Capital Flows, Cross-Border Banking and Global Liquidity*

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Abstract

This paper develops a model of global liquidity with international banks as the carriers of liquidity conditions across borders. Global banks raise wholesale funding from financial centers which is deployed globally through centralized portfolio allocation decisions from headquarters. As the shadow value of bank funding is equalized across regions, permissive credit conditions in financial centers are transmitted across borders. We derive closed-form solutions for banking sector capital flows and domestic private credit in the recipient economies and find empirical support for the key predictions.

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1 Introduction

The renewed surge in capital flows to emerging economies in the aftermath of the global financial crisis has ignited a lively debate on the nature of “global liquidity” and its transmission across borders. Low interest rates and permissive monetary policy pursued by advanced economy central banks are often cited in the press and popular commentary\textsuperscript{1} as a key factor in driving the capital flows. One of the tasks in our paper is to shed light on the validity of this claim.

Our paper develops a theory of global liquidity centered on the fluctuating leverage of cross-border banks as the channel through which permissive financial conditions are transmitted globally. We then subject the key predictions to an empirical investigation.

Our theory draws on two themes. The first is the role of financial intermediaries in driving fluctuations in risk premiums and financial conditions, especially in connection with the growing use of wholesale (or market-based) bank funding. When credit is growing rapidly, the core funding such as household deposits available to the banking sector is likely to be insufficient to finance the rapid growth in new lending. Other sources of wholesale (or “non-core”) funding is then tapped to finance bank lending. Global banks intermediate such funding, and the composition of their liabilities can be expected to reflect the state of the financial cycle and risk premiums ruling in the financial system.

The second element of our theory is the role of interlocking claims and obligations in transmitting credit availability conditions across borders. In a financial system with interlocking claims and obligations, one party’s obligation is another party’s asset. When global banks apply more lenient conditions on local banks, the more lenient credit conditions are transmitted to the recipient economy. In this way, more permissive liquidity conditions in the sense of greater availability of credit will be transmitted across borders through the interactions of global and local banks.

Understanding the institutional backdrop for global banking and the pivotal role of the U.S. dollar is important for the understanding of global liquidity. As well as being the world’s

\textsuperscript{1}See, for instance, the full page feature in the Financial Times entitled “Carried Away”, April 30th, 2010.
most important reserve currency and an invoicing currency for international trade, the US dollar is the funding currency of choice for global banks. A recent BIS (2010) study notes that as of September 2009, the United States hosted the branches of 161 foreign banks who collectively raised over $1 trillion dollars’ worth of wholesale bank funding, of which $645 billion was channeled for use by their headquarters. Money market funds in the United States are an important source of wholesale bank funding for global banks. Baba, McCauley and Ramaswamy (2009) note that by mid-2008, over 40% of the assets of U.S. prime money market funds were short-term obligations of foreign banks, with the lion’s share owed by European banks.

Even in net terms, foreign banks have been channeling large amounts of dollar funding to head office. That is, the funding channeled to head office is much larger than the funding received by the branch from head office. The BIS (2010) study finds that foreign bank branches had a net positive interoffice position in September 2009 amounting to $468 billion vis-à-vis their headquarters. Figure 1 plots the interoffice assets of foreign bank branches in the U.S. together
with the net interoffice series. Interoffice assets increased steeply in the last two decades, saw a sharp decline in 2008, but bounced back in 2009. Net interoffice assets were negative in the 1980s and most of the 90s, but in 1999, net interoffice assets surged into positive territory and increased steeply thereafter.

Some of the funds channeled to headquarters may be redirected to the US to finance the purchase of mortgage-backed securities and other assets. However, as noted by the BIS (2010) report, many banks use a centralized funding model in which available funds are deployed globally through a centralized portfolio allocation decision. At the margin, the shadow value of bank funding will be equalized across regions through the portfolio decisions of the global banks, so that global banks become carriers of dollar liquidity across borders. The role of the US dollar as the funding currency for global banking is key to understanding both the expansion phase of the financial cycle, as well as the acute dollar shortage that ensues in the subsequent reversal.

The role of global banks highlights the importance of gross capital flows in influencing credit conditions, as emphasized by Forbes and Warnock (2011) and Borio and Disyatat (2011). Whereas net flows and the net external asset positions of countries are important for assessing the long-run sustainability of the current account, they may not be informative about credit conditions. European banks have played a key role in providing US dollar intermediation capacity, raising wholesale funds in the US and reinvesting it in US mortgage backed securities. However, since the eurozone has a roughly balanced current account while the UK is actually a deficit country, their collective net capital flows vis-à-vis the United States do not reflect the influence of their banks in setting overall credit conditions in the US.

The structure of the global banking system examined in our paper can be sketched in Figure 2. Global banks occupy the central position in the system, and supply cross-border funding to

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2Cetorelli and Goldberg (2009, 2010) provide extensive evidence that internal capital markets serve to reallocate funding within global banking organizations.

3See McGuire and von Peter (2009) for an account of the dollar shortage in global banking in the recent financial crisis.

4See Lane and Milesi-Ferretti (2007) and Gourinchas and Rey (2007) and the post-crisis updated evidence in Gourinchas, Govillot and Rey (2010).
regional banks, who in turn provide private credit to firms and households in their respective regions. The empirical counterpart to the link from the global bank to the regional banks in Figure 2 can be found in the Bank for International Settlements (BIS) banking statistics.

Figure 3 plots the time series of the claims of the BIS reporting country banks on borrowers in countries listed on the right. The series have been normalized to equal 100 in March 2003. Although the borrowers have wide geographical spread, ranging from Australia, Chile, Korea and Turkey, there is a remarkable degree of synchronization in the boom in cross-border lending before the recent financial crisis.

The run-up in cross-border lending in Figure 3 closely mirrors the increase in wholesale funding raised by the global banks in Figure 1. In effect, Figure 1 reflects the liabilities side of global banks’ balance sheets, while Figure 3 gives (a small part of) the asset side of global banks’ balance sheets. This relationship will be examined as part of our empirical investigation.

We model the interaction of global and local banks through a “double decker” model of credit supply where the liabilities of local banks serve as the assets of the global banks, and the
total cross-border capital flows through the banking sector is the result of the market clearing condition between the demand for wholesale (non-core) funding by the local banks and the supply of non-core funding by the global banks. Calvo, Leiderman and Reinhart (1996) distinguished the “push” and “pull” factors that drive capital flows into emerging economies. In our model, by solving explicitly for the demand and supply functions for non-core wholesale funding, we can quantify the relative importance of the “push” and “pull” factors in driving capital flows.

Our model of credit supply is the flip side of a credit risk model where lending expands to fill up any spare balance sheet capacity when measured risks are low. The balance sheet constraint binds all the time, so that in periods of low measured risks, balance sheets must be large enough so that the risk constraint binds in spite of the low measured risks. The focus on the up-phase of the cycle in addition to the crisis dynamics distinguishes our approach from macro models of financial frictions that focus on constraints that keep lending inefficiently low and amplify crises.
in the downswing.\footnote{See Devereux and Yetman (2010), Bianchi and Mendoza (2010), Dedola and Lombardo (2009) and Bacchetta and van Wincoop (2010) for alternative models of financial frictions in the downturn motivated by the recent financial crisis.}

By drawing attention to the expansion phase of bank lending, our theory is in the spirit of Borio and Disyatat (2011), who coined the term “excess elasticity” to describe the tendency of the banking system to expand when financial constraints are relaxed. We show how risk premiums in the capital recipient economy become compressed with increased capital inflows, although our model is not sufficiently refined to address issues of the optimal level of risk premium or quantity of credit.

The closed form solution for capital inflows in the recipient economy takes the form:

\[
\text{Total capital inflow in banking sector} = \frac{\text{Weighted bank capital (regional + global)}}{1 - \text{spread} \times \text{regional leverage} \times \text{global leverage}}
\]  

where leverage is normalized to lie between 0 and 1. We know from Adrian and Shin (2008, 2010a) that the VIX index of implied volatility in equity index options is a good measure of the underlying Value-at-Risk measures that drive bank leverage, so that the VIX index can be predicted to play a pivotal role in fluctuations in capital flows. We find in our empirical investigation that the VIX index does, indeed, perform remarkably well as an explanatory variable both for cross-border capital flows in the banking sector as well as for domestic private credit in the recipient economy, echoing the earlier findings of Forbes and Warnock (2011). Our approach also complements macro business cycle studies such as Gourio, Siemer and Verdelhan (2010) and Adrian, Estrella and Shin (2010), who show that shocks to risk can generate macro time series that match many of the stylized facts.

Our empirical investigation proceeds in three steps, in line with the three links in the radiating chain of Figure 2. First, we show that the funding decisions of global banks conform closely to the VIX index. Adrian and Shin (2008, 2010a) showed that repo financing of the
Wall Street investment banks is explained by the VIX. Our results here suggest that European global banks that raise wholesale funding in the US dance to the same tune.

For the second link in the chain in Figure 2, we show that the VIX index and interoffice assets are highly significant in explaining banking sector capital flows, confirming the impact of fluctuations in bank leverage. VIX and the growth in interoffice assets remain significant even at the third (and final) stage of the radiating chart in Figure 2 for domestic private credit growth.

Taken together, our results suggest that global liquidity is a meaningful concept, explaining both the growth in private credit in recipient countries and cross-border lending. The VIX index is a key indicator of global liquidity due to its close association with banking sector leverage. The driving force behind capital flows turns out to be the leverage cycle of the global banks.

The outline of the paper is as follows. We begin by outlining our theoretical framework for the determination of global liquidity by formalizing a “double-decker” model of credit supply of the international banking system. We derive closed form solutions for total non-core funding of the global banks, banking sector capital flows and domestic private credit. By using the closed form solutions, we lay out the empirical hypotheses with an emphasis on the implications of the corporate finance of banking and the role of risk appetite and balance sheet capacity. The empirical investigation follows next, where the key predictions are put to the test. We conclude with an overview of some of the implications for the measurement of global liquidity.

2 Model of Global Banking

We begin by outlining the structure of cross-border banking in our model. The notation is summarized in Figure 4. The regional banks provide private credit (denoted $C$) to local borrowers at the rate $1 + r$. This private credit is funded by cross-border liabilities (denoted by $L$) drawn from the global banks at the funding rate $1 + f$. For the global banks, the cross-border lending $L$ appears on the asset side of the balance sheet, and the funding rate $1 + f$ is the rate earned on its assets. The global banks finance themselves by drawing on wholesale
money market funds $M$ at the interest rate $1 + i$. The equity of the regional bank is denoted by $E_R$ while the equity of the global bank is denoted by $E_G$. As we will see shortly, our model has an aggregation property across banks, so that $E_R$ and $E_G$ can be interpreted as the aggregate banking sector capital of the regional banks and global banks, respectively.\(^6\)

In our model, the exogenous variables are the equity terms $E_R$ and $E_G$ and the funding rate $i$ for the global banks, which we assume is fixed by the Federal Reserve. The other variables will be solved within the model.

### 2.1 Regional Banks

We first consider the credit supply decision of a regional bank. Each regional bank has a well diversified loan portfolio consisting of loans to many borrowers. Credit risk follows the Vasicek (2002) model, which is the model adopted by the Basel Committee as the basis for the Basel capital requirements (BCBS (2005)). Borrower $j$ repays the loan when $Z_j > 0$, where $Z_j$ is the random variable given by

\[ Z_j = -\Phi^{-1}(\varepsilon) + \sqrt{\rho}Y + \sqrt{1 - \rho}X_j \tag{2} \]

\(^6\)In our model, we will abstract away from the fluctuations in exchange rates and conduct our analysis as if the global and regional banks use the same currency. However, it should be borne in mind that fluctuations in risk premiums will have an impact on exchange rate movements (see Adrian, Etula and Shin (2009)).

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\[(2)\]
where $\Phi(.)$ is the c.d.f. of the standard normal, $\varepsilon$ is the probability of default on the loan and $Y$ and $\{X_j\}$ are mutually independent standard normal random variables. $Y$ is the common risk factor while each $X_j$ are the idiosyncratic component of credit risk for the particular borrower $j$. The parameter $\rho \in (0, 1)$ is the weight given to the common factor $Y$. To verify that $\varepsilon$ is the probability of default, note that

$$
\Pr(Z_j < 0) = \Pr\left(\sqrt{\rho}Y + \sqrt{1-\rho}X_j < \Phi^{-1}(\varepsilon)\right)
= \Phi\left(\Phi^{-1}(\varepsilon)\right) = \varepsilon
$$

Private credit extended by the bank is $C$ at interest rate $r$ so that the notional value of assets (the amount due to the regional bank at date 1) is $(1 + r)C$. Conditional on $Y$, defaults are independent. Taking the limit where the number of borrowers becomes large while keeping the notional assets fixed, the realized value of the bank’s assets can be written as a deterministic function of $Y$, by the law of large numbers. The realized value of assets at date 1 is the random variable $w(Y)$ defined as:

$$
w(Y) \equiv (1 + r)C \cdot \Pr(Z_j \geq 0|Y)
= (1 + r)C \cdot \Pr\left(\sqrt{\rho}Y + \sqrt{1-\rho}X_j \geq \Phi^{-1}(\varepsilon) |Y\right)
= (1 + r)C \cdot \Phi\left(\frac{Y\sqrt{\rho} - \Phi^{-1}(\varepsilon)}{\sqrt{1-\rho}}\right)
$$

The c.d.f. of the realized value of the loan portfolio at date 1 is given by

$$
F(z) = \Pr(w \leq z)
= \Pr(Y \leq w^{-1}(z))
= \Phi(w^{-1}(z))
= \Phi\left(\frac{1}{\sqrt{\rho}} \left(\Phi^{-1}(\varepsilon) + \sqrt{1-\rho}\Phi^{-1}\left(\frac{z}{(1 + r)C}\right)\right)\right)
$$

As prescribed by the Basel capital requirements (BCBS (2005))\(^7\), assume that the regional bank follows the Value-at-Risk (VaR) rule of keeping enough equity to limit the insolvency

\(^7\)The regulatory requirement was intended to emulate private sector best practice. See Adrian and Shin (2008) for a possible derivation of the VaR rule in a contracting setting.
probability to $\alpha > 0$. The bank is risk-neutral otherwise. The bank’s objective is to maximize expected profit subject only to its Value-at-Risk constraint.

The bank remains solvent as long as the realized value of $w(Y)$ is above its notional liabilities at date 1. Since the funding rate on liabilities is $f$, the notional liability of the bank at date 1 is $(1 + f) L$. The bank grants private credit $C$ so that its VaR constraint just binds.

$$\Pr (w (1 + f)L) = \Phi \left( \frac{\Phi^{-1}(\epsilon) + \sqrt{1 - \rho} \Phi^{-1}(\frac{(1 + f)L}{(1 + f)L})}{\sqrt{\rho}} \right) = \alpha$$

(5)

Figure 5 illustrates the Value-at-Risk condition. Re-arranging (5), we can write the ratio of notional liabilities to notional assets as follows.

$$\frac{\text{Notional liabilities}}{\text{Notional assets}} = \frac{(1 + f)L}{(1 + r)C} = \Phi \left( \frac{\sqrt{\rho} \Phi^{-1}(\alpha) - \Phi^{-1}(\epsilon)}{\sqrt{1 - \rho}} \right)$$

(6)

We will use the shorthand:

$$\varphi (\alpha, \epsilon, \rho) \equiv \Phi \left( \frac{\sqrt{\rho} \Phi^{-1}(\alpha) - \Phi^{-1}(\epsilon)}{\sqrt{1 - \rho}} \right)$$

(7)

Clearly, $\varphi \in (0, 1)$. From (6) and the balance sheet identity $E_R + L = C$, we can solve for
the bank’s supply of private credit. When private credit supply is positive, we have

\[ C = \frac{E_R}{1 - \frac{1}{1+r} \cdot \varphi} \quad (8) \]

Note that \( C \) is proportional to the bank’s equity \( E_R \), and so (8) also denotes the aggregate supply of private credit as a function of the aggregate equity of the sector. The leverage of the bank (and the sector) is the ratio of assets to equity, and is

\[ \text{Leverage} = \frac{1}{1 - \frac{1}{1+r} \cdot \varphi} \quad (9) \]

Since the probability of default on private credit is \( \varepsilon \), the expected profit to the bank from one unit of private credit is

\[ (1 - \varepsilon) (1 + r) - 1 \quad (10) \]

Therefore \( C = 0 \) when \( (1 - \varepsilon) (1 + r) < 1 \). Figure 6 illustrates the supply of private credit as function of the lending rate \( r \).

On the liabilities side of the balance sheet, the regional bank’s demand for cross-border
funding $L$ can be solved from (6) and the balance sheet identity $E_R + L = C$.

$$L = \frac{E_R}{\frac{1+f}{1+r} \cdot \frac{1}{\varphi} - 1}$$

(11)

By equating (11) with the supply of loans by the global banks, we can solve for the equilibrium stock of cross-border lending.

## 2.2 Global Banks

We will construct a “double-decker” version of the Vasicek model as follows. There are many regions and each global bank has a well-diversified portfolio of cross-border loans to regional banks across many regions. However, the global banks bear global risk that cannot be diversified away. The credit risk structure for global banks is depicted in Figure 7.

The box in Figure 7 represents the population of borrowers across all regions. Regional bank $k$ holds a portfolio that is diversified against idiosyncratic shocks, but not to regional shocks. Global banks hold a portfolio of loans to regional banks, and is diversified against regional shocks, but it faces undiversifiable global shocks.
In equation (2), we introduced the random variable \( Z_j \) that determined whether a particular borrower \( j \) defaults or not. We now introduce a subscript \( k \) to indicate the region that the borrower belongs to. Thus, let

\[
Z_{kj} \equiv -\Phi^{-1}(\varepsilon) + \sqrt{\rho} Y_k + \sqrt{1-\rho} X_{kj}
\]  

(12)

where

\[
Y_k = \sqrt{\beta} G + \sqrt{1-\beta} R_k
\]  

(13)

In (13), the risk factor \( Y_k \) is further decomposed into a regional risk factor \( R_k \) that affects all the private credit recipients in region \( k \) and a global risk factor \( G \) that affects all private credit recipients everywhere. The random variables \( G, \{R_k\} \) and \( \{X_{kj}\} \) are mutually independent standard normals.

The credit risk borne by a global bank arises from the possibility (which happens with the VaR threshold probability \( \alpha \)) that a regional bank defaults on the cross-border loan granted by the global bank. Although each regional bank has a diversified portfolio against the idiosyncratic risk of its regional borrowers, it bears the risk \( Y_k \), which is the linear combination of the global risk \( G \) and the region-specific risk \( R_k \).

A global bank has a fully-diversified portfolio across regions, and it can diversify away the regional risks \( R_k \) in the sense that the number of borrower regions becomes large for a fixed size of notional assets. From (4), a regional bank \( k \) defaults on its cross-border liability when

\[
Y_k < w^{-1} ((1 + f) L) = \frac{1}{\sqrt{\beta}} \left( \Phi^{-1}(\varepsilon) + \sqrt{1-\rho} \Phi^{-1}(\varphi) \right)
\]  

(14)

where \( \varphi \) is the notional debt/assets ratio given in (7). A regional bank from \( k \) defaults when \( \xi_k < 0 \), where \( \xi_k \) is the random variable:

\[
\xi_k \equiv \sqrt{\rho} Y_k - \Phi^{-1}(\varepsilon) - \sqrt{1-\rho} \Phi^{-1}(\varphi)
\]

(15)

\[
= \sqrt{\rho \beta} G + \sqrt{\rho (1-\beta)} R_k - \Phi^{-1}(\varepsilon) - \sqrt{1-\rho} \Phi^{-1}(\varphi)
\]

For a global bank with notional assets of \( (1 + f) L \) which is fully diversified across regions, its
asset realization is a deterministic function of the global risk factor $G$ only, and is given by

$$w(G) = (1 + f) L \cdot \Pr (\xi_k \geq 0 | G)$$

$$= (1 + f) L \cdot \Pr \left( R_k \geq \frac{\Phi^{-1}(\varepsilon) + \sqrt{1 - \rho \Phi^{-1}(\varphi)}}{\sqrt{\rho(1 - \beta)}} - \sqrt{\frac{\beta}{1 - \beta}} G \right)$$

$$= (1 + f) L \cdot \Phi \left( \sqrt{\frac{\beta}{1 - \beta}} G - \frac{\Phi^{-1}(\varepsilon) + \sqrt{1 - \rho \Phi^{-1}(\varphi)}}{\sqrt{\rho(1 - \beta)}} \right)$$

The quantiles of the asset realizations follow from the c.d.f. of $w(G)$.

$$F(z) = \Pr (w(G) \leq z)$$

$$= \Pr (G \leq w^{-1}(z))$$

$$= \Phi \left( w^{-1}(z) \right)$$

where

$$w^{-1}(z) = \sqrt{\frac{1 - \beta}{\beta}} \left[ \Phi^{-1} \left( \frac{z}{1 + f} \right) + \frac{\Phi^{-1}(\varepsilon) + \sqrt{1 - \rho \Phi^{-1}(\varphi)}}{\sqrt{\rho(1 - \beta)}} \right]$$

The global bank follows the Value-at-Risk (VaR) rule of keeping enough equity to limit the insolvency probability to $\alpha > 0$. The bank is risk-neutral and aims to maximize expected profit subject to its Value-at-Risk constraint. The bank remains solvent as long as the realized value of assets is above its notional liabilities. The notional liability of the global bank is $(1 + i) M$. The probability that its asset realization falls short of this level is set equal to $\alpha$. Hence,

$$\alpha = \Pr (w(G) < (1 + i) M)$$

$$= \Phi \left( \sqrt{\frac{1 - \beta}{\beta}} \left[ \Phi^{-1} \left( \frac{(1+i)M}{1+f} \right) + \frac{\Phi^{-1}(\varepsilon) + \sqrt{1 - \rho \Phi^{-1}(\varphi)}}{\sqrt{\rho(1 - \beta)}} \right] \right)$$

Re-arranging (18), we can write the ratio of notional liabilities to notional assets of the global bank as:

$$\frac{\text{Notional liabilities}}{\text{Notional assets}} = \frac{(1 + i) M}{(1 + f) L}$$

$$= \Phi \left( \frac{\sqrt{\beta(\Phi^{-1}(\alpha) - \Phi^{-1}(\varepsilon)) - \sqrt{(1 - \rho \Phi^{-1}(\varphi))}}}{\sqrt{\rho(1 - \beta)}} \right)$$

$$\equiv \psi(\alpha, \beta, \varepsilon, \rho)$$
Clearly $\psi \in (0, 1)$. From (19) and the balance sheet identity $E_G + M = L$ of the global bank, we can solve for the supply of cross-border lending as

$$L = \frac{E_G}{1 - \frac{1 + f}{1 + \psi}} \quad (21)$$

$L$ is proportional to equity $E_G$, and so (21) also denotes the aggregate supply of cross-border lending as a function of the aggregate equity of the global banking sector. The leverage of the global bank (and of the sector) is the ratio of assets to equity:

$$\text{Leverage} = \frac{1}{1 - \frac{1 + f}{1 + \psi}} \quad (22)$$

Since the probability of default on cross-border lending is $\alpha$, the expected profit to the global bank (and hence the risk premium) from one unit of lending is

$$(1 - \alpha) (1 + f) - 1 \quad (23)$$

Since global banks are risk-neutral profit maximizers, $L = 0$ when $(1 - \alpha) (1 + f) < 1$. From the demand and supply relationships for $L$ in (11) and (21), we will solve for the equilibrium $L$ and $f$ in closed form. Figure 8 illustrates the demand and supply curves for $L$.

### 2.3 Capital Flows and Domestic Credit

We can now solve explicitly for cross-border lending and private credit. Begin with the market clearing condition for $L$, which is

$$\frac{E_R}{1 + f} \cdot \frac{1}{\varphi} - 1 = \frac{E_G}{1 - \frac{1 + L}{1 + \psi}} \quad (24)$$

The funding rate $f$ can be solved as

$$1 + f = \frac{1}{\mu \cdot \frac{1}{1 + \varphi} + (1 - \mu) \frac{\psi}{1 + \varphi}} \quad (25)$$
where

\[ \mu = \frac{E_G}{E_G + E_R} \]  

(26)

We can then solve for the private credit in the regions by substituting (25) into the supply of private credit given by (8), giving the succinct expression:

\[ C = \frac{E_G + E_R}{1 - \frac{1+\varphi}{1+\psi}} \]  

(27)

This is a useful expression, which we can re-write in long hand as:

Total private credit = \frac{Aggregate bank capital (regional + global)}{1 - spread \times \frac{regional \ leverage}{global \ leverage}}  

(28)

The variables \( \varphi \) and \( \psi \) can be seen as normalized leverage measures (regional and global) that lie in the unit interval (0, 1).
Our model address how domestic risk premiums are affected by global “push” factors. Note that since the default probability of loans is \( \varepsilon \), the risk premium in the domestic credit market in the recipient country is given by

\[
\pi \equiv (1 - \varepsilon)(1 + r) - 1
\]  

(29)

For any downward-sloping credit demand curve, the risk premium \( \pi \) is a monotonic function of the total supply of credit, given by (28). Since domestic private credit supply in the recipient country is a function of global factors (such as leverage of global banks) as well as local factors, we can appeal to the formula (28) in attributing (at least in principle) the compression of risk premiums to global and local factors - i.e. to “push” and “pull” factors.

We now turn to cross-border lending and the consequent capital inflows through the banking sector. Substituting the solution for the funding rate \( f \) into (21), we can solve for the equilibrium stock of cross-border lending \( L \) as

\[
L = \frac{E_G + E_R \cdot \frac{1 + r}{1 + \varphi} \varphi \psi}{1 - \frac{1 + r}{1 + i} \varphi \psi}
\]  

(30)

In long hand, we can express equilibrium \( L \) as

\[
\text{Total cross-border lending} = \frac{\text{Global and weighted regional bank capital}}{1 - \text{spread} \times \frac{\text{regional leverage}}{\text{global leverage}}}
\]  

(31)

Thus, the predicted total cross-border lending has qualitatively similar features to the predictions regarding regional private credit. The BIS banking statistics on external claims would be the empirical counterpart to \( L \). The important point to note is that cross-border banking sector flows are a combination both of “push” and “pull” factors. Push factors include the capital of global banks the leverage of global banks. Pull factors include the capital of regional banks and the leverage of regional banks.
2.4 Empirical Implications for Capital Flows

In preparation for our empirical investigation, we draw some implications for the interaction between “push” and “pull” factors in bank capital flows from our closed form solution for $L$ given by (30). Consider banking sector capital flows driven by two archetypal push and pull factors - local bank equity $E_R$ that expands capacity to borrow (pull factor) and global bank leverage $\psi$ that increases loan supply (push factor). Global bank equity $E_G$ would have a similar effect to $\psi$. Then, neglecting the interest spread term for notational economy, banking sector capital flows can be written as

$$\Delta L \simeq \frac{\partial L}{\partial E_R} \Delta E_R + \frac{\partial L}{\partial \psi} \Delta \psi$$

$$= \frac{\varphi \psi}{1-\varphi \psi} \Delta E_R + \left( \frac{(1-\varphi \psi) E_R \varphi - (E_G + E_R \varphi \psi) (-\varphi)}{(1-\varphi \psi)^2} \right) \Delta \psi$$

$$= \frac{\varphi \psi}{1-\varphi \psi} \Delta E_R + C \frac{\varphi}{1-\varphi \psi} \Delta \psi$$ (32)

where $C$ is private credit in the recipient economy, as given in (27).

The first term in (32) is the levels effect of $\psi$ that interacts with equity growth, while the second term is the change effect of $\psi$. Banking sector capital flow ($\Delta L$) is therefore increasing in $\psi$ and in $\Delta \psi$. Since $\psi$ is inversely related to VIX (Adrian and Shin (2008, 2010a)), banking sector capital flow ($\Delta L$) is decreasing in VIX and the change in VIX. Moreover, we should also expect to see the growth in bank equity as well as the interaction between VIX and bank equity growth to be positively related to capital flows.

Having laid out the logic of our argument and the role of specific variables in influencing capital flows and private credit, we will investigate these empirical hypotheses more closely.

3 Data Description and Methodology

Our sample comprises data on 47 countries, encompassing both developed economies and emerging and developing economies, but excluding offshore financial centers. The criterion for inclusion is whether foreign banks play an economically significant role in the country’s financial
Table 1. **Summary Statistics.** This table summarizes our key variables in terms of their frequency (quarterly or annual), mean, standard deviation, minimum and maximum.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Frequency</th>
<th>Obs</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
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</thead>
<tbody>
<tr>
<td>External Loans Growth</td>
<td>quarter</td>
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<td>0.030</td>
<td>0.102</td>
<td>-0.777</td>
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We select countries with the largest foreign bank penetration, as measured by the number of foreign banks and on the share of domestic banking assets held by foreign-owned local institutions. We use the ranking on foreign banks penetration from Claessens, van Horen, Gurcanlar and Mercado (2008).

The countries included in our sample are Argentina, Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Chile, Cyprus, Czech Republic, Denmark, Egypt, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Indonesia, Ireland, Israel, Italy, Japan, Latvia, Lebanon, Lithuania, Malaysia, Malta, Mexico, Netherlands, Norway, Poland, Portugal, Romania, Russia, Slovakia, Slovenia, South Korea, Spain, Sweden, Switzerland, Thailand, Turkey, Ukraine, United Kingdom and Uruguay. Table 1 gives the main summary statistics of our sample of 47 countries. As well as data from the capital flow recipient countries, we use the series on interoffice assets of foreign banks in the United States published by the Federal Reserve.\(^8\)

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We track the global consequences of the channeling of funds raised in the US through two key variables: the annual growth in private credit and the quarterly growth in external claims of BIS reporting country banks. Private credit is the annual average domestic credit provided by the banking sector (IFS line 22d). External claims are the quarterly external loans and deposits of BIS reporting banks obtained from the BIS locational statistics data (Table 7A). The key organizational criteria of the BIS locational statistics data are the country of residence of the reporting banks and their counterparties as well as the recording of all positions on a gross basis, including those vis-à-vis own affiliates. This methodology is consistent with the principles underlying the compilation of national accounts and balances of payments, thus making the locational statistics appropriate for measuring capital flows in a given period.

To address the role of banking sector leverage and measured risks, we use the Chicago Board Options Exchange (CBOE) Volatility Index (VIX) of implied volatility in S&P 500 stock index option prices. The VIX Index is generally considered the barometer of investor sentiment and market volatility. For us, the more specific justification is the close link between the VIX index and measures of bank Value-at-Risk, so that banking sector leverage is closely tied empirically to the VIX index (Adrian and Shin (2008, 2010a)).

We also control for additional push and pull factors that the literature has identified as determinants of cross-border bank flows. Global push factors include interest rates, money stock, and GDP growth. We use the country-level banking series constructed by Beck and Demirgüç-Kunt in the World Bank (2009) Financial Structure Database. We use the spread between the ECB repo rate and the US Fed Fund target rate (Interest Spread) to assess the role of interest rate spreads in affecting capital flows. The annual growth in the global money supply ($\Delta Money stock$) is calculated as the sum of M2 in the US, Eurozone and Japan and M4 in the UK (from the IFS); global GDP growth ($Global Growth$) is computed as the volume change from the previous year (from the IFS). Domestic pull factors include the annual average return on equity for banks (Net Income/Total Equity, ROE) from Beck and Demirgüc-Kunt (2009), winsozizred at the 1% percentile. We include a dummy which equals 1 in the years a country

\footnote{We use the Lombard rate instead of the ECB repo rate before 1999.}

4 Empirical Findings

4.1 Funding of Global Banks

We first investigate how the fluctuations in the interoffice assets of foreign banks in the US relate to the VIX index and the interest rate spread between the Euro repo rate and the Fed Funds rate from the following regression.

\[ \Delta \text{Interoffice}_t = \alpha + \beta \text{VIX}_t + \gamma \text{Spread}_t + \delta \text{Controls} + \varepsilon_{i,t} \]  

\( \Delta \text{Interoffice}_t \) is the one quarter log difference in the interoffice assets of foreign banks in the US. \text{VIX} is the within-quarter average of the VIX index. \text{Spread} is the difference between the ECB Repo rate and the US Fed Fund target rate, averaged over the quarter. As controls we use the annual growth in the global money stock (\( \Delta \text{Money stock} \)), global GDP growth (Global Growth). Data are for 56 quarters for the period 1996 to 2009.

Table 2 shows the results. We see that the VIX Index is the only explanatory variable that is statistically significant in the regression and it has a negative sign, as hypothesized. Adrian and Shin (2008, 2010a) showed that the leverage of the five Wall Street investment banks varies inversely with the VIX index, where VIX proxies for Value-at-Risk. The significant effect of VIX on the interoffice assets of non-US banks suggest that the leverage of these banks also dances to the tune of the VIX. Baba, McCauley and Ramaswamy (2009) show that European banks are heavily represented in the group of foreign banks that channel US dollar funding to head office by tapping of the prime money market funds in the United States.

Interestingly, the interest rate spread between the ECB Repo rate and the US Fed Funds
Table 2. **Determinants of Interoffice Assets.** The dependent variable is the quarterly growth in the Interoffice Assets of foreign banks in the US. VIX is the quarterly average of the CBOE Volatility Index. Interest Spread is the spread between the ECB repo rate and the US Fed Fund target rate, averaged within quarter. ∆Money stock is the annual growth in the global money supply calculated as the sum of M2 in the US, eurozone and Japan and M4 in the UK (from the IFS). Global Growth is the global GDP, volume change from the previous year (from the IFS). Data are for 1996-2009. p-values are in parentheses.

<table>
<thead>
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<th>4</th>
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</thead>
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<td>VIX</td>
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<td>-0.0039*</td>
<td>-0.0049**</td>
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<td>-0.0043</td>
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<td>56</td>
<td>56</td>
<td>56</td>
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<td>R-squared</td>
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<td>0.05</td>
<td>0.144</td>
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rate does not show up as being significant in Table 2. Indeed, the insignificance of the interest rate spread variable turns out to be a consistent theme throughout our empirical investigation. One likely reason why the interest rate spread does not turn out to be significant is the central banks’ decisions concerning the policy rate react to financial conditions. We return to this issue shortly.

### 4.2 Capital Flows

Next we investigate the determinants of banking sector capital flows. We do this by investigating the external claims from BIS reporting country banks to our sample of 47 countries. We employ a panel regression with quarterly data. Our closed-form solution for banking sector capital flows is given by (31), and the empirical predictions on capital flows follow from (32). They suggest that VIX should enter both in levels and in changes (both negatively) while the growth in banking sector equity should enter positively with a positive interaction term with leverage.

We run panel regressions with quarterly data with country fixed effects and clustered stan-
ard errors at the country level of the form:

\[
\Delta L_{c,t} = \beta_0 + \beta_1 \cdot \Delta \text{Interoffice}_t + \beta_2 VIX_{t-1} + \beta_3 \cdot \Delta VIX_{t-1} + \beta_4 \text{ROE}_{c,t} + \beta_5 VIX_{t-1} \ast \text{ROE}_{c,t} + \text{controls}_{c,t} + \epsilon_{c,t}
\]  

(34)

where \(\Delta L_{c,t}\) is banking sector capital inflow into country \(c\) in period \(t\), as given by the quarterly log difference in the external claims of BIS reporting country banks on country \(c\) between quarters \(t\) and \(t - 1\); \(VIX_{t-1}\) is the within-quarter average of the VIX index lagged by one quarter; \(\Delta \text{Interoffice}_t\) is the growth in interoffice assets of foreign banks in the US from the quarter before given by the quarterly log difference. \(\text{ROE}_{c,t}\) is the country-level return on equity in country \(c\) in period \(t\), as a measure of the growth in banking sector equity. Note that we have VIX entering both in levels and in changes, and it interacts with ROE also, in accordance with the predictions in equation (32). Other controls are as described in the data section. The results are presented in Table 3.

The VIX level and \(\Delta \text{Interoffice}\) variables are highly significant and of the predicted sign. Indeed, looking across the columns of Table 3, we see that the coefficients on these variables remain stable to different specifications and highly significant throughout (the p-values being zero to three decimal places in every instance except one). The \(\Delta VIX\) variable is significant when it enters by itself, but is knocked out when appearing with VIX levels. The ROE variable and its interaction with VIX also figures prominently in the regressions with the predicted sign.

Taking the comparative statics from equation (32) as a package, the theoretical predictions receive broad support from Table 3. The only slight disappointment is that \(\Delta VIX\) does not appear as resiliently as the other variables from the theoretical prediction.

The interest spread variable in the policy rate between the ECB repo and Fed Funds rate is insignificant, echoing the earlier findings in Forbes and Warnock (2011). Given the endogenous response of central banks to financial conditions, a deeper study of the link between monetary policy and global liquidity would be warranted. Bekaert, Hoerova, and Lo Duca (2010) find in structural vector autoregression studies that low policy rates are followed by low VIX levels around five months later, while distressed financial conditions lead to lowering of policy rates,
Table 3. **Determinants of banking sector capital flows.** This table reports the panel regressions for banking sector capital flows with country fixed effects. The dependent variable is the quarterly log difference of BIS reporting bank external loans and deposits (BIS Table 7A). VIX is the within-quarter average VIX index lagged one quarter. ΔInteroffice is the growth in interoffice assets of foreign banks in the US from the quarter before. ROE is the banking sector return on equity. Interest spread is the difference between the ECB Repo rate and the US Fed Fund target rate, quarter average lagged one quarter. ΔMoney stock is the annual growth in sum of M2 in the US, eurozone and Japan and M4 in the UK (from the IFS). Global Growth is the global GDP volume change from previous year (from the IFS). Openness is the Chinn-Ito index of capital account openness. Bank crisis is a crisis year dummy. p-values are reported in parentheses. Standard errors are clustered at the country level. Data are for 1996-2009.

<table>
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<td>R-squared</td>
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<td>47</td>
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</table>
as one might expect. In any case, the arguments associated with the “risk-taking” channel of monetary policy (Borio and Zhu (2008) and Adrian and Shin (2010b)) suggest the need for further study of the role of the banking sector in the monetary transmission mechanism. In contrast to Forbes and Warnock (2011) we also find that the growth of the G4 money stock is an important determinant of banking sector capital flows. During a banking crisis capital flows decrease, but the coefficients of VIX and of ∆Interoffice remain highly significant. Our results do not change after including trade openness, country GDP growth, inflation, or when we use the annual growth in external loans in lieu of the quarterly growth (results not shown).

4.3 Domestic Private Credit

Next we investigate the determinants of private credit growth. The role of the VIX index as an explanatory variable follows from our theoretical prediction given by (28). Since the relationship between domestic private credit growth and the leverage of the global banks is indirect (going through an extra layer of financial intermediation domestically), we might conjecture that the effects are somewhat weak and open to a range of possible confounding effects. Nevertheless, we show that the VIX and interoffice asset growth retain considerable explanatory roles.

We run panel regressions with annual data with country fixed effects and clustered standard errors at the country level of the form:

\[
\Delta C_{c,t} = \beta_0 + \beta_1 \cdot \Delta \text{Interoffice}_t + \beta_2 \text{VIX}_{t-1} + \beta_4 \text{ROE}_{c,t} \\
+ \beta_3 \text{VIX}_{t-1} \ast \text{ROE}_{c,t} + \text{controls}_{c,t} + e_{c,t}
\]

(35)

where \(\Delta C_{c,t}\) is annual growth in private credit in country \(c\) in year \(t\), as given by the annual log difference in private credit (from IFS); \(\text{VIX}_{t-1}\) is the within-year average of the VIX index lagged by one year; \(\Delta \text{Interoffice}_t\) is the growth in interoffice assets of foreign banks in the US from the year before, given by the annual log difference. \(\text{ROE}_{c,t}\) is the country-level return on equity in country \(c\) in year \(t\). We include the control variables described in the data section (\(\Delta \text{Money stock}, \text{Global Growth}, \text{Openness}, \text{and Banking Crisis}\)). As additional control
variables, we include the annual log difference in the consumer price index (Inflation) and the Djankov, McLiesh, and Shleifer (2007) Creditor Rights Index which is only available until 2002.

The results are presented in Table 4. Although the statistical significance falls relative to Table 3, we see that the key role played by the VIX and growth of interoffice assets remains in place, adding weight to the main predictions given by our theory that global liquidity spills over into the domestic private credit growth of the recipient economies. In contrast to the panel regression for banking sector capital flows, neither the ROE variable, nor the interaction term with VIX appears as being significant. The growth in money supply also ceases to be significant, except for the final specification when the creditor rights variable (only available until 2002) enters the regression for a truncated sample period.

Taken together, the results from Tables 3 and 4 suggest that global liquidity consistently explains both the growth in private credit in recipient countries and cross-border lending. The VIX index is a key indicator of global liquidity due to its close association with banking sector leverage. In this respect, the significance of the interoffice assets series sheds much light on the precise mechanism for why the VIX index is so significant. The driving force behind emerging economy capital flows turns out to be the leverage cycle of the global banks.

4.4 Individual Countries Effects

We complement our panel regressions with an investigation of the sensitivity of individual countries to fluctuations in the VIX and $\Delta$Interoffice variables. We make use of the panel structure to run panel regressions with country fixed effects and standard errors clustered at the country level of the form:

$$\Delta L_{c,t} = \beta_{c,0} + \beta_{c,1} VIX_{t-1} + \beta_{c,2} VIX_{t-1} * \text{Country}_c$$

$$+ \beta_{c,3} \Delta \text{Interoffice}_t + \text{controls}_{c,t} + e_{c,t}$$

(36)

where $\Delta L_{c,t}$ is banking sector capital flows given by the quarterly log difference in the external claims of BIS reporting country banks to country $c$, as before, and Country$_c$ is a dummy equal to
Table 4. **Determinants of private credit growth.** The dependent variable is the annual log difference of private credit (IFS). VIX is the within-year average VIX index lagged one year. $\Delta$Interoffice is the growth in interoffice assets of foreign banks in the US from the year before. ROE is the banking sector return on equity. Interest Spread is the difference between the ECB Repo rate and the US Fed Fund target rate, annual average lagged one year. Other variables are defined in the text. p-values are reported in parantheses. Standard errors are clustered at the country level. Data are for 1996-2009.

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<tbody>
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<td>$\Delta$Interoffice</td>
<td>0.2728***</td>
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<td>[0.039]</td>
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<td>VIX</td>
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1 for country $c$ and 0 otherwise. The key feature in (36) is the interaction term $VIX_{t-1}*\text{Country}_c$, which gives the excess sensitivity of country $c$ to VIX. The controls are as in Table 3.

The panel regression (36) is run separately for each individual country $c$. Thus, the coefficients $\{\beta_{c,i}\}$ have a country subscript $c$. The coefficient $\beta_{c,1}$ indicates the average effect of VIX on all countries except country $c$, whereas the coefficient $\beta_{c,2}$ indicates the incremental effect for country $c$. The sum of the coefficients $\beta_{c,1} + \beta_{c,2}$ measures the total effect of VIX on country $c$.

We run analogous panel regressions to show the country-level effects of $\Delta\text{Interoffice}$ as follows.

$$
\Delta L_{c,t} = \beta_{c,0} + \beta_{c,1}\Delta\text{Interoffice}_t + \beta_{c,2}\Delta\text{Interoffice}_t * \text{Country}_c \\
+ \beta_{c,3}VIX_{t-1} + \text{controls}_{c,t} + \epsilon_{c,t}
$$

Again, the sum of the coefficients $\beta_{c,1} + \beta_{c,2}$ measures the total effect of $\Delta\text{Interoffice}$ on country $c$. For reasons of space, we select and show the results of the interaction term coefficients for the following countries (a mix of developing and developed countries): Estonia, Latvia, Lithuania, Romania, Turkey, Brazil, Chile, Spain, Ireland, UK, Germany, France, Italy, Australia. Table 5 shows the results.

The first row reports the $\beta_{c,1}$ coefficient estimate interval. Because the regressions are run separately for each country, the average effect $\beta_{c,1}$ varies slightly across regressions. The subsequent rows report the individual countries interaction coefficients $\beta_{c,2}$.

Column 1 shows that that the VIX interaction terms $\beta_{c,2}$ for the Baltic countries, Romania, Turkey and Brazil are highly negative and significant, indicating greater sensitivity relative to other countries in the sample. The $\beta_{c,2}$ interaction terms for Chile, Spain, Ireland, Germany, Italy, and Australia are positive and significant, suggesting that at the margin, the impact of global liquidity for these countries is mitigated. The overall impact remains negative for Spain, Ireland, Italy and Australia (the F-test in column 2 rejects that the sum of the coefficients $\beta_{c,1} + \beta_{c,2}$ is equal to zero) or zero for Chile and Germany (the F-test in column 2 does not reject that the sum of the coefficients $\beta_{c,1} + \beta_{c,2}$ is different from zero). Global liquidity as measured by VIX does not seem to have a differential impact for UK or France.

Column 3 reports the results where the $\Delta\text{Interoffice}$ variable is interacted with each individual
Table 5. **Individual country sensitivity analysis.** This table summarizes panel regressions run for each country with an interaction country dummy with VIX or interoffice asset growth. The dependent variable is the quarterly log difference of BIS reporting bank external loans and deposits (BIS Table 7A), as in Table 3. See text for explanation of methodology. p-values are reported in parantheses. Standard errors are clustered at the country level. Data are for 1996-2009.

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country dummy instead of VIX. The coefficient estimates $\beta_{c,2}$ of the Baltic countries and Brazil are positive and highly significant with large coefficients. As in the case for VIX, the marginal effect $\beta_{c,2}$ of $\Delta \text{Interoffice}$ for these countries is higher than the average effect for the others, suggesting that these countries are relatively more sensitive to fluctuations in the leverage of global banks. The marginal effect $\beta_{c,2}$ for all the other countries is not different from the average effect $\beta_{c,1}$, with the exception of Chile, Germany, and Australia for which the effect of the interoffice variable at the margin is lower than the average. Interestingly, as in the case of VIX, the total impact of $\Delta \text{Interoffice}$ is zero for Chile (the F-test in column 4 does not reject $\beta_{c,1} + \beta_{c,2} = 0$). Taken together, these results suggest that developing economies (especially emerging Europe and the Baltic countries) have been the most sensitive to global liquidity in the sample period.

5  Measuring Global Liquidity

The evidence in our paper suggests that the driving force behind banking sector capital flows is the leverage cycle of the global banks. Furthermore, credit growth in the recipient economy is explained, in part, by the fluctuations in global liquidity that follow the leverage cycle of the global banks. Our findings reinforce the argument in Borio and Disyatat (2011) on the importance of gross capital flows between countries in determining financial conditions, rather than net flows. Gross flows, and in particular measures of banking sector liabilities should be an important source of information for risk premiums and hence financial sector vulnerability.\textsuperscript{10} We conclude with some remarks on measuring global liquidity.

The distinction between core and non-core bank liabilities depends on the particular economy and the context of financial development. For advanced economies with developed debt markets, non-core liabilities will include non-deposit funding that is raised in the wholesale bank funding market, such as repos or financial commercial paper. We may conjecture that core liabilities, such as retail deposits, are more stable (or “sticky”) than non-core liabilities.

\textsuperscript{10}See Shin and Shin (2010) and Hahm, Shin and Shin (2011) for empirical analyses of this issue.
For financial systems at an early stage of development or where the banking sector is restricted by regulation from having access to the global banking system, the distinction between core and non-core liabilities will fall within M2, depending on who holds the claim. When the domestic banking sector is mostly closed, it may be more meaningful to decompose M2 itself into its core and non-core components. The non-core component of deposits then may includes the deposits of non-financial companies who end up recycling funding within the economy and hence become integrated into the intermediary sector itself. China and India are two examples where this distinction between core and non-core liabilities may be usefully employed.

The detailed classifications will need to build on further analytical study of the attributes of various funding aggregates of the intermediary sector. For countries with open capital markets, international capital flows into the banking sector will be key indicators of financial vulnerability. For countries with relatively closed financial systems, where domestic banks do not have ready access to funding provided by the global banking system, a better approach would be to adapt existing conventional monetary aggregates to address financial stability concerns. The distinction between household retail deposits and corporate deposits in the banking sector could play an important role in this regard.

At the heart of global liquidity is the role of cross-border banking. Monitoring the funding aggregates of these global banks through their activities in the major financial centers and their movement cross border flows through the BIS banking statistics will be important in keeping track global liquidity.
References


Adrian, Tobias and Hyun Song Shin (2010b) “Financial Intermediaries and Monetary Economics” in Handbook of Monetary Economics, Benjamin Friedman and Michael Woodford (eds), Elsevier, chapter 12, 601-650, 2010


