Capital Flows and the Risk-Taking Channel of Monetary Policy*

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Abstract

This paper examines the relationship between low interests maintained by advanced economy central banks and credit booms in emerging economies. In a model with cross-border banking, low funding rates increase credit supply, but the initial shock is amplified through the "risk-taking channel" of monetary policy where greater risk-taking interact with dampened measured risks that are driven by currency appreciation to create a feedback loop. In an empirical investigation using VAR analysis, we find that expectations of lower short-term rates dampens measured risks and stimulate cross-border banking sector capital flows.

JEL Codes: F32, F33, F34
Keywords: Capital flows, exchange rate appreciation, credit booms

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1 Introduction

Low interest rates maintained by advanced economy central banks have led to a lively debate on the nature of global liquidity and its transmission across borders. A popular narrative among financial commentators is that low interest rates in advanced economies act as a key driver of cross-border capital flows, resulting in overheating and excessive credit growth in the recipient economies. However, the precise economic mechanism behind such a narrative has been difficult to pin down.

One way to shed light on the debate is to start with the empirical evidence on the cyclical nature of leverage and financial conditions. Gourinchas and Obstfeld (2012) conduct an empirical study using data from 1973 to 2010 for both advanced and emerging economies on the determinants of financial crises. They find that two factors emerge consistently as the most robust and significant predictors of financial crises, namely a rapid increase in leverage and a sharp real appreciation of the currency. Their finding holds both for emerging and advanced economies, and holds throughout the sample period. Thus, one way to frame the debate on the role of monetary policy in the transmission of global liquidity is to ask how monetary policy in advanced economies may influence leverage and real exchange rates in capital flow recipient economies.[1]

One channel that is often neglected in conventional monetary economics is the role of the banking sector in driving financial conditions and risk premiums over the cycle. Banks are intermediaries who borrow short and lend long, so that the size of the term spread (i.e. slope of the yield curve) influences the profitability of new lending. Since long rates are less sensitive than short rates to shifts in the central bank's policy rate, monetary policy exerts considerable influence on the size of the term spread, at least for short periods of time. Through this channel, the central bank's policy rate may act directly on the economy through greater risk-taking by the banking sector. Borio and Zhu (2008) coined the term "risk-taking channel of monetary

[1]Our questions is related to the debate on whether monetary policy was "too loose" in the run-up to the crisis with respect to the Taylor Rule (Taylor (2007), Bernanke (2010)). However, our focus is narrower in that we examine the risk-taking channel more explicitly.

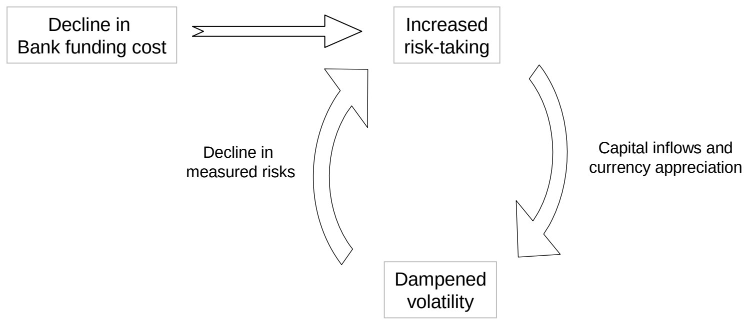


Figure 1. Risk-taking channel of monetary policy in the cross-border context

policy", and Adrian and Shin (2008, 2011) and Adrian, Estrella and Shin (2012) have explored the workings of the risk-taking channel empirically, finding empirical support for the risk-taking channel for the United States. In this paper, we will explore the workings of the risk-taking channel in an international setting through the cross-border activity of global banks.

The risk-taking channel works through the incentives of banks to take on leverage, thereby influencing financial conditions directly. Focusing attention on the banking sector allows us to connect the two factors identified by Gourinchas and Obstfeld (2012) - real appreciation of the currency and increased leverage. The link can be traced to an amplification mechanism built into the risk-taking channel, which can be illustrated schematically as in Figure 1.

Figure 1 traces the impact of a monetary policy shock that lowers the dollar funding cost of banks in capital flow-recipient economies. The lowering of funding costs gives an initial impetus for greater risk-taking, as banks in the recipient economy take advantage of lower dollar funding costs by increasing lending to domestic entities - either corporates or households, or both. However, any initial appreciation of the recipient economy's currency strengthens the balance sheet position of domestic borrowers. From the point of view of the banks that have lent to them, their loan book becomes less risky, creating spare capacity to lend even more. In this way, the initial impetus is amplified through a reinforcing mechanism in which greater risk-taking by banks dampens volatility, which elicits even greater risk-taking, thereby completing the circle.

The upward phase of the cycle will give the appearance of a virtuous circle, where the mutually reinforcing effect of real appreciation and improved balance sheets operate in tandem. However, once the cycle turns, the amplification mechanism works exactly in reverse, serving to reinforce the financial distress of borrowers and the banking sector. Our formal model will provide a more precise analysis of the amplifying mechanism depicted in Figure 1.

The risk-taking channel stands in contrast to models of monetary economics commonly used at central banks, which tend to downplay the importance of short-term interest rates as price variables in their own right. Instead, the emphasis falls on the importance of managing market expectations. The emphasis is on charting a path for future short rates and communicating this path clearly to the market, so that the central bank can influence long rates such as mortgage rates, corporate lending rates, as well as other prices that affect consumption and investment.[2]

We complement our theoretical exposition of the risk-taking channel by examining how it operates in the international context. We conduct a vector autoregression (VAR) study and study the impulse responses of balance sheet adjustments to changes in monetary policy. We build on the work of Bekaert, Hoerova and Lo Duca (2010) who conduct a VAR study of the relationship between the policy rate chosen by the Federal Reserve (the target Fed Funds rate) and measured risks given by the VIX index of implied volatility on US equity options, and show that there is a close two-way interaction between the two variables. In particular, they show that a cut in the Fed Funds rate is followed by a dampening of the VIX index, while an increase in the VIX index elicits a response from the Federal Reserve who react by cutting the target Fed Funds rate.

We extend their analysis in two ways. First, in line with the underlying mechanism of the risk-taking channel, we show the importance of the term spread in influencing market conditions. An upward shock to the VIX index elicits a sharp widening of the 12 month forward term spread, indicating market expectations of imminent cuts in the Fed Funds rate. In turn, the widening of the 12 month forward term spread is followed by cuts in the Fed funds rate over the next

[2]This "expectations channel" of monetary is explained in Blinder (1998), Bernanke (2004), Svensson (2004), and Woodford (2003, 2005).

several quarters.

Second, we find that an increase in the expected term spread feeds through eventually to an increased pace of capital flows through the cross-border operation of the global banks. We find evidence that cross-border claims of the BIS-reporting banks respond sensitively to the forward term spread, adding weight to the conclusion that the risk-taking channel channel of monetary operates through the balance sheet management of the global banks.

The combination of the theory and empirical evidence paints a consistent picture of the fluctuations in "global liquidity" and what role monetary policy has in moderating global liquidity. By identifying the mechanisms more clearly, we may hope that policy debates on the global spillover effects of monetary policy can be given a firmer footing. The recent BIS report on global liquidity (BIS (2011)) has served as a catalyst for further work in this area, and our paper can be seen as one component of the analytical follow-up to the report.

2 Background

2.1 Institutional Background

Understanding the institutional backdrop for the banking sector is important in addressing the link between capital flows and leverage. As well as being the world's 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

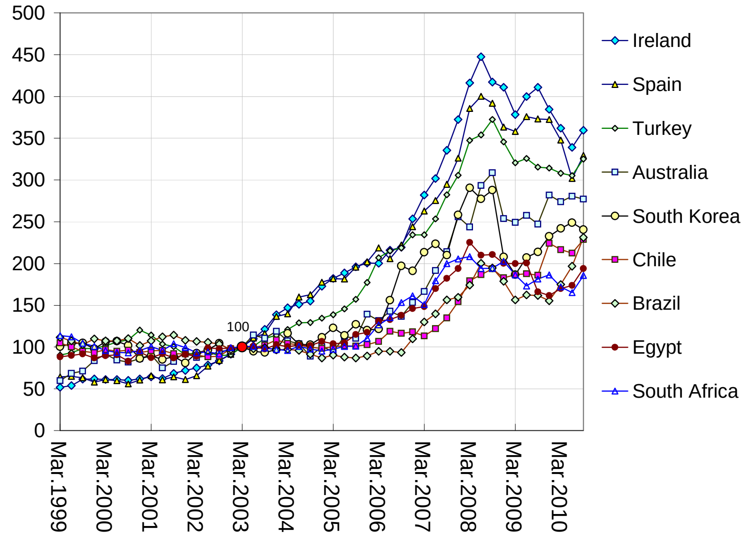


Figure 2. External claims (loans and deposits) of BIS reporting country banks on borrowers in countries listed. The series are normalized to 100 in March 2003 (Source: BIS Locational Banking Statistics, Table 7A)

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.

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.[3]

Figure 2 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.

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

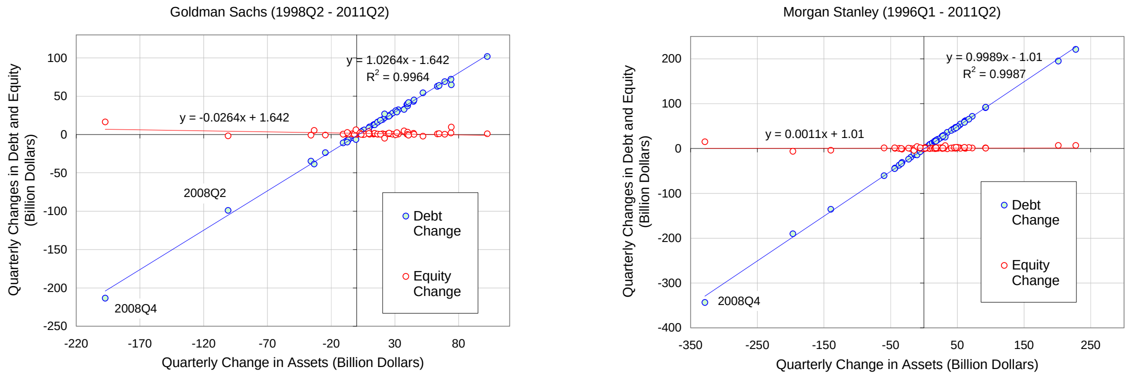


Figure 3. Scatter chart of quarterly changes in assets, equity and debt of Goldman Sachs and Morgan Stanley (Source: SEC 10Q filings)

2.2 Bank Leverage

Our model of the risk-taking channel is designed to capture some key attributes of bank balance sheet management, which depart in significant ways from standard models of portfolio choice. These departures turn out to be important in capturing the cyclical properties of capital flows.

Bank balance sheet management is illustrated in Figure 3 for Goldman Sachs and Morgan Stanley, the two US investment banks that came through the crisis unscathed. Figure 5 plots $\{(\Delta A_t, \Delta E_t)\}$ and $\{(\Delta A_t, \Delta D_t)\}$ where ΔA_t is the change in the banks' assets at quarter t, and where ΔE_t and ΔD_t are the change in equity and change in debt, respectively.

For both banks the fitted line through $\{(\Delta A_t, \Delta D_t)\}$ has slope very close to 1, meaning that the change in lending is met dollar for dollar by a change in debt, with equity remaining "sticky". The short-term nature of these institutions' assets and liabilities implies that book equity tracks closely the difference between the market value of assets and the market value of liabilities.[4] In this respect, Figure 5 yields insights on how market conditions influence balance sheet management.

[4]In contrast, market capitalization is the discounted value of free cash flows, and may differ from the gap between market values of assets and liabilities, for instance, due to fee income. The slopes of the two fitted lines add up to 1 in Figure 5 as a consequence of the balance sheet identity: $\Delta A_t = \Delta E_t + \Delta D_t$ and the additivity of covariance.

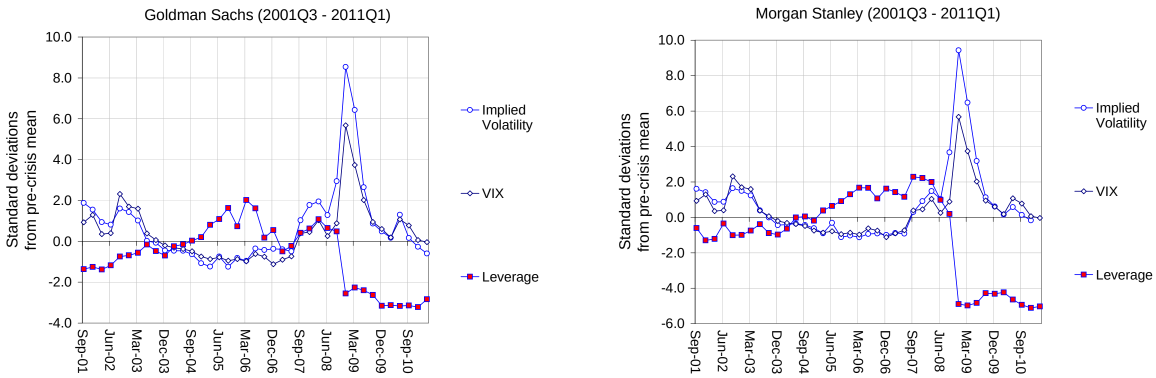


Figure 4. Plots of the VIX index, leverage of Goldman Sachs and Morgan Stanley and the implied volatility of their equity options. All series are measured as standard deviations from the mean during 2001Q3 - 2006Q4. (Source: SEC 10Q and CBOE)

Figure 4 plots the leverage of Goldman Sachs and Morgan Stanley through the crisis period. Leverage is measured in units of standard deviations from the mean during the period 2001Q3 - 2006Q4. Also plotted is the VIX index and the implied volatility embedded in the equity options of the two banks. All series are measured in standard deviations from the mean during 2001Q3 - 2006Q4. We see that leverage of both Goldman Sachs and Morgan Stanley increase in the period before the crisis, only to fall sharply with the onset of the 2008 crisis.

Adrian and Shin (2010, 2012) highlight the role of measured risks, and in particular the bank's Value-at-Risk (a quantile measure of potential losses) as a key determinant of the expansion or contraction of lending. They show that a good rule of thumb is that banks adjust lending in order to keep their probability of failure constant in the face of changing financial conditions. In periods of market stress, banks contract lending and shed risky exposures, while in tranquil conditions, banks expand lending.

In turn, the Value-at-Risk measures of individual banks move closely in step with fluctuations in measures of financial stress, most notably the VIX index, but also in spreads of individual bank credit default swaps (CDS) and the implied volatility of the banks' equity options. For this reason, the VIX index takes on particular significance in our empirical investigation which

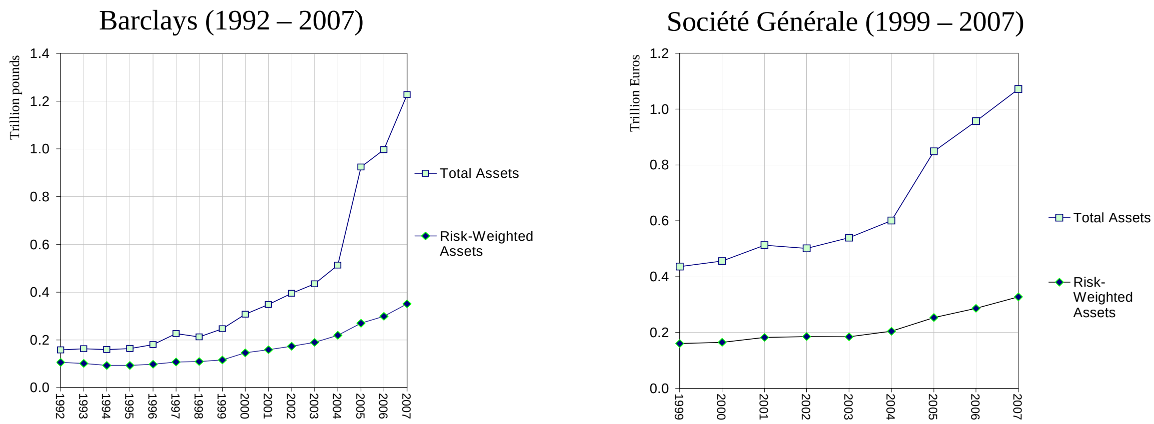


Figure 5. Total assets and risk-weighted assets of Barclays and Société Générale (Source: Bankscope)

follows.

A consequence of banks' model of balance sheet management is that leverage depends sensitively on the prevailing measured risks in the financial system. During tranquil times when measured risks are low, bank lending increases rapidly to use up the slack in lending capacity as suggested by the lower perceived risks. In effect, lending expands in tranquil times so that the bank's risk constraint binds *in spite of* the low measured risks. Borio and Disyatat (2011) have coined the term "excess elasticity" to describe the tendency of the banking system to expand when financial constraints are relaxed. Figure 5 illustrates such excess elasticity. It plots the total assets and risk-weighted assets of two typical European global banks - Barclays and Société Générale. Even as total assets were growing rapidly up to the eve of the crisis in 2007, the risk-weighted assets of the banks were growing moderately, reflecting the low levels of measured risks, and implying low levels of equity capital on the banks' balance sheets.

Our model of bank credit supply below is faithful to this empirical feature of bank balance sheet management, where asset increases are driven by lower credit risk and the corresponding increase in "balance sheet capacity". For risk-neutral profit maximizing banks, the balance sheet constraint binds all the time, so that in periods of low measured risks, balance sheets must

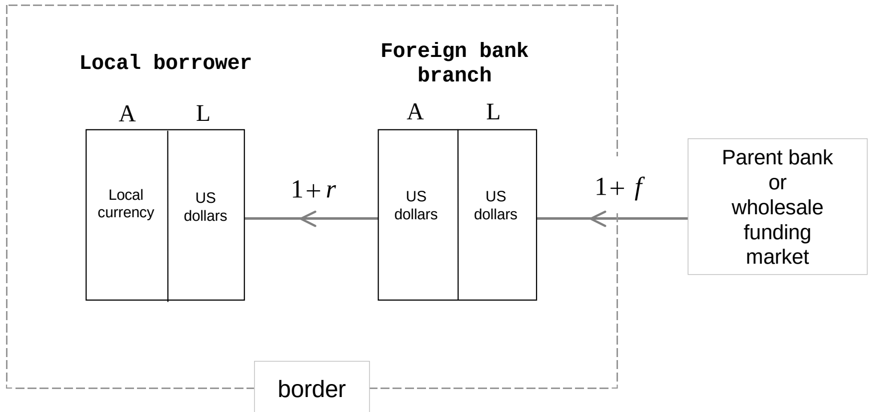


Figure 6. This figure depicts the lending relationships examined in the model. A foreign bank branch lends to local borrowers in dollars and finances its lending from the wholesale dollar funding market.

be large enough so that the risk constraint binds *in spite of* the low measured risks.[5]

3 Model

Our model is based on the relationships depicted in Figure 6. A foreign bank branch based in the capital flow-recipient economy lends to local borrowers in dollars and finances its lending either by borrowing from the wholesale dollar funding market, or by sourcing the funding from its parent. We describe each constituent of the model in more detail.

3.1 Local Borrowers

Local borrowers could be either household or corporate borrowers. For corporate borrowers, incurring liabilities in foreign currency is one way for exporting companies to hedge their future dollar export receivables. Even for non-exporters, borrowing in foreign currency is a means toward speculating on currency movements. For households, mortgage borrowing in foreign

[5]Adrian and Shin (2012) propose a micro-founded contracting model to explain the observed behavior. The model complements existing macro models of financial frictions where banks' lending constraint binds only in the downturn.

currency (Swiss francs and euros) was prevalent in Hungary and other coutnries in emerging Europe, often encouraged by subsidiaries of Western European banks that could fund themselves from their parents.

We model the local borrowers according to the Vasicek (2002) model of credit risk, which has served as the backbone of the Basel capital regulations (BCBS (2005)).

The value of the borrower's project in dollar terms at date 0 is denoted by V_0. Each borrower j has dollar-denominated debt with face value F, maturing at date T. The value of the borrower's project (in US dollar terms) at date T is denoted V_T, and is a lognormal random variable given by

$$V_T = V_0 \exp\left\{\left(\mu - \frac{s^2}{2}\right)T + s\sqrt{T}W_j\right\} \tag{1}$$

where W_j is a standard normal random variable. The borrower defaults when $V_T < F$.

The probability of default viewed from date 0 is

$$\begin{aligned} \text{Prob}\left(V_T < F\right) &= \text{Prob}\left(W_j < -\frac{\ln\left(V_0/F\right) + \left(\mu - \frac{s^2}{2}\right)T}{s\sqrt{T}}\right) && (2) \\ &= \Phi\left(-d_j\right) && (3) \end{aligned}$$

where $\Phi(.)$ is the c.d.f. of the standard normal and d is the *distance to default* in units of standard deviations of the standard normal W_j.

$$d = \frac{\ln\left(V_0/F\right) + \left(\mu - \frac{s^2}{2}\right)T}{s\sqrt{T}} \tag{4}$$

Denote by θ the value of the local currency in terms of dollars, so that an increase in θ corresponds to an appreciation of the domestic currency. The effect of currency appreciation is to shift the outcome density upward in Figure 7 so that the probability of default declines. We deal with currency appreciation in more detail below.

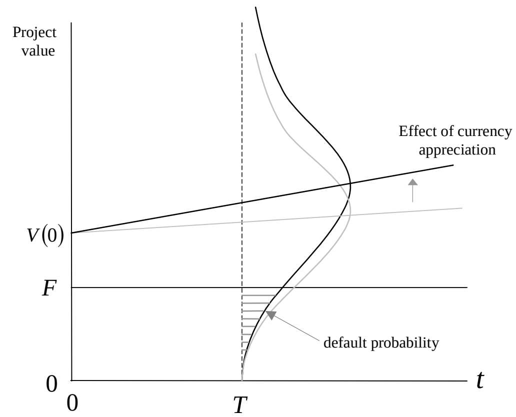


Figure 7. Project value V_T and notional debt F for local borrowers. The borrower defaults when V_T falls short of the notional debt F. The effect of a currency appreciation is to shift the outcome density upward, lowering the default probability.

3.2 Loan Portfolio of Banks

Banks provide dollar-denominated private credit (denoted C) to local borrowers at the rate $1+r$. We suppose that there is an infinitely elastic demand for dollar-denominated credit at the rate $1 + r$, so that we may assume r to be fixed.

The private credit is funded by cross-border bank liabilities (denoted by L) drawn from wholesale markets or from the parent bank at the funding rate $1 + f$. Both C and L are denominated in dollars.

Each bank has a well diversified loan portfolio consisting of loans to many borrowers. Credit risk follows the Vasicek (2002) model. We assume that the standard normal W_j defined in (2) can be written as the linear combination:

$$W_j = \sqrt{\rho} Y + \sqrt{1-\rho} X_j \tag{5}$$

where Y and $\{X_j\}$ are mutually independent standard normals. Y is the common risk factor while each X_j are the idiosyncratic component of credit risk for the particular borrower j. The parameter $\rho \in (0, 1)$ determines the weight given to the common factor Y.

Then borrower j repays the loan when $Z_j \geq 0$, where Z_j is the random variable:

$$\begin{aligned} Z_j &= d_j + W_j \\ &= d_j + \sqrt{\rho} Y + \sqrt{1-\rho} X_j \end{aligned} \tag{6}$$

where d_j is the distance to default of borrower j. The probability of default by borrower j is $\Phi(-d_j)$. Let ε be the probability of default. Hence, borrower j repays the loan when $Z_j \geq 0$ where

$$Z_j = -\Phi^{-1}(\varepsilon) + \sqrt{\rho} Y + \sqrt{1-\rho} X_j \tag{7}$$

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:

$$\begin{aligned} w(Y) &\equiv (1+r) C \cdot \Pr(Z_j \geq 0 | Y) \\ &= (1+r) C \cdot \Pr\left(\sqrt{\rho} Y + \sqrt{1-\rho} X_j \geq \Phi^{-1}(\varepsilon) | Y\right) \\ &= (1+r) C \cdot \Phi\left(\frac{Y\sqrt{\rho} - \Phi^{-1}(\varepsilon)}{\sqrt{1-\rho}}\right) \end{aligned} \tag{8}$$

Figure 8 plots the densities over asset realizations, and shows how the density shifts to changes in the default probability ε (left hand panel) or to changes in ρ (right hand panel). Higher values of ε imply a first degree stochastic dominance shift left for the asset realization density, while shifts in ρ imply a mean-preserving shift in the density around the mean realization $1-\varepsilon$.

From here on, we will assume that ε is a small number, and in particular, $\varepsilon < 0.5$. The

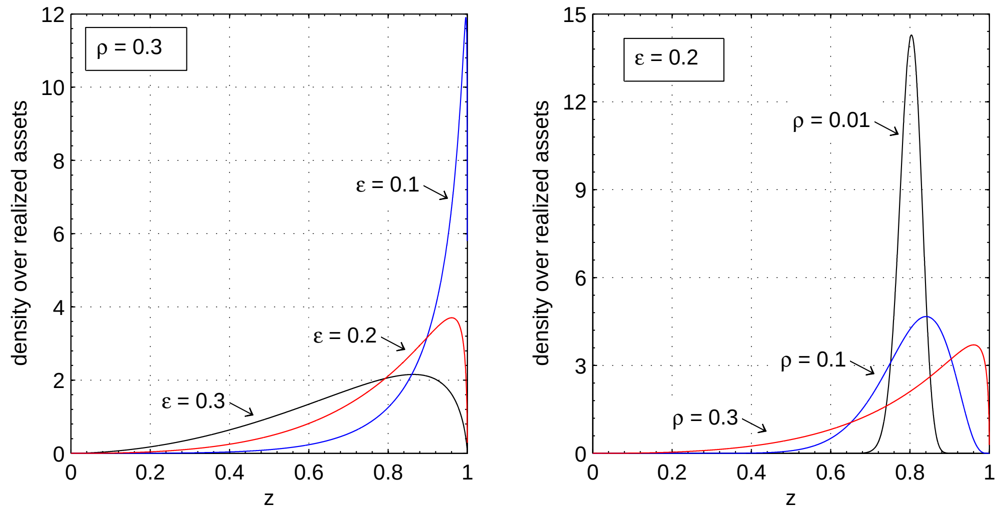


Figure 8. The two charts plot the densities over realized assets when $C(1+r) = 1$. The left hand charts plots the density over asset realizations of the bank when $\rho = 0.1$ and ε is varied from 0.1 to 0.3. The right hand chart plots the asset realization density when $\varepsilon = 0.2$ and ρ varies from 0.01 to 0.3.

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

$$\begin{aligned} F(z) &= \Pr(w \le z) \\ &= \Pr\left(Y \le w^{-1}(z)\right) \\ &= \Phi\left(w^{-1}(z)\right) \\ &= \Phi\left(\frac{1}{\sqrt{\rho}}\left(\Phi^{-1}(\varepsilon) + \sqrt{1-\rho}\,\Phi^{-1}\left(\frac{z}{(1+r)C}\right)\right)\right) \end{aligned} \tag{9}$$

Assume that the regional 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 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.

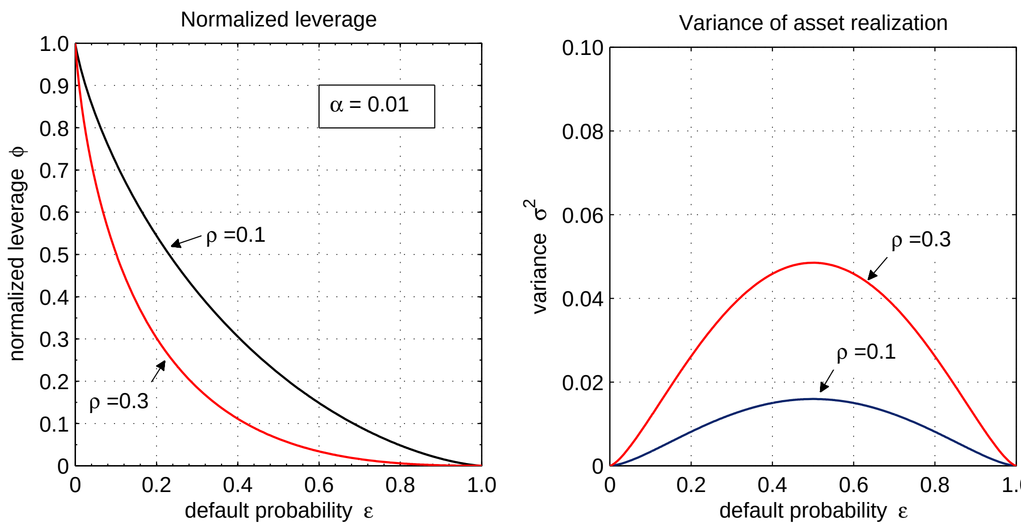


Figure 9. Left hand panel plots the normalized leverage ratio φ as a function of ε. The right hand panel plots the variance σ^2 as a function of epsilon for two values of ρ.

$$\Pr\left(w < (1+f)\,L\right) = \Phi\left(\frac{\Phi^{-1}(\varepsilon)+\sqrt{1-\rho}\,\Phi^{-1}\left(\frac{(1+f)L}{(1+r)C}\right)}{\sqrt{\rho}}\right) = \alpha \tag{10}$$

Re-arranging (10), we can write the ratio of notional liabilities to notional assets as follows.

$$\frac{\text{Notional liabilities}}{\text{Notional assets}} = \frac{(1+f)\,L}{(1+r)\,C} = \Phi\left(\frac{\sqrt{\rho}\Phi^{-1}(\alpha) - \Phi^{-1}(\varepsilon)}{\sqrt{1-\rho}}\right) \tag{11}$$

We will use the shorthand:

$$\varphi(\alpha,\varepsilon,\rho) \equiv \Phi\left(\frac{\sqrt{\rho}\Phi^{-1}(\alpha)-\Phi^{-1}(\varepsilon)}{\sqrt{1-\rho}}\right) \tag{12}$$

Clearly, $\varphi \in (0,1)$. Denote by σ^2 the variance of $w(Y)/C(1+r)$. In the appendix, we show[6] that the variance σ^2 is given by

$$\sigma^2 = \Phi_2\left(\Phi^{-1}(\varepsilon), \Phi^{-1}(\varepsilon); \rho\right) - \varepsilon^2 \tag{13}$$

[6]See Vasicek (2002), which states this and other results for the asset realization function $w(Y)$.

where $\Phi_2(\cdot, \cdot; \rho)$ is the cumulative bivariate standard normal with correlation ρ. The right hand panel of Figure 9 plots the variance σ^2 as a function of ε. The variance is maximized when $\varepsilon = 0.5$, and is increasing in ρ. The left hand panel of Figure 9 plots the ratio of notional liabilities to notional assets φ as a function of ε.

From (11) and the balance sheet identity $E + L = C$, we can solve for the bank's supply of private credit. When private credit supply is positive, we have

$$C = \frac{E}{1 - \frac{1+r}{1+f} \cdot \varphi} \tag{14}$$

Note that C is proportional to the bank's equity E, and so (14) also denotes the *aggregate* supply of private credit when E is the *aggregate* equity of the banking sector. The leverage of the bank (and the sector) is the ratio of assets to equity, and is

$$\text{Leverage} = \frac{1}{1 - \frac{1+r}{1+f} \cdot \varphi} \tag{15}$$

On the liabilities side of the balance sheet, the banks' demand for cross-border funding L can be solved from (11) and the balance sheet identity $E + L = C$.

$$L = \frac{E}{\frac{1+f}{1+r} \cdot \frac{1}{\varphi} - 1} \tag{16}$$

3.3 Risk-Taking Channel of Monetary Policy

We are now ready to examine the impact of monetary policy through changes in the bank funding cost f.

In conducting our comparative statics exercise, we assume that greater capital inflows through the banking sector (i.e. higher L) will put upward pressure on the exchange rate.

Assumption 1. θ is increasing in L.

We will take the bank funding rate f as given and conduct comparative statics analysis with respect to changes in f. A more sophisticated treatment of the funding rate f would have been

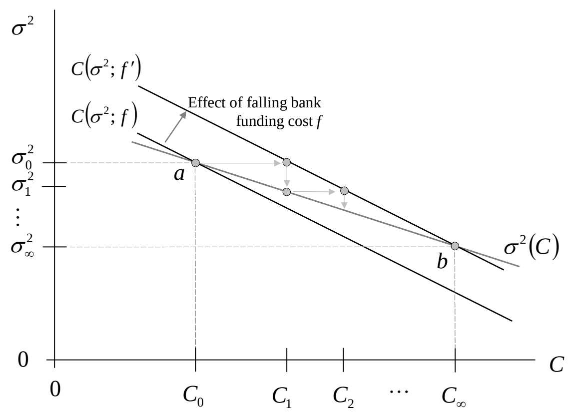


Figure 10. Impact of a decline in bank funding cost f consisting of the initial impact and the amplification effect.

to model the lending behavior of the global banks for whom f is the lending rate in wholesale funding markets. See Bruno and Shin (2011) for such an analysis.

Consider a fall in the funding cost f. The impact of this fall in funding cost can be decomposed into the *initial impact* and the *amplification effect*. Figure 10 illustrates the two effects. The initial impact of the cut in funding cost f is depicted by the rightward pointing arrow in Figure 10. There is an increase in lending from C_0 to C_1 following the solution for bank credit supply given by (14). However, the increase in lending is mirrored on the liabilities side by an increase in L, as given by (16). In other words, a lowering of bank funding cost results in the increased capital inflow through the banking sector, as given by a larger L.

Then, from Assumption 1, the increase in L results in an appreciation in the exchange rate θ. Denote by $G(z)$ the c.d.f. of the borrowers' project realization depicted in Figure 7, where the c.d.f. is given in local currency terms. Then, in US dollar terms, the project realization c.d.f. is given by

$$G\left(\frac{z}{\theta}\right) \tag{17}$$

Therefore, an appreciation of the currency (increase in θ) results in a first-degree stochastic shift of the outcome density as illustrated in Figure 7, resulting in a fall in the default probability. If we denote by ε' the default probability with currency appreciation and ε the default probability without currency appreciation, we have

$$\varepsilon' < \varepsilon < 0.5 \tag{18}$$

The decline in the default probability ε sets in motion the amplification mechanism where bank lending increases through an increase in φ, which implies even greater capital inflows through L, which then results in further declines in the default probability ε. Since the variance σ^2 of the asset realization is increasing in the default probability ε for $\varepsilon < 0.5$, we can state the amplification mechanism in terms of the mutually reinforcing effect of greater lending C financed with greater capital inflows L, which dampens the volatility of outcome, which in turn creates spare lending capacity of the banks.

The stepwise adjustment process depicted in Figure 10 illustrates the amplification mechanism. Greater risk-taking by banks results in dampened volatility, which in turn leads to even further risk-taking. The circular diagram we had at the outset of the paper (Figure 1) has its counterpart in Figure 10. The stepwise adjustment is in logical time, as in our model, as our model is a static one. However, the stepwise adjustment process is useful in thinking through the interaction effects.

Formally, we can write $C(\sigma^2; f)$ as the total lending by the banking sector as a function of σ^2, with the funding rate f as a parameter. In turn, the variance of asset realization σ^2 can be written as a function of total lending C, since C determines the banking sector liabilities L and hence the exchange rate θ. Thus, the equilibrium is given by the solution to the pair of equations:

$$\begin{cases} C = C(\sigma^2; f) \\ \sigma^2 = \sigma^2(C) \end{cases} \tag{19}$$

Both relationships are downward-sloping, so that a decline in the funding cost f can result in substantial shifts in total lending and volatility.

To gauge the comparative statics, begin with the expression for credit supply C given by (14). Taking the derivative of C with respect to the funding rate f, we have

$$\frac{dC}{df} = -\frac{C}{\frac{1+f}{1+r}\frac{1}{\varphi} - 1}\left[\frac{\varphi'(\varepsilon)}{\varphi}\frac{d\varepsilon}{dC} \cdot \frac{dC}{df} - \frac{1}{1+f}\right] \tag{20}$$

Solving for the elasticity in credit supply with respect to the gross funding rate $1+f$,

$$\frac{dC}{df}\frac{1+f}{C} = -\frac{1}{\frac{1+f}{1+r}\frac{1}{\varphi} - \left(1 + C \cdot \frac{\varphi'}{\varphi}\frac{d\varepsilon}{dC}\right)} \tag{21}$$

The term associated with the risk-taking channel is $d\varepsilon/dC$, which can be unpacked as follows:

$$\begin{aligned} \frac{d\varepsilon}{dC} &= \frac{d\varepsilon}{d\theta} \cdot \frac{d\theta}{dL} \cdot \frac{dL}{dC} \\ &= \frac{dG(z^*/\theta)}{d\theta} \cdot \frac{d\theta}{dL} \\ &= -\frac{z^*}{\theta^2} \cdot g\left(\tfrac{z^*}{\theta}\right) \cdot \frac{d\theta}{dL} \end{aligned} \tag{22}$$

where $g(.)$ is the density over project outcomes for the borrowers and z^* is the default threshold in domestic currency terms. Note that $dL/dC = 1$ from the balance sheet identity with fixed equity.

The amplification effect associated with a decline in bank funding rate f can be seen from (21). With feedback, the impact of a fall in bank funding cost is magnified by the decline in measured risks associated with currency appreciation.

It is worth noting that the amplification associated with the risk-taking channel is distinct from the more commonly discussed "carry trade" phenomenon that exploits interest rate differences across currencies. The risk-taking channel works through the feedback loop from greater

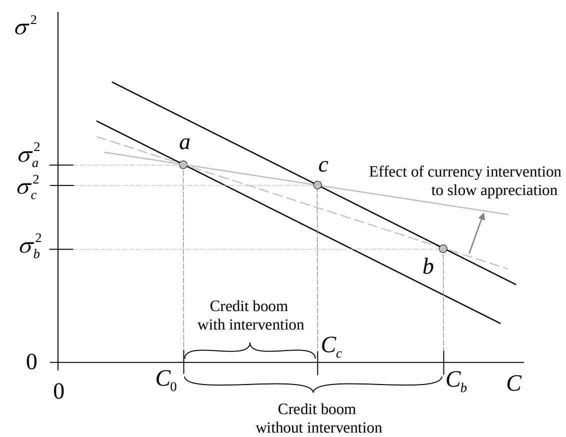


Figure 11. Effect of intervention to mitigate currency appreciation

risk-taking to the dampening of measured risks. It would have been possible to interpret θ as an asset price, rather than the exchange rate, and have the risk-taking channel take effect in a purely domestic context.

3.4 Effect of Currency Intervention

A key quantity that determines the magnitude of the amplification effect is the sensitivity of the exchange rate θ to capital inflows. A large appreciation of the exchange rate relative to the increase in L translates into a large decline in the probability of default ε, and hence a large decline in the measured risks of lending. As such, intervention in the currency market that can mitigate or slow the rate of currency appreciation may play a role in mitigating the effects of global liquidity driven by a fall in bank funding costs.

Figure 11 illustrates the effect of currency intervention. The economy starts at point a and experiences a decline in funding cost f. With no intervention, the economy shifts to point b, implying a large increase in lending financed by large capital inflows, and a commensurate decline in measured risks σ^2. However, when currency intervention limits the appreciation of the currency, the balance sheet effect for the borrowers is dampened, leading to a smaller credit boom, smaller capital inflows and only a moderate decrease in measured risks.

The effect illustrated in Figure 11 does not take account of the long run fundamentals for the economy. However, if there are suspicions that the sharp appreciation of the currency is driven by short-term distortions in global capital markets driven by excessive risk-taking by banks, then intervention to mitigate those distortions may be justified.

Intervention in the currency market is not the only way to "lean against the wind" of global liquidity. Direct macroprudential policy tools that either restrain lending (restrain C), or to impose a levy on foreign currency-denominated banking sector liabilities (restrain L) as is the policy in Korea, are alternatives to intervention in the currency market.

4 Empirical Analysis

We now move to an empirical analysis that examines whether (and to what extent) dollar funding costs determine banking sector cross-border capital flows. We consider a four-variable vector autoregression (VAR) examining the dynamic relationship between the VIX index of implied volatility on equity index options, the forward term premium between the 10 year and 3 month US treasury rates, the target Feds Funds rate of the Federal Reserve, and aggregate cross-border banking sector flows given by the growth in the total cross-order loans and deposits of the BIS reporting banks. Our focus is on the period before the crisis in order to examine the workings of the risk-taking channel on the up-swing of the global liquidity cycle. We use quarterly data from the last quarter of 1995 to the third quarter of 2007. The fourth quarter of 1995 is the first available quarter for the capital flows data that we use (BIS locational statistics, Table 7A) and the third quarter of 2007 was chosen to mark the beginning of the financial crisis. Our choice of sample period also helps to compare our results to those of Bekaert et al. (2010), who also used data up to the crisis.

The Fed Funds rate is computed for the end of the quarter as the target Fed Fund rate minus the CPI inflation rate ($FEFU$). The Fed Funds target rates are obtained from the St. Louis Fed website (FRED) and the Consumer Price Indexes are from the Bureau of Labor statistics website. We use the end of the quarter Chicago Board Options Exchange (CBOE) Volatility

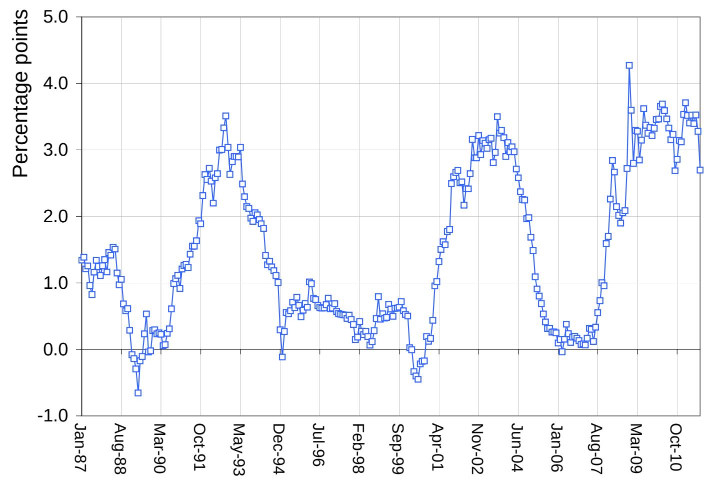


Figure 12. Twelve month forward term premium between 10 year and 3 month US Treasury rates. The series is computed following the methodology of Gurkaynak, Sack, and Wright (2006)

Index (*VIX*) for the implied annualized volatility in the S&P500 stock index options. We work with the log of VIX. We use the 12 months forward rate for the US Treasury 10 year - 3 month spread computed by Gurkaynak, Sack, and Wright (2006), and updated using their methodology. This series is plotted in Figure 12.

Our measure of aggregate banking sector capital flows is the log difference of the external loans and deposits of BIS reporting banks (denoted as *LOANS*) 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 with respect to their own affiliates. This methodology is consistent with the principles underlying the compilation of national accounts and balance of payments, thus making the locational statistics appropriate for measuring capital flows in a given period. Table 1 provides summary statistics of our variables.

Some insight into the relationship between monetary policy and the risk-taking channel can be illustrated by examining the cross-correlations between the forward term premium and the

Table 1. **Summary Statistics** This table summarizes our key variables in terms of their number of observations, mean, standard deviation, minimum and maximum.

Variable	Obs	Mean	Std. Dev.	Min	Max
VIX	47	20.52	6.85	11.39	40.95
FTP	47	1.11	1.11	-0.34	3.29
FEFU	47	1.46	1.76	-2.02	4.13
LOANS	47	2.51%	3.33%	-6.49%	9.87%

VIX index. Table 2 provides the cross-correlogram between VIX and FTP, which plots the cross-correlation between the log of the VIX and the 12 month forward term premium i quarters ahead (columns on the left) and for the cross-correlation between the 12 month forward term premium and the log of the VIX i quarters ahead (columns on the right). The length of horizontal bars indicate level of significance for the cross-correlations.

The message from Table 2 is that monetary policy both *reacts to* but also *has an impact on* the volatility in the capital markets. The left side of Table 2 shows that today's VIX is highly correlated with current and future forward term premiums, indicating that the market expects the yield curve to steepen. We will verify shortly that the term premium increases through a decline in the target Fed Funds rate through an easing of monetary policy. In other words, any spike in the VIX gives rise to expectations of easing of monetary policy.

The columns on the right hand side of Table 2 indicate that such easing of monetary policy eventually has the effect of quelling market turbulence. That is, we see that the cross-correlation between the forward term premium today and the future values of the VIX are negative and highly significant. The maximum impact comes around 9 quarters later.

Taken together, the initial evidence in Table 2 suggests an intimate link between monetary policy and market volatility. Monetary policy both reacts to volatility, but it also has an impact on the volatility, by soothing market distress. These correlograms are analogous to those of Bekaert et al. (2010) who examined the relationship between the Fed Funds rate and the VIX, who also find that monetary policy both reacts to, but also has an impact on volatility.

Table 2. **Cross-correlogram of VIX and FTP.** The length of horizontal lines indicate level of significance for the cross-correlation between the log of the VIX and the 12 month forward term premium i quarters ahead (left columns) and for the cross-correlation between the 12 month forward term premium and the log of the VIX i quarters ahead (right columns).

VIX, FTP $(+i)$			FTP, VIX $(+i)$		
	i			i	
——	0	0.4132		0	0.0284
——	1	0.4540		1	-0.0928
——	2	0.4720	-	2	-0.1925
——	3	0.4556	–	3	-0.3004
——	4	0.4115	——	4	-0.4361
——	5	0.3838	——-	5	-0.5481
–	6	0.3555	———	6	-0.628
–	7	0.2814	———	7	-0.7339
–	8	0.2617	————	8	-0.7716
-	9	0.2163	————	9	-0.7767
-	10	0.2226	———	10	-0.7176
-	11	0.1842	———	11	-0.6544
-	12	0.1648	——-	12	-0.5752
-	13	0.1934	——-	13	-0.5007
-	14	0.2019	——	14	-0.4117
-	15	0.2019	–	15	-0.3436
-	16	0.1973	–	16	-0.2631
-	17	0.1657	-	17	-0.1944
-	18	0.1643		18	-0.1190
	19	0.098		19	-0.0409

4.1 Identification

In order to explore the dynamic relationships in our sample, we conduct an empirical investigation using a vector autoregression (VAR). We examine vector autoregressions involving the four series *LOANS, FEFU, VIX and FTP,* where *LOANS* is the external claims of BIS reporting banks, *FEFU* is the real Fed Funds target rate, *VIX* is the VIX volatility index, and *FTP* is the 12 months forward term premium. We consider the structural VAR $A(L)y_t = \varepsilon_t$, where $A(L)$ is a matrix of polynomial in the lag operator L, y_t is the data vector and ε_t is a vector of orhogonalized distrurbances.

Formal lag selection procedures (the Akaike information criterion (AIC), the Hannan and Quinn information criterion (HQIC) and the Bayesian information criterion (BIC)) suggest one or three lags. However, the Lagrange multiplier test for autocorrelation in the residuals of the VAR shows that only the model with two lags eliminates all serial correlation in the residuals. We therefore choose two lags. For a stable VAR model we want the eigenvalues to be less than one and the formal test confirms that all the eigenvalues lie inside the unit circle. The choice of only two lags is also motivated by the need for a parsimonius system given our relatively small sample of quarterly observations (47 quarters). Longer lags may also create instability in the impulse-response functions.

We obtain structural identification by imposing a Cholesky decomposition of the estimate of the variance-covariance matrix. We impose the Cholesky restrictions by applying the following exclusion restrictions on contemporaneous responses in the matrix A to fit a just-identified model:

$$A = \begin{bmatrix} a_{11} & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix}$$

Of our four variables, two are market prices - VIX and the forward term premium - which adjust instantaneously to news. As such, they should be modeled as depending on the contemporaneous values of the two slower-moving series - the Fed Funds target rate and the capital flows in the previous quarter given by the *LOANS* variable. Thus, we order *FTP* and *VIX* below *LOANS* and *FEFU.* The ranking between *LOANS* and *FEFU,* is motivated by the fact that *LOANS* reflect capital flows over the previous quarter, so that it can be seen as being the most sluggish of our four series. The Fed Funds target rate will have been chosen some time before the end of the quarter, and so we rank *FEFU* as being second.

However, the choice in ranking between the two price variables - *FTP* and *VIX* - is more difficult, as both are market prices that adjust instantaneously. For this reason, we run two separate VAR analyses, where we examine both orderings of *FTP* and *VIX.* Thus, our two analyses of structural VAR runs are as follows:

- The first structural VAR has the ordering *LOANS, FEFU, VIX, FTP* and the impulse responses are presented in Figure 13.
- Our second structural VAR has the ordering *LOANS, FEFU, FTP, VIX* and the impulse responses are presented in Figure 14.

We compute bootstrapped confidence intervals based on 1000 replications. Given our relative small number of quarterly observations, we make the small-sample adjustment when estimating the variance-covariance matrix of the disturbances.

4.2 Evidence from Structural VAR

Figures 13 and 14 give our main empirical findings through the orthogonalized impulse-response functions (IRFs) of the variables included in the SVAR, along with 90 percent confidence bands. Each box of the tables gives the impulse responses over 20 quarters to a one-standard-deviation variable shock identified in the first column. The responding variables are listed in the first row. Figure 13 shows the results relative to the order (*LOANS*, *FEFU*, *VIX*, *FTP*) whereas Figure 14 refers to the order (*LOANS*, *FEFU*, *FTP, VIX*).

In Figure 13 we first note that the impulse response functions of *FEFU* (impulse) to *VIX* (response) confirm the evidence found in Bekaert et al. (2010) that a contractionary monetary

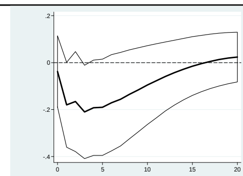
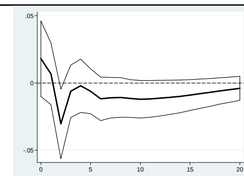
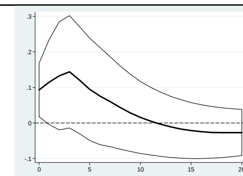
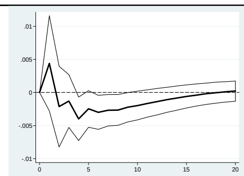
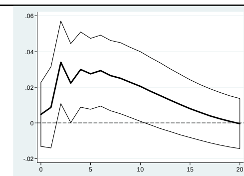
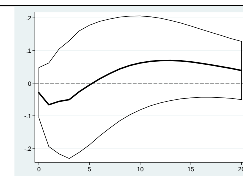
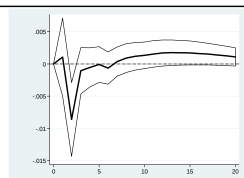
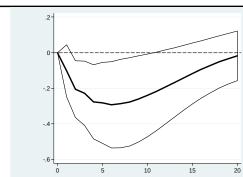
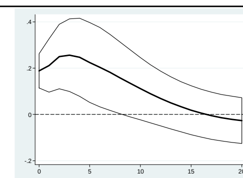
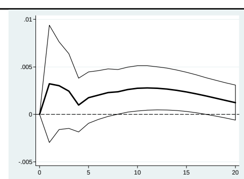
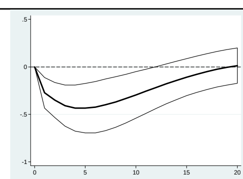
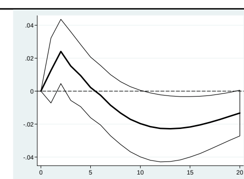
Structural VAR	Cholesky ordering 1	2	3	4
Impact of (↓)	On LOANS	On Fed Funds	On VIX	On FTP
LOANS				
Fed Funds				
VIX				
FTP				

Figure 13. **Impulse response functions in Structual VAR.** This figure presents estimated structural impulse-response functions for the four variable structual VAR (LOANS, FEFU, VIX, FTP) and 90 percent bootstrapped confidence intervals for the model with two lags, based on 1000 replications.

policy shock leads to an increase in the *VIX* after 2 quarters and remains significant until quarter 10.[7] A positive shock to the Fed Funds rate also decreases banking sector capital flows by a maximum of 0.4% in quarter 4, although the impact is only marginally significant in quarter 4 and between quarters 6 and 9.

A positive shock to *VIX* has a significant impact on *FTP*, *FEFU*, and *LOANS*. In particular, the shock to volatility increases the forward term premium for up to 8 quarters, with a maximum impact of 25 basis points in the third quarter. In other words, a shock to *VIX* leads to expectations of a steeper yield curve 12 months ahead. When we examine the impact of the FTP shock to the target Fed Funds rate, we see that the steepening of the yield curve is achieved primarily through the lowering of the target Fed Funds rate. In this way, the increase in market distress leads immediately to expectations of a more accommodative monetary policy. The effect can be seen in the increase in the forward term premium, as well as a cut in the Fed Funds rate from quarter 2 to quarter 10, with maximum of 29 basis points after 6 quarters. The impact on the cross-border banking sector capital flows happens after 2 quarters and dissipates quickly afterwards. In periods of heightened market stress, banks contract lending by almost 1 percent at a quarterly rate, which is a sizeable contraction relative to the average growth of lending of 2.5% every quarter.

As for the 12 month forward premium (*FTP*), the impact on the *VIX* is positive and significant in quarter 2 and then it becomes negative and significant after 11 quarters. The impact on the real Fed Funds target rate follows a similar pattern of the *VIX* impulse, with a significant negative impact from quarter 1 to quarter 11 and with a maximum of 43 basis points in quarter 5. The impact on *LOANS* is positive (0.3% maximum) and significant between quarters 8 to 17. Finally, when *LOANS* is the impulse variable, we observe a feedback effect on *VIX* in quarter 2 and on *FEFU* in quarter 3.

The above results are confirmed in Figure 14, where the ordering of the VIX and forward term premium are reversed. We see that the main themes in Figure 13 are preserved in this

[7]Bekaert et al. (2010) find that the impact of the real rate on risk-adversion becomes significant after 4 months and remains significant till month 34.

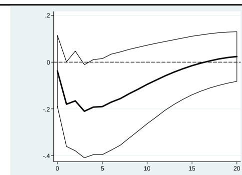
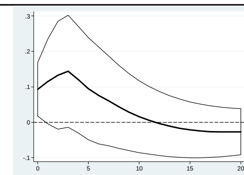
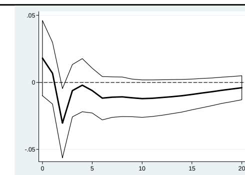
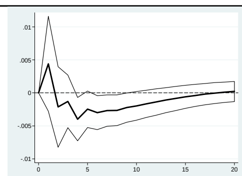
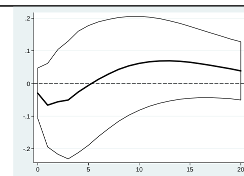
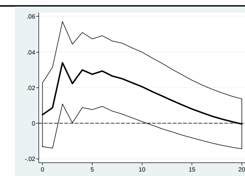
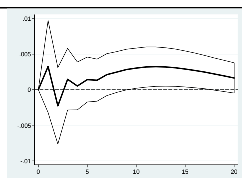
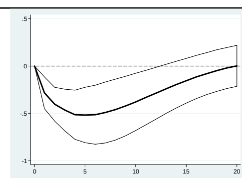
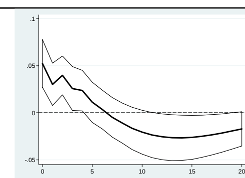
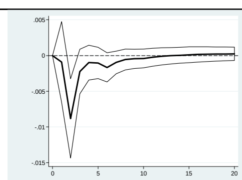
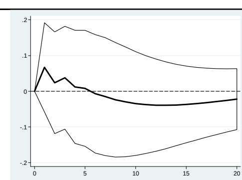
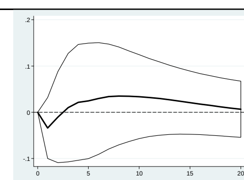
Structural VAR	Cholesky ordering 1	2	3	4
Impact of (↓)	On LOANS	On Fed Funds	On FTP	On VIX
LOANS				
Fed Funds				
FTP				
VIX				

Figure 14. **Impulse response functions in Structual VAR.** This figure presents estimated structural impulse-response functions for the four variable structual VAR (LOANS, FEFU, FTP, VIX) and 90 percent bootstrapped confidence intervals for the model with two lags, based on 1000 replications.

run of the VAR both in the relevant significant quarters and magnitude of the economic impact. The one exception is the impulse response functions of *VIX* (impulse) on *FEFU* (response) and on *FTP* (response) which are no longer significant. The Cholesky's decomposition seems to be sensitive to the ordering of *VIX* and *FTP* variables only for these specific impulse response functions. Taken together, we can summarize our findings in Figures 13 and 14 as follows.

- The widening of the 12 month forward term premium is followed by cuts in the Fed Funds rate after one quarter and lasting over several months
- The cross-border claims of the BIS-reporting banks respond sensitively to shocks to the forward term spread, the VIX, and Fed Funds rate. In this sense, global liquidity and US monetary policy is intimately linked.
- The economic magnitude of the impact is larger when the VIX is the impulse, which suggests that the VIX is the primary channel of transmission.

5 Concluding Remarks

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 determing 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.[8] 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

[8] See Shin and Shin (2010) and Hahm, Shin and Shin (2011) for empirical analyses of this issue.

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.

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.

Appendix

In this appendix, we present the derivation of the variance of the normalized asset realization $\hat{w}(Y) \equiv w(Y)/(1+r)C$ in Vasicek (2002). Let $k = \Phi^{-1}(\varepsilon)$ and $X_1, X_2, \cdots, X_n$ be i.i.d. standard normal.

$$\begin{aligned}
E\left[\hat{w}^n\right] &= E\left[\left(\Phi\left(\frac{Y\sqrt{\rho}-k}{\sqrt{1-\rho}}\right)\right)^n\right] \\
&= E\left[\prod_{i=1}^n \Pr\left[\sqrt{\rho}Y + \sqrt{1-\rho}X_i > k \middle| Y\right]\right] \\
&= E\left[\Pr\left[\sqrt{\rho}Y + \sqrt{1-\rho}X_1 > k, \ldots, \sqrt{\rho}Y + \sqrt{1-\rho}X_n > k \middle| Y\right]\right] \\
&= \Pr\left[\sqrt{\rho}Y + \sqrt{1-\rho}X_1 > k, \ldots, \sqrt{\rho}Y + \sqrt{1-\rho}X_n > k\right] \\
&= \Pr\left[Z_1 > k, \ldots, Z_n > k\right]
\end{aligned}$$

where $(Z_1, \ldots, Z_n)$ is multivariate standard normal with correlation ρ. Hence

$$E\left[\hat{w}\right] = 1 - \varepsilon$$

and

$$\begin{aligned}
\mathrm{var}\left[\hat{w}\right] &= \mathrm{var}\left[1-\hat{w}\right] \\
&= \Pr\left[1 - Z_1 \leq k, 1 - Z_2 \leq k\right] - \varepsilon^2 \\
&= \Phi_2\left(k, k; \rho\right) - \varepsilon^2 \\
&= \Phi_2\left(\Phi^{-1}(\varepsilon), \Phi^{-1}(\varepsilon); \rho\right) - \varepsilon^2
\end{aligned}$$

where $\Phi_2(\cdot, \cdot; \rho)$ cumulative bivariate standard normal with correlation ρ.

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