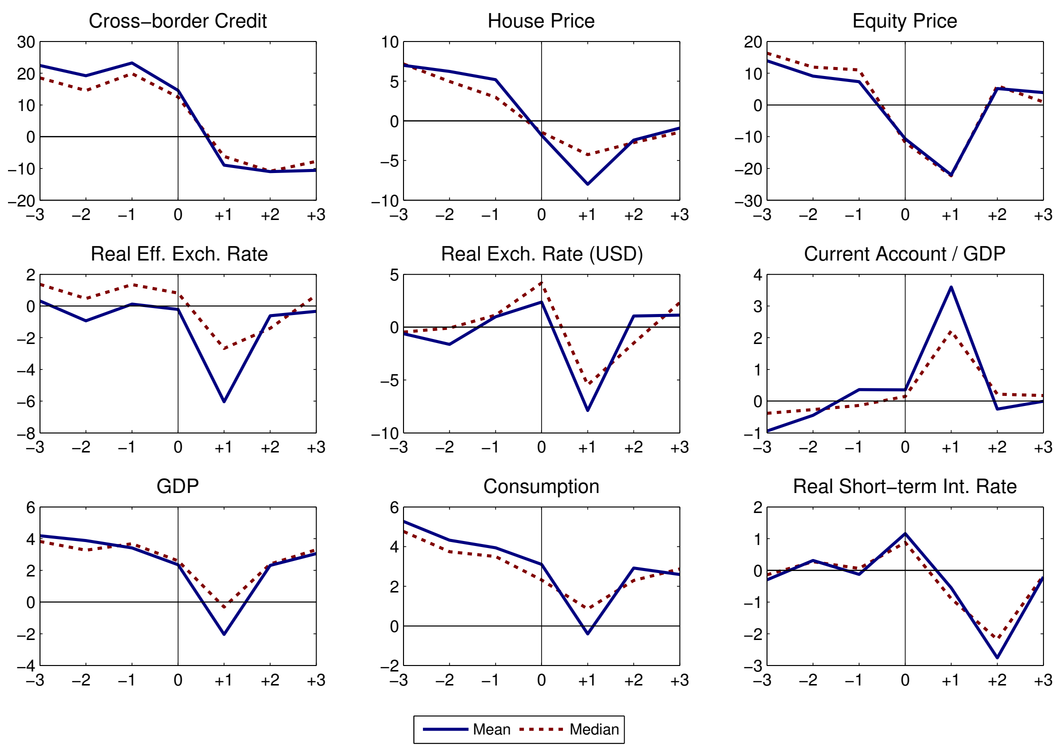
This procedure identifies 134 booms, 81 busts, and 50 boom-bust episodes.[3] We then plot the behavior of other macro and financial variables around the identified boom-bust episodes. Figure 1 reports the results. It plots the mean and the median (solid line and dotted line, respectively) across all episodes, using a 6-year window that goes from three year before the peak to three years

[2]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.

[3]The summary statistics for these episodes (such as duration and amplitude) are reported in the Appendix.

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.

**Figure 1** Event Study: Boom-Bust Episodes In Cross-border Lending




Note. Each panel plots the mean and the median (solid line and dotted line, respectively) across all boom-bust episodes, 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 claim growth (i.e., the last period of a boom in which cross-border bank claims displays 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 points.

Figure 1 shows that a boom in cross-border banking claims is associated with an economic expansion, as both GDP and consumption display positive and elevated rate of growth (of about 3-5 percent per year). The boom is also accompanied by very fast growing house and equity prices. Real interest rates increase only the year before the peak and are associated with a fall in asset prices and a slowdown in economic activity. On average, the real effective exchange rate seems unaffected by the capital inflow, but we can see an appreciation vis-a-vis the US dollar during the last year of the boom episode. Moreover, about half of the episodes are associated with large real appreciations. The current account deteriorates sharply for most episodes, and it starts to adjust gradually in about half of them during the last year of the expansion.

During the bust phase, these dynamics partially revert. The economy experiences a contraction, with both GDP and to a lesser extent consumption falling. House prices and equity prices collapse. The real exchange rate depreciates sharply, and the current account reverts abruptly into a temporary large surplus. While both GDP and consumption stabilize quickly, both house prices and cross-border flows remain depressed for several years.

This evidence provides support for the view that capital inflows are expansionary and associated with large swings in asset prices. So we now set up a simple model in which house prices and exchange rate can amplify the trasmission of a capital flow shock.

## 3 Model

This section presents a stylized model of international financial intermediation and collateralized borrowing. We will use the model to establish causality in the empirical analysis and to interpret the empirical evidence presented below. We first present a more general version of the model. And then make a set of simplifying assumptions to illustrate its core properties by means of an example that admits a near close-form solution.

Time is discrete and indexed by $t$. The world consists of two blocks of countries, Home (H) and the rest of the world (F for Foreign), of size $n \in (0,1)$ and $1-n$, respectively. Each block is endowed with one good. In each block, the representative household consumes a bundle of the two goods, as well as housing services, assumed to be proportional to the stock of housing.

The two blocks only differ in the degree of patience. In particular, the domestic representative household is relatively impatient. Housing purchases are subject to a collateral constraint. The representative household in the rest of the world saves via deposits and equity in a "global" financial intermediary. The financial intermediary channels funds internationally from lenders to borrowers and is subject to a leverage constraint (or, equivalently, a capital requirement).

### 3.1 Goods Markets

The representative H household consumes a basket that combines Home and Foreign goods. Preferences are CES over the two goods:

$$c_t = \left[\alpha^{\frac{1}{\gamma}} c_{Ht}^{\frac{\gamma-1}{\gamma}} + (1-\alpha)^{\frac{1}{\gamma}} c_{Ft}^{\frac{\gamma-1}{\gamma}}\right]^{\frac{\gamma}{\gamma-1}}, \tag{2}$$

where $\gamma > 0$ is the elasticity of substitution between goods, and $\alpha \in (0,1)$ is the steady state consumption share on Home goods. If $\alpha > n$, preferences exhibit consumption home bias. Preferences over the two goods in the foreign country are symmetric, with $\alpha^* \in (0,1)$ representing the foreign consumption share of imported goods.

The weight on imported goods in the Home consumption basket is a function of the relative size of the foreign economy $(1-n)$ and of the degree of openness $\lambda \in (0,1)$, which is assumed to be equal in both countries:

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

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

$$c_{Ht} = \alpha \left(\frac{P_{Ht}}{P_t}\right)^{-\gamma} c_t \qquad \text{and} \qquad c_{Ft} = (1-\alpha)\left(\frac{P_{Ft}}{P_t}\right)^{-\gamma} c_t, \tag{3}$$

where $P_{Ht}$ and $P_{Ft}$ are the Home currency prices of the Home and Foreign goods, respectively, and $P_t$ is the overall price level, which are related to each other according to

$$P_t = \left[\alpha P_{Ht}^{1-\gamma} + (1-\alpha) P_{Ft}^{1-\gamma}\right]^{\frac{1}{1-\gamma}}. \tag{4}$$

The Foreign block has a similar consumption bundle (foreign variables are denoted by an asterisk):

$$c_t^* = \left[\alpha^{*\frac{1}{\gamma}} c_{Ht}^{*\frac{\gamma-1}{\gamma}} + (1-\alpha^*)^{\frac{1}{\gamma}} c_{Ft}^{*\frac{\gamma-1}{\gamma}}\right]^{\frac{\gamma}{\gamma-1}}, \tag{5}$$

[4] The size of home bias decreases with the degree of openness and disappears when $\lambda = 1$ (Sutherland, 2005). This specification encompasses the small open economy case when $n \to 0$.

with $\alpha^* \equiv n\lambda$. The associated demand functions for the Home and Foreign goods are

$$c^*_{Ht} \quad = \quad \alpha^* \left(\frac{P^*_{Ht}}{P^*_t}\right)^{-\gamma} c^*_t \qquad \text{and} \qquad c^*_{Ft} = (1-\alpha^*)\left(\frac{P^*_{Ft}}{P^*_t}\right)^{-\gamma} c^*_t, \tag{6}$$

and the associated price index is

$$P^*_t = \left[\alpha^* P^{*1-\gamma}_{Ht} + (1-\alpha^*)P^{*1-\gamma}_{Ft}\right]^{\frac{1}{1-\gamma}}. \tag{7}$$

### 3.2 Exchange Rates and Relative Prices

The nominal exchange rate $\mathcal{E}_t$ is defined as the number of units of Home currency to buy one unit of Foreign currency, so that an increase of the nominal exchange rate corresponds to depreciation of the Home currency.

We assume that the law of one price (LOOP) holds for each good:

$$P_{Ht} = \mathcal{E}_t P^*_{Ht} \qquad \text{and} \qquad P_{Ft} = \mathcal{E}_t P^*_{Ft}. \tag{8}$$

The terms of trade $\tau_t$ 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:

$$\tau_t = \frac{\mathcal{E}_t P^*_{Ft}}{P_{Ht}}. \tag{9}$$

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 $\tau_t$ represents a deterioration of the terms of trade for the Home country (i.e. a depreciation).

Relative prices are a function of the terms of trade:

$$p_{Ht} = \left[\alpha + (1-\alpha)\tau_t^{1-\gamma}\right]^{\frac{1}{\gamma-1}} \qquad \text{and} \qquad p_{Ft} = \left[\alpha\tau_t^{\gamma-1} + (1-\alpha)\right]^{\frac{1}{\gamma-1}}, \tag{10}$$

where $p_{kt} \equiv P_{kt}/P_t$, for $k = \{H, F\}$. Similarly, for the Foreign country, we have:

$$p^*_{Ht} = \left[\alpha^* + (1-\alpha^*)\tau_t^{1-\gamma}\right]^{\frac{1}{\gamma-1}} \qquad \text{and} \qquad p^*_{Ft} = \left[\alpha^*\tau_t^{\gamma-1} + (1-\alpha^*)\right]^{\frac{1}{\gamma-1}}. \tag{11}$$

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

$$s_t \equiv \frac{\mathcal{E}_t P^*_t}{P_t}. \tag{12}$$

An increase in $s_t$ 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:

$$s_t \equiv \frac{\mathcal{E}_t P^*_t}{P_t} = \frac{\mathcal{E}_t P^*_{Ft}}{P_{Ht}} \frac{P_{Ht}}{P_t} \frac{P^*_t}{P^*_{Ft}} = \tau_t \left[\frac{\alpha + (1-\alpha)\tau_t^{1-\gamma}}{\alpha^*\tau_t^{\gamma-1} + (1-\alpha^*)}\right]^{\frac{1}{\gamma-1}}. \tag{13}$$

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

### 3.3 Domestic Households

Domestic households are impatient borrowers. The representative household consists of a continuum of members of measure $n$. All members are identical and maximize the present discounted value of an instantaneous felicity function defined over consumption of non-durable goods and housing services, assumed to be proportional to the housing stock $h_t$:

$$\max_{\{c_t, h_t, f_t\}} \mathbb{U}_t = \sum_{t=0}^{\infty} \beta^t \left[u(c_t) + v(h_t)\right], \tag{14}$$

where $\beta \in (0,1)$ is the individual discount factor, $u'$ and $v' > 0$, and $u''$ and $v'' \leq 0$.

The budget constraint is

$$c_t + q_t h_t - s_t f_t = p_{Ht} y_t + q_t h_{t-1} - s_t R^b_{t-1} f_{t-1}, \tag{15}$$

where $q_t$ is the price of houses in terms of the consumption good, $y_t$ is the per-capita endowment of domestic consumption goods, and $f_t$ is the amount of one-period debt (denominated in units of Foreign consumption goods) accumulated by the end of period $t$ and carried into period $t+1$, with gross real interest rate $R^b_t$.

Following Kiyotaki and Moore (1997), a collateral constraint limits debt to a fraction $\theta \in (0,1)$ of the value of the owned housing stock:

$$s_t f_t \leq \theta q_t h_t. \tag{16}$$

A common interpretation of this constraint is that the parameter $\theta$ represents the maximum admissible loan-to-value (LTV) ratio, like in our empirical analysis. We depart from the typical specification in the housing literature by expressing this borrowing constraint in terms of foreign-currency denominated liabilities. Because debt is denominated in units of foreign goods, an appreciation of the real exchange rate relaxes the borrowing constraint, holding constant the value of housing. This mechanism provides an additional amplification channel on top of the standard one due to house prices. The evidence reported above suggests that both play a role, with the cross-sectional evidence favoring the foreign-liabilities channel.

As in Kiyotaki and Moore (1997), house prices can amplify exogenous shocks in our model *only* through the collateral constraint. When the collateral constraint is not binding, the feedback from house prices to the rest of the economy disappears. But when the collateral constraint is binding, an increase in house prices boosts the value of the collateral and expands the households' borrowing capacity, thus increasing consumption.

The real exchange rate amplifies exogenous shocks in both regimes. An appreciation of the domestic currency increases the value of the endowment (endowment valuation effect). But borrowing is denominated in foreign currency, thus the purchasing power of debt is reduced (debt valuation effect). These two effects are present independently of whether the collateral constraint binds or not. In addition, when the collateral constraint does bind, an appreciation increases the value of the collateral in the same vein as an increase in house prices, therefore expanding households' borrowing capacity (collateral valuation effect).

The problem for the domestic representative household is to maximize (14) subject to (15) and (16). Let $\mu_t u'(c_t)$ be the normalized Lagrange multiplier on the borrowing constraint. The first order condition for the optimal choice of debt is:

$$1 - \mu_t = \beta R^b_{t-1} \mathbb{E}_t \left[ \frac{u'(c_{t+1})}{u'(c_t)} \frac{s_{t+1}}{s_t} \right]. \tag{17}$$

Expression (17) is the consumption Euler equation that relates the marginal benefit of higher consumption today to the marginal cost of lower consumption tomorrow. The equation shows how a tighter borrowing constraint (i.e., a higher $\mu_t$) reduces the marginal benefit of higher consumption today.

The first order condition for the optimal choice of housing services is:

$$(1 - \theta\mu_t) q_t = \frac{v'(h_t)}{u'(c_t)} + \beta \mathbb{E}_t \left[ \frac{u'(c_{t+1})}{u'(c_t)} q_{t+1} \right]. \tag{18}$$

Expression (18) prices housing. Among other factors, this equation shows that house prices are higher when (i) the maximum loan-to-value ratio $\theta$ is high and (ii) the borrowing constraint is tight (high $\mu_t$). Both these factors contribute to increase the demand for housing because of its collateral value.

### 3.4 Foreign Households

Foreign households are patient lenders. The representative household consists of a continuum of members of measure $1 - n$ who derive utility from consumption ($c^*_t$) and maximize the following utility function:

$$\max_{\{c^*_t, d_t, e_t\}} \mathbb{U}_t = \sum_{t=0}^{\infty} \beta^{*t} u(c^*_t), \tag{19}$$

with $\beta^* \in (\beta, 1)$.[5]

[5]Because of this assumption, the borrowing constraint of the foreign household is never binding in equilibrium. For simplicity, we abstract from foreign housing purchases altogether. The only difference from explicitly incorporating

Because in equilibrium Foreign households are savers, we abstract from their housing decisions.[6] Foreign households save via deposits and equity holdings of financial intermediaries, which, however, are subject to some adjustments costs. Foreign households are subject to the following budget constraint:

$$c_t^* + d_t + e_t + \psi(e_t) = p_{Ft} y_t^* + R_{t-1}^d d_{t-1} + R_{t-1}^e e_{t-1}, \tag{20}$$

where $d_t$ are deposits in a financial intermediary in period $t-1$, which pay a gross interest rate $R_t^d$; $e_t$ represents the amount of equity capital in the financial intermediary, with gross rate of return $R_t^e$; $\psi(e_t)$ represents a convex cost of changing equity position; and $y_t^*$ is the per-capita endowment of non-durable F consumption goods. As in Jermann and Quadrini (2012), the adjustment cost function $\psi(\cdot)$ is positive (and so are its first two derivatives), and creates a pecking order of liabilities whereby intermediaries always prefer to issue debt relative to equity.

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

$$1 = \beta^* R_t^d \mathbb{E}_t \left[ \frac{u'(c_{t+1}^*)}{u'(c_t^*)} \right], \tag{21}$$

and

$$1 + \psi'(e_t) = \beta^* R_t^e \mathbb{E}_t \left[ \frac{u'(c_{t+1}^*)}{u'(c_t^*)} \right]. \tag{22}$$

Expression (21) is the standard Euler equation for consumption-savings decisions. Expression (22) is also a standard Euler equation, except for the presence of the adjustment cost term $\psi'(\cdot)$, which introduces a spread on the return of equity over deposits.

## 3.5 Global Financial Intermediary

A representative global financial intermediary channels loans from patient foreign lenders to impatient domestic borrowers, funding such lending with a mix of equity and deposits. Deposits and loans are denominated in Foreign goods to capture the idea that global financial intermediaries

foreign housing decisions would be to price housing in the lending country—something our empirical evidence has little to say about.

[6] A borrowing constraint like the one for Home households would never bind for Foreign households, and the equilibrium in the housing market would not affect the rest of the economy.

do not bear the costs of currency exposure by directly matching the denomination of assets and liabilities.[7] Given borrowers and lenders' decisions, Table 1 describes the balance sheet of the global financial intermediary at time $t$.

**Table 1** Global Financial Intermediaries' Balance Sheet

| **Assets** | | **Liabilities** | |
|---|---|---|---|
| Loans: | $nf_t$ | Deposits: | $(1-n)d_t$ |
| | | Equity: | $(1-n)e_t$ |

Next period's profits are:

$$\max_{\{f_t,d_t,e_t\}} \Upsilon_{t+1} = R_t^b n f_t - R_t^d (1-n) d_t - R_t^e (1-n) e_t. \tag{23}$$

The financial intermediary is subject to a capital constraint:

$$(1-n)e_t \geq \chi_t n f_t, \tag{24}$$

with $\chi_t \in (0, \bar{\chi})$. Because equity is more expensive than deposits, financial intermediaries would like to leverage their balance sheet without bounds. The capital constraint imposes a limit to the leverage ratio that financial intermediaries can achieve.[8] We will study shocks to $\chi_t$ in the model, and map the results to the empirical evidence in the previous sections. For this purpose, we focus on an equilibrium in which the capital constraint is binding. If not, financial intermediaries would be irrelevant, and changing this constraint would have no effect on macroeconomic variables.

The problem for the representative global financial intermediary is to maximize (23) subject to the balance sheet constraint

$$n f_t = (1-n)\left(d_t + e_t\right), \tag{25}$$

and to the leverage constraint (24). After substituting for deposits from the balance sheet constraint

[7] We could allow for some loans to be denominated in Home currency while still retaining the idea that global banks do not bear currency risk by assuming that financial intermediaries purchase instruments to hedge their positions. In this formulation, the cost of the hedging activity would be passed onto depositors and equity holders.

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

and for equity from the binding capital constraint, intermediaries profits become

$$\Upsilon_{t+1} = \left[R_t^b - (1-\chi_t)R_t^d - \chi_t R_t^e\right] nf_t. \tag{26}$$

Competition among financial intermediaries requires the lending rate to be a (time-varying) linear combination of the return on equity and the return on deposits intermediaries pay out to savers:

$$R_t^b = \chi_t R_t^e + (1-\chi_t)R_t^d. \tag{27}$$

where the weight on the return on equity correspond to the capital requirement. Tighter regulation (a higher $\chi_t$) implies a higher cost for financial intermediaries that is passed on to borrowers in the form of a higher loan rate, and vice versa.

### 3.6 Equilibrium

In equilibrium, the assumption of a relative impatient domestic household implies that the Home country borrows from the Foreign country at the prevailing market interest rate. Therefore, borrowers can use their endowment, together with new loans, to buy non-durable consumption goods and new houses, and to repay principal and interest rates on old loans. For simplicity, we abstract from construction, and assume that the supply of housing is fixed (land) and normalized to 1 ($h_t = h = 1$).

We solve for an equilibrium in which the leverage constraint is binding. An equilibrium is a set of stationary processes

$$\{q_t, \mu_t, R_t^b, R_t^d, R_t^e, f_t, e_t, \tau_t, s_t, c_t, c_t^*, c_{Ht}, c_{Ht}^*, c_{Ft}, c_{Ft}^*\}$$

for $t \geq 0$ such that:

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

$$
\begin{aligned}
c_{Ht} &= \alpha \left(p_{Ht}\right)^{-\gamma} c_t, \\
c_{Ft} &= (1-\alpha)\left(p_{Ft}\right)^{-\gamma} c_t, \\
1-\mu_t &= \beta R_t^b \mathbb{E}_t \left[\frac{u'(c_{t+1})}{u'(c_t)} \frac{s_{t+1}}{s_t}\right], \\
(1-\mu_t\theta) q_t &= \frac{v'(1)}{u'(c_t)} + \beta \mathbb{E}_t \left[\frac{u'(c_{t+1})}{u'(c_t)} q_{t+1}\right], \\
s_t d_t &\leq \theta q_t, \\
s_t f_t &= s_t R_{t-1}^b f_{t-1} + c_t - p_{Ht} y_t.
\end{aligned}
$$

with $\mu_t \geq 0$.

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

$$
\begin{aligned}
c_{Ht}^* &= \alpha^* \left(p_{Ht}^*\right)^{-\gamma} c_t^*, \\
c_{Ft}^* &= (1-\alpha^*)\left(p_{Ft}^*\right)^{-\gamma} c_t^*, \\
1 &= \beta^* R_t^d \mathbb{E}_t \left[\frac{u'(c_{t+1}^*)}{u'(c_t^*)}\right], \\
1+\psi'(e_t) &= \beta^* R_t^e \mathbb{E}_t \left[\frac{u'(c_{t+1}^*)}{u'(c_t^*)}\right].
\end{aligned}
$$

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

$$
\begin{aligned}
R_t^b &= \chi_t R_t^e + (1-\chi_t) R_t^d, \\
n f_t &= (1-n)(d_t + e_t), \\
(1-n) e_t &= \chi_t n f_t.
\end{aligned}
$$

4. Goods market clear:

$$
\begin{aligned}
n y_{Ht} &= n c_{Ht} + (1-n) c_{Ht}^*, \\
(1-n) y_{Ft}^* &= n c_{Ft} + (1-n) c_{Ft}^*.
\end{aligned}
$$

5. Relative prices are related to the terms of trade according to:

$$
\begin{aligned}
p_{Ht} &= \left[\alpha + (1-\alpha)\tau_t^{1-\gamma}\right]^{\frac{1}{\gamma-1}}, \\
p_{Ft} &= \left[\alpha\tau_t^{\gamma-1} + (1-\alpha)\right]^{\frac{1}{\gamma-1}}, \\
p_{Ht}^{*} &= \left[\alpha^{*} + (1-\alpha^{*})\tau_t^{1-\gamma}\right]^{\frac{1}{\gamma-1}}, \\
p_{Ft}^{*} &= \left[\alpha^{*}\tau_t^{\gamma-1} + (1-\alpha^{*})\right]^{\frac{1}{\gamma-1}}, \\
s_t &= \tau_t \left[\frac{\alpha + (1-\alpha)\tau_t^{1-\gamma}}{\alpha^{*}\tau_t^{\gamma-1} + (1-\alpha^{*})}\right]^{\frac{1}{\gamma-1}}.
\end{aligned}
$$

### 3.7 A Simple Example

To illustrate the core properties of the model, we solve a two-period version that admits a near closed-form solution.

We make five additional assumptions for tractability:

1. Households are risk-neutral with respect to consumption ($u'(c) = \bar{c}$, for some constant $\bar{c}$);

2. The consumption bundle is Cobb-Douglas ($\gamma = 1$);

3. The Home country is small ($n \to 0$);

4. The adjustment cost function is such that $\psi'(0) = \zeta$;

5. The model has two periods and the initial international asset position is balanced ($f_0 = 0$).

Assumption 1. is necessary to simplify the asset pricing relationship, abstracting from risk, and to focus on the credit market. Assumption 2. and 3 are crucial to solve in closed form for the terms of trade. Assumption 4. maintains a well defined credit supply even in the small open economy case. Assumption 5 simplifies the solution in terms of state variables.

As we show in the appendix, the model equilibrium can then be summarized by the following set of equations:

1. **Credit supply:**

$$R^b = \frac{1 + \zeta\chi}{\beta^{*}}. \tag{28}$$

2. **Credit demand:**

$$R^b = \begin{cases} \frac{1}{\beta}\frac{s_1}{s_2} & \text{if } \; s_1 f_1 < \theta q \\ \frac{1}{\beta}\frac{s_1}{s_2}\left(\frac{v'(1)}{s_1 f_1} - \frac{1-\theta}{\theta}\right) & \text{if } \; s_1 f_1 = \theta q \end{cases} \tag{29}$$

3. **Real exchange rate:**

$$s_1 = \left[\frac{\lambda y_{H1}}{\lambda y^*_{F1} + (1-\lambda) f_1}\right]^{1-\lambda} \tag{30}$$

$$s_2 = \left[\frac{\lambda y_{H2}}{\lambda y^*_{F2} - (1-\lambda) R^b f_1}\right]^{1-\lambda} \tag{31}$$

We characterize the equilibrium of the simplified model in the space $\{R^b, f_1\}$. Equation (28) expresses the interest rate offered as function of the capital requirement. In particular, it shows that an increase in leverage of financial intermediaries (a reduction of the capital requirements) shifts down the credit supply schedule and reduces the interest rate on loans issued to the Home country, like we assumed for identification purposes in our VAR model in Section 4.[9]

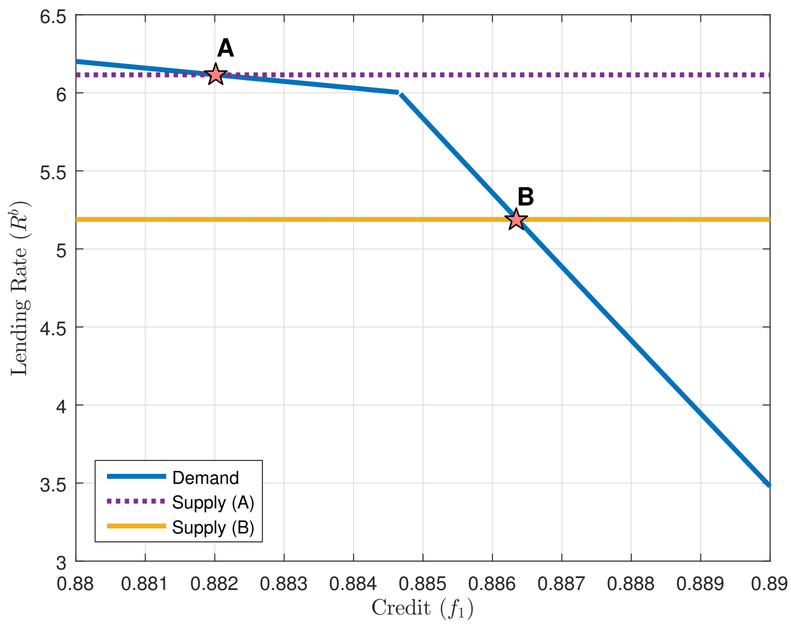
From the demand of credit (29), however, we cannot explicitly express the interest rate as a function of the quantity of credit. In neither the binding nor the non-binding regime, equations (29)-(30)-(31) admit a closed-form expression that links $R^b$ to $f_1$. Consequently, we characterize the equilibrium in the credit market for numerically for reasonable parameter values.

Starting with the supply of credit, we set the capital ratio to $\chi = 0.1$ consistent with a leverage ratio of 10, a value that is close to the average leverage ratio in the data. The foreign discount factor is set to its standard value of $\beta^* = 0.99$. Finally, we use the equity adjustment cost parameter $\zeta$ as a free parameter to find an equilibrium in both the binding and in the non-binding region. Moving to the demand of credit, we normalize all endowments to $y_{H1} = y_{H2} = y_{F1} = y_{F2} = 1$ and the marginal utility of housing $v(1) = 1$. We set $\theta = 0.9$, consistent with the observed maximum the LTV limit in our sample of countries (on average). The openness parameter is set to $\lambda = 0.8$, slightly larger than the value in GaliMonacelli2005. The domestic discount factor is set to $\beta = 0.90$ to yield an equilibrium interest rate in the credit market that is within a reasonable range. Under

[9]Because the Home country is small, the quantity of credit issued does not enter expression (28). Under a more general calibration whereby the Home country is not atomistic relative to the rest of the world, credit supply would be increasing in the quantity of credit.

this parametric assumption we can fully pin down the equilibrium in the credit market.

**Figure 2** Graphical Representation Of The Equilibrium In Credit Market




Note. The intersection of demand and supply of funds determines an equilibrium quantity of credit $f_1$ that flows from the foreign to the domestic economy, and an associated interest rate $R^b$. Depending on the parameter values, two equilibria may arise. If the borrowing constraint does not bind (point A), the interest rate is relatively high and credit low. Vice versa, if the borrowing constraint is binding (point B), the interest rate is relatively low.

Figure 2 reports the graphical representation of this equilibrium in the $\{R^b, f_1\}$ space. As noted above, the credit supply schedule is horizontal. Credit demand is a piece-wise function in the space $\{R^b, f_1\}$. Unlike Justiniano et al. (2015), the first portion of this curve is downward sloping, due to the endowment and debt valuation effects associated with the real exchange rate and discussed above. The second part of the demand schedule is also downward-sloping. In this region, the real exchange rate plays the additional amplification role (collateral valuation effect) also discussed above. The borrowing constraint at equality pins down the kink of the demand function. [10]

The intersection of demand and supply of funds determines an equilibrium quantity of credit $f_1$ that flows into the domestic economy, and an associated interest rate $R^b$. As Figure 2 shows, depending on the parameter values, two equilibria may arise. If the borrowing constraint does not bind (point A in Figure 2), the interest rate is relatively high and credit low. Vice versa, if the

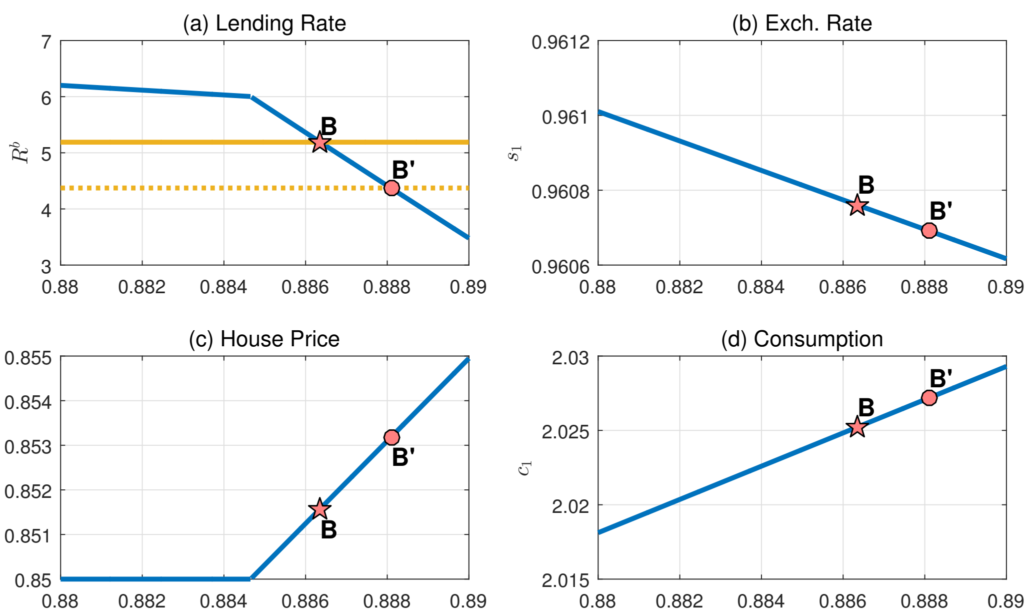
[10] In the Appendix, we show analytically that, in the binding region, the demand curve is downward sloping by taking a log-linear approximation of the equilibrium conditions around the steady state.

borrowing constraint is binding (point B in Figure 2), the interest rate is relatively low, while credit and house prices are high.

### 3.7.1 A Credit Supply Shock

In this simplified version of the model, we can also study the response of the domestic economy to a leverage shock consistent with the one identified in the empirical analysis of section 4. Specifically, consider a foreign credit supply shock in the binding region caused by the relaxation of the international intermediary's leverage constraint (a reduction in $\chi$). The shock shifts the supply of credit downwards, which leads to increased cross-border bank lending and a lower interest rate on loans. In response to the shock, the exchange rate appreciates while house prices and consumption both increases. Figure 3 plots the results.

**Figure 3** THE IMPACT OF A CREDIT SUPPLY SHOCK




NOTE. Panel (a) reports the equilibrium in the credit market, as in Figure 2, which is depicted by point $B$. The dashed line displays how the credit supply curve shifts when leverage increases, with the new equilibrium depicted by point $B'$. Panels (b), (c), and (d) report the equilibrium levels of the real exchange rate, house price, and consumption as a function of the amount of credit in the economy.

The domestic economy starts from an equilibrium in the binding region, where credit supply is relatively high and the interest rate relatively low—as in point $B$ depicted in Figure 2, which we report in panel (a) of Figure 3. The increase in leverage ($\chi \downarrow$) shifts the supply schedule downward (dashed line in the panel (a) of Figure 3). The new equilibrium is in a point like $B'$, in which the interest rate on loans is lower and the equilibrium amount of loans is higher.

The increase in credit availability leads to an appreciation of the exchange rate (panel (b) of Figure 3). An appreciation of the domestic currency increases the value of the endowment (endowment valuation effect). But borrowing is denominated in foreign currency, thus the purchasing power of debt is reduced (debt valuation effect).

As the interest rate falls, the shadow value of housing increases and leads to an increase in house prices (panel (c) of Figure 3). With a binding collateral constraint, domestic households spend the additional credit for both goods and housing services. Furthermore, the appreciation of both house prices and the real exchange rate relaxes the borrowing constraint even further, thus creating a feedback effect on the demand for credit.

A similar shock in the non-binding region would lead to a different adjustment. Since the collateral constraint is slack, the increase in credit availability only funds consumption of non-durable goods, while house prices remain constant.

## 4 The Impact of an International Credit Supply Shock

In this section, we identify an international credit supply shock empirically, analyze its trasmission and relative importance for a subset of the variables considered in this event study. We use panel-vector autoregressive model (PVAR) framework that allows us to investigate both the behavior of the typical economy and the cross countries differences in this transmission.

### 4.1 A PVAR Model

The PVAR model includes a small set of variables which have a direct counterpart in the model. We include the leverage ratio of US Broker-Dealers (described below), cross-border bank claims to all sectors, real GDP, real private consumption, real house prices, the real (ex-post) short-term interest rate, the real exchange rate vis-a-vis the US Dollar, and the current account balance over GDP. To keep the size of the VAR model as small as possible, we do not include inflation and nominal interest rate separately. Thus, the real ex-post short-term interest rate is meant to reflect the monetary policy stance. A stabilizing monetary policy response should manifests itself with a change in the real short-term interest rate.

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 $\Sigma_{iu}$. All variables considered enter in log-levels, except the interest rate, which enter in levels.[11] The 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 shorter sample period for some of the emerging economies in the sample, we include one lag of each variable in every system. The sample period is 1985:Q1-2012:Q4.

We estimate the model using the *mean group estimator* of Pesaran and Smith (1995) and Pesaran et al. (1996).[12] In the estimation, we drop all countries which have less than 40 observations or have unstable dynamics (i.e., with eigenvalues larger than 1). This leaves us with 51 of the original 57 countries in our event study.[13]

## 4.2 Identification

We want to identify a push shock to the international supply of credit like in the model above. The model shows that changes in leverage of international financial intermediaries lead to an increase in the international supply of credit. Thus, 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. We label this shock a "global liquidity" shock.[14]

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

[12] This is because pooled estimators are inconsistent in a dynamic panel data model with slope coefficients varying across countries.

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

[14] Since the leverage of US Broker-Dealers is endogenous to the US, we drop US from the sample, leaving us with a sample of 50 countries.

Consistent with the model, our key assumption is that changes in the leverage of US Broker-Dealers lead to changes in the international supply of credit, but leverage of US Broker-Dealers is not affected by conditions in individual countries outside the United States.[15]

US Broker-Dealers' leverage can be driven by US monetary policy, financial regulation and innovation, as well shifts in risk appetite, (see for example Bruno and Shin, 2015, Rey, 2013, Bekaert et al., 2013). For our purposes, however, we do not need to identify these underlying, more structural sources of change. 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 below.

Leverage of US Broker-Dealers, together with cross-border bank claims (aggregated over all countries in our sample) are plotted in Figure 4. The two series share a secular upward trend and also cyclical variation at relatively low frequency. Albeit to a different degree and with different timing, the two series increase sharply, and then collapse during the global 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. So the shock that we identify is a persistent cyclical deviation of leverage from its long run mean value.

In practice, the impulse responses of all other variables in the system to this shock can be obtained 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.[16]

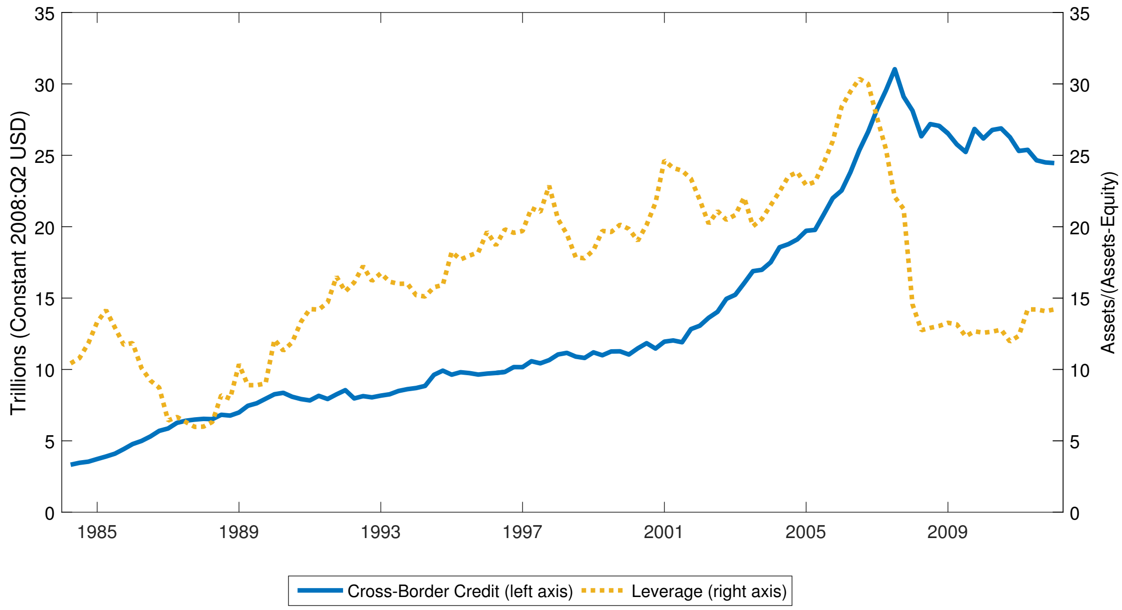
This procedure is the same as regressing the reduced form residual of cross-border credit of country $i$ on the reduced form residual of the VAR equation for the US broker-dealer leverage. This two stage strategy, in turn, can be used to consider a wider set of variables possibly driving cross border credit. In this spirit, in the Appendix we assessed the robustness of our results to the use of the external instruments approach proposed by Stock and Watson (2012) and Mertens and Ravn (2013).

Note finally that country specific VARs are estimated without imposing the restriction that lagged domestic variables do not affect the dynamics of leverage. Proceeding in this way we loose

[15] 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.

[16] Note that the order of the other endogenous variables in the VAR system does not matter for the trasmission of the shock identified.

**Figure 4** LEVERAGE OF US BROKER-DEALERS & 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 (equity + total liabilities)/equity.

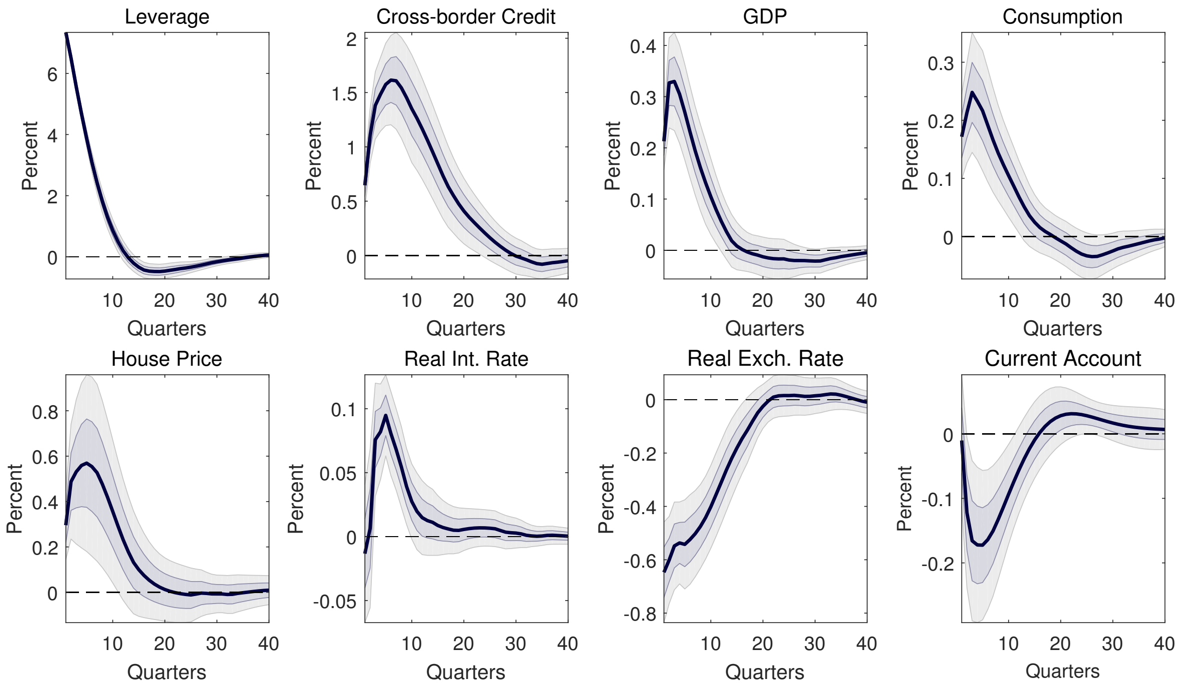
only efficiency for the estimation of the leverage equation, but not consistency. But given that we do not use country specific standard errors to construct the variance of the mean group estimator, this is not a concern. On the other hand, this simplifies matters significantly by allowing us to use OLS rather than maximum likelihood to estimate the reduced form of the country systems.

## 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.[17] 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 7.3%. 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 outlier on the cross-country average. The dark and light shaded areas represent the one- and two-standard deviation confidence intervals, respectively.

[17] 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 A GLOBAL LIQUIDITY SHOCK

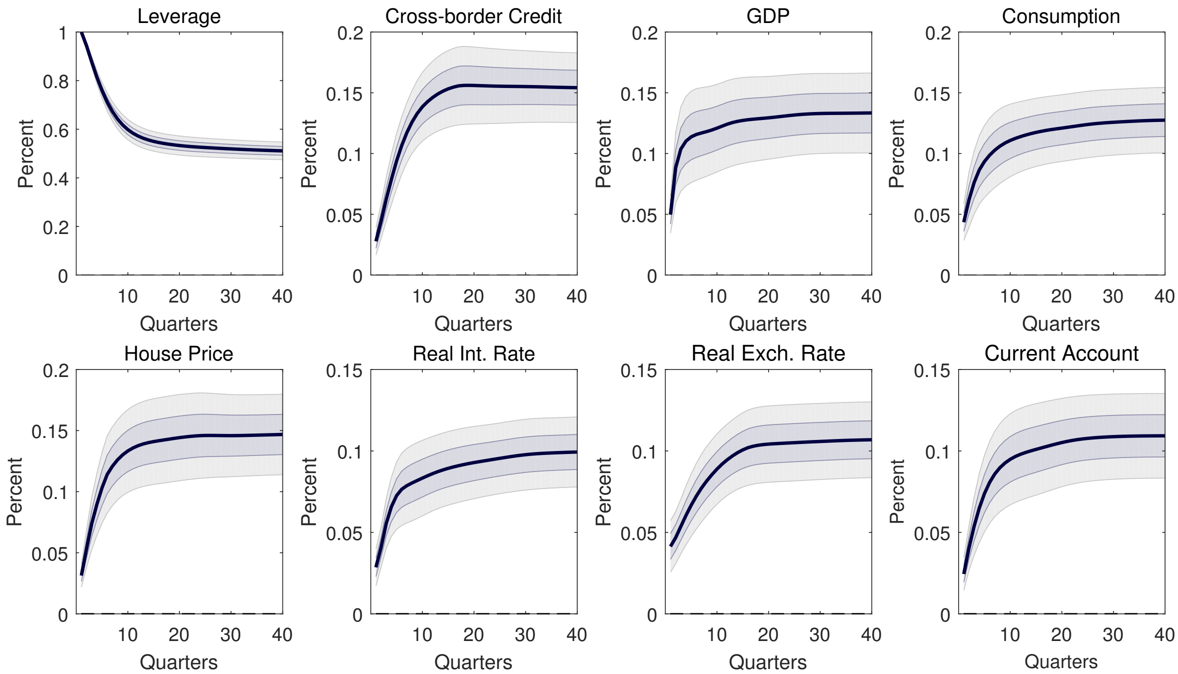



NOTE. Impulse responses to a one standard deviation increase (7.3%) in the leverage of US Broker-Dealers. The dark and light shaded areas are the one and two standard deviation confidence intervals.

In the typical small open economy represented here, our leverage shock leads to a statistically significant and persistent increase in cross-border claims, real GDP, real consumption and real house prices, a hump shaped response of real interest rate, a prolonged real exchange rate appreciation, and a deterioration of the current account balance. Cross-border bank claims display a hump-shaped response, with an impact response of 0.6% and a peak response of 1.5%. Similarly, consumption and real house prices increase by about 0.2% and 0.5% above their long-run levels, respectively, within a year. The real exchange vis-a-vis the US Dollar appreciates on impact by about 0.6%, arguably driven by the nominal exchange rate, and then reverts very slowly to its equilibrium level. The response of the short-term real interest rate is initially muted, if not accommodative. The real interest rate then increases more slowly than consumption and house prices, but steadily for about two years, peaking at about 10 basis points above its long-run level.

Figure 6 reports the mean group estimates of the forecast error variance decomposition for the global liquidity shock. The shock explains a significant share of variance of all other variables in the system. But is explained largely by itself within the first a year or so. The shock can

**Figure 6** Forecast Error Variance Decomposition of a Global Liquidity Shock




Note. Forecast error variance decomposition of a shock to global liquidity. The dark and light shaded areas are the one and two standard deviation confidence intervals.

explain about 15 percent of the forecast error variance of cross-border credit, house prices, GDP, and consumption; and a slightly smaller share for the remaining variables. These magnitudes are economically meaningful and exceed the share of forecast error variance that is typically explained by monetary policy shocks. For example, in our PVAR, a US monetary policy shock explains roughly 5% of the forecast error variance of cross-border bank claims, consumption, house prices and exchange rates (i.e., between half and one third less than the global liquidity shock.[18]

Summarizing, this transmission is consistent with the findings of our event study and the mechanisms at work in the model, and suggests an expansionary effect of the capital flow shock, possibly mitigated by a tightening monetary policy response. The evidence also show that the shock that we identified explain a sizable share of macroeconomic dynamics of the typical small open economy.

[18]We identified the US monetary policy by simply using a series of high-frequency US monetary policy surprises (constructed by Gurkaynak et al. (2005) and used, among others, by Gertler and Karadi (2015) in a monetary VAR for the US) instead of the leverage of Broker-Dealers in the VAR estimation. Specifically, we used the series of monetary surprises based on the 3-month Euro-Dollar futures (*ED4*), which covers a longer sample period relative to the baseline series used by Gertler and Karadi (2015).

## 4.4 Understanding Cross-country Differences

As we can see from Figure 5, the error bands of the responses of consumption, house price and exchange rate are relatively wide, reflecting significant differences across countries. In this section we investigate whether this heterogeneity follow specific patterns.

We conjecture that asset prices might amplify the impact of an increase in the international supply of credit to varying degrees. Consider for example the following collateral constraint, which is similar to the one in our model below:

$$f_t \leq \theta \left( q_t h_t \right),$$

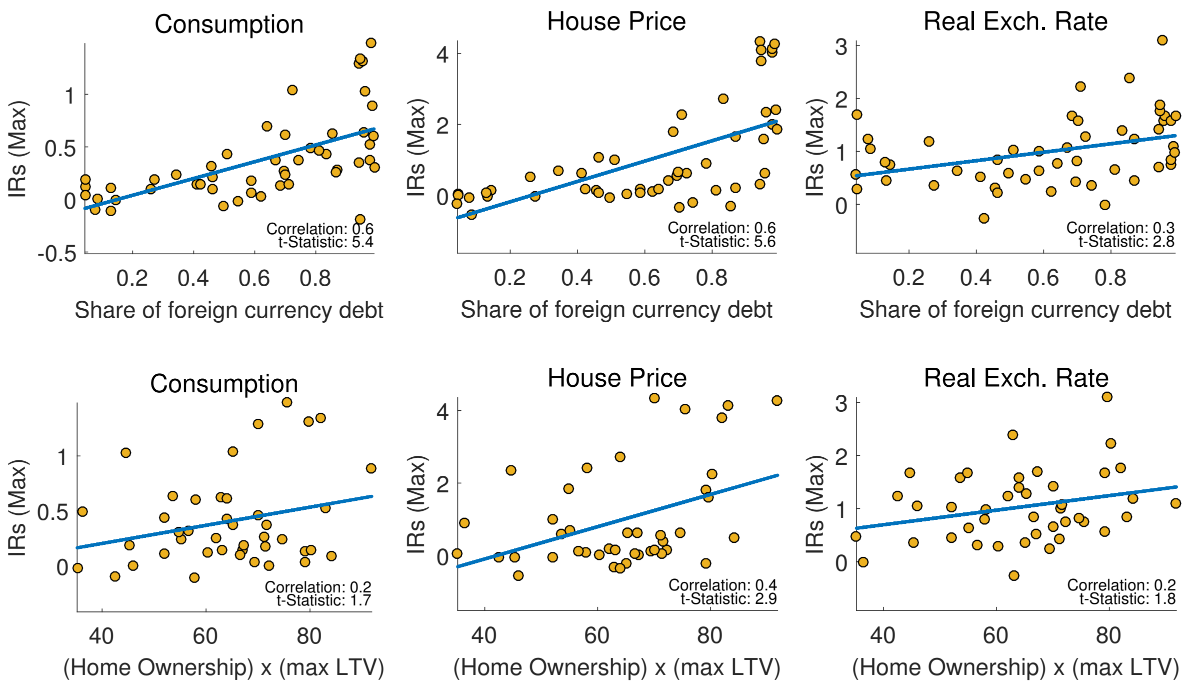
where $f_t$ is borrowing, $q_t h_t$ is the value of the house, and $\theta$ represents the maximum admissible loan-to-value (LTV) ratio (see Kiyotaki and Moore, 1997). When this constraint is binding, an increase in the house price leads to an increase in the borrowing capacity through increased collateral value. However, if borrowing is denominated in foreign currency, an exchange rate appreciation can also play a similar role by increasing the foreign currency value of $q_t h_t$. In what follows, we explore the pattern of cross country differences in sensitivity to our international credit supply shock.

Our conjecture is that the intensity of each country's response to the global liquidity shock is related to the share of foreign currency liabilities and the maximum LTV limit prevailing in that country. Higher LTV allows for higher leverage at the borrower level. All else equal, foreign currency borrowing is cheaper the more appreciated is the exchange rate. We therefore relate the country peak impulse response of consumption, house prices, and exchange rates to these two characteristics, which also have a counterpart in our model below.

For consistency with the VAR, we compute the share of foreign currency liabilities using a confidential version of the BIS data set that permits to sort out different currencies. The share is computed as cross-border bank claims in foreign currency over total cross-border bank claims. We obtain data on maximum LTVs from Cerutti et al. (2015) and we weight them by the share of home-ownership that we obtain from HOFINET. We weight with home-ownership to capture both availability of leverage in the local financial system and availability of housing collateral.

The responses of consumption, the exchange rate, and house prices are reported in Figure 7

**Figure 7** Cross country differences in vulnerability to international credit supply shock




Note. The upper panels plots the peak impulse response to the global liquidity shock (vertical axis, *IRs (max)*) against the share of foreign currency liabilities computed using BIS banking data (upper horizontal axis). The lower panels plot the same peak impulse responses (vertical axis, *IRs (max)*) against the maximum LTV weighted by the homeownership ratio (lower panel horizontal axis, *Home Ownership* × *max LTV*). Results robust to using average response over the first 4 quarters in the Appendix.

(together with the correlation coefficient and the associated t-statistic). Figure 7 shows that the impact of the shock in countries with a high share of foreign currency liabilities is stronger than in countries with a low share of foreign currency liabilities. The correlation for the consumption responses is very high, at 0.6 and highly statistically significant. Each country's share of foreign currency liabilities is also associated with the intensity of the asset price appreciations, more so for house prices (correlation of 0.6) than for the exchange rate (correlation of 0.3). The intensity of the country-specific responses to the global liquidity shock is also related to the maximum LTV (weighted by the home-ownership ratio), even though the correlation coefficients are smaller and less strongly statistically significant than for the share of foreign currency liabilities.

Summarizing, we found that an international credit supply shock has a expansionary trasmission and explain a significant share of the variance decomposition of the macroeconomic dynamics. In the cross country dimension, we also find that higher vulnerability to the shock is associated with higher share of foreign currency liabilities and higher access to leverage via housing collateral.

## 5 Conclusions

In this paper we documented that boom-bust in capital flows are expansionary and associated with appreciating asset prices. We then identified a shock to the international supply of credit in a panel VAR empirical framework, consistent with a simple general equilibrium model of of collateralized borrowing in foreign currency. Consistent with the predictions of the model that we set up, we find that this shocks can trigger a consumption boom, amplified by collateral value inflation, the more so the higher the share of foreign currency liability and the higher the maximum LTV in the domestic credit market. Empirically, we also document that this shock explains about twice as much consumption variance as a US monetary shock.

Our findings have policy implications and suggest important areas for future research. As Rey (2013, 2016) noted, flexible exchange rates may not have insulated individual economies from capital flow shocks as much as traditional theory would have predicted, 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 tool in helping to 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 stock and house prices are relaxing domestic borrowing constraints, macro-prudential tools, such as loan-to-value (LTV) requirements on individual borrowers or leverage caps on 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 these issues for future research.

## References


Aizenman, J. and Y. Jinjarak (2009): "Current account patterns and national real estate markets," *Journal of Urban Economics*, 66, 75–89.

Almeida, H., M. Campello, and C. Liu (2006): "The Financial Accelerator: Evidence from International Housing Markets," *Review of Finance*, 10, 321–352.

Bekaert, G., M. Hoerova, and M. Lo Duca (2013): "Risk, uncertainty and monetary policy," *Journal of Monetary Economics, Elsevier*, 60, 771–788.

Benigno, G., N. Converse, and L. Fornaro (2015): "Large capital inflows, sectoral allocation, and economic performance," *Journal of International Money and Finance*, 55, 60–87.

Berger, D., V. Guerrieri, G. Lorenzoni, and J. Vavra (2015): "House Prices and Consumer Spending," NBER Working Papers 21667, National Bureau of Economic Research, Inc.

Blanchard, O., J. D. Ostry, A. R. Ghosh, and M. Chamon (2015): "Are Capital Inflows Expansionary or Contractionary? Theory, Policy Implications, and Some Evidence," NBER Working Papers 21619, National Bureau of Economic Research, Inc.

Boz, E. and E. G. Mendoza (2014): "Financial innovation, the discovery of risk, and the U.S. credit crisis," *Journal of Monetary Economics*, 62, 1–22.

Brunnermeier, M. and Y. Sannikov (2014): "A Macroeconomic Model with a Financial Sector," *American Economic Review*, 104, 379–421.

Bruno, V. and H. S. Shin (2015): "Cross-Border Banking and Global Liquidity," *Review of Economic Studies*, 82, 535–564.

Caballero, J. A. (2014): "Do Surges in International Capital Inflows Influence the Likelihood of Banking Crises?" *The Economic Journal*, -, 1–36.

Calza, A., T. Monacelli, and L. Stracca (2013): "Housing Finance And Monetary Policy," *Journal of the European Economic Association*, 11, 101–122.

Cardarelli, R., S. Elekdag, and M. A. Kose (2010): "Capital inflows: Macroeconomic implications and policy responses," *Economic Systems*, 34, 333–356.

Cerutti, E. M., J. Dagher, and G. Dell'Ariccia (2015): "Housing Finance and Real-Estate Booms; A Cross-Country Perspective," IMF Staff Discussion Notes 15/12, International Monetary Fund.

Cespedes, L. F., R. Chang, and A. Velasco (2017): "Financial intermediation, real exchange rates, and unconventional policies in an open economy," *Journal of International Economics, forthcoming.*

Chari, V., P. J. Kehoe, and E. R. McGrattan (2005): "Sudden Stops and Output Drops," *American Economic Review*, 95, 381–387.

Favilukis, J., S. C. Ludvigson, and S. Van Nieuwerburgh (2017): "The Macroeconomic Effects of Housing Wealth, Housing Finance, and Limited Risk-Sharing in General Equilibrium," *Journal of Political Economy, forthcoming*, -, –.

Fernandez, A., A. Rebucci, and M. Uribe (2015): "Are capital controls countercyclical?" *Journal of Monetary Economics*, 76, 1–14.

Ferrero, A. (2015): "House Price Booms, Current Account Deficits, and Low Interest Rates," *Journal of Money, Credit and Banking*, 47, 261–293.

Forbes, K., D. Reinhardt, and T. Wieladek (2016): "The Spillovers, Interactions, and (Un)Intended Consequences of Monetary and Regulatory Policies," NBER Working Papers 22307, National Bureau of Economic Research, Inc.

Gabaix, X. and M. Maggiori (2014): "International Liquidity and Exchange Rate Dynamics," NBER Working Papers 19854, National Bureau of Economic Research, Inc.

Gertler, M. and P. Karadi (2015): "Monetary Policy Surprises, Credit Costs, and Economic Activity," *American Economic Journal: Macroeconomics*, 7, 44–76.

Gete, P. (2009): "Housing Markets and Current Account Dynamics," MPRA Paper 20957, University Library of Munich, Germany.

Gourinchas, P.-O., R. Valdes, and O. Landerretche (2001): "Lending Booms: Latin America and the World," *Economia*, 1, 47–100.

Gurkaynak, R., B. Sack, and E. Swanson (2005): "Do Actions Speak Louder than Words? The Response of Asset Prices to Monetary Policy Actions and Statements," *International Journal of Central Banking*, 1, 55–93.

He, Z. and A. Krishnamurthy (2013): "Intermediary Asset Pricing," *American Economic Review*, 103, 732–770.

Jappelli, T. and M. Pagano (1989): "Consumption and Capital Market Imperfections: An International Comparison," *American Economic Review*, 79, 1088–1105.

Jermann, U. and V. Quadrini (2012): "Macroeconomic Effects of Financial Shocks," *American Economic Review*, 102, 238–71.

Justiniano, A., G. E. Primiceri, and A. Tambalotti (2015): "Credit Supply and the Housing Boom," NBER Working Papers 20874, National Bureau of Economic Research, Inc.

Kaplan, G., K. Mitman, and G. L. Violante (2016): "Non-durable Consumption and Housing Net Worth in the Great Recession: Evidence from Easily Accessible Data," NBER Working Papers 22232, National Bureau of Economic Research, Inc.

Kiyotaki, N. and J. Moore (1997): "Credit Cycles," *Journal of Political Economy*, 105, 211–48.

Mendoza, E. G. and M. E. Terrones (2008): "An Anatomy Of Credit Booms: Evidence From Macro Aggregates And Micro Data," NBER Working Papers 14049, National Bureau of Economic Research, Inc.

Mertens, K. and M. O. Ravn (2013): "The Dynamic Effects of Personal and Corporate Income Tax Changes in the United States," *American Economic Review*, 103, 1212–47.

Mian, A., A. Sufi, and E. Verner (2016): "Household Debt and Business Cycles Worldwide," Unpublished, Princeton University.

Pesaran, M. H. and R. Smith (1995): "Estimating long-run relationships from dynamic heterogeneous panels," *Journal of Econometrics*, 68, 79–113.

Pesaran, M. H., R. Smith, and K. Im (1996): "Dynamic Linear Models for Heterogenous Panels," in *The Econometrics of Panel Data*, ed. by L. Mtys and P. Sevestre, Kluwer Academic Publishers, Dordrecht, The Netherlands, chap. 8, 145–195.

Rey, H. (2013): "Dilemma not trilemma: the global cycle and monetary policy independence," *Proceedings - Economic Policy Symposium - Jackson Hole*, -, 1–2.

——— (2016): "International Channels of Transmission of Monetary Policy and the Mundellian Trilemma," *IMF Economic Review*, 64, 6–35.

Sims, C. A., J. H. Stock, and M. W. Watson (1990): "Inference in Linear Time Series Models with Some Unit Roots," *Econometrica*, 58, 113–44.

Stock, J. and M. Watson (2012): "Disentangling the Channels of the 2007-2009 Recession," *Brookings Papers on Economic Activity*, Spring, 81–135.

Stock, J. H., J. H. Wright, and M. Yogo (2002): "A Survey of Weak Instruments and Weak Identification in Generalized Method of Moments," *Journal of Business & Economic Statistics*, 20, 518–29.

Sutherland, A. (2005): "Incomplete pass-through and the welfare effects of exchange rate variability," *Journal of International Economics*, 65, 375–399.

# A Appendix. Data Sources

This appendix provides a description of the data used in the empirical analysis and on their 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 data 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 A.1.

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

**Exchange rate vis-à-vis US dollar**. US dollars per unit of domestic currency. A real exchange rate is obtained with US and domestic consumer price inflation. Source: Datastream.

**Real effective exchange rate**. Index (such that a decline of the index 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

**Table A.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 the extended appendix on the sources of house price series extended with historical data.

# B Appendix. Derivation of the Simplified Model

Using the assumptions discussed in the text, this section derives the equilibrium in the goods and credit market of the simplified model.

**Goods market and exchange rate**. We start from the Home goods market equilibrium in period $t = 1$

$$ny_{H1} = nc_{H1} + (1-n)c^*_{H1}. \tag{B.1}$$

The demand for Home goods by Home and Foreign households are

$$c_{H1} = \alpha p_{H1}^{-1} c_t \qquad \text{and} \qquad c^*_{H1} = \alpha^* p_{H1}^{*-1} c^*_t. \tag{B.2}$$

The Home and Foreign relative price of Home goods is a function of the terms of trade

$$p_{H1} = \tau_1^{\alpha-1} \qquad \text{and} \qquad p^*_{H1} = \tau_1^{\alpha^*-1}. \tag{B.3}$$

Replacing the last two sets of expressions in the Home goods market equilibrium yields

$$ny_{H1} = n\alpha\tau_1^{1-\alpha} c_1 + (1-n)\alpha^*\tau_1^{1-\alpha^*} c^*_1, \tag{B.4}$$

which we can rewrite as

$$y_{H1} = \alpha\tau_1^{1-\alpha} c_1 + \frac{1-n}{n}\alpha^*\tau_1^{1-\alpha^*} c^*_1. \tag{B.5}$$

The small open economy assumption implies that $c^*_1 = y^*_{F1}$ is exogenous. As mentioned earlier, we also assume that the weight on Home goods in the consumption bundle are a function of the country size and of the degree of openness $\lambda \in (0,1)$ according to

$$\alpha = 1 - (1-n)\lambda \qquad \text{and} \qquad \alpha^* = n\lambda.$$

We replace these relations into the Home goods market equilibrium and take the limit for $n \to 0$ to obtain

$$y_{H1} = (1-\lambda)\tau_1^{\lambda} c_1 + \lambda\tau_1 y^*_{F1}. \tag{B.6}$$

Given a zero initial credit, the law of motion of debt from the Home household budget constraint gives

$$c_1 = s_1 f_1 + p_{H1} y_{H1}. \tag{B.7}$$

Using the small open economy assumption, the relation between the real exchange rate, terms of trade, and relative prices is

$$s_t = \tau_t^{1-\lambda} \qquad \text{and} \qquad p_{H1} = \tau_1^{-\lambda}. \tag{B.8}$$

We can then rewrite the first period consumption as

$$c_1 = \tau_1^{1-\lambda} f_1 + \tau_1^{-\lambda} y_{H1}. \tag{B.9}$$

We replace this expression in the Home goods market equilibrium and solve for the terms of trade to obtain

$$\tau_1 = \frac{\lambda y_{H1}}{\lambda y_{F1}^* + (1-\lambda) f_1},$$

and thus

$$s_1 = \left[ \frac{\lambda y_{H1}}{\lambda y_{F1}^* + (1-\lambda) f_1} \right]^{1-\lambda}. \tag{B.10}$$

Intuitively, higher foreign debt implies higher Home demand, and hence an appreciation of the terms of trade (and consequently of the real exchange rate). Because of the two-period horizon, $f_2 = 0$. Therefore, the law of motion of debt in period 2 is

$$c_2 = p_{H2} y_{H2} - R_1^b s_2 f_1.$$

We substitute in the goods market equilibrium (together with $s_2 = \tau_2^{1-\lambda}$ and $p_{H2} = \tau_2^{-\lambda}$) to get an expression for the terms of trade and the real exchange rate

$$\tau_2 = \frac{\lambda y_{H2}}{\lambda y_{F2}^* - (1-\lambda) R_1^b f_1}, \tag{B.11}$$

and

$$s_2 = \left[ \frac{\lambda y_{H2}}{\lambda y_{F2}^* - (1-\lambda) R_1^b f_1} \right]^{1-\lambda}. \tag{B.12}$$

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.

**Credit supply**. Next, we can characterize the equilibrium in the credit market. We start with the credit supply. First of all, risk neutrality implies

$$R^d = \frac{1}{\beta^*} \qquad \text{and} \qquad R^e = \frac{1 + \psi'(e)}{\beta^*}.$$

Substituting these two expressions in the optimal pricing condition for financial intermediaries, together with the binding capital constraint yields an expression for credit supply

$$R^b = \frac{1}{\beta^*} \left[ 1 + \chi \psi' \left( \frac{n}{1-n} \chi f_1 \right) \right].$$

As we take the limit for $n \to 0$, we use the assumption about the functional form of the equity adjustment cost, which gives

$$R^b = \frac{1+\zeta\chi}{\beta^*}.$$

**Credit demand**. We start from the optimal choice of housing services. If the borrowing constraint is not binding, the equilibrium conditions for domestic households boil down to$q = \kappa$, $\mu = 0$, $s_1 f_1 < \theta q$ and

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

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

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

We plug this expression in the house price equation to obtain

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

Solving for $q$ and plugging into the borrowing constraint yields

$$s_1 f_1 = \frac{\theta\kappa}{1 - \theta + \theta\beta R^b s_2/s_1}. \tag{B.15}$$

We solve this equation for the return on loans to get

$$R^b = \frac{1}{\beta}\frac{s_1}{s_2}\left(\frac{\kappa}{s_1 f_1} - \frac{1-\theta}{\theta}\right).$$

This expression completes the characterization of the equilibrium in the simplified model presented in the text.

# C Appendix. Log-linear Solution of the Simplified Model

In this section we show that the credit demand schedule is downward sloping in the neighborhood of a steady state in the region where the collateral constraint is binding.

**Goods market and exchange rate**. Start with period 1 and rewrite $s_1$ as

$$s_1 = \left(\frac{y^*_{F1}}{y_{H1}} + \frac{1-\lambda}{\lambda}\frac{f_1}{y_{H1}}\right)^{\lambda-1}.$$

The linear approximation around the steady state is

$$s_1 = \bar{s}_1 - (1-\lambda)\left(\frac{y^*_{F1}}{y_{H1}} + \frac{1-\lambda}{\lambda}\frac{\bar{f}_1}{y_{H1}}\right)^{\lambda-2}\frac{1-\lambda}{\lambda}\frac{1}{y_{H1}}\left(f_1 - \bar{f}_1\right)$$

Now note that $s_1^{\frac{1}{1-\lambda}} = \left(\frac{y_{F1}^*}{y_{H1}} + \frac{1-\lambda}{\lambda}\frac{f_1}{y_{H1}}\right)^{-1}$, so that we can write

$$s_1 - \bar{s}_1 = -\frac{(1-\lambda)^2}{\lambda y_{H1}} \bar{s}_1^{1+\frac{1}{1-\lambda}} \left(f_1 - \bar{f}_1\right)$$

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

$$\hat{s}_1 = -\frac{(1-\lambda)^2}{\lambda y_{H1}} \bar{s}_1^{\frac{1}{1-\lambda}} \bar{f}_1 \hat{f}_1$$

Now consider period 2 and rewrite $s_2$ as

$$s_2 = \left(\frac{y_{F2}^*}{y_{H2}} + \frac{1-\lambda}{\lambda}\frac{R_1^b f_1}{y_{H2}}\right)^{\lambda-1}.$$

The linear approximation around the steady state is

$$s_2 = \bar{s}_2 + (1-\lambda)\left(\frac{y_{F2}^*}{y_{H2}} + \frac{1-\lambda}{\lambda}\frac{R_1^b f_1}{y_{H2}}\right)^{\lambda-2} \frac{1-\lambda}{\lambda}\frac{1}{y_{H2}}\left[R_1^b\left(f_1 - \bar{f}_1\right) + f_1\left(R_1^b - \bar{R}_1^b\right)\right]$$

Now note that $s_2^{\frac{1}{1-\lambda}} = \left(\frac{y_{F2}^*}{y_{H2}} + \frac{1-\lambda}{\lambda}\frac{R_1^b f_1}{y_{H2}}\right)^{-1}$ so that we can write

$$s_2 - \bar{s}_2 = \frac{(1-\lambda)^2}{\lambda y_{H2}} \bar{s}_2^{1+\frac{1}{1-\lambda}} \left[\bar{R}_1^b\left(f_1 - \bar{f}_1\right) + \bar{f}_1\left(R_1^b - \bar{R}_1^b\right)\right]$$

and dividing by $\bar{s}_2$, $\bar{f}_1$, and $\bar{R}_1^b$ we get

$$\hat{s}_2 = \frac{(1-\lambda)^2}{\lambda y_{H2}} \bar{s}_2^{\frac{1}{1-\lambda}} \left[\bar{f}_1\bar{R}_1^b\frac{\left(f_1 - \bar{f}_1\right)}{\bar{f}_1} + \bar{f}_1\bar{R}_1^b\frac{\left(R_1^b - \bar{R}_1^b\right)}{\bar{R}_1^b}\right]$$

that is

$$\hat{s}_2 = \frac{(1-\lambda)^2}{\lambda y_{H2}} \bar{s}_2^{\frac{1}{1-\lambda}} \bar{f}_1\bar{R}_1^b\left(\hat{f}_1 + \hat{R}^b\right).$$

**Supply**. The linear approximation of the supply function around the steady state is

$$R^b = \bar{R}^b + \frac{\zeta}{\beta^*}(\chi - \bar{\chi})$$

Now move $\bar{R}^b$ on the left hand side and divide by $\bar{R}^b$ to get

$$\frac{R^b - \bar{R}^b}{\bar{R}^b} = \frac{\zeta\bar{\chi}}{\beta^*\bar{R}^b}\frac{\chi - \bar{\chi}}{\bar{\chi}}$$

or

$$\hat{R}^b = \frac{\zeta\bar{\chi}}{1+\zeta\bar{\chi}}\hat{\chi}.$$

**Demand**. We consider the binding region only ($s_1 f_1 = \theta q$). The demand function can be re-written more conveniently as

$$R^b = \frac{1}{\beta}\left(\frac{\kappa}{s_2 f_1} - \frac{s_1}{s_2}\frac{1-\theta}{\theta}\right)$$

The linear approximation of the demand function around the steady state is

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

and dividing by $\bar{R}_1^b$, $\bar{f}_1$, and $\bar{s}_2$ we get

$$\hat{R}^b = -\frac{\kappa}{\bar{R}^b \beta}\frac{1}{\bar{s}_2 \bar{f}_1}\left(\hat{f}_1 + \hat{s}_2\right) - \frac{\bar{s}_1}{\beta \bar{s}_2}\frac{1-\theta}{\theta}\left(\hat{s}_1 - \hat{s}_2\right)$$

To summarize, equilibrium in the international credit market is determined by:

1. SUPPLY

$$\hat{R}^b = \frac{\zeta \bar{\chi}}{1 + \zeta \bar{\chi}}\hat{\chi}. \tag{C.1}$$

2. DEMAND

$$\hat{R}^b = -\frac{\kappa}{\bar{R}^b \beta}\frac{1}{\bar{s}_2 \bar{f}_1}\left(\hat{f}_1 + \hat{s}_2\right) - \frac{\bar{s}_1}{\beta \bar{s}_2}\frac{1-\theta}{\theta}\left(\hat{s}_1 - \hat{s}_2\right) \quad \text{if} \;\; s_1 f_1 = \theta q \tag{C.2}$$

3. REAL EXCHANGE RATE

$$\hat{s}_1 = -\frac{(1-\lambda)^2}{\lambda y_{H1}}\bar{s}_1^{\frac{1}{1-\lambda}}\bar{f}_1 \hat{f}_1 \tag{C.3}$$

$$\hat{s}_2 = \frac{(1-\lambda)^2}{\lambda y_{H2}}\bar{s}_2^{\frac{1}{1-\lambda}}\bar{f}_1 \bar{R}_1^b\left(\hat{f}_1 + \hat{R}^b\right) \tag{C.4}$$

We can plug the expression for $\hat{s}_2$ in the demand function to recover an expression for the demand function in the $\{\hat{R}^b, \hat{f}_1\}$ space. We make a further simplifying assumption and take the limiting case where $\theta \to 1$. Solving for $\hat{R}^b$ yields

$$\hat{R}^b = -\frac{\kappa}{\beta \bar{R}^b \bar{s}_2 \bar{f}_1}\frac{\beta \lambda y_{H2} + \beta (1-\lambda)^2 \bar{f}_1 \bar{R}_1^b \bar{s}_2^{\frac{1}{1-\lambda}}}{\beta \lambda y_{H2} + \kappa (1-\lambda)^2 \bar{s}_2^{\frac{\lambda}{1-\lambda}}}\hat{f}_1.$$

As the coefficient in front of credit in the last expression is always positive, the demand schedule, in a neighborhood of the steady state with binding collateral constraint, is downward sloping in the space $\{\hat{R}^b, \hat{f}_1\}$.

# D Appendix. Robustness

## D.1 Identification of Global Liquidity Shock with External Instruments

In this Appendix we show that our results are robust to the adoption of an alternative (and complementary) strategy for the identification of a global liquidity shock. Specifically, we apply the external instruments identification approach proposed by Stock and Watson (2012) and Mertens and Ravn (2013) (technical details reported below).

The main differences relative to the specification considered in the main text are as follows. First, we exclude leverage from the vector of endogenous variables (as we use it as an external instrument). Second, we attenuate the influence of country-specific pull factors by aggregating banking flows across all sending countries. As long as countries are relatively small, innovations to this variable cannot be contaminated by domestic shocks. Third, to rule out that demand factors common among all countries in the sample, or that any particular country affects the aggregate measure, we apply the external instruments identification approach proposed by Stock and Watson (2012) and Mertens and Ravn (2013).

The candidate instruments that we consider are the log of US broker-dealers' leverage, as well as the US effective federal funds rate, the log of US M2, the slope of the US yield curve, the VIX index, and the TED spread. Note that, since the candidate instruments are all US variables, we exclude the US from the PVAR.

As in the main text all variables considered enter in log-levels, except the interest rate, which enter in levels, and the lag length is set to 1. Equipped with the reduced-form residuals from the OLS estimation of this new VAR system country-by-country, we can regress them on the above instruments (i.e., the first stage regressions described by equation (E.6) below).[19] For each country, we select the instrument that maximizes the $F$-statistic associated with the first stage regression, and drop from the analysis all countries for which the $F$-statistic of the first stage regression is below 5, leaving us with 33 countries out of the 49 for which we estimated the VAR model.[20,21] For each country-specific VAR, both the $R^2$ and the $F$-statistic associated with the first stage regressions are reasonably high, averaging 0.73 and 8.7 across all countries, respectively.

The impulse responses, reported in Figure D.1, show that our results are robust to this alternative identification strategy.

## D.2 Heterogeneity of The Impulse Responses

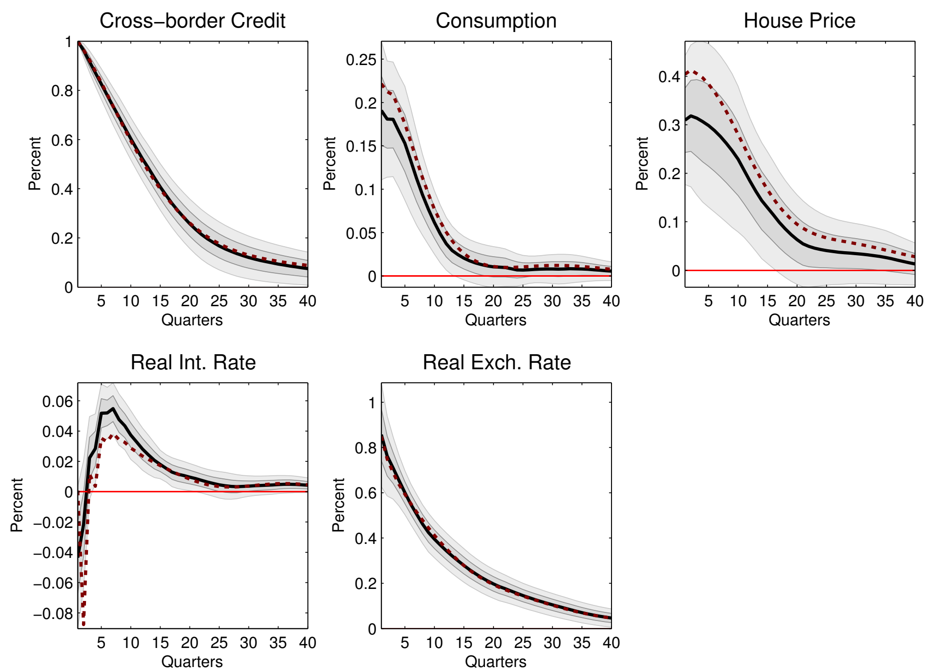
We show here that the results we obtain on the heterogeneity of the impulse responses hold also when we use a different statistic of the impulse response functions. Specifically, Figure D.2 reports

[19] We enter the instruments both in levels and first differences.

[20] To check the robustness of our results, in the Appendix we conduct two additional exercises. First we keep all 48 countries in the mean group estimator irrespective of their $F$-statistic. Second, we drop all countries for which the $F$-statistic is smaller than 10 (as recommended by Stock et al. (2002) to avoid problems related to weak instruments). The results from these exercises display little difference from our baseline.

[21] Specifically, we drop the following countries: China, Czech Republic, Israel, Latvia, Lithuania, Luxembourg, Malta, Peru, Poland, Russia, Serbia, Slovenia, Slovakia and South Africa.

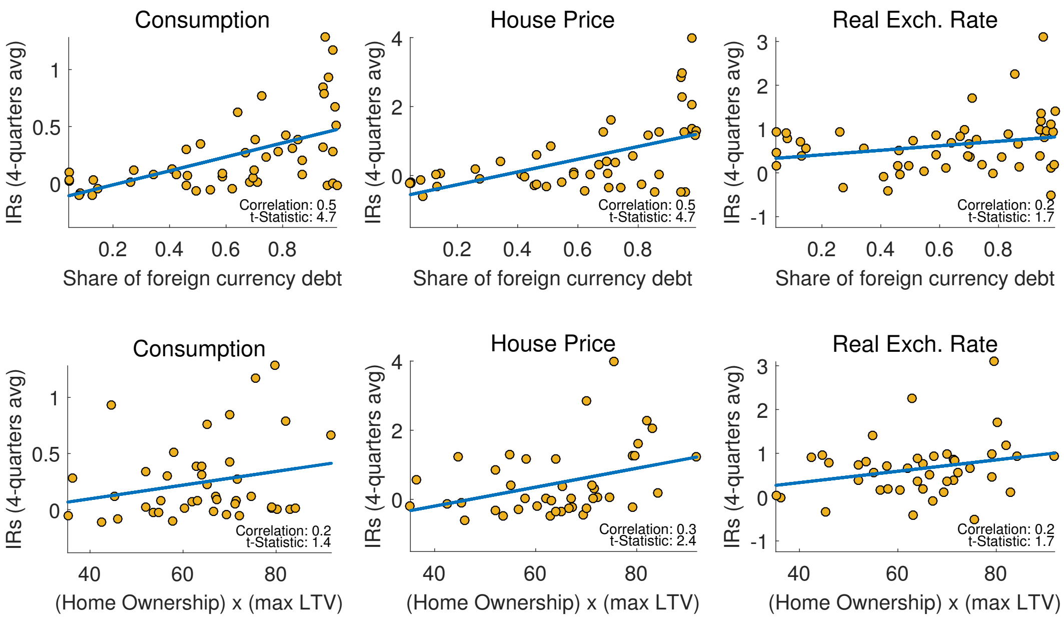
**Figure D.1** IRFs to a Global Liquidity Shock – External Instruments Approach




Note. Censored impulse responses to a shock to global liquidity that raises cross-border credit by 1 percent. The dark and light shaded areas are the one and two standard deviation confidence intervals. The dashed line reports the uncensored impulse responses.

the scatter plot of the country-specific IRFs (with the share of foreign currency liabilities and the maximum LTV limit, respectively) using the average of the first 4 quarters of the IRFs (instead of the peak response). Figure D.2 shows that also in this case the intensity of the country-specific responses are associated with the determinants that we consider.

**Figure D.2** Impulse Response Heterogeneity: The Role Share of Foreign Currency Debt & LTV Limits




Note. On the horizontal axis is the share of foreign currency debt computed using BIS banking data. On the vertical axis is the peak impulse response to the global liquidity shock in the VAR.

# E Appendix. External Instruments Identification: Algebra

Consider the following reduced form VAR (with only one lag and no constant or trend for simplicity):

$$x_t = Fx_{t-1} + u_t, \tag{E.1}$$

where $x_t$ is a $(m \times 1)$ vector of endogenous variables; $F$ is a $(m \times m)$ matrix of coefficients; and $u_t$ is a $(m \times 1)$ vector of residuals with variance-covariance matrix $\Sigma_u$. The objective is to recover the structural form of the above VAR, i.e.:

$$Ax_t = Bx_{t-1} + \varepsilon_t, \tag{E.2}$$

where $A$ and $B$ are $(m \times m)$ matrices of coefficients; and $\varepsilon_t$ is an $(m \times 1)$ vector of structural residuals with variance-covariance matrix $\Sigma_\varepsilon = I$. Note that the reduced form residuals are a linear combination of the structural residuals. Specifically, letting $\tilde{A} = A^{-1}$, we have that $u_t = \tilde{A}\varepsilon_t$.

If we partition the vector of endogenous variables $x_t$ as $(GL_t', x_{p,t}')'$ —where $GL_t$ is global liquidity and $x_{p,t}$ is the $(m-1 \times 1)$ vector of remaining endogenous variables— we can re-write the reduced-form VAR as:

$$\begin{bmatrix} GL_t \\ x_{p,t} \end{bmatrix} = \begin{bmatrix} f_{11} & f_{12} \\ f_{21} & f_{22} \end{bmatrix} \begin{bmatrix} GL_{t-1} \\ x_{p,t-1} \end{bmatrix} + \begin{bmatrix} \tilde{a}_{11} & \tilde{a}_{12} \\ \tilde{a}_{21} & \tilde{a}_{22} \end{bmatrix} \begin{bmatrix} \varepsilon_t^{GL} \\ \varepsilon_t^{x_p} \end{bmatrix}, \tag{E.3}$$

where $f_{11}$ and $\tilde{a}_{11}$ are scalars; $f_{12}$ and $\tilde{a}_{12}$ are $(1 \times m-1)$ vectors; $f_{21}$ and $\tilde{a}_{21}$ are $(m-1 \times 1)$ vectors; $f_{22}$ and $\tilde{a}_{22}$ are $(m-1 \times m-1)$ matrices; and $\varepsilon_t^{GL}$ and $\varepsilon_t^{x_p}$ are the structural residuals associated to global liquidity and the remaining endogenous variables, respectively.

For the sake of argument, let's assume that the structural matrix $\tilde{A}$ is known. Then, we would be able to compute the impulse response to a global liquidity shock. Specifically, the contemporaneous responses of $GL$ and $x_p$ to a unit shock to $\varepsilon^{GL}$ would be given by:

$$\begin{bmatrix} \mathcal{IRF}_0^{GL} \\ \mathcal{IRF}_0^{x_p} \end{bmatrix} = \begin{bmatrix} \tilde{a}_{11} \\ \tilde{a}_{21} \end{bmatrix},$$

which, since the model is linear, can be normalized to:

$$\begin{bmatrix} \mathcal{IRF}_0^{GL} \\ \mathcal{IRF}_0^{x_p} \end{bmatrix} = \begin{bmatrix} 1 \\ \frac{\tilde{a}_{21}}{\tilde{a}_{11}} \end{bmatrix}. \tag{E.4}$$

Finally, the impulse response functions at longer horizons can be computed as:

$$\mathcal{IRF}_n = F^{n-1} \cdot \mathcal{IRF}_{n-1} \qquad \text{for} \quad n = 2, ..., N. \tag{E.5}$$

Note that if we are interested in computing the impulse responses to the global liquidity shock only we do not need to know all the coefficients of $\tilde{A}$, but rather only the elements of the first column of $\tilde{A}$, namely $\tilde{a}^1$.

We now consider the case of $\tilde{A}$ unknown. To achieve identification, we follow the external instrument identification approach pioneered by Stock and Watson (2012) and Mertens and Ravn (2013). Let $u^{GL}$ and $u^{x_p}$ be the OLS estimates of the reduced form residuals in (E.1). Also, let $Z_t$ be a $(z \times 1)$ vector of instrumental variables that satisfy:

$$\begin{aligned} \mathbb{E}\left[\varepsilon^{GL} Z_t'\right] &= \phi, \\ \mathbb{E}[\varepsilon^{x_p} Z_t'] &= 0, \end{aligned}$$

i.e., the instruments are correlated with the global liquidity shock ($\varepsilon^{GL}$) but are orthogonal to all the other domestic shocks (the elements of $\varepsilon^{x_p}$). We can obtain consistent estimates of $\tilde{a}^1$ from the two-stage least squares regression of $u^{x_p}$ on $u^{GL}$ using $Z_t$ as instruments. In other words, since the reduced form residuals of the global liquidity equation ($u_t^{GL}$) are an imperfect measure of true structural shock ($\varepsilon^{GL}$), in the first stage we regress them on the set of instruments ($Z_t$):

$$u_t^{GL} = \beta Z_t + \xi_t, \tag{E.6}$$

to construct the fitted values $\hat{u}_t^{GL}$. Then we regress the reduced form residuals of the domestic equations ($u_t^{x_p}$) on the fitted values ($\hat{u}_t^{GL}$) to get a consistent estimate of the ratio $\tilde{a}_{21}/\tilde{a}_{11}$:

$$u_t^{x_p} = \frac{\tilde{a}_{21}}{\tilde{a}_{11}} \hat{u}_t^{GL} + \zeta_t, \tag{E.7}$$

where note that $\hat{u}_t^{GL}$ is orthogonal to $\zeta_t$ under the assumption that $E[\varepsilon^{x_p} Z_t'] = 0$.

Finally, we can use the OLS estimates of the matrix $F$ to compute the impulse response functions of all variables to a global liquidity shock using the formula in (E.5).