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Non-US global banks and dollar (co-)dependence: how housing markets became internationally synchronized

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Abstract

US net capital inflows drive the international synchronization of house price growth. An increase (decrease) in US net capital inflows improves (tightens) US dollar funding conditions for non-US global banks, leading them to increase (decrease) foreign lending to third-party borrowing countries. This induces a synchronization of lending across borrowing countries, which translates into an international synchronization of mortgage credit growth and, ultimately, house price growth. Importantly, this synchronization is driven by non-US global banks' common but heterogenous exposure to US dollar funding conditions, not by the common exposure of borrowing countries to non-US global banks. Our results identify a novel channel of international transmission of US dollar funding conditions: As these conditions vary over time, borrowing country pairs whose non-US global creditor banks are more dependent on US dollar funding exhibit higher house price synchronization.

Key words: house price synchronization, US dollar funding, global US dollar cycle, global imbalances, capital inflows, global banks, global banking network

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The authors are affiliated with the BIS, the University of Zurich (UZH) and the Graduate Institute Geneva, respectively. Hoffmann is also affiliated with UZH's Research Priority Program in Financial Regulation, the UZH Center for Urban and Real Estate Management (CUREM) and is a fellow of CESifo Munich and the Centre for Applied Macroeconomic Analysis at the Australian National University. Raabe is also affiliated with CUREM. The views in this paper are those of the authors and do not reflect those of the institutions with which they are affiliated. Contact: torsten.ehlers@bis.org, mathias.hoffmann@econ.uzh.ch, alexander.raabe@graduateinstitute.ch

1 Introduction

House prices co-move considerably across country pairs and time, as shown in Figure (1). Measured as the pairwise product of the four quarter ahead country-level house price growth in the period 1970 to 2015, international house price synchronization reached significant peaks in 1971-73, 1986-88 and in the 2000s in the run-up to the Global Financial Crisis. Over the same period, the dispersion of house price synchronization across country pairs measured by the interquartile range varies significantly. In most countries, housing wealth represents the largest component of net household wealth and it is the single most important collateralizable asset. Identifying the drivers of the international synchronization of house prices is therefore paramount for understanding macro-financial linkages at the global level.

This paper highlights a new international spillover channel through which variations in US dollar funding conditions affect the international synchronization of house prices. Specifically, following Hoffmann and Stewen (2020), we argue that net capital flows into the US represent a positive refinancing shock to the US financial system, leading to improved funding conditions of US banks. In their ability to explain the dynamics of non-US global lending and the international synchronization of house prices, we find that US net capital inflows dominate other price-based indicators of US dollar funding conditions proposed in the literature. The improvement in refinancing conditions coming from a more ample supply of US dollars not only benefits banks domiciled in the US, but also non-US banks seeking to raise funding from the US financial system, and thus funding denominated in US dollars. Non-US banks significantly depend on funding in US dollars to finance the issuance of US dollar-denominated loans. Figure (2) reveals that their share of liabilities denominated in US dollars stands at 45 percent on average. This dollar dependence is what makes non-US banks susceptible to variations in US dollar funding conditions induced by US net capital inflows. An increase in US net capital inflows loosens non-US banks' leverage constraints and enables them to provide more credit to counterparty banks in various foreign borrowing countries, consistent with the double-decker structure of the global banking system first emphasized by Bruno and Shin (2014) and also highlighted in Hale and Obstfeld (2016). These counterparty banks absorb the foreign credit, and channel the additional funds obtained from abroad into domestic mortgage credit, resulting in upward pressure on house prices. As this pattern replicates itself across borrowing countries, house prices become internationally synchronized. Accordingly, a decrease in US net capital inflows also results in higher house price synchronization.

This mechanism entails that the synchronization of house prices between two arbitrary borrowing countries hinges on the extent to which their respective non-US global creditor banks on average depend on US dollar funding. This is what we call dollar co-dependence. Hence, the mechanism goes beyond the role of common lenders and focuses on the exposure of global lenders — common or otherwise — to global US dollar funding conditions. We show that dollar co-dependence is a key driver of house price synchronization over time and across countries.

To our knowledge, ours is the first paper to explore empirically how the topography of the global banking network affects the synchronization of real outcomes, and in particular of real estate markets. A key feature of the global banking network is that banks headquartered in a few advanced non-US economies, notably Germany, France, the UK, the Netherlands, Switzerland and Japan, account for the bulk of global international credit as well as for the largest-sized bilateral lending flows between countries (Aldasoro and Ehlers (2019)). Our empirical analysis documents that these non-US global banks play the biggest role in facilitating the international spillover of US net capital inflows to real estate markets worldwide.

To identify the mechanism, we develop a statistical model that relates US dollar funding conditions and the dollar dependence of non-US banks to the international synchronization of house prices. The model allows us to derive an empirically testable relationship between the pairwise international house price synchronization and borrowing countries' dollar co-dependence. The dollar co-dependence reflects borrowing countries' pairwise indirect exposure to fluctuations in US dollar funding conditions through their respective non-US global creditor banks. Higher dollar co-dependence implies that two borrowing countries jointly rely on creditors that are more dependent on dollar funding.

The construction of the dollar co-dependence is one of our key conceptual contributions. We construct this novel measure by combining granular data from the BIS consolidated (CBS) and locational international banking statistics (LBS). More formally, the dollar co-dependence captures a combination of non-US global banks' dollar dependence and borrowing countries' heterogeneous exposure to their respective non-US global creditor banks. Our empirical counterpart of non-US banks' dollar dependence is the fraction of global US dollar-denominated foreign bank borrowing that non-US global banks account for. As we show, this measure differs considerably across non-US banks and thus captures their heterogeneous response to shifts in US dollar funding. The computation of the fraction is based on the BIS locational banking statistics by nationality (LBSN), which provides information about the currency composition of the cross-border positions of banks' foreign offices. We aggregate the positions booked in each location to assess non-US banks' US dollar positions, subtract interoffice positions denominated in US dollars, and add the local positions in US dollars of non-US banks vis-à-vis the United States from the CBS. A borrowing country's exposure to a non-US global creditor bank is given by the share of that non-US bank in the borrowing country's market for foreign credit provision. Equipped with these market shares and non-US banks' dollar dependence, for each pair of borrowing countries i and j, we derive the dollar co-dependence as the pairwise product of the weighted average of the respective non-US global creditor banks' dollar dependence. The weighting is determined by the market shares of non-US global creditor banks in each borrowing country. We show empirically that the dollar co-dependence is a key driver of house price synchronization over time and across countries.

Our model is based on the theoretical framework by Landier et al. (2017), which we adapt and extend to the international context. They document that the banking liberalization in the United States which took place between 1970 and the mid-1990s increased the synchronization of house price movement across states. The banking liberalization led to the rise of large banks with high market shares in many states. That is, a common exposure of states to the same creditor banks emerged. Landier et al. (2017) show that, for a given pair of US states, house price synchronization is a function of this common exposure to the same creditor banks. Thus, house prices across states became more exposed to idiosyncratic shocks to the same banks and, as a result, more synchronized.

We extend their framework to an international context. That is, instead of focusing on individual banks, our adaptation focuses on entire *banking systems*, i.e. the country level aggregate of banks providing and receiving foreign credit. Data from the CBS available from the Bank for International Settlements (BIS) allow us to construct bilateral country-level exposures of a borrowing country's banking system to the banks headquartered in the countries providing foreign credit, henceforth called *lending banking systems*. Coupled with an empirical measure of non-US global banks' dollar dependence obtained from the BIS's LBSN, we construct an empirical counterpart to the dollar co-dependence.

Importantly, and differently from Landier et al. (2017), our focus is not on the impact of idiosyncratic shocks to common creditor banks, and in our context, common lending banking systems on synchronization. Rather, we adapt the framework to take into account the differential exposures of lending banking systems to US dollar funding shocks. In our framework, the synchronization of house prices between two arbitrary borrowing countries will depend not only on whether they are exposed to common lending banking systems, as suggested by Landier et al. (2017), but also on their — common or otherwise — lending banking systems' dependence on US dollar funding. To see the gist of our argument, consider two countries A and B, with A borrowing exclusively from lending banking system C and B from lending banking system D, respectively. Hence, the two countries have no common lender. Neither country A nor country B directly borrows from US headquartered banks. Idiosyncratic shocks to the lending banking system C affect only country A, and idiosyncratic shocks to lending banking system D only affect country B. Therefore, uncorrelated lending banking system specific shocks will not lead to co-movement in the foreign lending supply to A and B. However, if both C and D have correlated funding sources because both ultimately borrow in US dollars, then fluctuations in US dollar funding conditions will affect both C and D and therefore lead to synchronized outcomes for countries A and B. Hence, A and B are effectively co-dependent on US dollar funding although they do not share common lending banking systems.

As we show empirically, it is indeed borrowing countries' dollar co-dependence rather than a common exposure to lending banking systems that qualifies as significant driver of international house price synchronization. An increase in dollar co-dependence implies that the respective lending banking systems of two arbitrary borrowing countries become more dependent on US dollar funding, strengthening the link between shifts in US dollar funding conditions and the international synchronization of house prices. To show this, we test our model empirically by translating it into panel regressions. The results indicate a positive statistically significant relationship between the dollar co-dependence and the international synchronization of house prices. In particular, an increase in dollar co-dependence of the average country pair by 10 percentage points is associated with an increase of house price synchronization by 38 percent relative to its mean. This result is confirmed when we explore several intermediate steps in the mechanism outlined above. An important intermediate step is that the foreign lending supply induced by shifts in US dollar funding conditions affects mortgage credit growth of banks in borrowing countries. We demonstrate a positive statistically significant relationship between dollar co-dependence and the international synchronization of mortgage credit growth. Furthermore, we show that the effect of changes in US dollar funding conditions on mortgage credit growth and on house price growth is increasing in the dollar dependence of borrowing countries through the exposure of their non-US global creditor banks to the variations in US dollar funding. We also find that the effect of US dollar funding conditions on non-US global creditor banks' foreign lending supply is increasing in their dollar dependence, in particular when foreign lending is denominated in US dollars and when non-US global banks lend to borrowing countries' banks as opposed to non-banks. These results are robust to a battery of robustness checks, including a rich set of controls and fixed effects.

Our analysis builds on and contributes to several strands of the literature. A first strand comprises recent studies on the international synchronization of house price growth. Alter et al. (2018) and Alter et al. (2018) show that the variation in the cross-country correlation between real estate markets is associated with global financial conditions inferred from financial condition indices. Our paper sheds light on the specific mechanism through which US dollar funding conditions affect the international co-movement of house prices. Alter et al. (2018) and Alter et al. (2018) also show that the cross-country correlation between real estate markets increased over time. Miles (2017) does not find evidence in support of a rising international co-movement. Regardless of the trend of co-movement, these studies highlight the variation both over time and across countries. Both the theoretical and empirical results in this paper show that a considerable part of the time and cross-country variation in co-movement can be explained by the dollar co-dependence. Other studies on the pairwise international co-movement of house prices, notably Milcheva and Zhu (2016), have focused on the bilateral integration through bank capital flows rather than the triangular relationship between borrowing country pairs and non-US global banks explored in this paper.

A second strand of literature pertinent to our paper deals with the global financial cycle (Bruno and Shin (2015); Boz et al. (2019); Cerutti et al. (2017); Habib and Venditti (2019); Miranda-Agrippino and Rey (2019); Rey (2015)). This literature has shown that capital flows around the globe are driven by a dominant common factor that can directly be related to shocks to the balance sheets of globally active financial intermediaries. Recent research converges on the insight that the role of the dominant common factor is assigned to the US dollar in terms of its influence on both capital and trade flows (Avdjiev et al. (2018); Boz et al. (2018, 2017); Bruno and Shin (2019); Gopinath and Stein (2018a,b)). Avdjiev et al. (2018) argue that the value of the US dollar reflects the international shadow price of bank leverage. A cheaper US dollar relaxes financing conditions for global banks, directly affecting credit supply and investment in borrowing countries. Barajas et al. (2019) provide further evidence that an increase in US dollar funding costs reduces non-US banks' foreign lending, increasing the probability of financial stress in borrowing countries. Our focus in this paper is to show how US dollar funding conditions proliferate through intermediary non-US lending banking systems in the global banking network rather than directly through internationally active US or ultimate borrowing country banks, and how this mechanism affects house prices worldwide.

Different from the literature cited above, however, we draw attention to the role of net capital inflows into the United States as an important driver of US dollar refinancing conditions. Our analysis builds on Hoffmann and Stewen (2020) who show that capital inflows into the United States relax the funding conditions of US domestic banks. This contributed to the run-up in house prices across the United States prior to the recent financial crisis. Our paper extends this logic to non-US global banks that borrow in US dollars to fund foreign lending. We verify empirically that, in direct comparison with other price-based indicators of US dollar funding conditions, only US net capital inflows significantly affect bank lending by non-US banks and house price developments worldwide. The idea that US aggregate borrowing — which is predominantly denominated in dollars — effectively amounts to a provision of dollar liquidity to the rest of the world has a venerable tradition, going back to Triffin (1960) and has recently been given a modern interpretation in Krishnamurthy and Lustig (2019). Given how central dollar liquidity is for the funding conditions of non-US global banks (Avdjiev et al. (2018)), our results provide a novel perspective on the link between US aggregate borrowing and international banking flows.

Our focus on net capital inflows is also justified by a large literature that has argued that persistent capital inflows into the US ultimately reflect a savings glut — a global excess demand for safe assets denominated in US dollars — and that these capital inflows contribute to house price developments (Aizenman and Jinjarak (2009); Cesa-Bianchi et al. (2018); Favilukis et al. (2012); Ferrero (2015); Hoffmann and Stewen (2020); Justiniano et al. (2014)). In fact, this literature has documented a strong link between capital inflows and house prices across countries or US regions. However, all of these papers focus on how capital inflows affect house prices in the country to which the capital is flowing. Our analysis here draws attention to how capital inflows into a hegemonic country and provider of the world's dominant currency ripple through the global banking network to affect house prices in third-party countries that are not the destination of the original capital inflows. Our results provide evidence in favor of international spillovers from US net capital inflows as an important driver of house price developments around the world.

Our focus on non-US global banks is motivated by a recent literature which suggests that the impact of changes in funding conditions in the US dollar funding market is more relevant for non-US banks than US-domiciled banks, and applies in particular to non-US global banks that face demand for US dollar-denominated credit. As argued by Ivashina et al. (2015), variations in US dollar funding conditions affect non-US banks more strongly as they are US dollar funding constrained for several reasons. First, a lack of a branch network in the United States prevents non-US banks from issuing insured US dollar-denominated retail deposits. Second, synthetic US dollar borrowing in the forward market of the home currency of these banking systems has become more expensive since the Global Financial Crisis due to limited capital to take the other side of a foreign exchange swap trade, as evidenced by persistent CIP deviations (Borio et al. (2017, 2016)). Third, post-crisis regulatory reforms further tightened the US dollar funding supply for non-US banks (Du et al. (2018); Iida et al. (2018); Barajas et al. (2019)). Fourth, central banks other than the US Federal Reserve cannot create US dollar liquidity to alleviate US dollar funding shortages of non-US global banks headquartered in their jurisdiction. These central banks' ability to provide US dollars is limited by the exchange rate regime or limited by the availability of US dollar reserves (McGuire and von Peter (2012)). For these reasons non-US global banks are more exposed to fluctuations in wholesale US dollar funding conditions than are US banks. Empirical studies from the literature on international monetary policy spillovers underscore the sensitivity of non-US global banks to US dollar funding conditions (Avdjiev et al. (2018); Buch et al. (2019); Lindner et al. (2018); Schmidt et al. (2018)).

The remainder of the paper is organized as follows. Section (2) formally introduces the concept of dollar (co-)dependence and provides first empirical evidence that its variation across borrowing countries is fundamental to an explanation of the effect of US dollar funding conditions on house price growth and house price growth synchronization worldwide. Section (2) also explains the statistical model used to guide the empirical analysis. Section (3) discusses features of the data relevant to the empirical application of our model. We present the empirical framework and main findings in section (4), and results for intermediate steps of the transmission mechanism in section (5). Section (6) concludes.

2 Theoretical framework

2.1 Dollar (co-)dependence: the concept

To study the effect of variations in US dollar funding conditions on house price growth through non-US global banks, we introduce the concepts of dollar dependence and dollar co-dependence. These concepts formalize the indirect exposure of borrowing countries to US dollar funding conditions via their respective lending banking systems' exposure to US dollar funding conditions. For each borrowing country i, we define the dollar dependence as the average fraction of global foreign bank borrowing denominated in US dollars accounted for by banks headquartered in the banking systems lending to country i at a given point in time. More formally, let $\omega_t^{b,i}$ be the market share that lending banking system b has in total foreign bank lending to borrowing country i at time t, i.e.

$$\omega_t^{b,i} = \frac{L_t^{b,i}}{L_t^i} \tag{1}$$

where L_t^i are aggregate foreign claims on country i, and can be decomposed into bilateral claims from its respective lending banking systems b

$$L_t^i = \sum_{b \in \mathcal{B}(i)}^{N} L_t^{b,i} \tag{2}$$

where $L_t^{b,i}$ measures the bilateral foreign claims of lending banking system b on borrowing country i and $\mathcal{B}(i)$ is the set of lending banking systems providing foreign credit to banks in country i. Further, let λ_t^b be the fraction of global bank borrowing denominated in US dollars accounted for by banks headquartered in lending banking system b, i.e.

$$\lambda_t^b = \frac{L_t^{b,(USD)}}{\sum_b^N L_t^{b,(USD)}} \tag{3}$$

where $L_t^{b,(USD)}$ denotes the US dollar-denominated borrowing by lending banking system b. Effectively, λ_t^b represents the market share of lending banking system b in the global market for US dollar-denominated bank borrowing, notably the US money market. Combining $\omega_t^{b,i}$ and λ_t^b , we define the dollar dependence of country i as

$$\text{DD}_t^i = \sum_{b \in \mathcal{B}(i)}^{N} \omega_t^{b,i} \lambda_t^b \tag{4}$$

DD_t^i represents each borrowing country i's weighted average of the dollar dependence λ_t^b of banks headquartered in the banking systems lending to country i at time t, with the market shares $\omega_t^{b,i}$ serving as weights.

Our identification strategy relies on cross-country heterogeneity in DD_t^i. Figure (6) indeed depicts considerable variation of the time average of the dollar dependence DD_t^i across borrowing countries i, as the time average of DD_t^i ranges from 3.45 percent for Slovakia to 11.84 percent for South Africa. Following the definition of DD_t^i, this variation across borrowing countries i is driven by either the heterogenous exposure of borrowing countries i to lending banking systems b as given by $\omega_t^{b,i}$, or the heterogenous exposure of lending banking systems b to variations in US dollar funding as given by λ_t^b, or by a combination of both. To consider two extreme examples, for any two borrowing countries i and j sharing exactly the same set of lending banking systems b as common lenders, i.e. λ_t^b identical across i and j, heterogeneity in $\omega_t^{b,i}$ and $\omega_t^{b,j}$ explains the difference between DD_t^i and DD_t^j. In contrast, for any two countries i and j borrowing from a completely distinct set of lending banking systems b_1 and b_2, heterogeneity in $\lambda_t^{b_1}$and $\lambda_t^{b_2}$ in addition to heterogeneity in $\omega_t^{b,i}$ and $\omega_t^{b,j}$ accounts for the variation in DD_t^i and DD_t^j. Section (3) provides further empirical insights into the cross-country heterogeneity of $\omega_t^{b,i}$,λ_t^b and DD_t^i.

In the next section, we first show that house prices in countries with high dollar dependence are particularly exposed to our key measure of US dollar funding conditions, US net capital inflows. We then propose a statistical model that rationalizes this finding and which allows us to explore its implications for the synchronization of house price growth across borrowing countries. It is in this context that the notion of dollar co-dependence will become relevant. We define the dollar co-dependence between any two borrowing countries i and j as the product of the individual countries' dollar dependencies:

$$\text{CoDD}_t^{i,j} = \text{DD}_t^i \times \text{DD}_t^j \tag{5}$$

As we will show both theoretically and empirically, the synchronization of house price growth in two arbitrary borrowing countries i and j increases directly in $\text{CoDD}_t^{i,j}$. While we provide a detailed proof and example in the subsequent sections (2.2) and (2.3), the basic intuition is simple: For a pair of borrowing countries to have a high level of dollar co-dependence the individual dollar dependencies of both countries need to be relatively high. As we will show in section (2.2), house price growth in a borrowing country directly increases in a borrowing country's dollar dependence. Thus, a high dollar co-dependence means that house price growth in both borrowing countries will co-move strongly in response to changes in US dollar funding conditions.

Importantly, high levels of dollar co-dependence and thus a high synchronization of house price growth can occur between borrowing countries with exposure to entirely distinct sets of lending banking systems. All that matters for the role of the dollar co-dependence is that both borrowing countries are exposed to lending banking systems that are themselves, on average, highly dependent on US dollar funding.

2.2 House prices, US capital inflows, and dollar dependence: first evidence

In this section, we provide a first look at the data to illustrate one key point: House prices around the globe co-move with US net capital inflows and the strength of this co-movement depends on a country's dollar dependence.

Our interpretation of this finding builds on earlier work by Hoffmann and Stewen (2020). These authors demonstrate that US net capital inflows represent a positive refinancing shock to the US financial system, allowing banks in the US to increase their lending in the US. In this paper, we extend this logic to argue that an increase in US net capital inflows not only improves refinancing conditions of US banks, but of any non-US banks procuring funding from the US financial system, and thus funding denominated in US dollars. Figure (2) exhibits that non-US global banks raise a significant fraction of their funding in US dollars, with the fraction exceeding 45 percent for most of our sample period. This is why the bank lending capacity of non-US global banks is susceptible to US net capital inflows, leading them to adjust the provision of foreign credit, and US dollar-denominated foreign credit in particular.

Figure (3) depicts the development of US net capital inflows during our sample period, and shows that there is considerable time variation in US dollar funding conditions. We scale the US net capital inflows in one of two ways: either by total US commercial bank equity to account for the risk taking capacity of the US financial system, or by all lending banking systems' total outstanding US dollar denominated foreign claims worldwide. The risk taking capacity is an especially relevant scaling factor, since the level of US commercial bank equity determines the extent to which US banks are financing constrained, leaving more room for non-US banks to absorb available US dollar funding.

To illustrate the link between house price growth and US capital inflows, for each borrowing country i in our sample and for the period 2000Q1 to 2015Q1 we run the simple time series regressions

$$\frac{\Delta \text{HP}_t^i}{\text{HP}_{t-4}^i} = \beta^i \text{CAPFLOW}_t + \mu^i + \varepsilon_t^i \tag{6}$$

where $\frac{\Delta \text{HP}_t^i}{\text{HP}_{t-4}^i}$ is the growth rate of house prices in borrowing country i over four quarters ahead and CAPFLOW_t denotes US net capital inflows scaled as mentioned above. Akin to an asset pricing-model, for each borrowing country i, the coefficient β^i measures the sensitivity of country-specific house price changes to the aggregate risk factor, CAPFLOW_t. Figure (4) plots the estimates of β^i against each borrowing country i's dollar dependence DD_t^i. A clear positive relationship emerges between the sensitivity of borrowing countries' house price growth to US net capital inflows and countries' dollar dependence. That is, the effect of US dollar funding conditions — as measured by US net capital inflows — on house price growth worldwide is increasing in borrowing countries' indirect exposure to US dollar funding conditions through the dollar dependence λ_t^b of the lending banking systems

b providing foreign credit to country i. It is this empirical observation that constitutes our point of departure into the investigation of how the dollar dependence of non-US global banks constitutes a concrete link between the variations in US dollar funding conditions and house price growth around the world.

Figure (5) plots the estimates of β^i obtained from time series regressions similar to equation (6) for potential drivers of US dollar funding conditions other than US net capital inflows. The relationship between the sensitivity of countries' house price growth to those other alternative drivers of US dollar funding conditions and countries' dollar dependence is largely absent or negative. This lends support to the notion that US net capital inflows are an important independent driver for US dollar funding conditions that is not easily driven out by other factors that have been suggested in the literature. Section (4) below further buttresses this point and discusses the alternative drivers of US dollar funding conditions.

2.3 International house price synchronization: a stylized model

To study the impact of US net capital inflows on the synchronization of housing markets, we adapt and extend the methodological framework of Landier et al. (2017). They show that an increase in the co-movement of house prices across US states between the late 1970s and the mid 1990s can be associated with the emergence of multi-state banks in the wake of the US interstate banking liberalization implemented over the same period. The lynchpin of their framework is a common lender effect: House prices in US states in which multi-state banks have relatively large market shares exhibit higher co-movement as these states are relatively more exposed to the idiosyncratic shocks of multi-state banks.

Relative to their setting, we innovate along two dimensions. First, we take their setup to the international level and analyze the effect on house price co-movement across countries. That is, our unit of analysis are entire country level banking systems, i.e. the aggregate of all banks headquartered in a country instead of individual banks. Therefore, our framework is based on bilateral country-level exposures to *banking systems* providing foreign credit rather than bilateral US state-level exposures to individual banks.

Second, and more importantly, we uncover that the international synchronization of house price growth between borrowing countries crucially depends on their respective lending banking systems' heterogenous exposure to refinancing conditions in US dollars, as captured by borrowing countries' dollar co-dependence. Importantly, the lending banking systems that two arbitrary borrowing countries are exposed to do not need to be common lenders. For the effect of US dollar refinancing conditions on house price growth synchronization to be increasing in borrowing countries' dollar co-dependence, it is sufficient to consider borrowing countries' exposure to their respective lending banking systems' dollar dependence λ_t^b — independent of whether these lending banking systems are common to both countries in a pair.

In addition to dollar co-dependence, our framework leaves room for a common lender effect as the theoretical setup allows for borrowing countries' exposure to idiosyncratic shocks of common lending banking systems. Empirically, however, section (4) shows that this common lender effect is dwarfed by borrowing countries' indirect exposure to US dollar refinancing conditions through their respective lending banking systems, i.e. our dollar co-dependence. The common lender effect pales at the international level compared to the dollar co-dependence because of the relatively high dependence on dollar funding of the largest lending banking systems that account for the bulk of bank borrowing in US dollars — in particular Germany, France, UK, Switzerland, the Netherlands and Japan. It is this dependence on US dollar funding that makes foreign lending by particularly these banking systems susceptible to variations in US dollar funding conditions, and that ultimately makes borrowing countries' dollar co-dependence a powerful vector of transmission of US dollar funding shocks to the international synchronization of house price growth.

Specifically, following Landier et al. (2017), we conjecture that foreign bank credit supply to banks in borrowing country i drives house price growth $\frac{\Delta \mathrm{HP}_t^i}{\mathrm{HP}_{t-1}^i}$ in borrowing country i with an elasticity of α, so that

$$\frac{\Delta \mathrm{HP}_t^i}{\mathrm{HP}_{t-1}^i} = \alpha \frac{\Delta L_t^i}{L_{t-1}^i} + \nu_t^i \tag{7}$$

where ν_t^i is a shock specific to borrowing country i and captures credit demand.[1] Furthermore, for the foreign lending supply provided by lending banking system b to banks in country i we posit that

$$\frac{\Delta L_t^{b,i}}{L_{t-1}^{b,i}} = \gamma_t + \lambda_{t-1}^b \zeta_t + \eta_t^b \tag{8}$$

where γ_t is a global factor that is homogeneous in its impact across borrowing countries and lending banking systems alike, and where η_t^b is an idiosyncratic shock specific to lending banking system b. Our analysis in this paper focuses on the role of ζ_t, to which we assign the role of a common US dollar

[1]As housing represents the most important collateralizable financial asset around the world, banks in country i are likely to channel additional funds borrowed from abroad into mortgage lending. In fact, mortgage lending constitutes about 90 percent of household lending in the borrowing countries of our sample. The literature on the effect of capital inflows on house prices provides further evidence for the central role of the domestic banking sector in translating capital inflows into mortgage credit. Aizenman and Jinjarak (2009) demonstrate that the effect of capital inflows on house prices is increasing in countries' financial depth measured as bank credit to GDP. Sá et al. (2014) show that the effect of capital inflows on house prices in OECD countries correlates positively with the degree of mortgage market development, and in particular with loan-to-value ratios. The latter points at borrowing country banks' fundamental role as financial intermediaries in creating a link between capital inflows and house price growth. The study by Hoffmann and Stewen (2020) also assigns a prominent role to domestic banks in funneling capital inflows into mortgage lending, thus driving house prices. Indeed, we show in section (4) below that borrowing country banks' mortgage credit provision is a key vector of transmission of foreign borrowing to housing markets, and that mortgage credit growth is synchronized in a similar way as house prices.

funding shock. Specifically, we argue that this funding shock corresponds to net capital inflows into the United States, denoted by CAPFLOW_t in our empirical specifications. We therefore propose that

$$\zeta_t = \text{CAPFLOW}_t. \tag{9}$$

Importantly, based on the first evidence in subsection (2.2), we argue that the US dollar funding shock ζ_t in (8) loads differentially on lending banking systems, with the loading given by λ^b_{t-1},the share that these lending banking systems have in the global market for US dollar funding at time $t-1$. As we will show, this assumption drives the empirical implications of our theory concerning the impact of co-dependence on the synchronization of housing markets. Next, we briefly discuss the economic intuition behind this assumption.

The notion that the variation in US dollar funding supply affects foreign lending by non-US banks in proportion to their previous shares in the US dollar funding market can be justified by the presence of various forms of balance sheet constraints, all of which matter in practice. One type of constraint pertains to maturity mismatches as banks typically refinance long-term assets with short term liabilities. Thus, a lending banking system's need for short-term US dollar funding could be pre-determined by the amount of longer-term US dollar-denominated claims accumulated in previous periods.[2] Another type of constraint applies to currency mismatches on banks' balance sheets. This could be because of regulatory constraints or because synthetic US dollar funding in global banks' home currency has become costlier after the Global Financial Crisis (Barajas et al. (2019); Ivashina et al. (2015); Borio et al. (2016)).[3] These balance sheet constraints result in non-US lending banking systems being US dollar funding constrained.[4] To the extent that non-US banks fully match their US dollar lending with US dollar liabilities, fluctuations in US dollar funding conditions should directly translate into variation in foreign lending in direct proportion to the lending banking system's share in the US dollar funding market. This is exactly what our loading λ^b_{t-1} captures.

Consolidating equations (7) and (8), we obtain

[2] Such US dollar-denominated claims result from borrowing countries' demand for credit denominated in US dollars as the world's dominant currency, because borrowing countries seek to benefit from the advantages that the dominant currency bestows in trade invoicing and international borrowing (Gopinath and Stein (2018a,b); Maggiori et al. (2019)).

[3] Basel regulations impose regulatory capital charges on unhedged foreign exchange risk, meaning that banks would find it optimal to avoid foreign exchange mismatches to save scarce capital (Ivashina et al. (2015)). Furthermore, a number of post-crisis regulatory reforms have increased the cost of non-US global banks' funding in US dollars (Du et al. (2018)). An example is the 2016 money market mutual fund reform in the United States, which in a first instance reduced access to US dollar funding for non-US banks (Aldasoro et al. (2017)). Moreover, the rise of non-banks in US dollar funding markets rendered the supply of US dollar funding more procyclical, further tightening the supply of US dollars to non-US global banks in times of stress (Iida et al. (2018)).

[4] Beyond these balance sheet constraints, non-US banks are by definition US dollar funding constrained because central banks other than the US Federal Reserve cannot create US dollar liquidity to alleviate US dollar funding shortages. The ability of non-US central banks to provide US dollars is limited by the exchange rate regime or by the availability of finite US dollar reserves (McGuire and von Peter (2012)). Also, non-US banks cannot tap dollar funding by issuing insured US dollar-denominated retail deposits because they do not dispose of a branch network in the United States.

$$\frac{\Delta \mathrm{HP}_t^i}{\mathrm{HP}_{t-1}^i} = \alpha \left(\sum_{b \in \mathcal{B}(i)}^{N} \left(\lambda_{t-1}^b \zeta_t + \eta_t^b + \gamma_t \right) \omega_{t-1}^{b,i} \right) + \nu_t^i$$

or equivalently

$$\frac{\Delta \mathrm{HP}_t^i}{\mathrm{HP}_{t-1}^i} = \alpha\gamma_t + \alpha \left(\sum_{b \in \mathcal{B}(i)}^{N} \omega_{t-1}^{b,i} \eta_t^b \right) + \alpha \underbrace{\left(\sum_{b \in \mathcal{B}(i)}^{N} \omega_{t-1}^{b,i} \lambda_{t-1}^b \right)}_{\text{Dollar dependence}} \times \zeta_t + \nu_t^i \tag{10}$$

As indicated by the under-braced term, equation (10) provides for a direct link between house price growth of borrowing country i and US dollar funding conditions depending on country i's US dollar dependence. The second term describes the average of lending banking systems' idiosyncratic shocks η_t^b weighted by their share in the market for international credit provision in borrowing country i in the previous period.

Assuming that the lending banking system specific supply shocks, η_t^b, the borrowing country specific shock, ν_t^i, the global factor γ_t and the factor ζ_t reflecting US dollar refinancing conditions are mutually uncorrelated, we can derive an expression for the time-varying conditional covariance of house price growth between any two borrowing countries i and j:

$$\mathrm{HPsync}_t^{i,j} = \alpha^2\sigma_\gamma^2 + \alpha^2\sigma_\eta^2 \underbrace{\left(\sum_{b \in \mathcal{B}(i) \cup \mathcal{B}(j)}^{N} \omega_{t-1}^{i,b} \omega_{t-1}^{j,b} \right)}_{\text{co-Herfindahl}} + \alpha^2\sigma_\zeta^2 \underbrace{\left(\sum_{b \in \mathcal{B}(i)}^{N} \omega_{t-1}^{i,b} \lambda_{t-1}^b \right) \left(\sum_{b \in \mathcal{B}(j)}^{N} \omega_{t-1}^{j,b} \lambda_{t-1}^b \right)}_{\text{dollar co-dependence}} \tag{11}$$

where $\mathrm{HPsync}_t^{i,j}$ denotes the conditional covariance of house price growth between borrowing countries i and j. The first under-braced term on the right hand side captures the effect on synchronization that stems from the idiosyncratic shocks affecting common lending banking systems, i.e. the common lender effect. This term is familiar from Landier et al. (2017) who refer to it as the co-Herfindahl index. For lending banking system specific shocks to have a big impact on house price growth synchronization, a lending banking system must have high market shares in both borrowing countries i and j so that the product of the market shares $\omega_{t-1}^{i,b}$ and $\omega_{t-1}^{j,b}$ becomes big.

The second under-braced term is the focus of our analysis in this paper. This term equals the product of the dollar-dependence of each borrowing country, i.e. the dollar co-dependence as defined in equation (5) above. The term reflects the impact of any two borrowing countries' simultaneous indirect exposure to fluctuations in US dollar funding conditions through their respective lending banking systems on the synchronization of house price growth between these two countries. Hence, the two countries i and j could be highly dollar co-dependent even though they borrow from a distinct set of lending banking systems.

To illustrate how shifts in the dollar co-dependence affect the synchronization of house price growth, consider the following example. Suppose lending banking system C's dollar dependence stands at $\lambda_t^C = 15$ percent, and lending banking system D's dollar dependence equals $\lambda_t^D = 10$ percent respectively. Let lending banking system C's market shares in borrowing countries A and B take the values $\omega_t^{C,A} = 5$ percent and $\omega_t^{C,B} = 8$ percent, respectively. The corresponding market shares for lending banking system D are $\omega_t^{D,A} = 2$ percent and $\omega_t^{D,B} = 12$ percent. This results in dollar dependencies $\text{DD}_t^A = 0.95$ percent and $\text{DD}_t^B = 2.4$ percent for borrowing countries A and B respectively, and results in the dollar co-dependence $\text{CoDD}_t^{A,B} = 0.0228$ percent. At time $t+1$, let λ_{t+1}^D increase by one percentage point to $\lambda_{t+1}^D = 11$, keeping all else constant. Thus, the dollar co-dependence rises to $\text{CoDD}_{t+1}^{A,B} = 0.0244$ percent, or by 7.2 percent compared to $\text{CoDD}_t^{A,B}$ at time t. In line with equation (11), the increase in the dollar co-dependence $\text{CoDD}_t^{i,j}$ translates into higher synchronization of house price growth. Similarly, to study the cross-sectional variation of a change in borrowing countries' dollar dependence DD_t^i, we introduce borrowing country F, with lending banking systems' market shares $\omega_t^{C,F} = 1$ percent and $\omega_t^{D,F} = 3$ percent respectively. The dollar dependence of borrowing country F yields $\text{DD}_t^F = 0.45$ percent. Hence, the dollar co-dependence of the borrowing country pairs A,F and B,F are $\text{CoDD}_t^{A,F} = 0.0043$ and $\text{CoDD}_t^{B,F} = 0.01$ respectively. Given that $\text{CoDD}_t^{A,B} > \text{CoDD}_t^{B,F} > \text{CoDD}_t^{A,F}$, our model implies that the house price growth synchronization of country pair A,B exceeds the synchronization for country pairs B,F and A,F in this order.

3 Data and stylized facts

Our analysis on the relevance of the dollar dependence for house price growth relies on a panel of OECD countries from 2000Q1 to 2015Q1 at quarterly frequency and covers house price growth, empirical counterparts of the dollar dependence DD_t^i as well as the variables driving US dollar funding conditions. Additionally, the analysis on the main mechanism for dollar co-dependence and house price growth synchronization uses empirical counterparts of house price growth synchronization $\text{HPsync}_t^{i,j}$, the co-Herfindahl index $\text{CoHFI}^{i,j}$ and dollar co-dependence $\text{CoDD}^{i,j}$ as well as bilateral economic integration measures as controls. The analysis of intermediate steps draws on mortgage credit growth, mortgage credit growth synchronization, and the growth in bilateral and aggregate foreign claims of lending banking system b. Table (A.1) in the appendix provides an overview of variable definitions and sources along with summary statistics. Here we discuss the sources of the most important data and describe some stylized facts.

House prices and mortgage credit: We measure house price growth over four quarters ahead based on a country-level residential real house price index available from the OECD for 36 borrowing countries.[5] Similarly, mortgage credit growth is computed over four quarters ahead based on the times series of credit to households and non-profit institutions serving households, provided by the BIS. For borrowing countries i and j, the international synchronization of house price growth and mortgage credit growth is measured as the product of house price and mortgage credit growth, resulting in 666 and 561 unique country pairs in the sample used for regression analysis, respectively.

US net capital inflows: Our primary measure of US dollar funding conditions are net capital inflows into the United States. Specifically, we use net financial inflows from the US balance of payments statistics as our measure of the variable CAPFLOW. We consider two normalizations of this variable throughout the paper: First, following Hoffmann and Stewen (2020), we normalize with the total equity of all US commercial banks. Secondly, we set US net capital inflows in relationship to the total volume of all lending banking systems' outstanding US dollar denominated foreign claims recorded in the CBS.

Dollar dependence: The dollar dependence λ_t^b of lending banking system b is defined as the share of a lending banking system's stock of foreign liabilities denominated in US dollars relative to the sum of all lending banking systems' US dollar-denominated stock of foreign liabilities. We obtain this data from the locational banking statistics by nationality, which provides information about the currency composition of the cross-border positions of banks' foreign offices. Aggregating the positions booked in each location allows for assessing the overall currency composition of a consolidated banking system's liabilities. Equipped with the currency composition, we compute λ_t^b as defined in equation (3) for 28 lending banking systems.[6] Figure (8) demonstrates that lending banking systems differ considerably in their reliance on US dollar funding.

Importantly, a small number of non-US lending banking systems account for the bulk of the market for US dollar funding. In particular, the German, French, UK, Japanese, Swiss and Dutch lending banking systems combined account for 73 percent of the average global US dollar-denominated stock of foreign liabilities during the sample period.[7] Due to their dominant position in the US dollar funding market, it is this set of non-US global banking systems that are most relevant for translating

[5] Our sample covers the following borrowing countries: Australia, Belgium, Brazil, Canada, Chile, China, Colombia, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Indonesia, Ireland, Israel, Italy, Japan, Korea, Luxemburg, Mexico, Netherlands, Norway, New Zealand, Portugal, Russia, Slovakia, Slovenia, South Africa, Spain, Sweden, Switzerland, Turkey, UK, United States. For further details on the OECD house price index please refer to appendix (7.1).

[6] The following lending banking systems are included: Austria, Australia, Belgium, Brazil, Canada, Chile, Denmark, Finland, France, Germany, Greece, India, Ireland, Italy, Japan, Korea, Luxemburg, Mexico, Netherlands, Norway, Panama, Portugal, Spain, Sweden, Switzerland, Turkey, Chinese Taipei and the UK. For further details on the computation of the dollar dependence, please refer to appendix (7.2).

[7] Including the US lending banking system, the figure stands at 89 percent.

shifts in US dollar funding conditions into foreign credit provision to borrowing countries, and thus house price growth.

The market for foreign credit provision to borrowing countries mirrors the high market concentration in US dollar funding. This means that the same set of non-US global banking systems have the highest market shares in borrowing countries, as shown in Figure (7). Specifically, the German, French, UK, Japanese, Swiss and Dutch lending banking systems cumulatively take a 58 percent market share in borrowing countries, averaged over the sample period. In light of the high degree of concentration in the global banking network, some of the results presented in section (4) focus on these six key lending banking systems, further referred to as "G6 lending banking systems".

Our analysis categorically excludes the US as lending banking system. The reasons are twofold: First, the US is the currency's home country, and thus in terms of timing — but not in terms of absolute amounts — the primary provider of US dollar funding, and hosts with the US Federal Reserve the lender of last US dollar funding resort. However, US net capital inflows — our preferred measure of US dollar funding variations — are a priori not exogenous to the funding demand from US banks, while this is more likely to hold for non-US lending banking systems. Second, the exclusion of US banks ensures that we more sharply identify the channel through which US dollar liquidity is intermediated outside of the domain of the currency's home country and home country affiliated banks.

Market shares: The market shares $\omega^{i,b}$ and $\omega^{j,b}$ of lending banking systems are essential inputs for the empirical counterparts of the co-Herfindahl index $\textsc{CoHFI}^{i,j}$ and the dollar co-dependence $\textsc{CoDD}^{i,j}$. We compute these market shares based on positions of outstanding foreign claims recorded in the consolidated banking statistics (CBS) on immediate counterparty basis, maintained as part of the international banking statistics (IBS) by the BIS.[8]

The CBS provide a uniquely suitable database to capture the network topography of lending banking systems' foreign claims as it records banking groups' consolidated "foreign claims". "Foreign" refers to the fact that these claims capture international credit by banks that are headquartered in a country other than the borrowing country, i.e. banks that are of foreign nationality, irrespective of whether this credit is cross-border or extended by a local subsidiary or branch. A consolidated view of international bank lending is most suitable to our research question, as US dollar funding conditions affect a banking group as a whole, regardless of the location of its offices. Internationally active banking groups obtain US dollar funding through various channels — notably deposits, debt securities issuance, wholesale funding, FX derivatives — and from various locations (Aldasoro and Ehlers

[8]Foreign claims in the BIS terminology are the sum of international credit and local credit in local currency. International credit is defined as the sum of cross-border credit in both local and foreign currency and local credit in foreign currency. Local credit is defined as credit extended by a foreign banking group's affiliates located in the borrowing country itself.

(2018)). Moreover, they actively shift US dollar funds across offices in different locations (Cetorelli and Goldberg (2012)). The CBS record bank claims at a group level and thus abstract from interoffice positions that mainly reflect the internal funding within a banking group. Foreign claims reflect the full foreign credit exposure of a bank, as they not only comprise loans, but also debt securities holdings and net derivative exposures. We use data on the bilateral country-level claims of 28 lending banking systems on the 36 borrowing countries in our sample.[9]

For the same lending banking system b, the market shares vary considerably across borrowing countries, and substantially across lending banking systems for the same borrowing country. For instance, consider the market shares of the three biggest lending banking systems in the global banking network: Germany, France and the UK. The German lending banking system's market shares vary between 7 percent and 35 percent on average over the sample period, compared to 3 percent and 20 percent for the French banking system on average over the sample period. The UK lending banking system's market shares range from 2 percent to 31 percent averaged over the sample period. German banks hold on average over the sample period a combined market share in the borrowing countries with the top three highest shares of about 34 percent, compared to 26 percent and 19 percent for UK and French banks, respectively.

Moreover, borrowing countries in which a particular lending banking system has a comparable market share are similarly exposed to global US dollar funding shocks transmitted through that lending banking system. For instance, UK banks have roughly the same market share in both Brazil and Chile. Hence, conditional on the dollar funding dependence of UK banks, and conditional on the sensitivity of Brazilian and Chilean domestic banks' mortgage lending to foreign borrowing from UK banks, both Brazil's and Chile's house prices should react in similar fashion to US dollar funding shocks channeled through UK banks. However, what matters in our context is not exposure to US dollar funding shifts through just one lending banking system, but the average exposure through all lending banking systems providing credit to Brazil and Chile as captured by the dollar dependence concept.

Keeping in mind lending banking systems' heterogenous exposure to global US dollar funding shocks, a comparison of the market shares across lending banking systems for the same borrowing country shows a heterogenous exposure to changes in US dollar funding conditions depending on which lending banking system is dominant in the respective borrowing country's market. For instance, the German lending banking system's market share in Hungary dominates the market share of the French and UK lending banking systems. This implies that variations in US dollar funding conditions are more likely to affect house price growth in Hungary through foreign claims of the German lending banking system as compared to the French and UK lending banking systems.

[9] For further details on the computation of the market shares, please refer to appendix (7.3). Appendix (7.4) provides a detailed view on the suitability of the CBS.

The combination of the market shares $\omega^{i,b}$ and the dollar funding dependence λ^b of lending banking systems in country pairs' dollar funding dependence DD_t^i yields considerable heterogeneity across borrowing countries, as shown in Figure (6). As a consequence, this variation over borrowing countries spills over into variation of $\text{CoDD}^{i,j}$ over borrowing country pairs. Our identification in equations (12) and (13) depends on this cross-country pair heterogeneity. For G6 lending banking systems data is available throughout the entire sample period. The later availability of data for some other lending banking systems only marginally affects the computation of the dollar dependence DD_t^i.

4 Empirical framework and main results

In this section, we first establish that US net capital inflows affect house prices globally and that the strength of this effect depends on the dollar dependence of borrowing countries. This result is a necessary condition for our analysis of the international synchronization of house prices, and the role of the dollar co-dependence. Specifically, the results will reveal that US net capital inflows are unique in their impact on house prices as compared to other drivers of US dollar funding conditions discussed in the literature. To this end, we take equation (10) on first conditional moments of house price growth to the data. In essence, this step examines more formally the first evidence shown in section (2.2). In a second step, we then explore the implications for international house price synchronization by taking equation (11) to the data. It is this second step that allows us to establish that the dollar co-dependence contributes significantly to house price synchronization.

4.1 House price growth, dollar dependence and US net capital inflows

We test equation (10) by running the following panel regression:

$$\text{HPgrowth}_t^i = const + \beta_1\, \text{DD}_{t-1}^i + \beta_{\mathbf{2}}'\, \text{DD}_{t-1}^i \times \mathbf{RF_t} + \nu_i + \tau_t + \xi_t^i \tag{12}$$

where HPgrowth_t^i is the rate of house price growth over four quarters ahead in borrowing country i, DD_{t-1}^i is country i's dollar dependence as defined in section (2.1) and $\mathbf{RF_t}$ denotes a vector of variables driving US dollar funding conditions.[10] Following Hoffmann and Stewen (2020), our focus in this paper is on US net capital inflows, either scaled by total US bank equity or by the total of all lending banking systems' outstanding US dollar denominated foreign claims, as they affect the bank lending capacity of non-US banks seeking refinancing in the US money market. To account for other potential drivers of US dollar funding conditions, we include the Federal funds rate including shadow

[10]Note that all variables driving US dollar funding conditions considered in vector $\mathbf{RF_t}$ are coded such that an increase in the variable implies improved US dollar funding conditions.

rates to account for the effect of US monetary policy, the US broker dealer leverage and the VIX.[11] This choice of variables emanates from the literature that has associated the latter three with the global financial cycle and global liquidity. Ex post, however, US net capital inflows will empirically remain the final contender determining the fluctuations in US dollar funding conditions that make lending banking systems adjust their provision of foreign credit and thus drive house price growth in borrowing countries. Following the discussion in section (2.3) the dollar dependence $\textsc{dd}^i_{t-1}$ enters the specification lagged as the US dollar funding needs of lending banking systems are pre-determined at time t when shifts in the US dollar funding conditions materialize. This allows us to study how the effect of shifts in the latter on house price growth is modulated by the exposure of a country's lending banking systems to the US dollar.

The coefficient vector β_2 is our main coefficient vector of interest. The coefficient should be positive in line with the first evidence on the role of the dollar dependence $\textsc{dd}^i_t$, as portrayed in Figure (4). The specification (12) is a more formal test of this first evidence, and allows us to identify the most relevant driver of US dollar funding conditions. To isolate the supply driven lending channel in response to a change in US dollar funding conditions, we include country and time fixed effects, ν_i and τ_t, to control for time-invariant country characteristics and time-varying factors affecting all borrowing countries at the same point in time homogeneously, respectively. Note that the stand alone term of the vector $\mathbf{RF_t}$ is absorbed by the full set of time effects. We cluster standard errors by the time dimension to account for correlation across borrowing countries at each point in time.

Table (1) shows the results of estimating equation (12). Columns (1) to (4) and (5) to (8) show the effect of the dollar dependence interacted with our two measures of US net capital inflows — scaled either by total US banking equity or by the total of all lending banking systems' outstanding US dollar denominated foreign claims —, respectively, on their own and in combination with other candidate measures of US dollar funding variations. The specification includes borrowing country and year-quarter fixed effects. Standard errors are clustered by the time dimension. Given the high concentration in the global banking network, the results focus on the G6 lending banking systems as identified in section (3).

Notably, only the coefficient on the dollar dependence interacted with the US net capital flows, scaled in either way, enters positively and statistically significantly. Thus, the effect of US net capital inflows on house price growth is increasing in borrowing countries' dollar dependence. The coefficients on the other interaction terms do not withstand statistically significantly in a horserace with US net capital inflows, as shown in in columns (2) to (4) and (6) to (8).

Prior to proceeding with the analysis on synchronization, these results provide us with two insights. First the dollar dependence matters for the effect of US dollar funding conditions on house

[11]The VIX is a volatility index constructed by the Chicago Board Options Exchange and recognized as "fear gauge" in global financial markets.

price growth worldwide. The estimates for coefficient β_2 in equation (12) imply that house price growth increases by 2 to 3 percentage points in response to an increase in a borrowing country's dollar dependence DD_t^i by 10 percentage points, evaluated at the mean of US net capital inflows, regardless of the scaling factor. Second, in line with the conjecture presented in section (2.2), the results validate US net capital inflows as the relevant measure of fluctuations in US dollar funding conditions. That is, the other potential drivers of US dollar funding conditions do not stand for a notion of shifts in US dollar funding conditions that improve the funding conditions of non-US banks, in turn leading to an increase in their foreign lending and house price growth in borrowing countries. In contrast, the relationship only holds for US net capital inflows as determinant of non-US banks' funding conditions in US dollars.

4.2 House price synchronization and dollar co-dependence

In the next step, we explore the implications of our framework for house price synchronization. We translate equation (11) from the theoretical setup into the following panel regression

$$\text{HPsync}_t^{i,j} = const + \delta\, \mathbf{CoHFI}_{t-s}^{i,j} + \beta\, \mathbf{CoDD}_{t-s}^{i,j} + \text{CONTROLS}_t + \theta_{i,j} + \mu_{i,t} + \phi_{j,t} + \epsilon_t^{i,j} \tag{13}$$

where $\text{HPsync}_t^{i,j}$ denotes the conditional covariance of house price growth between borrowing countries i and j. Our empirical measure of $\text{HPsync}_t^{i,j}$ is the product of the rates of house price growth over four quarters ahead in country i and j. The co-Herfindahl index $\mathbf{CoHFI}_{t-s}^{i,j}$ captures the common lender effect adapted from Landier et al. (2017) to the international context. The regressor of special interest is the dollar co-dependence $\mathbf{CoDD}_{t-s}^{i,j}$. Consistent with equation (10), the specification imposes a lag s on both regressors as exposures to lending banking systems and US dollar funding need to be pre-determined. The coefficient β should be unambiguously positively signed as an increase in the dollar co-dependence implies that borrowing countries i and j are simultaneously more exposed to their lending banking systems' reaction to fluctuations in US dollar funding conditions, strengthening the link between US dollar funding conditions and the international synchronization of house price growth. Intuitively, and in line with the theoretical setup in equation (11), US dollar funding conditions do not feature explicitly in equation (13), because the identification rests on borrowing country pairs' heterogenous dollar co-dependence at each point in time, and not on the time variation in US dollar funding conditions.

The vector CONTROLS comprises variables controlling for the time-varying bilateral integration between borrowing countries i and j, notably bilateral trade integration to control for demand driven house price co-movement resulting from income growth generated by bilateral trade. Standard errors are clustered at the country pair level to account for serial correlation within country pairs. Note that the saturation with a rich set of fixed effects results in a demanding specification that allows us to control for most conceivable confounders and therefore helps us to considerably strengthen the causal interpretation of our results. In particular, the specification contains country-time fixed effects, $\mu_{i,t}$ and $\phi_{j,t}$, for both borrowing countries i and j . They absorb any observed and unobserved time-varying heterogeneity at the country level, including factors accounting for credit demand and time-varying structural characteristics of the respective domestic financial and mortgage market sectors. Country pair fixed effects $\theta_{i,j}$ control for time-invariant factors at the country pair level, and thus also for time-invariant features for each country separately. Moreover, global shocks affecting borrowing countries and lending banking systems alike are captured by time-fixed effects spanned by the country-time fixed effects.

Having established a statistically significant effect of US dollar funding conditions on house price growth, we now turn to synchronization and take equation (13) to the data. Our analytical framework does not provide guidance about the time horizon at which the dollar co-dependence and US dollar funding conditions should affect house price synchronization. Therefore, we test equation (13) at several lags s of the regressors $\mathbf{CoHFI}^{i,j}_{t-s}$ and $\mathbf{CoDD}^{i,j}_{t-s}$.

Columns (1), (4), (7), and (10) in Table (2) show the benchmark results and provide strong evidence in favor of our hypothesis. The coefficient on the dollar co-dependence is positive and statistically significant at the 1 percent significance level, in line with the prediction that an increasing dollar co-dependence strengthens the link between the synchronization of house prices and US dollar funding conditions. The estimate in column (10) implies that a 10 percentage point increase in the dollar co-dependence of an average country pair is associated with a 0.0005 percentage point increase in house price synchronization, or 38 percent increase relative to the mean of house price synchronization.

The addition of country-time fixed effects for each borrowing country in columns (5), (8) and (11), lowers the statistical significance compared to the benchmark, but leaves the coefficient on the dollar co-dependence significant at the 10 percent significance level. This implies that the rich set of fixed effects is effective at filtering out confounding factors at the borrowing country level, leaving our results robust to the elimination of demand side drivers of house price growth such as the demand for mortgage credit.

The result is robust to increasing the number of lags for each specification. Regardless of the specification, the coefficient on $\mathbf{CoDD}^{i,j}_{t-s}$ increases in line with lag s from columns (1-3) to (10-12), suggesting that it takes some time for changes in US dollar funding conditions to percolate through the global banking system until banks in borrowing countries translate foreign funds into mortgages, finally driving house prices and synchronization patterns.

We further buttress our result by including time-varying controls at the borrowing country pair level. Specifically, we control for bilateral trade integration. Trade integration is measured as the sum of bilateral imports of country i and j, scaled by the sum of respective nominal GDPs. At the quarterly level, this measure is noisy by construction. We therefore expect that this control introduces attenuation bias and further increases standard errors on our coefficient of interest on $\textbf{CoDD}^{i,j}_{t-s}$. The results in columns (3), (6), (9), (12) are in line with this reasoning, as shown by the loss of significance at conventional levels of statistical significance. Importantly, however, the coefficient estimates remain largely unchanged in magnitude, albeit slightly smaller in line with attenuation bias manifesting itself. The coefficient on bilateral trade does not enter significantly, meaning that bilateral trade integration does not drive house price synchronization. Note that this control is not available for all borrowing country pairs. This leads to a lower number of observations when controlling for the bilateral integration of trade.

The analytical framework put forward by Landier et al. (2017) suggests that the idiosyncratic shocks affecting common lending banking systems should be a major driver of house price synchronization. At the international level, however, we do not find supportive evidence, as shown by the mostly insignificant coefficient estimate for δ on the co-Herfindahl index $\textbf{CoHFI}^{i,j}_{t-s}$. The coefficient estimate for δ is negative and statistically significant in columns (7), (10) and (11), but in terms of magnitude does not offset the coefficient on the dollar co-dependence, as the estimate for δ is smaller by a factor of 10^{-1}. That is, if anything, the common exposure of borrowing countries slightly dampens the house price synchronization, and generally does not seem to be driving house price synchronization at the international level. Instead, it is the dollar co-dependence that is the relevant driver of house price synchronization in the international setting. The coefficient on the co-Herfindahl index possibly remains mostly insignificant because the variance of the idiosyncratic shock η^b_t — comprised in the theoretical counterpart $\alpha^2\sigma^2_\eta$ of coefficient δ in equation (11) — is too small for the coefficient δ to become significant.

5 Transmission mechanism

The previous section documents that the reduced-form implications of the statistical model regarding the sensitivity of house price growth to US net capital inflows and the international synchronization of house prices hold up well in the data. In addition, the theoretical framework posits that it is foreign lending by non-US banks that is the key transmitter of fluctuations in US dollar funding conditions to house prices around the globe. Furthermore, as fluctuations in US dollar funding conditions trigger an international credit supply shock to borrowing country banks, one would expect that an expansion of mortgage credit growth is a key transmitter of an easing of US dollar funding conditions to local housing markets. Therefore, mortgage lending of borrowing country banks should be more sensitive to US net capital inflows in more dollar dependent borrowing countries, and mortgage lending should be more synchronized among pairs of borrowing countries that are more co-dependent on US dollar funding. Similarly, foreign lending of lending banking systems with relatively high dollar dependence should respond more to US net capital inflows. We expect the effect to be especially pronounced when foreign lending is denominated in US dollars given that in our theoretical framework foreign lending in US dollars is financed by US dollar liabilities. We also expect the effect to be stronger for foreign lending to borrowing country banks as opposed to non-banks, as the former are the central intermediaries of foreign funds. In this section, we explore these implications.

5.1 Implications for mortgage credit growth and its synchronization

The results reported in the previous section demonstrate how US net capital inflows drive the international synchronization of house price growth through their effect on the US dollar funding conditions of non-US global banks. Next, we present evidence for an important intermediate step in this mechanism. A reminder is in order: The mechanism relies on US net capital inflows causing shifts in US dollar funding conditions, which in turn makes non-US banks adjust the foreign lending to banks in borrowing countries. In a first instance, banks in borrowing countries are conjectured to channel the additional foreign funds into mortgage credit. House prices then react due to the change in mortgage credit supply. Thus, the effect on house price growth and its synchronization should first and foremost show up in an effect on mortgage credit growth and its synchronization across borrowing countries, respectively.

To test this idea, we adapt equation (12) by replacing house price growth as dependent variable with mortgage credit growth in borrowing country i, and estimate the panel regression

$$\text{MGgrowth}_t^i = const + \beta_1\,\mathbf{DD}_{t-1}^i + \beta_{\mathbf{2}}'\,\mathbf{DD}_{t-1}^i \times \mathbf{RF_t} + \nu_i + \tau_t + \xi_t^i \tag{14}$$

where MGgrowth_t^i is the rate of mortgage credit growth over four quarters ahead in borrowing country i. All other variables are as defined in equation (12). Coefficient vector β_2 is our main coefficient vector of interest, and should be positively signed. The specification includes country and time fixed effects ν_i and τ_t and standard errors are cluster by the time dimension as in equation (12).

Table (3) reveals that the dollar dependence is at work for this intermediate step in the causal chain of our mechanism. Focusing on the G6 lending banking systems, columns (1) to (4) and (5) to (8) show the effect of the dollar dependence interacted with the two measures of US net capital inflows, on their own and in a horse race with other variables driving US dollar funding conditions. The coefficient on the dollar dependence interacted with US net capital flows, regardless of scaling, enters almost exclusively positively and statistically significantly. In terms of quantitative effect, an increase in a borrowing country's dollar dependence DD_t^i by 10 percentage points is equivalent to a rise in mortgage credit growth in the range of 4.1 to 4.7 percentage points when evaluating US net capital inflows at their mean. This provides clear evidence that an increase in the dollar dependence

DD_t^i amplifies the effect of US dollar funding conditions on mortgage credit growth, and supports the notion that domestic banks channel additional funds obtained from lending banking systems into the domestic mortgage market. Moreover, the coefficient on the stand alone term DD_t^i is positively significant, implying that an increase in the dollar dependence itself raises mortgage credit growth. In addition, the dollar dependence also enhances the effect of a decline of the Federal funds rate on mortgage credit growth, albeit with a quantitatively smaller effect. The broker-dealer leverage has a negative statistically significant effect on mortgage credit growth worldwide, but the effect remains negligibly small. Hence, US net capital inflows prove to be the quantitatively most relevant determinant of non-US global banks' US dollar funding conditions.

The results show that the dollar dependence not only matters for the effect of US dollar funding conditions on house price growth, but in a first instance also for mortgage credit growth. This is evidence in favor of domestic banks forwarding the international credit supply induced by changes in US dollar funding conditions to domestic mortgages markets, leading to pressure on house prices. Next, we test whether the insights on the synchronization of house price growth derived in section (4.2) are mirrored by the synchronization of mortgage credit growth. To do so, we run the following panel regression

$$\text{MGsync}_t^{i,j} = const + \delta\, \mathbf{CoHFI}_{t-s}^{i,j} + \beta\, \mathbf{CoDD}_{t-s}^{i,j} + \text{CONTROLS}_t + \theta_{i,j} + \mu_{i,t} + \phi_{j,t} + \epsilon_t^{i,j} \tag{15}$$

where $\text{MGsync}_t^{i,j}$ denotes the conditional covariance of mortgage credit growth between borrowing countries i and j. Parallel to equation (13), we measure $\text{MGsync}_t^{i,j}$ as the product of the rates of mortgage credit growth over four quarters ahead in borrowing country i and j. All else remains as specified in equation (13). In particular, the coefficient β should enter positively such that a rising dollar co-dependence entails a higher synchronization of mortgage credit growth. In line with equation (13) for house price synchronization, the specification also includes the full battery of fixed effects to control for observed and unobserved time-varying factors at the levels of countries i and j, as well as for time-invariant country pair characteristics.

Results in columns (1), (4), (7), and (10) of Table (4) highlight that dollar co-dependence intensifies the effect of US dollar funding conditions on mortgage credit growth synchronization. As before, the coefficient on the dollar co-dependence is statistically significant at the 1 percent significance level. The results remain robust to saturating the specification with country-time fixed effects, leaving results significant at the 5 percent significance level as show in columns (2), (5), (8), (11). Also in line with the results for house price synchronization, we find that the effect of the dollar co-dependence is rising over time as given by the increase in lag order s.

In columns columns (3), (6), (9), (12) we control for bilateral trade. The attenuation bias introduced through this relatively noisy measure of bilateral trade lowers the magnitude of the coefficient. Nevertheless, the coefficient on the dollar co-dependence remains statistically significant at the 10 percent level. Coupled with the previous finding for house price synchronization, the result obtained from a demanding specification comprising country-time fixed effects in addition to a time-varying country pair-level control variable, bilateral trade, corroborates the importance of the dollar co-dependence for the effect of US dollar funding conditions on real estate markets in borrowing countries.

The results for equation (13) also help to shed further light on idiosyncratic shocks to common lending banking systems. The coefficient estimate for δ on the co-Herfindahl index $\textbf{CoHFI}^{i,j}_{t-s}$ comes in positively in several specifications, but is quantitatively dwarfed by the coefficient on the dollar co-dependence. Combined with the occasionally negative coefficient estimate for δ in the test for house price synchronization, at the international level evidence on the effect of the co-Herfindahl is mixed qualitatively, and negligible quantitatively. This is consistent with our earlier findings for house price synchronization, and makes the dollar co-dependence a key component of the effect of US dollar funding conditions on real estate markets globally.

5.2 Implications for foreign credit growth

In this section we go back one more step in the causal chain of our mechanism. For US dollar funding conditions to affect the mortgage credit provided by banks in borrowing countries, at first the foreign lending of lending banking systems to borrowing country banks should react to changes in US dollar funding conditions. We therefore study the effect of US dollar funding conditions on lending banking systems' foreign lending.

Similar to section (2.2), we provide a first look at the data to establish that the supply of foreign credit by lending banking systems co-moves with US net capital inflows, and that the co-movement is amplified by lending banking systems' dependence on US dollar funding. For each lending banking system b in our sample and for the period 2000Q1 to 2015Q1 we investigate the link between the foreign bank credit supply and US net capital inflows by running the time series regression

$$\frac{\Delta L^b_t}{L^b_{t-4}} = \beta^b \text{CAPFLOW}_t + \mu^b + \varepsilon^b_t \tag{16}$$

where $\frac{\Delta L^b_t}{L^b_{t-4}}$ is the growth rate of aggregate foreign credit provided by lending banking system b over four quarters ahead and CAPFLOW_t denotes US net capital inflows scaled by total US banking equity. The coefficient β^b measures the response of lending banking system b's foreign lending to CAPFLOW_t. Figure (9) plots the estimates of β^b against each lending banking system b's dollar dependence λ^b_t, i.e. the market share of lending banking system b in the global market for US dollar-denominated bank borrowing. The figure depicts a positive relationship between the dollar dependence λ_t^b and the sensitivity of lending banking systems' foreign lending to US net capital inflows, implying that the effect of US dollar funding conditions on foreign lending of lending banking systems is increasing in their exposure to US dollar funding. This positive relationship is robust to excluding the G6 lending banking systems. In line with the discussion in section (2.2), the positive relationship displayed in Figure (9) implies that the bank lending capacity of non-US global banks is indeed susceptible to US net capital inflows. This is because the inflows represent a positive refinancing shock to the US financial system and thus to any non-US banks seeking to raise funding from it.

We confirm the insights from this first look at the data more formally by testing the relationship between lending banking systems' foreign lending and US dollar funding conditions in the panel regression

$$\frac{\Delta L_t^{b,i}}{L_{t-4}^{b,i}} = const + \beta_1 \,\mathrm{D}_{t-1}^b + \beta_2' \,\mathrm{D}_{t-1}^b \times \mathbf{RF_t} + \theta_{b,i} + \mu_{i,t} + \psi_t^{b,i} \tag{17}$$

where $\frac{\Delta L_t^{b,i}}{L_{t-4}^{b,i}}$ measures the growth rate of bilateral claims of lending banking system b on borrowing country i over four quarters ahead, D_{t-1}^b denotes lending banking system b's dollar dependence, and $\mathbf{RF_t}$ denotes the vector of variables driving US dollar funding conditions.[12] The dollar dependence D_{t-1}^b enters the specification lagged as lending banking systems' US dollar funding needs are predetermined at time t when shifts in the US dollar funding conditions occur. The granularity of the bilateral data structure allows us to isolate the supply effect of fluctuations in US dollar funding by including borrowing country-time fixed effects $\mu_{i,t}$. Similar to the Khwaja and Mian (2008) estimators, these fixed effects absorb time-varying observed and unobserved heterogeneity at the borrowing country level, in particular demand for foreign credit. As the technique exploits the within-variation of each borrowing-country-time combination, we postulate that the foreign credit provided by different lending banking systems to the same borrowing country is broadly comparable e.g. in terms of average maturities and lending purpose. In addition, lending-banking-system-borrowing-country fixed effects $\theta_{b,i}$ control for time-invariant factors. The stand alone term of the vector $\mathbf{RF_t}$ is absorbed by the time fixed effects comprised in $\mu_{i,t}$. Standard errors are clustered at the borrowing

[12] For the purpose of this analysis, bilateral claims are measured by international claims, i.e. bilateral claims excluding foreign subsidiaries' local claims in local currency. This later allows us to distinguish between claims on the non-bank sector versus claims on the banking sector, i.e. interbank claims. This sectoral breakdown is available for international claims, while it is not for foreign claims. As an exception to the other parts of this paper, we therefore use international claims. Moreover, we argue that for this specific analysis international claims better identify the effect of US dollar funding shifts on foreign bank credit, as local credit in local currency is often financed by local currency deposits. The exclusion of local claims in local currency therefore allows focussing on the response of house price growth to mortgage credit financed by foreign credit obtained i) from foreign banks' subsidiaries in foreign currency, and ii) from abroad in foreign or local currency. We remove all observations with bilateral international credit below 10 million US dollars, and winsorize the growth rate of bilateral claims below the 1st and above the 99th percentile.

country level and by the time dimension. We estimate the regression by weighted least squares, using D^b as weight. The coefficient vector β_2 is our main coefficient vector of interest. The coefficient should be positively signed in line with the first evidence presented in Figure (9).

The results are recorded in Table (5). Columns (3) and (4) show the positive and statistically significant coefficients on the interaction of the dollar dependence D^b_{t-1} and the two measures of US net capital inflows. The coefficients indicate that an increase in a lending banking system's dollar dependence by 10 percentage points are associated with an increase in bilateral foreign credit growth by 4.8 to 5 percent for the two measures of US net capital inflows evaluated at their mean, respectively. The effect is offset by a small margin by the negative significant coefficient on the stand alone term of the dollar dependence D^b_{t-1}. The coefficient on this stand alone term implies that an increase in D^b_{t-1} by 10 percentage points is associated with a decline in foreign lending by 0.3 percentage points. Thus the overall effect of a change in D^b_{t-1} remains positive and economically significant. The implications of this result are twofold. First, the results confirm that shifts in US dollar funding conditions drive the foreign lending of lending banking systems. Second, lending banking systems' heterogenous exposure to US dollar funding is an essential ingredient for this intermediate step in the causal chain between US dollar funding conditions and house price growth. As shown in columns (1) and (2) of Table (5), the results hold when we focus on the G6 lending banking systems only. The coefficients in columns (1) and (2) signify that — evaluated at the mean of US net capital inflows — foreign credit growth of G6 lending banking systems increases by 3.5 to 3.8 percentage points in response to a 10 percentage point increase in a lending banking system's dollar dependence.

Next, we differentiate the results by counterparty sector in borrowing countries. That is, we study separately the effect of US net capital inflows on foreign lending to banks and non-banks in borrowing countries. Borrowing country banks are conjectured to translate foreign credit received from lending banking systems into mortgage credit, in turn affecting house prices. In contrast, non-banks do not perform this role as financial intermediary. Also, the maturity of bank-to-bank positions in the global banking network is known to be more short term compared to bank-to-non-bank positions, making bank-to-bank positions the more likely margin of adjustment of non-US global banks' foreign claims (McGuire and von Peter (2012)). Hence, when an increase in US net capital inflows eases the financing constraint of non-US lending banking systems, they provide more credit to banks abroad rather than to non-banks, in line with the "double-decker structure of international banking" (Bruno and Shin (2014)). Therefore, we expect that the effect of US dollar funding conditions on foreign lending of more dollar dependent lending banking systems is more pronounced for foreign lending to banks. Foreign lending to non-banks is expected to be less sensitive to fluctuations in refinancing conditions of global banks (Hoffmann et al. (2019)).

The results in columns (5) to (8) in Table (5) are consistent with this conjecture. For both measures of US net capital inflows, their effect on foreign lending by more dollar dependent lending banking systems is statistically more significant at the 1 percent level when a country borrows indirectly via its banks. Conversely, the effect enters at a lower significance level of 5 percent when a country's non-banks receive foreign lending from lending banking systems. We interpret this finding as evidence in favor of bank-to-bank lending being the primary transmission channel of the effect of US net capital inflows on house price growth.

Finally, we zoom in on the effect of US dollar funding conditions on foreign lending denominated in US dollars. A feature of the theoretical framework is the assumption that US dollar-denominated lending must be fully backed by US dollar-denominated liabilities, meaning that shifts in US dollar funding conditions directly translate into changes in foreign lending. Hence, we test whether the effect of fluctuations in US dollar funding conditions on foreign lending is stronger when the latter is denominated in US dollars as compared to other currencies. A consistent currency breakdown is not available for the bilateral foreign lending data. Hence, we work with the currency breakdown available for aggregate lending from lending banking system b to its respective borrowing countries i. Accordingly, we run the panel regression separately for foreign lending denominated in all currencies, US dollars, and other currencies:

$$\frac{\Delta L_t^{b,c}}{L_{t-4}^{b,c}} = const + \beta_1 \, \mathrm{D}_{t-1}^b + \beta_{\mathbf{2}}' \, \mathrm{D}_{t-1}^b \times \mathbf{RF_t} + \nu_b + \tau_t + \psi_t^{b,c} \tag{18}$$

where $\frac{\Delta L_t^{b,c}}{L_{t-4}^{b,c}}$ measures the growth rate in aggregate foreign claims of lending banking system b denominated in currency c over four quarters ahead, D_{t-1}^bdenotes lending banking system b's dollar dependence, and $\mathbf{RF_t}$ denotes again the vector of variables driving US dollar funding conditions. [13] The specification features lending banking system fixed effects ν_b and time fixed effects τ_t, and is estimated by weighted least squares, using D^b as weight. Standard errors are two-way clustered by lending banking system and time. The coefficient vector β_2 should be positively signed, indicating that the dollar dependence D_{t-1}^b enhances the co-movement between US dollar funding conditions and aggregate foreign lending.

Table (6) shows the results for foreign lending separately for each currency c. The coefficients on the interaction of the dollar dependence D_{t-1}^b and the two measures of US net capital inflows are partly not only more statistically significant, but also larger in magnitude when foreign lending is denominated in US dollars. In contrast, the coefficient on the interaction term does not enter

[13] Data on aggregate foreign lending by currency is derived from the BIS locational banking statistics by nationality.

statistically significantly for foreign lending denominated in other currencies.[14] These results lend further support to the importance of lending banking systems' dollar dependence in facilitating the transmission of fluctuations in US dollar funding conditions on house price growth and ultimately house price synchronization. They also provide evidence that foreign lending in US dollars is more sensitive to shifts in US dollar funding conditions as compared to foreign lending in other currencies, consistent with US dollar lending being fully funded by US dollar liabilities.

6 Conclusion

In this paper we have shown that capital inflows into the US are an important determinant of house price co-movement around the globe. Non-US global banks borrow in US dollars, which they lend on to borrowing countries. As capital inflows into the United States improve funding conditions for borrowers in US dollars, they contribute to the synchronization of foreign interbank lending to countries that borrow from US dollar-dependent non-US global creditor banks. This variation in lending supply then affects local real estate markets in the borrowing countries, leading to an international synchronization in mortgage credit growth and house price growth. As a result, borrowing country pairs whose non-US global creditor banks are more dependent on US dollar funding exhibit higher house price synchronization in response to shifts in US dollar funding conditions. Neither shocks to common lending banking systems nor direct borrowing from US banks is the main driver of synchronization. What we find to matter most is the dependence of a borrowing country on US dollar funding via its lending banking systems. A key feature of our results is that it is not US global banks that play the biggest role in transmitting the shifts in US dollar funding conditions to borrowing countries. Instead, the dollar dependence of non-US global banks accounts for the effect on house prices worldwide. Our findings highlight how the topography of international bank lending affects the synchronization of real outcomes, and in particular of real estate markets, illustrating that the "double decker structure of the global banking system" has first-order implications for the synchronization of real outcomes at the global level.

[14] Data on foreign lending denominated in other currencies than the US dollar are obtained as residual of foreign claims denominated in all currencies minus foreign claims denominated in US dollars.

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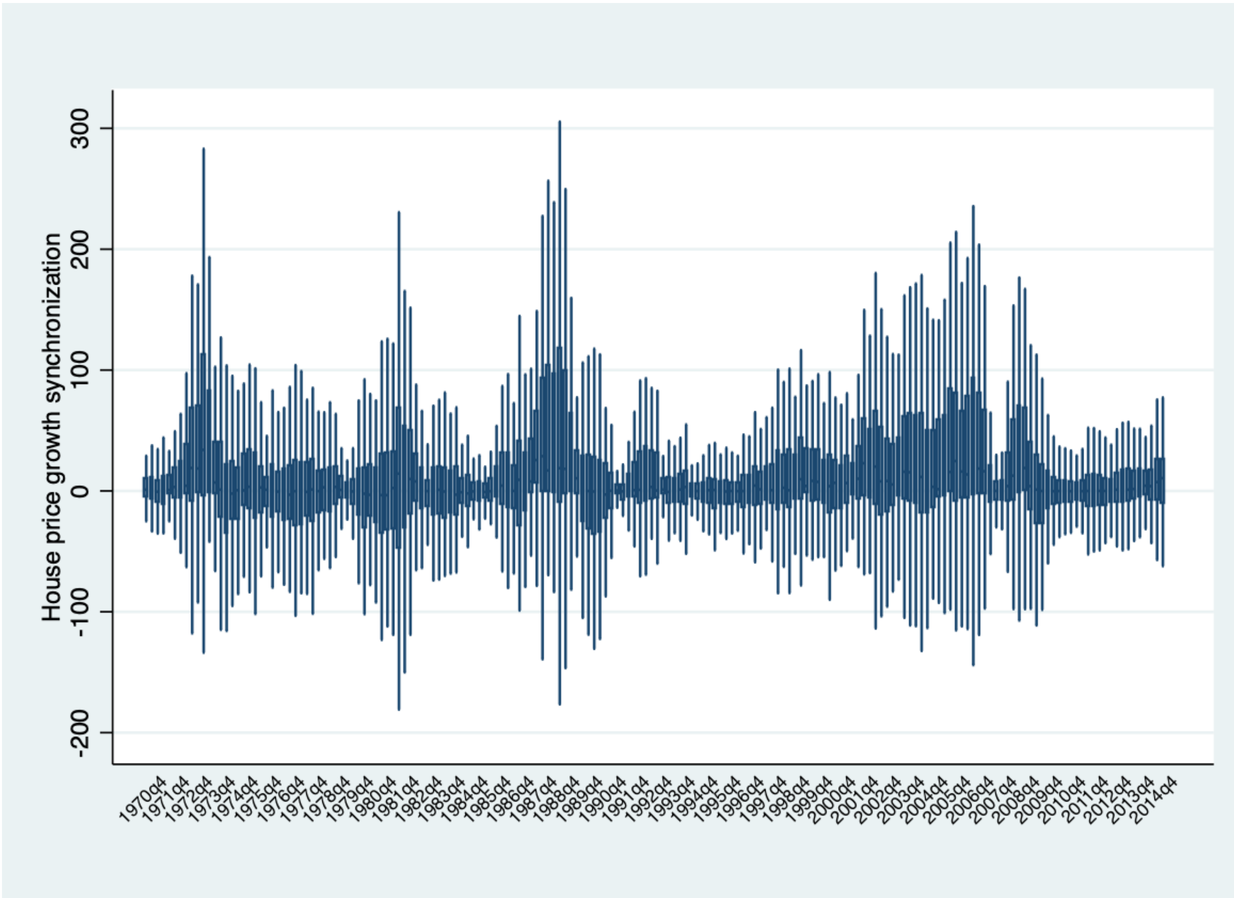
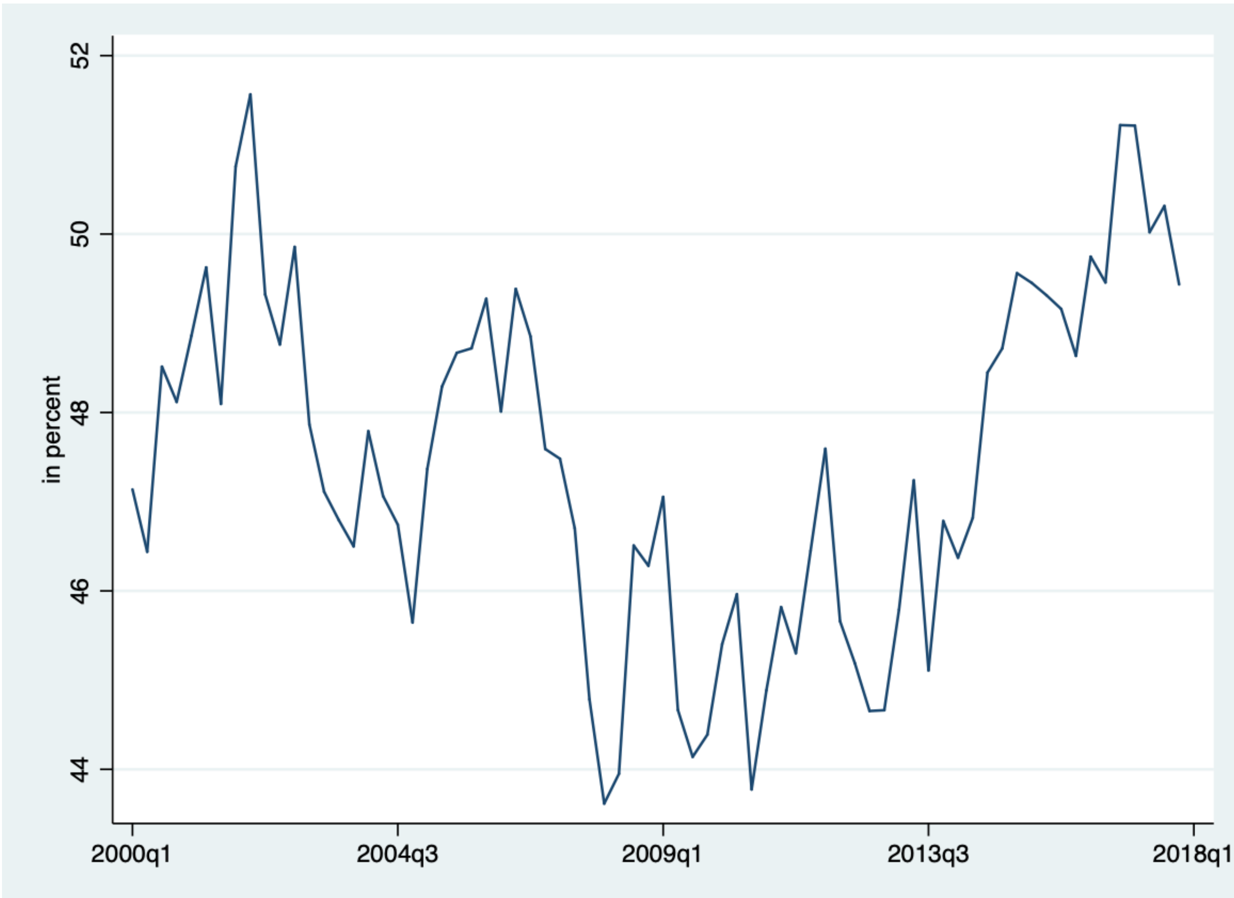
Figure 1:
House price synchronization, 1970Q1-2015Q1



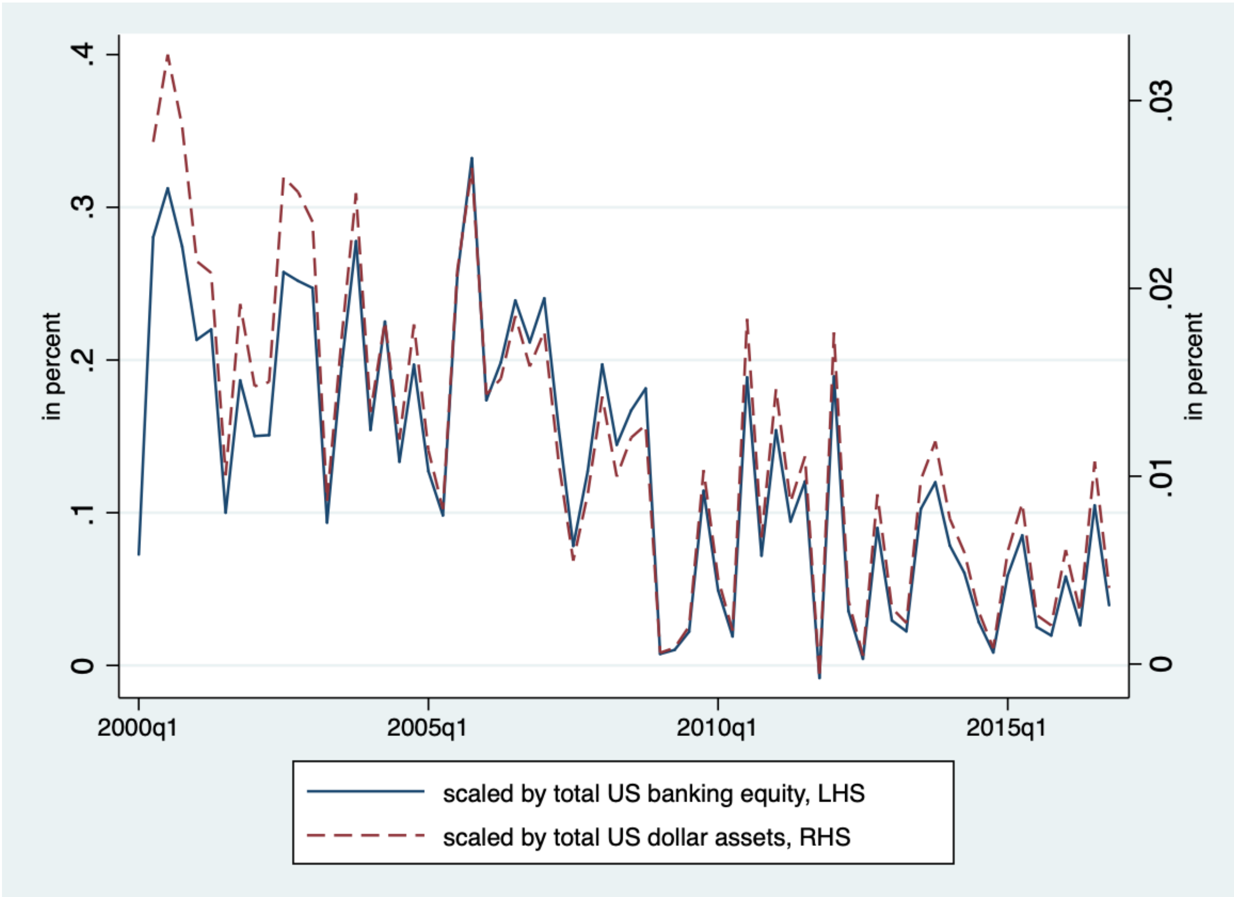
Note: This figure exhibits a box plot of the pairwise international house price synchronization over 782 country pairs at each point in time for the period 1970Q1-2015Q1, with the thick blue bars indicating the interquartile range. House price synchronization is computed as the product of the four quarter ahead house price growth in countries i and j constituting a country pair. House price growth is calculated based on the country-wide residential real house price indices obtained for 36 countries from the OECD.

Figure 2:
US dollar-denominated liabilities as share of total liabilities of non-US lending banking systems, 2000Q1-2017Q4



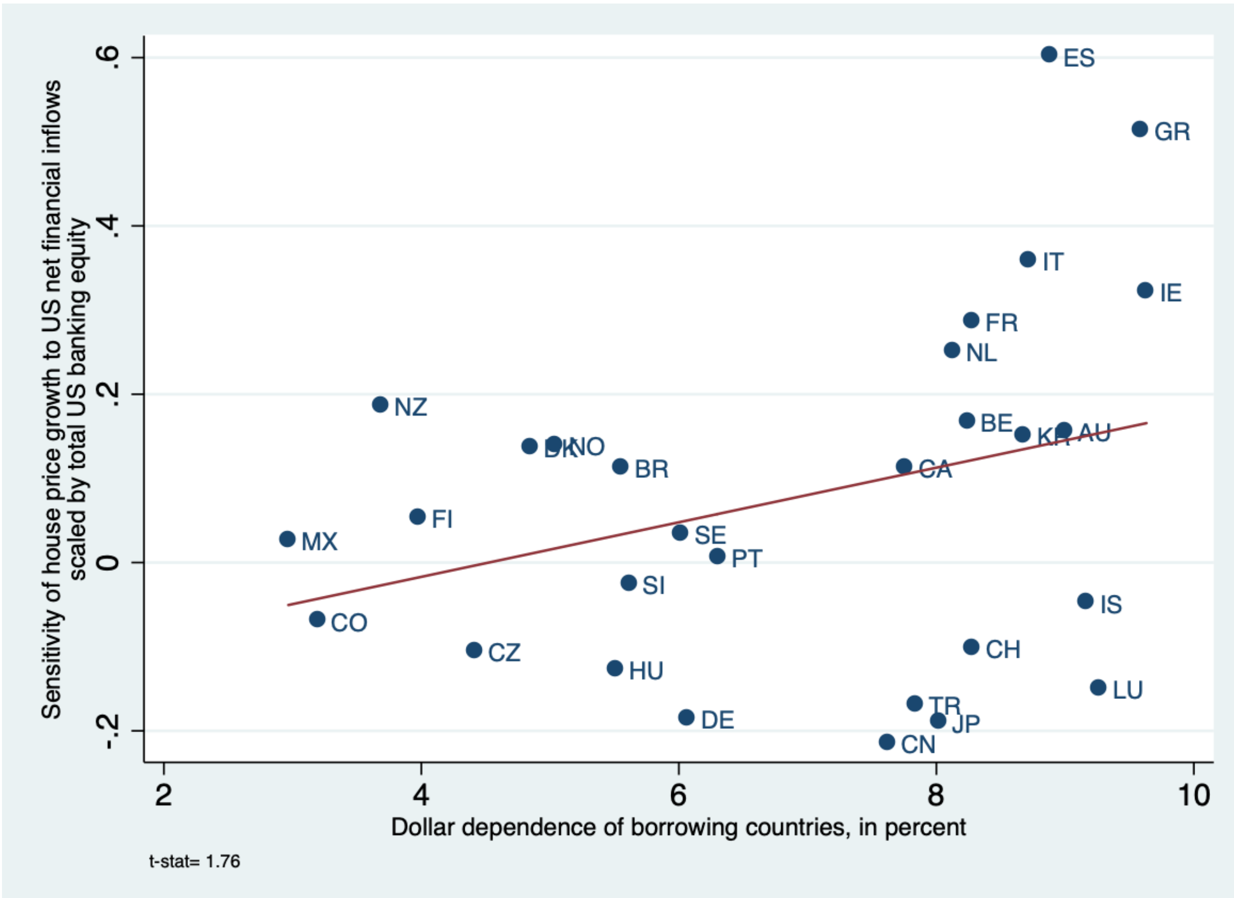
Note: This figure depicts non-US lending banking systems' stock of liabilities denominated in US dollars relative to their stock of liabilities denominated in all currencies, averaged over German, French, UK, Japanese, Swiss and Dutch lending banking systems that represent the set of major non-US global banks, based on the BIS locational banking statistics by nationality.

Figure 3:
US net capital inflows, 2000Q1 - 2016Q4



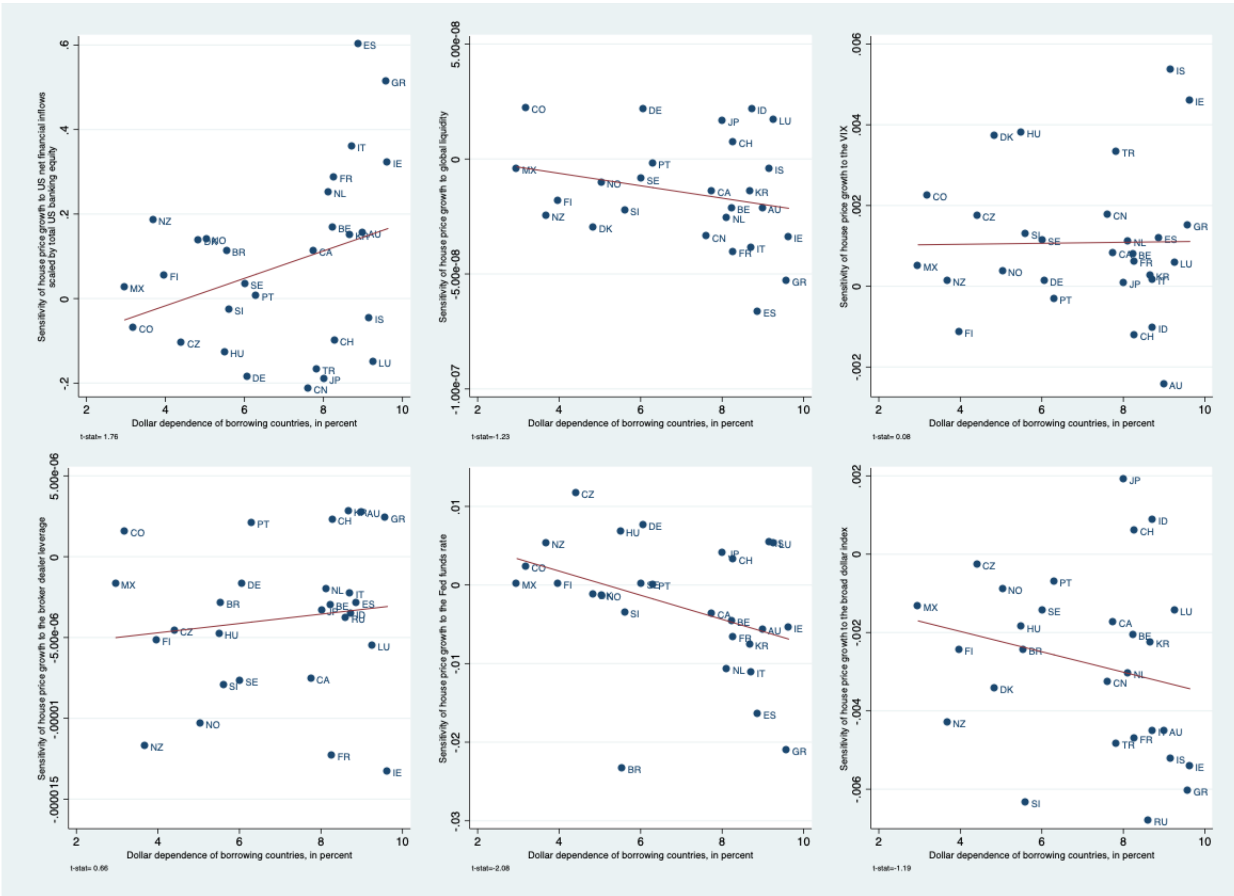
Note: US net capital inflows are obtained from the US Bureau of Economic Analysis International Transaction Statistics. Total US banking equity of commercial banks in the US stems from the Federal Financial Institutions Examination Council. Total US dollar assets denote all lending banking systems' outstanding US dollar denominated foreign claims recorded in the BIS consolidated banking statistics.

Figure 4:
Borrowing countries' dollar dependence and estimated sensitivity of house price growth to US net capital inflows



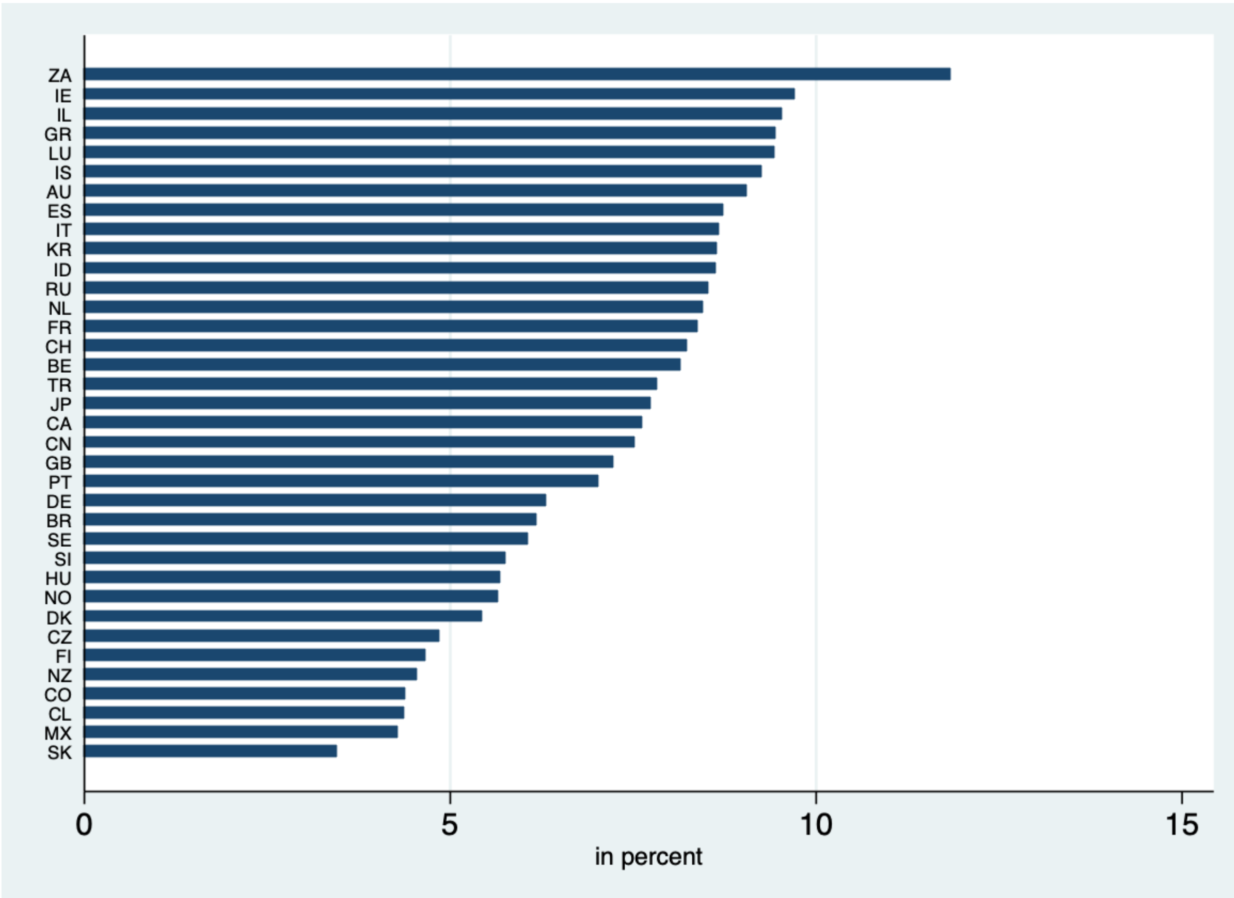
Note: This graph plots for each borrowing country i and for the period 2000Q1 to 2015Q1 the estimated sensitivity of house price growth to US net capital inflows scaled by total US commercial bank equity — obtained from running regression (6) — against a borrowing country's dollar dependence. House price growth is computed as the four quarter ahead change in the country-wide residential real house price index obtained from the OECD. US net capital inflows are obtained from the US Bureau of Economic Analysis International Transaction Statistics. Total US banking equity of commercial banks in the US stems from the Federal Financial Institutions Examination Council. A borrowing country's dollar dependence is computed as specified in equation (4). The sample is truncated at 5 and 95 percent of US net financial inflows scaled by total US banking equity, and of lending banking systems' dollar dependence, respectively.

Figure 5:
Borrowing countries' dollar dependence and estimated sensitivity of house price growth to other drivers of dollar refinancing conditions



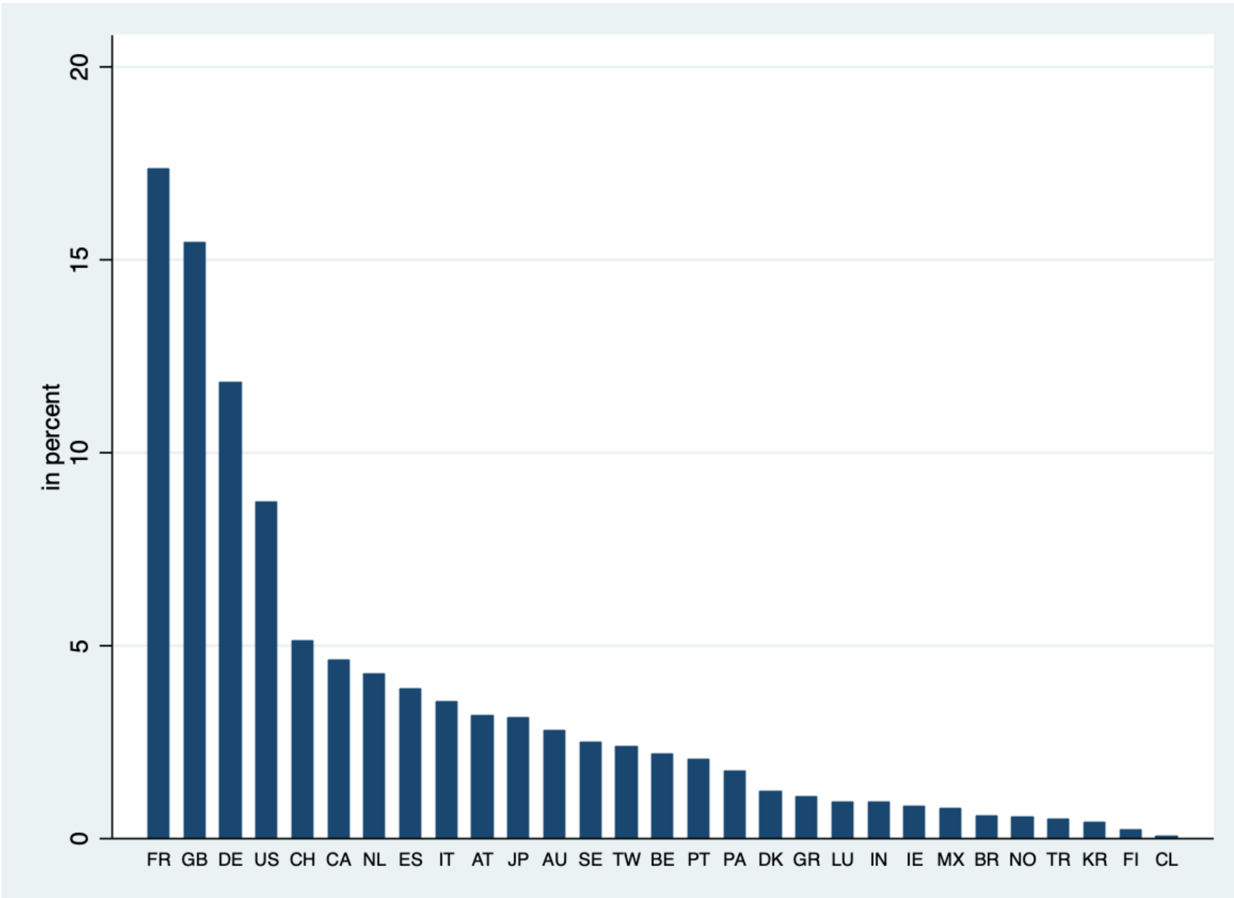
Note: This graph plots for each borrowing country i and for the period 2000Q1 to 2015Q1 the estimated sensitivity of house price growth to other drivers of dollar refinancing conditions — obtained from running regressions similar to equation (6) — against a borrowing country's dollar dependence, separately for each driver of dollar refinancing conditions. House price growth is computed as the four quarter ahead change in the country-wide residential real house price index obtained from the OECD. Alternative drivers of US dollar liquidity (global liquidity, VIX, broker-dealer leverage, Fed funds rate and the broad dollar index) are coded such that an increase implies an improvement in US dollar funding conditions. Table (A.1) indicates the definition and source of these alternative drivers. A borrowing country's dollar dependence is computed as specified in equation (4). The sample is truncated at 5 and 95 percent of US net financial inflows scaled by total US banking equity, and of lending banking systems' dollar dependence, respectively. For comparison to Figure (4), the upper left panel replicates the relationship between borrowing countries' dollar dependence and the sensitivity of house price growth to US net capital inflows.

Figure 6:
Dollar dependence by borrowing country



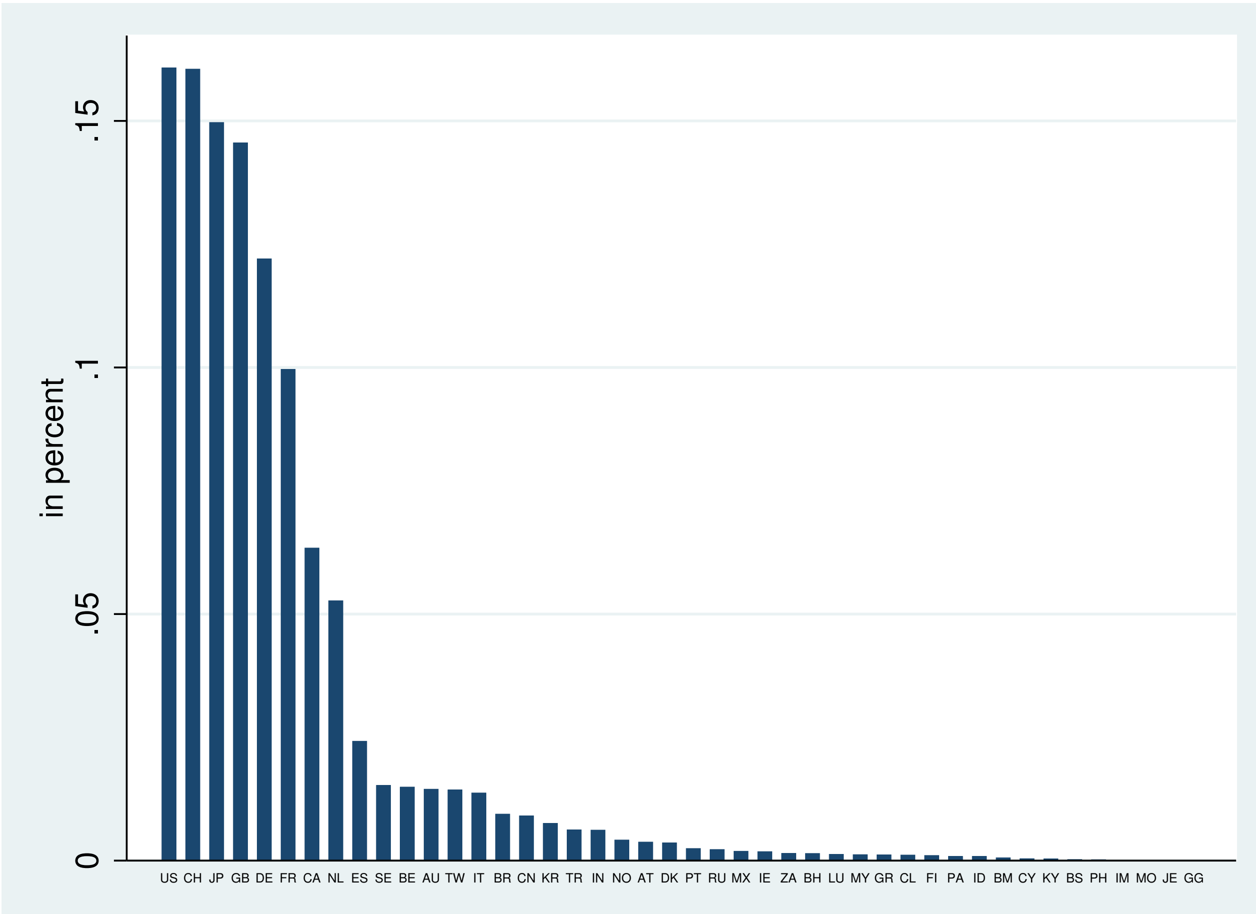
Note: A borrowing country's dollar dependence is computed as specified in equation (4), and for each borrowing country the dollar dependence is averaged over the period 2000Q1-2015Q1.

Figure 7:
Market shares of lending banking systems in foreign credit provision



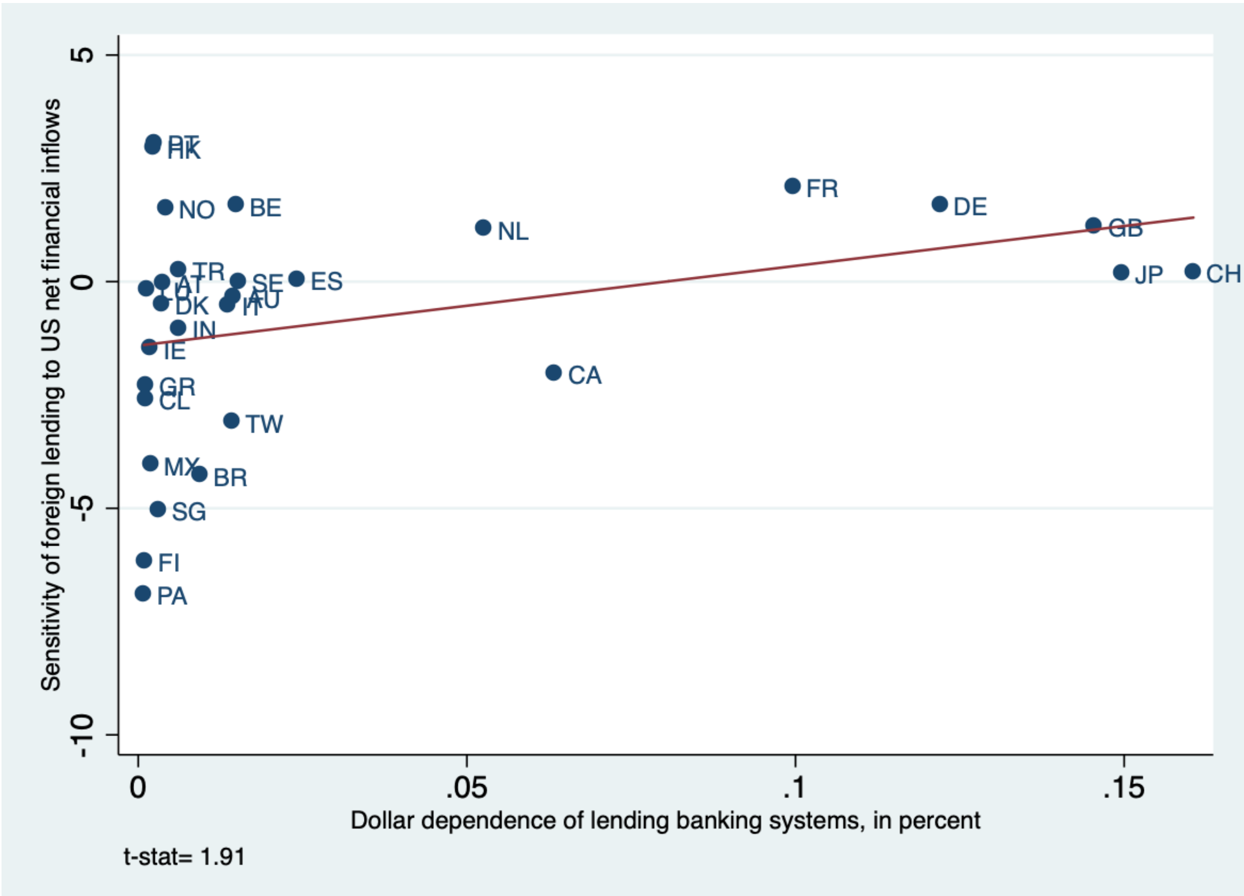
Note: Market shares are computed based on the BIS consolidated banking statistics, and averaged over the sample period 2000Q1-2015Q1 and over each lending banking system's borrowing countries.

Figure 8:
Dollar dependence by lending banking system



Note: The dollar dependence of lending banking systems is averaged over the period 2000Q1-2015Q1.

Figure 9:
Dollar dependence and estimated sensitivity of lending banking systems' foreign lending to US net capital inflows



Note: This graph plots for each lending banking system b and for the period 2000Q1 to 2015Q1 the estimated sensitivity of foreign lending to US net capital inflows scaled by total US commercial bank equity — obtained from running regression (16) — against a lending banking system's dollar dependence, i.e. the market share of lending banking system b in the global market for US dollar-denominated bank borrowing. Foreign lending is obtained as four quarter ahead change in lending banking systems' aggregate foreign claims. Foreign claims are obtained from the BIS consolidated banking statistics. US net capital inflows are obtained from the US Bureau of Economic Analysis International Transaction Statistics. Total US banking equity of commercial banks in the US stems from the Federal Financial Institutions Examination Council. A lending banking's dollar dependence is computed as specified in equation (3).

Table 1:
House price growth and US dollar funding conditions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable				**House price growth**				
DD^{i}_{t-1}	0.001	0.001	0.002	0.002	0.001	0.001	0.001	0.001
	[0.752]	[0.743]	[1.268]	[0.629]	[0.296]	[0.274]	[0.627]	[0.185]
DD^{i}_{t-1} X Capflow/equity$_t$	0.015**	0.016*	0.016*	0.016*				
	[1.972]	[1.872]	[1.882]	[1.861]				
DD^{i}_{t-1} X Capflow/dollar assets$_t$					0.243***	0.256***	0.253***	0.255**
					[2.494]	[2.357]	[2.332]	[2.329]
DD^{i}_{t-1} X Federal funds rate$_t$		0.00007	0.00001	-0.00003		0.00009	0.00004	-0.00001
		[0.211]	[0.023]	[-0.096]		[0.261]	[0.104]	[-0.039]
DD^{i}_{t-1} X Broker-dealer leverage$_t$			-0.00000	-0.00000			-0.00000	-0.00000
			[-1.039]	[-1.222]			[-0.678]	[-0.883]
DD^{i}_{t-1} X Vix$_t$				-0.00002				-0.00003
				[-0.307]				[-0.394]
country$_i$ FE	yes	yes	yes	yes	yes	yes	yes	yes
year-quarter FE	yes	yes	yes	yes	yes	yes	yes	yes
year-quarter clustering	yes	yes	yes	yes	yes	yes	yes	yes
Observations	1,264	1,264	1,264	1,264	1,264	1,264	1,264	1,264
R^2	0.386	0.386	0.386	0.386	0.387	0.387	0.387	0.388

Robust t-statistics in brackets
*** p<0.01, ** p<0.05, * p<0.1

Note: This table reports the results from estimating equation (12) for the period from 2000Q1 to 2015Q1. The dependent variable HPgrowth_t^i is the growth rate of house prices in borrowing country i over four quarters ahead. The explanatory variables are country i's dollar dependence $\mathbf{DD}_{t-1}^i$ lagged by one quarter and the interaction of the lagged dollar dependence with the following variables driving US dollar funding conditions: US net capital inflows scaled either by total US banking equity or by total outstanding US dollar denominated foreign claims (dollar assets), the Federal funds rate, the broker-dealer leverage and the VIX. These variables are coded such that an increase implies an improvement in US dollar funding conditions. The dollar dependence $\mathbf{DD}_{t-1}^i$ is computed based on borrowing countries' exposures to G6 lending banking systems. Column (1) and (5) show the result for the interaction using US net capital inflows, scaled by total US banking equity and by total outstanding US dollar denominated foreign claims (dollar assets), respectively. Columns (2) to (4) and (6) to (8) show the results for horse races of interactions using US net capital inflows against interactions using alternative drivers of US dollar funding conditions. The specification includes country and time fixed effects, and standard errors clustered by the year-quarter time dimension. Coefficients of stand alone terms of US net financial inflows and other drivers of US dollar funding conditions are not reported since they are eliminated by time fixed effects. The constant is omitted. T-statistics are shown in parentheses. *, ** and *** indicate statistical significance at the 10%, 5% and 1% level, respectively.

Table 2:
House price growth synchronization and dollar co-dependence

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Dependent variable	**House price growth synchronization**											
	s = 1			s = 2			s = 3			s = 4		
$CoHI_{t-s}$	-0.000001	-0.000001	-0.000000	-0.000001	-0.000001	-0.000000	-0.000001*	-0.000001	-0.000001	-0.000001*	-0.000001*	-0.000001
	[-1.2]	[-1.287]	[-0.477]	[-1.459]	[-1.514]	[-0.764]	[-1.65]	[-1.574]	[-0.924]	[-1.891]	[-1.684]	[-0.969]
$CoDD_{t-s}$	0.00004***	0.00003	0.00003	0.00004***	0.00003*	0.00003	0.00004***	0.00004*	0.00003	0.00005***	0.00003*	0.00003
	[2.919]	[1.62]	[1.349]	[2.898]	[1.748]	[1.475]	[2.79]	[1.787]	[1.524]	[3.132]	[1.832]	[1.537]
Bilateral trade integration$_t$			0.001			0.001			0.001			0.001
			[0.829]			[0.816]			[0.872]			[0.878]
countrypair$_{ij}$ FE	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
country$_i$-year-quarter FE		yes	yes		yes	yes		yes	yes		yes	yes
country$_j$-year-quarter FE		yes	yes		yes	yes		yes	yes		yes	yes
countrypair$_{ij}$ clustering	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	28,084	27,970	22,675	27,808	27,696	22,471	27,532	27,422	22,267	27,256	27,148	22,063
R^2	0.239	0.524	0.574	0.24	0.524	0.575	0.239	0.525	0.575	0.24	0.53	0.582

Robust t-statistics in brackets
*** p<0.01, ** p<0.05, * p<0.1

Note: This table reports the results from estimating equation (13) for the period from 2000Q1 to 2015Q1. The dependent variable $\text{HPsync}_t^{i,j}$ is the product of the growth rates of house prices in country i and j over four quarter ahead, denoting a measure for the conditional covariance of house price growth between borrowing countries i and j. The explanatory variables are the co-Herfindahl index $\mathbf{CoHFI}_{t-s}^{i,j}$ and the dollar co-dependence $\mathbf{CoDD}_{t-s}^{i,j}$. Results are reported for several lags s of these regressors, with $s = 1$ in columns (1) to (3) and increasing to $s = 4$ in columns (10) to (12). In addition to country pair fixed effects, columns (2), (3), (5), (6), (8), (9), (11) and (12) include country-time fixed effects for both borrowing countries i and j to absorb observed and unobserved time-varying confounders at the borrowing country level. Columns (3), (6), (9) and (12) additionally control for the bilateral integration of trade between countries i and j. Standard errors are clustered at the country pair level. The constant is omitted. T-statistics are shown in parentheses. *, ** and *** indicate statistical significance at the 10%, 5% and 1% level, respectively.

Table 3:
Mortgage credit growth and US dollar funding conditions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable				**Mortgage credit growth**				
DD^{i}_{t-1}	0.016***	0.015***	0.019***	0.017***	0.015***	0.014***	0.018***	0.016***
	[7.525]	[6.97]	[7.736]	[4.642]	[6.083]	[6.377]	[6.991]	[4.364]
DD^{i}_{t-1} X Capflow/equity$_{t}$	0.01	0.028**	0.028**	0.028**				
	[1.025]	[2.072]	[2.074]	[2.129]				
DD^{i}_{t-1} X Capflow/dollar assets$_{t}$					0.246*	0.398***	0.379***	0.38***
					[1.832]	[2.578]	[2.464]	[2.589]
DD^{i}_{t-1} X Federal funds rate$_{t}$		0.001***	0.001**	0.001**		0.001***	0.001***	0.001**
		[2.948]	[2.28]	[2.057]		[3.163]	[2.392]	[2.096]
DD^{i}_{t-1} X Broker-dealer leverage$_{t}$			-0.000**	-0.000**			-0.000**	-0.000**
			[-2.15]	[-2.064]			[-2.094]	[-2.025]
DD^{i}_{t-1} X Vix$_{t}$				-0.000				-0.000
				[-0.889]				[-1]
country$_{i}$ FE	yes	yes	yes	yes	yes	yes	yes	yes
year-quarter FE	yes	yes	yes	yes	yes	yes	yes	yes
year-quarter clustering	yes	yes	yes	yes	yes	yes	yes	yes
Observations	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310
R^2	0.506	0.508	0.510	0.51	0.507	0.509	0.511	0.511

Robust t-statistics in brackets
*** p<0.01, ** p<0.05, * p<0.1

Note: This table reports the results from estimating equation (14) for the period from 2000Q1 to 2015Q1. The dependent variable MGgrowth_t^i is the growth rate of mortgage credit in borrowing country i over four quarters ahead. The explanatory variables are country i's dollar dependence $\mathbf{DD}_{t-1}^i$ lagged by one quarter and the interaction of the lagged dollar dependence with the following variables driving US dollar funding conditions: US net capital inflows scaled either by total US banking equity or by total outstanding US dollar denominated foreign claims (dollar assets), the Federal funds rate, the broker-dealer leverage and the VIX. These variables are coded such that an increase implies an improvement in US dollar funding conditions. The dollar dependence dollar dependence $\mathbf{DD}_{t-1}^i$ is computed based on borrowing countries' exposures to G6 lending banking systems. Column (1) and (5) show the result for the interaction using US net capital inflows, scaled by total US banking equity and by total outstanding US dollar denominated foreign claims (dollar assets), respectively. Columns (2) to (4) and (6) to (8) show the results for horse races of interactions using US net capital inflows against interactions using alternative drivers of US dollar funding conditions. The specification includes country and time fixed effects, and standard errors clustered by the year-quarter time dimension. Coefficients of stand alone terms of US net financial inflows and other drivers of US dollar funding conditions are not reported since they are eliminated by time fixed effects. The constant is omitted. T-statistics are shown in parentheses. *, ** and *** indicate statistical significance at the 10%, 5% and 1% level, respectively.

Table 4:
Mortgage credit growth synchronization and dollar co-dependence

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Dependent variable	**Mortgage credit growth synchronization**											
	s = 1			s = 2			s = 3			s = 4		
$CoHI_{t-s}$	0.000005**	0.000002	0.000003	0.000005**	0.000002	0.000003*	0.000006**	0.000002	0.000004*	0.000006**	0.000003	0.000004*
	[2.324]	[1.203]	[1.503]	[2.323]	[1.386]	[1.685]	[2.316]	[1.427]	[1.724]	[2.239]	[1.427]	[1.707]
$CoDD_{t-s}$	0.0001***	0.00009**	0.00008*	0.0001***	0.00009**	0.00008	0.0001***	0.00009**	0.00008*	0.0002***	0.0001**	0.00009*
	[5.194]	[2.095]	[1.747]	[5.27]	[2.023]	[1.611]	[5.485]	[2.13]	[1.663]	[5.726]	[2.18]	[1.69]
Bilateral trade integration$_t$			-0.001			-0.001			-0.001			-0.001
			[-0.828]			[-0.915]			[-0.786]			[-0.900]
countrypair$_{ij}$ FE	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
country$_i$-year-quarter FE		yes	yes		yes	yes		yes	yes		yes	yes
country$_j$-year-quarter FE		yes	yes		yes	yes		yes	yes		yes	yes
countrypair$_{ij}$ clustering	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	31,010	30,890	24,052	30,632	30,514	23,759	30,254	30,138	23,466	29,876	29,762	23,173
R^2	0.244	0.562	0.576	0.251	0.575	0.59	0.263	0.591	0.609	0.282	0.612	0.633

Robust t-statistics in brackets
*** p<0.01, ** p<0.05, * p<0.1

Note: This table reports the results from estimating equation (15) for the period from 2000Q1 to 2015Q1. The dependent variable $\text{MGsync}_t^{i,j}$ is the product of the growth rates of mortgage credit in country i and j over four quarters ahead, denoting a measure for the conditional covariance of mortgage credit growth between borrowing countries i and j. The explanatory variables are the co-Herfindahl index $\mathbf{CoHFI}_{t-s}^{i,j}$ and the dollar co-dependence $\mathbf{CoDD}_{t-s}^{i,j}$. Results are reported for several lags s of these regressors, with $s = 1$ in columns (1) to (3) and increasing to $s = 4$ in columns (10) to (12). In addition to country pair fixed effects, columns (2), (3), (5), (6), (8), (9), (11) and (12) include country-time fixed effects for both borrowing countries i and j to absorb observed and unobserved time-varying confounders at the borrowing country level. Columns (3), (6), (9) and (12) additionally control for the bilateral integration of trade between countries i and j. Standard errors are clustered at the country pair level. The constant is omitted. T-statistics are shown in parentheses. *, ** and *** indicate statistical significance at the 10%, 5% and 1% level, respectively.

Table 5:
Foreign lending of lending banking systems and US dollar funding conditions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable	Bilateral foreign lending							
Lending banking systems	G6		all					
Borrowing country sector	bank and non-bank				bank		non-bank	
	WLS using weight = D^b							
D^b_{t-1}	-20.609*	-23.805*	-30.488**	-32.666**	-43.381*	-46.495**	-37.571	-38.213
	[-1.862]	[-1.819]	[-2.304]	[-2.285]	[-1.798]	[-2.199]		
D^b_{t-1} X Capflow/equity$_t$	237.499***		332.337***		367.388***		393.760***	
	[4.593]		[4.438]		[4.171]		[2.764]	
D^b_{t-1} X Capflow/dollar assets$_t$		2,997.422***		3,996.414***		4,468.573***		4,602.845***
		[3.988]		[4.204]		[3.638]		[2.694]
lending banking system$_b$-borrowing country$_i$ FE	yes	yes	yes	yes	yes	yes	yes	yes
borrowing country$_i$-year-quarter FE	yes	yes	yes	yes	yes	yes	yes	yes
lending banking system$_b$-year-quarter clustering	yes	yes	yes	yes	yes	yes	yes	yes
Observations	7,592	7,592	11,695	11,695	4,305	4,305	6,043	6,043
R^2	0.525	0.526	0.459	0.461	0.402	0.403	0.458	0.458

Robust t-statistics in brackets
*** p<0.01, ** p<0.05, * p<0.1

Note: This table reports the results from estimating equation (17) for the period from 2000Q1 to 2015Q1. The dependent variable $\frac{\Delta L_t^{b,i}}{L_{t-4}^{b,i}}$ is the growth rate in bilateral claims of lending banking system b on borrowing country i over four quarters ahead. The explanatory variables are lending banking system b's dollar dependence $\mathbf{D}_{t-1}^b$ lagged by one quarter and the interaction of this lagged dollar dependence with US net capital inflows scaled either by total US banking equity or by total outstanding US dollar denominated foreign claims (dollar assets). The specification includes borrowing country-time fixed effects to isolate the supply effect of foreign credit provided to borrowing countries. It also controls for lending-banking-system-borrowing-country fixed effects. The table contrasts the results for foreign lending provided by G6 lending banking systems in columns (1) and (2) with the results for foreign lending from all lending banking systems in columns (3) and (4) for the two measures of US net capital inflows, respectively. Results in columns (5), (6), (7) and (8) show the breakdown of the effect of shifts in US dollar funding conditions on foreign lending by counterparty sector, i.e. foreign lending to borrowing country banks and non-banks for both measures of US net capital inflows. Bilateral claims below 10 million US dollars are removed, and we winsorize the dependent variable below the 1st and above the 99th percentile. Standard errors are clustered at the borrowing country level and by the time dimension, and the regression is estimated by weighted least squares, using $\mathbf{D}^b$ as weight. Coefficients of stand alone terms of US net financial inflows are not reported since they are eliminated by time fixed effects. The constant is omitted. T-statistics are shown in parentheses. *, ** and *** indicate statistical significance at the 10%, 5% and 1% level, respectively.

Table 6:
Foreign lending of lending banking systems by currency and US dollar funding conditions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent variable					**Foreign lending**				
Currency denomination of foreign credit	**All**	**USD**	**Other**	**All**	**USD**	**Other**	**All**	**USD**	**Other**
					WLS using weight = D^b				
D^b_{t-1}	0.159	0.085	6.194***	0.375	-1.272	19.283	0.532	-1.141	13.804
	[0.696]	[0.275]	[3.022]	[0.553]	[-0.725]	[0.875]	[0.768]	[-0.674]	[0.697]
D^b_{t-1} X Capflow/equity$_t$	3.698***	4.559***	-40.558	2.319*	2.787***	-74.437			
	[2.99]	[3.15]	[-1.493]	[1.766]	[3.359]	[-1.242]			
D^b_{t-1} X Capflow/dollar assets$_t$							22.979	23.025*	-770.657
							[1.563]	[1.865]	[-1.265]
controls for other drivers of US dollar liquidity				yes	yes	yes	yes	yes	yes
lending banking system$_b$ FE	yes	yes	yes	yes	yes	yes	yes	yes	yes
year-quarter FE	yes	yes	yes	yes	yes	yes	yes	yes	yes
lending banking system$_b$-year-quarter clustering	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	1,779	2,281	1,779	1,629	2,076	1,629	1,629	2,076	1,629
R^2	0.438	0.111	0.045	0.457	0.116	0.05	0.454	0.115	0.049

Robust t-statistics in brackets

*** p<0.01, ** p<0.05, * p<0.1

Note: This table reports the results from estimating equation (18) for the period from 2000Q1 to 2015Q1. The dependent variable $\frac{\Delta L_t^{b,c}}{L_{t-4}^{b,c}}$ is the growth rate in aggregate foreign claims of lending banking system b denominated in currency c over four quarters ahead. The explanatory variables are lending banking system b's dollar dependence $\mathbf{D}_{t-1}^b$ lagged by one quarter and the interaction of this lagged dollar dependence with US net capital inflows scaled either by total US banking equity in columns (1) to (6) or by total outstanding US dollar denominated foreign claims (dollar assets) in columns (7) to (9). Results shown in columns (4) to (9) additionally control for other drivers of US dollar funding conditions. The specification includes lending banking system fixed effects and time fixed effects, and is estimated by weighted least squares, using $\mathbf{D}^b$ as weight. Coefficients of stand alone terms of US net financial inflows and other drivers of US dollar funding conditions are not reported since they are eliminated by time fixed effects. The constant is omitted. Standard errors are two-way clustered by lending banking system and time.

7 Appendix

7.1 OECD house price index

Our analysis is based on country-level residential house price indices provided by the OECD. This data source is particularly suitable since the underlying house price data feeding into the index construction are of comparable quality, abstracting from differences in the definitions of the types of dwellings. Moreover, the relative homogeneity of OECD member countries in terms of structural features of their economies and financial market developments is advantageous for our identification strategy as time fixed effects in the regression analysis eliminate many time-varying confounding factors relevant to this country group. In addition to actual OECD member countries, the house price indices are also available for Brazil, China, Russia and South Africa. The price indices of Estonia, Latvia and Lithuania are available but excluded due to a relatively short time series characterized by extreme variation. Our final sample consists of 36 borrowing countries.

7.2 Computation of dollar dependence

A lending banking system b's dollar dependence λ_t^b is defined as the fraction of global foreign bank borrowing denominated in US dollars accounted for by banks headquartered in lending banking system b. The computation of this ratio requires data on lending banking systems' stock of liabilities denominated in US dollars. To identify the currency composition, we use the BIS locational banking statistics by nationality (LBSN). The nationality information allows us to replicate the exposure on a banking group level consistent with the consolidated banking statistics (CBS). To calculate US dollar positions of non-US banks we aggregate the global dollar-denominated positions of banks of a given nationality, subtract interoffice positions denominated in US dollars, and add the local positions in local currency of banks of the same nationality vis-à-vis the United States from the CBS. This last addition is necessary to capture the US dollar-denominated position of foreign banks' offices in the US, which are not recorded in the LBSN. To capture the entire dollar liabilities, including (net) off-balance sheet borrowing, we use data on US dollar-denominated assets to proxy the liabilities (Borio et al. (2017)). As prudent risk management by banks as well as supervisory requirements in many jurisdictions dictate that currency mismatches are to be kept at a minimum, foreign currency liabilities closely match assets in the same currency. While foreign currency denominated assets should be fully funded by foreign currency denominated liabilities, risk management and supervision does not restrict the opposite case when foreign currency denominated liabilities exceed foreign currency denominated assets. To the extent that this opposite case applies — if anything — we underestimate the stock of liabilities denominated in US dollars. As long as any approximation error applies uniformly to all lending banking systems, it does not affect the dollar dependence computed for a single lending banking system, because the dollar dependence is computed as a ratio of a lending banking system's US dollar-denominated assets — as proxy for US dollar-denominated liabilities — to the total of lending banking systems' dollar-denominated assets — as proxy for total US dollar-denominated liabilities.

7.3 Computation of market shares

To define the market shares we argue that a lending banking systems' share in a borrowing country's market for foreign credit, i.e. credit provided by all foreign lending banking systems, is a more appropriate choice than the share in the market for total credit, i.e. foreign credit plus domestic credit provided by borrowing country banks. In this paper, our focus is on the effect of the foreign credit supply from lending banking systems induced by fluctuations in US dollar funding conditions. To isolate the effect of foreign as opposed to domestic credit on house price growth, our identification strategy in equation (13) employs country-time fixed effects that eliminate borrowing country specific economic and financial market developments, including the growth in domestic credit provided by borrowing country banks independent from the funding obtained through foreign borrowing. This allows us to abstract from domestic credit conditions, and to work with market shares based on foreign credit. Besides, taking into account domestic credit would merely scale down lending banking systems' market shares. However, the cross-sectional distribution over lending banking systems would stand largely unaffected by this scaling, because e.g. G6 lending banking systems have a large market share in every borrowing country, regardless of whether the share is computed in terms of foreign or total credit. Moreover, potential shifts in the cross-sectional distribution of the market shares due to scaling are negligible as the market shares only serve as weights in borrowing countries' dollar dependence as defined in equation (4). More relevant to the identification strategy than the question of whether to define market shares in terms of foreign or total credit is the lending banking systems' heterogenous exposure to US dollar funding shifts as measured by λ_t^b.

7.4 Locational versus consolidated banking statistics

The computation of the market shares is based on lending banking systems' foreign claims from the CBS on immediate counterparty basis, as opposed to the locational banking statistics (LBS). A practical reason for using the CBS is the availability of bilateral lending data, i.e. from a banking system of given nationality to a borrower country, for the entire time period of our sample. This data has only started to be available in the LBS since 2012Q1 — a time period too short to analyze house price cycles. In addition to the availability of bilateral data, there are three economic reasons for using the CBS.

First, the nationality of the lending bank coincides with the decision making unit of the bank

(Takáts and Temesvary (2016)). This is particularly relevant for global banks at the core of our analysis since decisions on leverage and foreign currency funding — such as from the US dollar money market — are taken at a bank's global headquarters. Consequently, a global bank's lending — including the lending by foreign offices in the borrowing country — is driven by factors better captured by nationality. Therefore, a borrowing country's exposure vis-a-vis the global bank's lending should also be measured based on consolidated claims.

Second, the CBS exclude interoffice positions by construction. Consider a British bank that extends a loan to a borrower in Chile. The exposure between the Chilean borrower and the British bank does not include any intermediate interoffice transactions, such as for instance between the British bank and its subsidiary in Mexico and from the Mexican subsidiary to the borrower in Chile. By virtue of consolidation, the CBS records only an exposure of the British bank vis-à-vis a borrower in Chile. This logic also applies to "looking through" financial centers through which a significant share of international transactions are routed. Suppose a German bank lends to a borrower in Finland through its German subsidiary in Luxemburg. The LBS would count two cross-border transactions, from the German bank to its subsidiary in Luxemburg and from the subsidiary to the borrower in Finland. The CBS, however, establish a direct link between the German bank and its borrower in Finland.

Third, the CBS take into account the two principal transaction forms of foreign credit provision. Foreign banks can provide credit either cross-border or through a local office in the borrowing country. As discussed by Kerl and Niepmann (2015), the choice depends on the "efficiencies of countries' banking sectors, differences in the return on loans across countries, and impediments to foreign bank operations". As the consolidated view does not differentiate between these two channels, it accounts for the entirety of foreign claims.

Table A.1:
Summary statistics and data sources

Variable	Unit	Definition	Source	Notes	N	mean	sd	min	max
Dependent variables									
house price growth	%	growth rate of the real residential country-level house price index over four quarters ahead	OECD	The types of dwellings entering in the price index for each country might differ across countries.	1395	2.17	7.78	-28.73	55.44
house price growth synchronization		product of the growth rates of the real residential country-level house price indeces of borrowing countries i and j, over four	OECD		28,360	13.06	63.44	-592.71	3243.75
mortgage credit growth	%	growth rate of country-level mortgage credit over four quarters ahead	credit to households and non-profit institutions serving households from the long series on total credit and domestic bank credit to the private non-financial sector, Bank for International Settlements		1,437	60.90	11.26	-17.57	105
mortgage credit growth synchronization		product of the growth rates of country-level mortgage credit in borrowing countries i and j, over four quarters ahead	credit to households and non-profit institutions serving households from the long series on total credit and domestic bank credit to the private non-financial sector, Bank for International Settlements		31,388	36.7	172.70	-3333.33	8647.06
bilateral lending from lending banking system b to borrowing country i	%	growth rate in bilateral international claims of lending banking system b on borrowing country i over four quarters ahead	consolidated banking statistics, Bank for International Settlements	We remove all observations with bilateral foreign credit below 10 million US dollars, and winsorize below the 1st and above the 99th percentile.	17,021	8.27	35.15	-86.20	1176.98
aggregate lending of borrowing country b in US dollars	%	growth rate in aggregate foreign claims of lending banking system b in US dollars over four quarters ahead	locational banking statistics by nationality, Bank for International Settlements		2,632	10.52	1463.68	-95.74	39317.95
aggregate lending of borrowing country b in all other currencies	%	growth rate in aggregate foreign claims of lending banking system b in all other currencies over four quarters ahead	locational banking statistics by nationality, Bank for International Settlements		2,019	32.13	605.59	-2678.45	19523.52
Explanatory variables									
dollar dependence of lending banking system	%	fraction of global US dollar-denominated bank borrowing accounted for by banks headquartered in the respective lending banking system	locational banking statistics by nationality, Bank for International Settlements		2,160	3.16	5.16	0	24.03
dollar dependence of borrowing country	%	products of lending banking systems' market shares in foreign credit provision to country i and the lending banking systems' dollar dependence, summed over banks headquartered in lending banking systems b that lend to country i	consolidated banking statistics and locational banking statistics by nationality, Bank for International Settlements		2232	7.13	2.78	0.91	15.66
dollar co-dependence		product of dollar dependence of borrowing countries i and country j	consolidated banking statistics and locational banking statistics by nationality, Bank for International Settlements		40,626	53.30	30.73	0	199.25
co-Herfindahl		product of lending banking systems' market shares in foreign credit provision to borrowing countries i and j, summed over banks headquartered in lending banking systems b that lend to country i	consolidated banking statistics, Bank for International Settlements		40626	690.36	444.05	0	3601.08
Drivers of US dollar funding conditions									
US net capital inflows scaled by total US banking equity	%	US net capital inflows scaled by total US banking equity	US net capital inflows: net US incurrance of liabilities excluding financial derivatives (net increase in liabilities / financial inflow (+)) minus net US acquisition of financial assets excluding financial derivatives (net increase in assets / financial outflow (+)): US Bureau of Economic Analysis, international transaction statistics; scaling factor: total US commercial banking equity: total equity capital for commercial banks in the US [USTEQC]: Federal Financial Institutions Examination Council (US), retrieved from FRED, Federal Reserve Bank of St. Louis		1,620	0.15	0.082	0.33	0.0043
US net capital inflows scaled by total US dollar-denominated assets	%	US net capital inflows scaled by total US dollar denominated assets	US net capital inflows: net US incurrance of liabilities excluding financial derivatives (net increase in liabilities / financial inflow (+)): US Bureau of Economic Analysis, international transaction statistics; scaling factor: total US dollar denominated assets: locational banking statistics by nationality, Bank for International Settlements		1,620	0.013	0.0072	0.00044	0.026
Federal funds rate	%	Wu-Xia shadow federal funds rate	Federal Reserve Bank of Atlanta		1,620	1.48	2.19	-1.7	5.35
Broker-dealer leverage	%	total financial assets of broker-dealers over equity of boker-dealers	US Flow of Funds, table L.128, Federal Reserve Board, retrieved through EconStats		1,620	4928	2030	3069	15841
VIX	index	SP500 Volatility Index	Chicago Board Options Exchange		1,620	21.13	9.14	11.03	58.60
Broad dollar index	index	trade weighted real effective exchange rate based on 26 bilateral exchange rates as selected by the Federal Reserve Board	Federal Reserve Board, retrieved from FRED, Federal Reserve Bank of St. Louis		1,620	108.41	9.33	95.23	129.15
Controls									
bilateral trade integration	%	sum of bilateral imports of country i and j as ratio of the sum of nominal GDPs of country i and j	imports: Direction of Trade Statistics, International Monetary Fund; nominal GDP: International Financial Statistics, International Monetary Fund		31653	0.00014	0.01	2.82E-13	1.68

Note: This table shows the definitions, data sources and summary statistics of the variables used in the analysis for the period 2000Q1-2015Q1.

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