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

Valentina Bruno
bruno@american.edu

Hyun Song Shin
hsshin@princeton.edu

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Abstract

This paper examines the relationship between low interest rates in advanced economies and credit booms amid currency appreciation in emerging economies. In a model with cross-border banking, the "risk-taking channel" of monetary policy operates through the feedback loop between increased leverage of global banks and falling risks driven by currency appreciation in emerging economies. Uncovered Interest Parity (UIP) fails in a strong sense; a fall US dollar interest rates leads to a *depreciation* of the US dollar, not an appreciation as predicted by UIP. In our VAR analysis, we find that higher bank leverage induced by low US interest rates stimulates cross-border capital flows accompanied by currency appreciation for the recipient economy.

JEL Codes: F32, F33, F34
Keywords: Capital flows, currency 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.

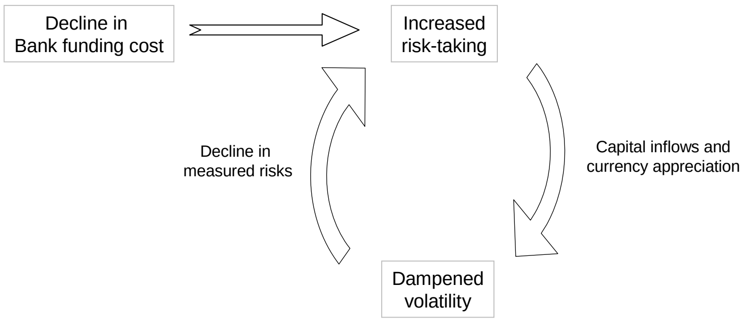


Figure 1. Risk-taking channel of monetary policy in the cross-border context

policy", and Adrian and Shin (2008, 2011) and Adrian, Estrella and Shin (2009) 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.

One robust prediction of our model is that Uncovered Interest Parity fails in a strong sense. Uncovered Interest Parity (UIP) predicts that a low interest rate currency will appreciate relative to a high interest rate currency. Not only does UIP fail to hold in our model, we have exactly the opposite prediction. When short-term US interest rates fall, the dollar *depreciates,* contrary to UIP. The reason for the strong failure of UIP in our model is that the initial dollar depreciation shock is amplified by lower credit risk of borrowers with currency mismatch, inducing greater risk-taking and leverage of global banks and an acceleration of capital inflows into the recipient economy. The usual intertemporal portfolio choice argument for UIP breaks down in our model as banks' leverage decisions are dictated by measures of risk, rather than the standard UIP logic. As we argue below, bank behavior as described in our model has strong empirical and theoretical support, so that our model may provide one possible rationalization of the strong failure of UIP actually observed in the data (Fama (1984)).

Our theoretical exposition of the risk-taking channel serves as the backdrop to our empirical study. We conduct a vector autoregression (VAR) analysis 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 (2012) 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.

Our contribution is to point to bank leverage as the linchpin in the mechanism that links the Fed Funds rate and measures of risk. We also show the importance of the leverage of global banks in explaining capital flows amid currency appreciation for the capital-recipient economies. In turn, the leverage of global banks is shown to be sensitive to the Fed Funds rate. We verify in our VAR analysis that a downward shock in the Fed Funds rate is followed by increased leverage of global banks, and an acceleration of capital flows. The narrative of the decline in the Fed Funds as a monetary policy shock receives further support when we replace the Fed Funds shock with other measures of monetary policy shocks, such as the residual from a Taylor Rule or a shock to the US M1 money stock.

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]

In contrast, our focus is on the impact of short-term rates on the feedback loop between leverage and measures of risk, especially in the international context. 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

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

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

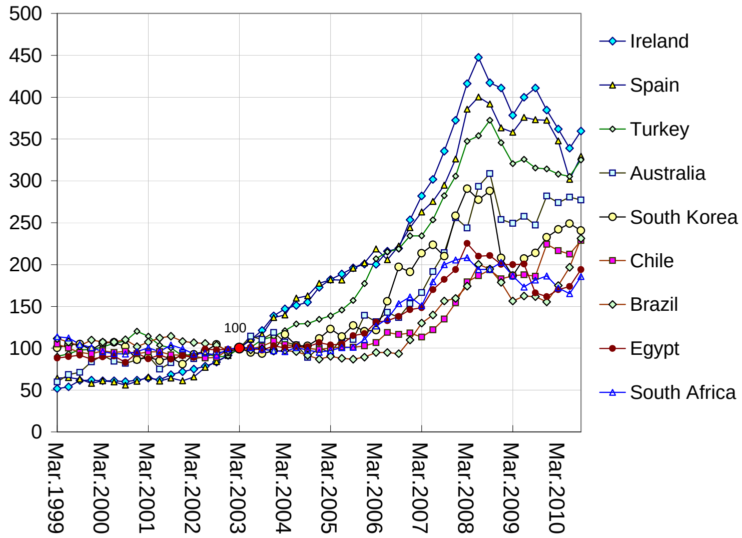


Figure 2. External claims (loans and deposits) of BIS reporting country banks on borrowers in countries listed. The series are normalized to 100 in March 2003 (Source: BIS Locational Banking Statistics, Table 7A)

currency of choice for global banks. A 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.[3] Some of the funds channeled to headquarters were redirected to the US to finance the purchase of mortgage-backed securities and other assets. However, as noted by the BIS (2010) report, global banks use a centralized funding allocation model where funds are directed to those destinations that are relatively more attractive.[4]

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

[3]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.

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

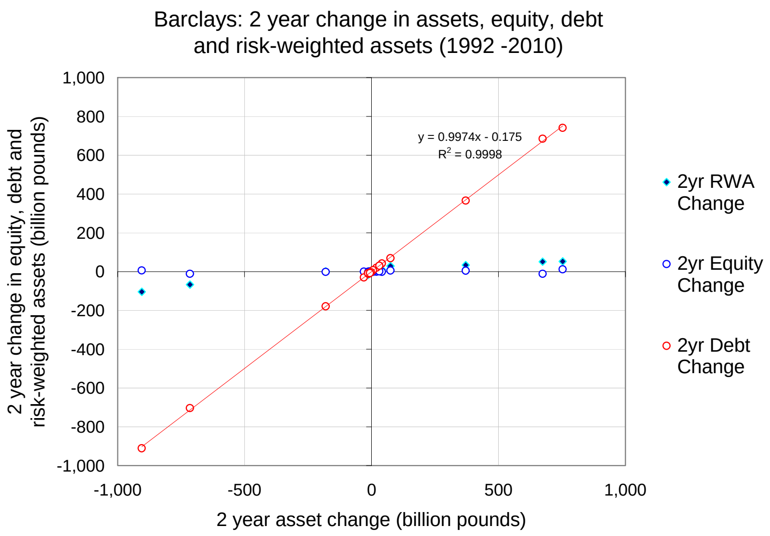


Figure 3. Scatter chart of relationship between the two year change in total assets of Barclays against two-year changes in debt, equity and risk-weighted assets (Source: Bankscope)

and Turkey, there is a remarkable degree of synchronization in the boom in cross-border lending before the recent financial crisis.

Our model explores how the cross-border activity of banks can be explained by the determinants of bank credit supply that operate through measures of risk. An illustration of the interaction between measured risks and lending for a typical global bank is given in Figure 3, which shows the scatter chart of the two-year changes in debt, equity and risk-weighted assets (RWA) to changes in total assets of Barclays. Figure 3 plots $\{(\Delta A_t, \Delta E_t)\}$, $\{(\Delta A_t, \Delta D_t)\}$ and $\{(\Delta A_t, \Delta \mathrm{RWA}_t)\}$ where ΔA_t is the two-year change in assets, and where ΔE_t, ΔD_t and $\Delta \mathrm{RWA}_t$ are the corresponding changes in equity, debt, and risk-weighted assets, respectively.

The first notable feature is how changes in assets are reflected dollar for dollar (or pound for pound) in the change in *debt*, not equity. We see this from the slope of the scatter chart relating changes in assets and changes in debt, which is very close to one. Leverage is thus procyclical; leverage is high when the balance sheet is large.

The second notable feature in Figure 3 is how the relationship between the changes in the total assets and its risk-weighted assets is very flat. In other words, the risk-weighted assets barely change, even as the raw assets change by large amounts. The fact that risk-weighted assets change little even as raw assets fluctuate by large amounts indicates the compression of measured risks during lending booms and heightened measured risks during busts. The equity in Figure 3 is book equity, not market capitalization. Hence, it measures the leverage as implied by the bank's portfolio, rather than the value of its traded shares. Since our focus is on the bank's portfolio - i.e. its lending decision - book equity is the right concept for our purpose.

Our model attempts to capture the two key features of Figure 3 - the procyclicality of leverage and the countercyclicality of measured risk - and uses this combination as the driver of the strong failure of Uncovered Interest Parity.

3 Model

Our model is based on the relationships depicted in Figure 4. 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, borrowing in foreign currency and holding local currency assets 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 currency (in Swiss francs and euros, rather than dollars) was prevalent in Hungary and other countries in emerging Europe, enabled by subsidiaries of Western European banks that could fund themselves from their parents.

Our model builds in currency mismatch by local borrowers. The local bank (interpreted as

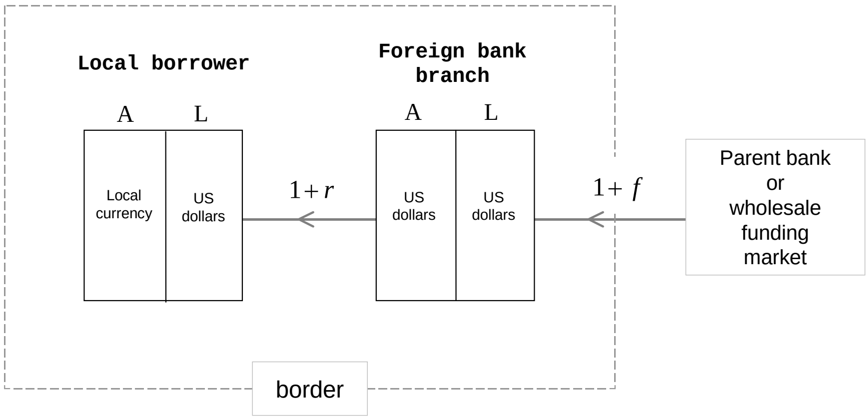


Figure 4. This figure depicts the lending relationships examined in the model. A foreign bank branch lends to local borrowers in dollars and finances its lending from the wholesale dollar funding market.

the branch or subsidiary of a global bank) has a well diversified loan portfolio consisting of loans to many local borrowers. Although the bank does not have a currency mismatch, the local borrowers do have a currency mismatch. They borrow in US dollars, but invest in projects whose outcome is denominated in local currency.

There are many identical borrowers indexed by j. Each borrower has a project maturing at date T which is financed by a loan of F dollars from the bank. Loans are granted at date 0 and repaid at date T. The value of the borrower's project in local currency terms at date t is denoted by V_t. Denote by θ_t the exchange rate at date t expressed as the price of local currency in dollars. Thus, an increase in θ_t corresponds to an appreciation of the local currency relative to the dollar. Let $\bar{\theta}_T$ denote the date 0 expected value of θ_T.

Credit risk follows the Merton (1974) model. There are many identical borrowers indexed by j. Suppose that the terminal value of the borrower's project in dollar terms is a lognormal random variable given by

$$\theta_T V_T = \theta_0 V_0 \exp\left\{\left(\mu\left(\bar{\theta}_T\right) - \frac{s^2}{2}\right) T + s\sqrt{T} W_j\right\} \tag{1}$$

where W_j is a standard normal, $s > 0$ is a constant, and $\mu(\cdot)$ is an increasing function of $\bar{\theta}_T$. The project outcome density reflects the higher expected return in dollar terms when the local

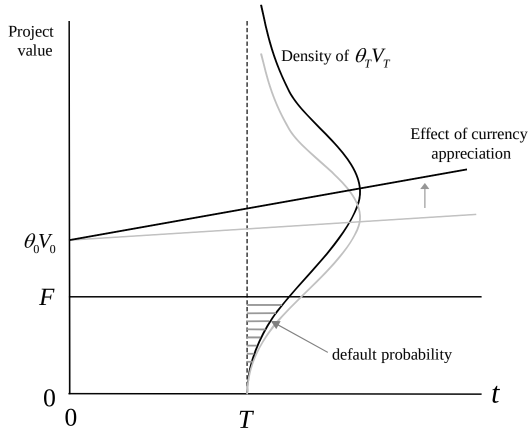


Figure 5. The borrower defaults when $\theta_T V_T$ falls short of the notional debt F. The effect of a currency appreciation is to shift the outcome density upward, lowering the default probability.

currency appreciates relative to the dollar.

The borrower defaults when the terminal value of the project in dollar terms falls short of the notional dollar debt F. Hence, the borrower defaults when

$$\theta_T V_T < F \tag{2}$$

Figure 5 illustrates the payoff from the borrower's project and the default probability as the area under the project outcome density below F. The probability of default viewed from date 0 is given by

$$\begin{aligned} \text{Prob}\left(\theta_T V_T < F\right) &= \text{Prob}\left(W_j < -\frac{\ln(\theta_0 V_0/F)+\left(\mu-\frac{s^2}{2}\right)T}{s\sqrt{T}} \right) \\ &= \Phi\left(-d_j\right) \end{aligned}$$

where d_j is the *distance to default* measured in units of standard deviations of W_j.

$$d_j = \frac{\ln\left(\theta_0 V_0/F\right) + \left(\mu\left(\bar{\theta}_T\right) - \frac{s^2}{2}\right)T}{s\sqrt{T}}$$

Note that the distance to default is increasing in $\bar{\theta}_T$ reflecting the stronger balance sheet of borrowers following currency appreciation when they have borrowed in dollars.

3.2 Banks

Banks provide dollar-denominated credit (denoted C) to local borrowers at the rate $1+r$. Our model will satisfy an aggregation feature (to be reported below), so that it is without loss of generality to assume there is a single bank. For simplicity, we will assume 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 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. The bank's book equity (also in dollars) is denoted by E.

The bank has a well diversified loan portfolio consisting of loans to many local borrowers. Credit risk for the bank follows the Vasicek (2002) extension of the Merton model.[5] Assume that the standard normal W_j can be written as the linear combination:

$$W_j = \sqrt{\rho}Y + \sqrt{1-\rho}X_j \tag{3}$$

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:

$$\begin{aligned} Z_j &= d_j + W_j \\ &= d_j + \sqrt{\rho}Y + \sqrt{1-\rho}X_j \end{aligned} \tag{4}$$

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. Then, borrower j repays the loan when $Z_j \geq 0$ where

$$Z_j = -\Phi^{-1}(\varepsilon) + \sqrt{\rho}Y + \sqrt{1-\rho}X_j \tag{5}$$

Since d_j is a function of the expected terminal exchange rate $\bar{\theta}_T$, the probability of default ε is also a function of $\bar{\theta}_T$.

[5] The Vasicek model is the workhorse credit risk model for banks, and has been adopted by the Basel Committee for Banking Supervision (2005) as the backbone of international bank capital rules.

Private credit extended by the bank is C at interest rate r so that the notional value of assets (the amount due to the bank at date T) 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 T is the random variable $w\,(Y)$ defined as:

$$\begin{aligned} w\,(Y) &\equiv (1+r)\,C \cdot \Pr\left(Z_j \geq 0|Y\right) \\ &= (1+r)\,C \cdot \Pr\left(\sqrt{\rho}Y + \sqrt{1-\rho}X_j \geq \Phi^{-1}\left(\varepsilon\right)|Y\right) \\ &= (1+r)\,C \cdot \Phi\left(\tfrac{Y\sqrt{\rho}-\Phi^{-1}(\varepsilon)}{\sqrt{1-\rho}}\right) \end{aligned} \tag{6}$$

From here on, we will assume that $\varepsilon < 0.5$. The c.d.f. of the realized value of the loan portfolio at the terminal date is given by

$$\begin{aligned} F\,(z) &= \Pr\left(w \leq z\right) \\ &= \Pr\left(Y \leq w^{-1}\left(z\right)\right) \\ &= \Phi\left(w^{-1}\left(z\right)\right) \\ &= \Phi\left(\frac{\Phi^{-1}(\varepsilon)+\sqrt{1-\rho}\Phi^{-1}\left(\frac{z}{(1+r)C}\right)}{\sqrt{\rho}}\right) \end{aligned} \tag{7}$$

Figure 6 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 $1-\varepsilon$.

3.2.1 Value-at-Risk Rule

We now introduce our key behavioral assumption. The bank is risk-neutral, and the bank's objective is to maximize expected profit subject only to its Value-at-Risk constraint that stipulates that the probability of default is no higher than some constant $\alpha > 0$.

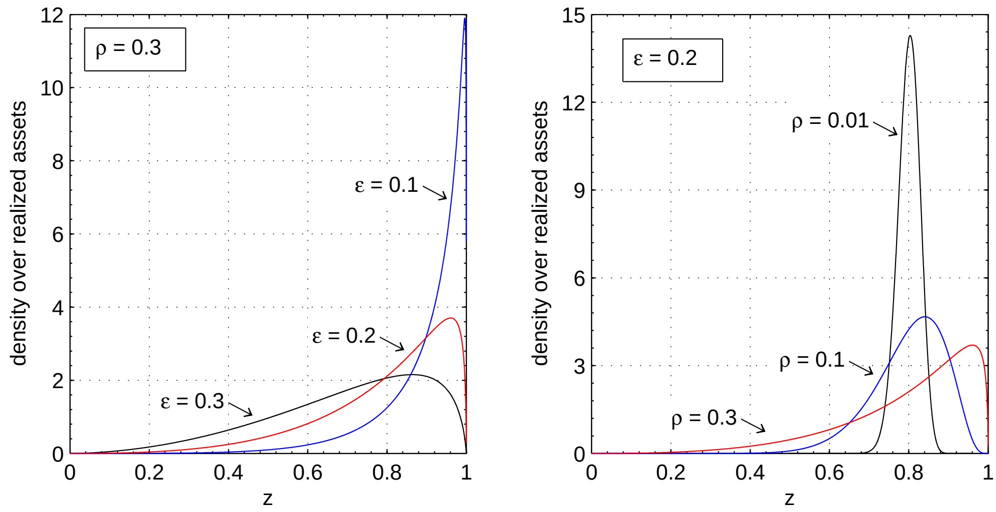


Figure 6. The two charts plot the densities over realized assets when $C(1+r) = 1$. The left hand charts plots the density over asset realizations of the bank when $\rho = 0.1$ and ε is varied from 0.1 to 0.3. The right hand chart plots the asset realization density when $\varepsilon = 0.2$ and ρ varies from 0.01 to 0.3.

The Value-at-Risk (VaR) constraint is well-known from the Basel bank capital regulations. However, our motivation for adopting the VaR constraint is not merely to appeal to the regulatory setting. Instead, our objective is to find a simple behavioral rule that conforms to the twin features that leverage is procyclical, and that fluctuations in leverage are driven by shifts in measured risks.

The reason for not appealing directly to the regulatory setting is twofold. First, the Basel regulators have motivated their adoption of the VaR rule in terms of following "private sector best practice". In other words, the behavior conforming to the VaR rule is prior to the regulations.

Second, we know from Adrian and Shin (2012) that a contracting model with moral hazard can yield a VaR-type rule as the outcome of the optimal contracting problem, even without any formal regulation imposed from the outside.[6] We will not address here the question of

[6]Adrian and Shin (2012) show that the Value-at-Risk rule is an exact solution to the contracting problem when the density of outcomes follows a general extreme value distribution.

microfoundations or the welfare issues, but merely build on existing work by adopting the Value-at-Risk constraint as a simple modeling assumption that captures the way that banks react to changing perceptions of risk.

We assume that the local 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 remains solvent as long as the realized value of $w(Y)$ is above its notional liabilities at date T. Since the funding rate on liabilities is f, the notional liability of the bank at date T is $(1+f)L$. Provided that $r > f$, the bank choice of C is such that its VaR constraint just binds.

$$\Pr\left(w < (1+f)L\right) = \Phi\left(\frac{\Phi^{-1}(\varepsilon)+\sqrt{1-\rho}\Phi^{-1}\left(\frac{(1+f)L}{(1+r)C}\right)}{\sqrt{\rho}}\right) = \alpha \tag{8}$$

Re-arranging (8), we can write the ratio of notional liabilities to notional assets as follows.

$$\frac{\text{Notional liabilities}}{\text{Notional assets}} = \frac{(1+f)L}{(1+r)C} = \Phi\left(\frac{\sqrt{\rho}\Phi^{-1}(\alpha) - \Phi^{-1}(\varepsilon)}{\sqrt{1-\rho}}\right) \tag{9}$$

We will use the shorthand:

$$\varphi(\alpha, \varepsilon, \rho) \equiv \Phi\left(\frac{\sqrt{\rho}\Phi^{-1}(\alpha)-\Phi^{-1}(\varepsilon)}{\sqrt{1-\rho}}\right) \tag{10}$$

Clearly, $\varphi \in (0,1)$. Denote by σ^2 the variance of $w(Y)/C(1+r)$. In the appendix, we show[7] that the variance σ^2 is given by

$$\sigma^2 = \Phi_2\left(\Phi^{-1}(\varepsilon), \Phi^{-1}(\varepsilon); \rho\right) - \varepsilon^2 \tag{11}$$

where $\Phi_2(\cdot, \cdot; \rho)$ is the cumulative bivariate standard normal with correlation ρ. The right hand panel of Figure 7 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 7 plots the ratio of notional liabilities to notional assets φ as a function of ε.

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

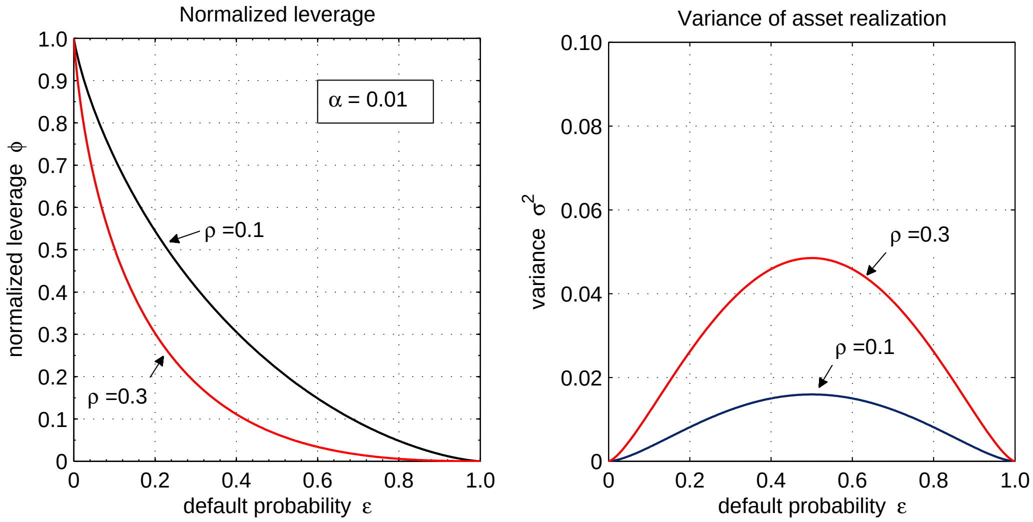


Figure 7. Left hand panel plots the normalized leverage ratio φ as a function of ε. The right hand panel plots the variance σ^2 as a function of epsilon for two values of ρ.

From (9) 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

$$C = \frac{E}{1 - \frac{1+r}{1+f} \cdot \varphi} \tag{12}$$

Note that C is proportional to the bank's equity E, and so (12) 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

$$\text{Leverage} = \frac{1}{1 - \frac{1+r}{1+f} \cdot \varphi} \tag{13}$$

On the liabilities side of the balance sheet, the banks' demand for cross-border funding L can be solved from (9) and the balance sheet identity $E + L = C$.

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

3.3 Failure of Uncovered Interest Parity

We now examine how changes in the dollar funding rate f will impact credit supply and the exchange rate through a comparative statics exercise.

Uncovered Interest Parity (UIP) states that a low interest rate currency will appreciate against a high interest currency, and that the extent of the appreciation is increasing in the interest rate differential. If we denote by $\hat{r}$ the local currency interest rate, the prediction of UIP is that

$$(1+\hat{r})\,\frac{\bar{\theta}_T}{\theta_0} = 1+f \tag{15}$$

The left hand side is the expected return to one dollar when it is used to buy local currency, and then converted back to dollars at the terminal date. UIP asserts that the expected return from such a strategy is equal to the dollar return from holding the unit in dollars. Hence, UIP predicts that a fall in the dollar funding rate f should result in a fall in $\bar{\theta}_T/\theta_0$ - an expected depreciation relative to the dollar.

Our model yields a very different prediction, provided that the local currency tends to appreciate with greater capital inflows. Such a feature would be reasonable in our context, as domestic corporate borrowers who borrow in dollars will pay for the project in local currency, and hence would sell dollars for local currency in the spot market. If the dollar exchange rate reflects the selling pressure of dollars on dealer inventories, it would be reasonable to suppose that the domestic currency appreciates when investment is financed by capital inflows. Formally, we could capture this feature in terms of the assumption that $\bar{\theta}_T/\theta_0$ is increasing in L

Under this assumption, we have exactly the opposite prediction from UIP. The local currency will *appreciate* when dollar funding cost f declines. To see this, note from (14) that when f falls, capital inflows L increase, reflecting the greater funding need of banks to finance their lending. Then, provided that $\bar{\theta}_T/\theta_0$ is increasing in L, we have an appreciation of the local currency relative to the dollar. The reason for our radical departure from UIP derives from the fact that capital inflows are driven by the lending decisions of banks, whose decisions are based on risks associated with lending.

Not only does our model depart from UIP, it also incorporates an amplification mechanism where the appreciation of the local currency fuels greater capital inflows, which in turn exerts further upward pressure on the value of the local currency. Such a response implies an upward-sloping demand response and may seem counterintuitive at first, but the theme of strong currency appreciation amid surging capital inflows is a familiar one in the literature on emerging market crises. Calvo, Leiderman and Reinhart (1993) pointed out the apparent mutually reinforcing relationship between capital inflows and currency appreciation in Latin America in the early 1990s, and such episodes have recurred with regularity across both time and distance since.

Indeed, we will see that our empirical exercise using VAR impulse response functions confirm all the key predictions of the risk-taking channel. First, Uncovered Interest Parity fails in a strong sense. Following a downward shock to the Fed Funds rate, there follows a depreciation of the US dollar, not an appreciation as predicted by UIP. At the same time, there follows an increase in the leverage of the banking sector and increased capital flows as measured by the BIS banking statistics. These features lend empirical support to our claim that capital flows are driven by the risk-taking channel of monetary policy and that the mechanism operates through banking sector leverage. Finally, we verify the role played by measures of risk in driving bank leverage. The dynamics of the VIX index corroborates the risk-taking channel of monetary policy. Various shocks that correspond to a loosening of monetary policy are followed by the dampening of the VIX measure, enabling banks to take on greater leverage, corroborating the findings of Bekaert et al. (2012).

The linchpin of our model is the impact of currency appreciation on the credit risk of lending to local borrowers. Since borrowers have dollar liabilities but operate local currency assets, an appreciation of the local currency reduces the probability of default ε (see Figure 5 given earlier). When ε declines, bank lending becomes less risky through the first-degree stochastic shift in the outcome densities (see Figure 6 above). For banks whose lending is dictated by measures of risk, the decline in ε leads to an increase in credit supply through an increase in leverage. We see this from our expression for total credit C in (12), which is increasing in φ. Finally, lending

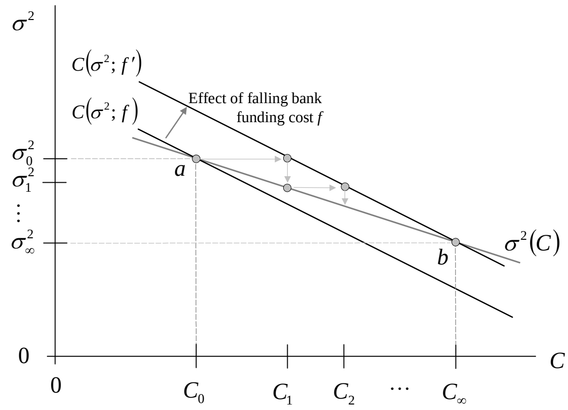


Figure 8. Impact of a decline in bank funding cost f consisting of the initial impact and the amplification effect.

is financed with capital inflows and currency appreciation, bringing us full circle.

The initial shock that sets in motion the feedback mechanism between currency appreciation and capital inflows could be anything that increases the lending by the banking sector. The shock could be purely a domestic one, such as an improvement in domestic fundamentals. However, in our model any increase in bank lending entails capital inflows to finance the lending, thereby setting the feedback mechanism in motion. Since the bank's leverage decision and hence its lending is sensitive to default risk, the decline in default risk creates an amplified response where the credit supply and currency appreciation feed off each other to create a credit boom in the capital recipient economy.

The amplified response following a cut in bank funding cost can be illustrated in schematically as follows. 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 8 illustrates the two effects. The initial impact of the cut in funding cost f is depicted by the rightward pointing arrow in Figure 8. There is an increase in lending from C_0 to C_1 following the solution for bank credit supply given by (12). However, the increase in lending is mirrored on the liabilities side by an increase in L, as given by (14). 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, provided that $\bar{\theta}_T/\theta_0$ is increasing in L, an expected appreciation of the currency associated with increased capital flows results in a first-degree stochastic shift of the outcome density as illustrated in Figure 5, resulting in a fall in the default probability. 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 risks attached to the loan book, which in turn creates spare lending capacity of the banks.

The stepwise adjustment process depicted in Figure 8 illustrates the amplification mechanism. The circular diagram we had at the outset of the paper (Figure 1) has its counterpart in Figure 8.

Formally, write $C\left(\sigma^2; f\right)$ 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 credit risk ε. Thus, the consistency between f and σ^2 entails solving the pair of equations:

$$\left\{ \begin{array}{c} C = C\left(\sigma^2; f\right) \\ \sigma^2 = \sigma^2\left(C\right) \end{array} \right. \tag{16}$$

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 size of the feedback effect in the comparative statics, begin with the expression for credit supply C given by (12). Taking the derivative of C with respect to the funding rate f, we have

$$\frac{dC}{df} = -\frac{C}{\frac{1+f}{1+r}\frac{1}{\varphi} - 1}\left[\frac{\varphi'\left(\varepsilon\right)}{\varphi}\frac{d\varepsilon}{dC}\cdot\frac{dC}{df} - \frac{1}{1+f}\right] \tag{17}$$

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

$$\frac{dC}{df}\frac{1+f}{C} = -\frac{1}{\frac{1+f}{1+r}\frac{1}{\varphi} - \left(1 + C \cdot \frac{\varphi'}{\varphi}\frac{d\varepsilon}{dC}\right)} \tag{18}$$

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

$$\begin{aligned} \frac{d\varepsilon}{dC} &= \frac{d\varepsilon}{d\theta} \cdot \frac{d\bar{\theta}_T}{dL} \cdot \frac{dL}{dC} \\ &= \frac{dG\left(z^*/\theta\right)}{d\bar{\theta}_T} \cdot \frac{d\bar{\theta}_T}{dL} \\ &= -\frac{z^*}{\bar{\theta}_T^2} \cdot g\left(\frac{z^*}{\bar{\theta}_T}\right) \cdot \frac{d\bar{\theta}_T}{dL} \end{aligned} \tag{19}$$

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

The magnitude of the amplification effect depends on the sensitivity of $\bar{\theta}_T$ 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 9 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 9 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.

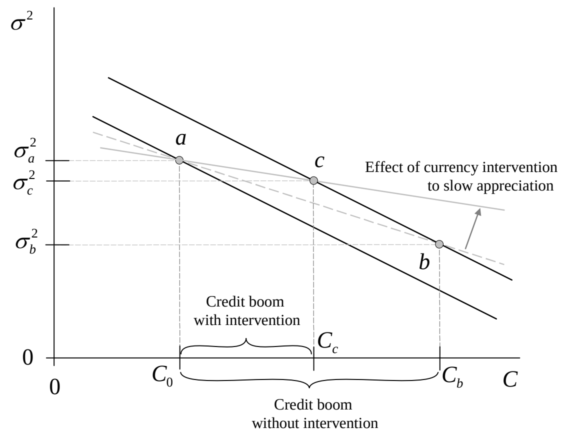


Figure 9. Effect of intervention to mitigate currency appreciation

4 Empirical Analysis

4.1 Data Description

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 recursive vector autoregression (VAR) examining the dynamic relationship between the VIX index of implied volatility on equity index options, the target Feds Funds rate of the Federal Reserve, a proxy for the leverage of global banks 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 last 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 fourth quarter of 2007 marks the beginning of the financial crisis. Our choice of sample period also helps to compare our results to those of Bekaert et al. (2012), who also used data up to the crisis.

The Fed Funds target rate is computed for the end of the quarter as the target Fed Fund rate minus the CPI inflation rate. 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. In some specifications to be reported below, we also employ the Effective Fed Funds rate, which are the actual prices observed in the Fed Funds interbank lending market.

Our theory reserves a central role for the fluctuating leverage of global banks and its interaction with exchange rate movements as the main transmission mechanism for the risk-taking channel of monetary policy. Shin (2012) shows that the European global banks were central in banking sector capital flows. Our empirical counterpart for global bank leverage should ideally be measured as the leverage of the broker dealer subsidiaries of the global banks that faciliated cross-border lending. However, the reported balance sheet data for European banks are the consolidated numbers at the holding company level that includes the much larger commercial banking unit, rather than the wholesale investment banking subsidiary alone. For the reasons discussed in Adrian and Shin (2010), broker dealers and commercial banks will differ in important ways in their balance sheet management.

For this reason, we use instead the leverage of the US broker dealer sector from the Flow of Funds series published by the Federal Reserve as our empirical proxy for global bank leverage. To the extent that US broker dealers dance to the same tune as the broker dealer subsidiaries of the European global banks, we may expect to capture the main forces at work.

The left panel of Figure 11 plots the leverage series of the US broker dealer sector from 1995Q4. Leverage increases up to 2007, and then falls abruptly with the onset of the financial crisis.

The right panel of Figure 11 shows how US broker dealer leverage is closely associated with the risk measure given by the VIX index of the implied volatility in S&P 500 stock index option prices from Chicago Board Options Exchange (CBOE). The dark squares in the scatter chart are the observations after 2007Q4 associated with the crisis and its aftermath. The scatter chart adds weight to our theory based on Value-at-Risk constrained banks, and corroborates the findings in Adrian and Shin (2010, 2012) who pointed to the close association between the

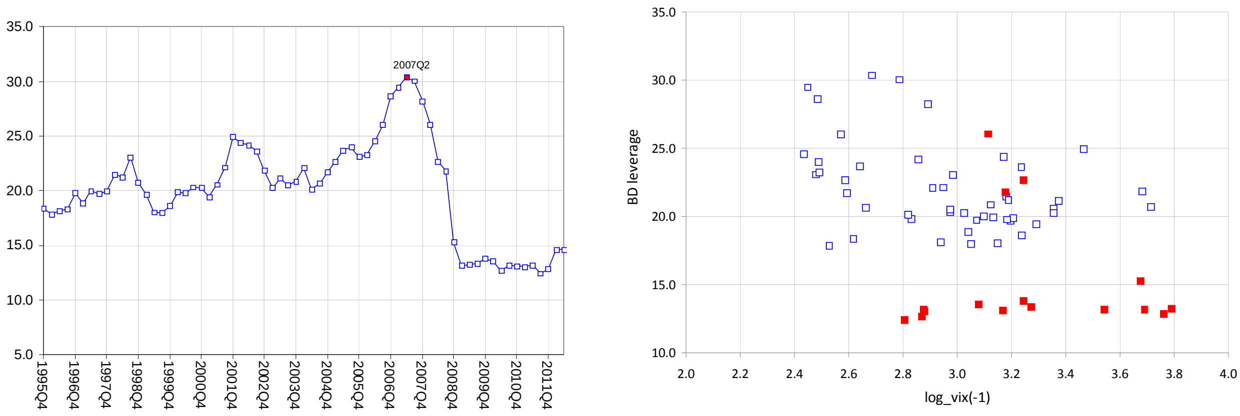


Figure 10. The left panel plots the leverage of the US broker dealer sector from the Federal Reserve's Flow of Funds series (1995Q4 - 2012Q2). Leverage is defined as (equity + total liabilities)/equity. The right panel plots the scatter chart of US broker dealer leverage against the log VIX index lagged one quarter. The dark shaded squares are the post-crisis observations after 2007Q4 (Source: Federal Reserve and CBOE)

leverage of the Wall Street investment banks and the VIX index. The close relationship between leverage and VIX also provides a point of contact between Gourinchas and Obstfeld (2012) who point to the importance of leverage with Forbes and Warnock (2012) who have highlighted the explanatory power of the VIX index for gross capital flows.

We use the end of the quarter Chicago Board Options Exchange (CBOE) Volatility Index (VIX) for the implied annualized volatility in the S&P500 stock index options. In our empirical work below, we work with the log of VIX. Our measure of aggregate banking sector capital flows is the log difference of the external loans of BIS reporting banks obtained from the locational statistics (Table 7A) of the Bank for International Settlements. The BIS locational data are organized according to 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.

The US dollar exchange rate is measured as the Real Effective Exchange Rate (REER) of

Table 1. **Summary Statistics** This table summarizes our key variables in terms of their number of observations, mean, standard deviation, minimum and maximum. The sample is from 1996Q4 to 2007Q3

Variable	Obs	Mean	Std. Dev.	Min	Max
VIX	49	20.40	6.81	11.39	40.95
Fed Funds	49	1.40	1.76	-2.02	4.12
BIS Loans	49	11.2	4.75	6.97	24.60
BD Leverage	49	21.94	3.24	17.85	30.37
USD REER	49	103.05	6.66	90.82	116.14

the US dollar, which is a trade-weighted index of the value of the dollar, obtained from the IMF's IFS database. An increase in REER indicates an appreciation of the US dollar relative to its trade-weighted basket of other currencies. Table 1 provides summary statistics of our variables.

4.2 Recursive Vector Autoregressions

In order to explore the dynamic relationships in our sample, we conduct an empirical investigation using a vector autoregression (VAR) using quarterly time series. The data series considered for inclusion in y_t are the Fed Funds target rate, the growth in lending by BIS-reporting banks, the log of the VIX index, the leverage of the US broker dealer sector, and the real effective exchange rate (REER) of the US dollar. From tests for stationarity, we include the US dollar REER as the log difference.

We will examine VAR with four or five variables, depending on the question of interest. The selection of the number of variables follows from the tradeoff between using a parsimonious model to avoid overfitting, while guarding against omitted variable bias that can undermine the interpretation of the results of the VAR. Sims (1980) and Stock and Watson (2001) describe the tradeoffs that are entailed in the selection of variables in the VAR. In our case, the selection of variables is motivated by our theory which has at its core the interaction between measured risks and banking sector leverage. By including both the VIX index and the broker-dealer leverage variable, we hope to capture the core mechanism underlying our theory.

Our interest is focused especially on the way that monetary policy interacts with measured risks and the risk-taking behavior of the banks - the so-called "risk-taking channel" of monetary policy. Additionally, we wish to gauge the impact of the risk-taking channel of monetary policy on the exchange rate and the capital inflows through the banking sector. These questions motivate the choice of our variables. As well as the Fed Funds target rate itself, we also examine additional VARs where other proxies for US monetary policy shocks are used instead, such as the residual from a (backward-looking) Taylor Rule regression, the effective Fed Funds rate and the growth in the M1 money stock in the United States.

We identify the impact of shocks by writing the vector autogression in recursive form. For the data series $\{y_t\}$ consisting of the vector y_t of the variables of interest, we consider the system

$$A(L)y_t = \varepsilon_t \tag{20}$$

where $A(L)$ is a matrix of polynomial in the lag operator L, and ε_t is a vector of orthogonalized distrurbances. As an illustration, for the four variable VAR, we impose the Cholesky restrictions by applying the following exclusion restrictions on contemporaneous responses in the matrix A to fit a just-identified model:

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

The ordering of the variables imposed in the recursive form implies that the variable with index 1 is not affected by the contemporaneous shocks to the other variables, while variable 2 is affected by the contemporaneous shock to variable 1, but not variables 3 and 4. In general, the recursive form implies that a variable with index j is affected by the contemporaneous shocks to variables with index $i < j$, but not by the contemporaneous shocks to variables with index $k > j$. Thus, slower moving variables (like the Fed Funds target rate) are better candidates to be ordered before the fast moving variables like REER and other market prices, although some caution is necessary even here, as explained in Stock and Watson (2001), since the realism of the assumptions underlying the recursive identification of shocks may depend on the frequency of the time series.

Formal lag selection procedures (the Akaike information criterion (AIC), the Hannan and Quinn information criterion (HQIC) and the Bayesian information criterion (BIC)) suggest onelag. 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 parsimonious system given our relatively small sample of quarterly observations (49 quarters). Longer lags may also create instability in the impulse-response functions. 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.

Of our five variables, two are market prices - VIX and the US dollar REER - which adjust instantaneously to news. The Fed Funds target rate reflects the periodic decision making process at the Federal Reserve and the slowly evolving nature of monetary policy. Capital flows and the adjustment of broker dealer leverage will reflect the speed of the balance adjustment of market-based intermediaries and so we may see them as being of intermediate sluggishness.

4.3 Evidence from Recursive VAR

Figures 12 presents the impulse response functions from a four variable recursive VAR with 90 percent confidence bands. The ordering of the four variables is (1) Fed Funds target rate (2) broker dealer leverage (3) VIX and (4) US dollar REER. Figure 12 is organized so that the rows of the matrix indicates the variable whose shock we are following and the columns of the matrix indicate the variable whose response we are tracking. Each cell of the tables gives the impulse responses over 20 quarters to a one-standard-deviation variable shock identified in the first column.

The panels in Figure 12 provide a narrative that is consistent with our model. Consider

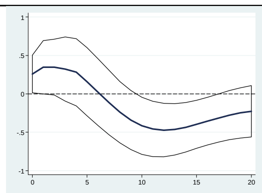
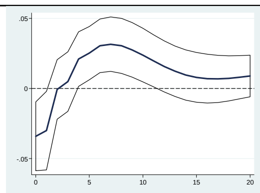
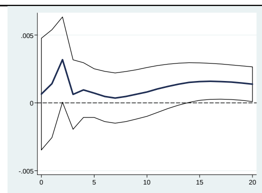
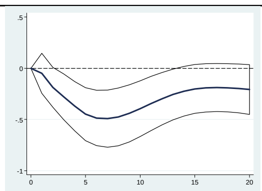
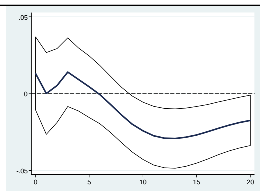
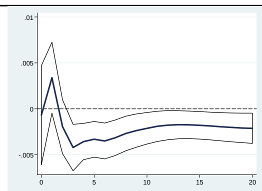
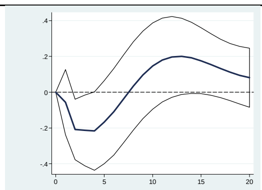
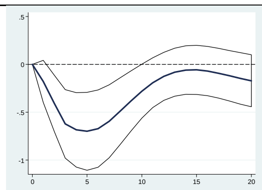
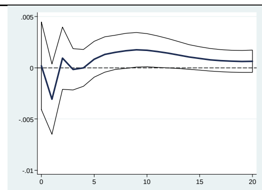
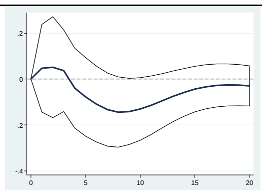
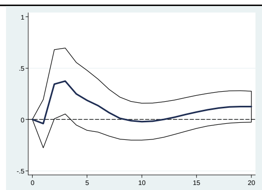
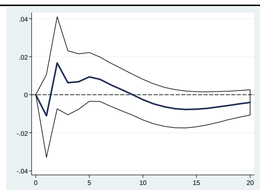
Recursive VAR	Ordering 1	2	3	4
Impact of (↓)	On Fed Funds	On BD Leverage	On VIX	On US dollar REER
Fed Funds				
BD Leverage				
VIX				
US dollar REER				

Figure 11. **Impulse response functions in recursive VAR.** This figure presents estimated impulse-response functions for the four variable recursive VAR (Fed Funds, BD leverage, VIX and REER) and 90 percent bootstrapped confidence intervals for the model with two lags, based on 1000 replications.

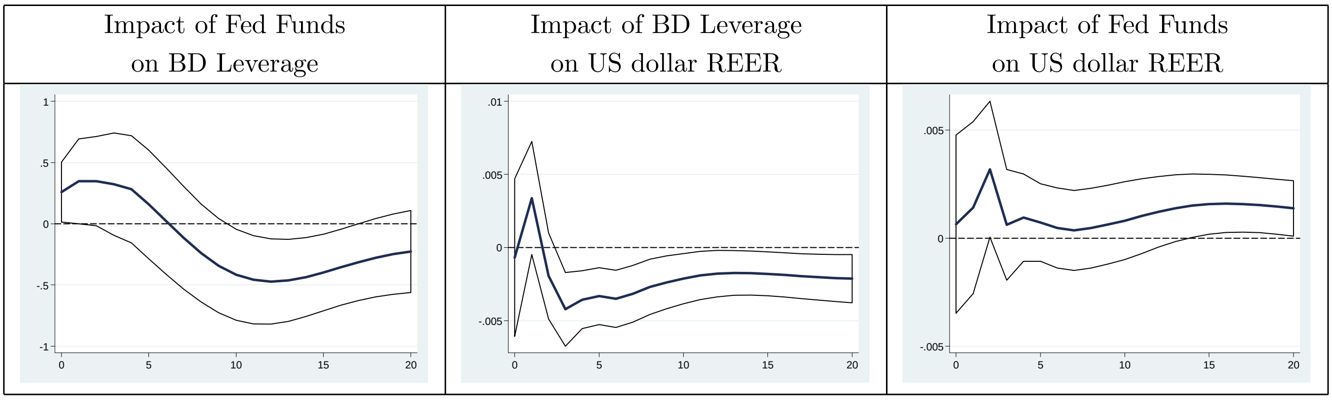


Figure 12. **Impulse response functions in recursive VAR.** This figure presents three panels from the impulse response functions of the four variable VAR (Fed Funds, BD leverage, VIX and REER) illustrating the impact of a Fed Funds target rate shock on the US dollar exchange rate. A positive Fed Funds target rate shock leads to an appreciation of the US dollar, via the fall in the leverage of the banking sector. The panels show 90 percent bootstrapped confidence intervals for the model with two lags, based on 1000 replications.

first the impact of a shock to the Fed Funds target rate, interpreted as a monetary policy shock and examine the impact of the shock on the US dollar exchange rate as given by REER. Figure 13 collects together the key panels for the narrative. We see from Figure 13 that a positive Fed Funds target rate shock leads to an appreciation of the US dollar after a long lag. The other panels reveal aspects of the mechanism for such an effect. The left panel shows the fall in leverage of the banking sector induced by higher bank funding costs while the middle panel shows that an increase in bank leverage leads to a fall in the value of the US dollar. Thus, the conjunction of the first two panels tells the story underlying the final panel - of how a fall in the US dollar bank funding costs results in a decline in the value of the US dollar.

The impulse responses depicted in Figure 13 is consistent with the strong failure of Uncovered Interest Parity, as flagged in our theory section. A fall in US dollar funding rates leads to a depreciation of the US dollar, rather than an appreciation as predicted by UIP. Moreover, Figure 13 reveals that the mechanism involved in the strong failure of UIP is consistent with the leveraging and deleveraging story as presented in our theory section.

The relationship between broker dealer leverage and the VIX index also bolsters our argument. The panel in Figure 12 that shows (Impact VIX, Response BD leverage) shows that an upward shock to the VIX index leads to a sharp decline in the leverage of the banking sector, as predicted by our theory. This panel provides indirect support for the behavioral rule for the banking sector based on Value-at-Risk.

4.3.1 Variance Decompositions

We saw from the VAR evidence in Figure 12 shows that monetary policy has a medium-run statistically significant effect on BD leverage and VIX, and that BD leverage has a statistically significant effect on exchange rate, VIX, and Fed Fund rate. Such effects are also economically significant. Figure 14 shows what fraction of the structural variance of the four variables in the VAR is due to monetary policy shocks or BD leverage shocks. We see that monetary policy shocks account for almost 30% of the variance of VIX and between 10% and 20% of the variance of BD leverage at horizons longer than 10 quarters. On the other hand, we see that monetary policy shocks are less important drivers of the variance of US dollar exchange rate as given by REER.

BD leverage shocks account for more than 20% of the variance of the exchange rate and for almost 40% of the variance of the Fed fund rate at horizons longer than 10 quarters. They also count for about 20% of the variance of VIX at horizons longer than 15 quarters. Our variance decomposition reveals a considerable degree of interactions between the variables in our model, and point to the importance of the leverage cycle of the global banks as being a key determinant of the transmission of monetary policy shocks.

4.3.2 Alternative Measures of Monetary Policy Shocks

Figure 15 shows the impulse-response functions and 90% confidence bands for alternative monetary policy shocks on REER, VIX and BD-leverage in the four-variable VAR with 2 lags and 1000 bootstrapped standard errors. Monetary policy shocks considered are residuals from a Taylor rule regression, M1 growth and nominal effective Fed Funds rate.

The first alternative measure of monetary policy shock is the difference between the nominal Fed Funds target rate and the Fed Funds rate implied by a backward looking Taylor rule. The

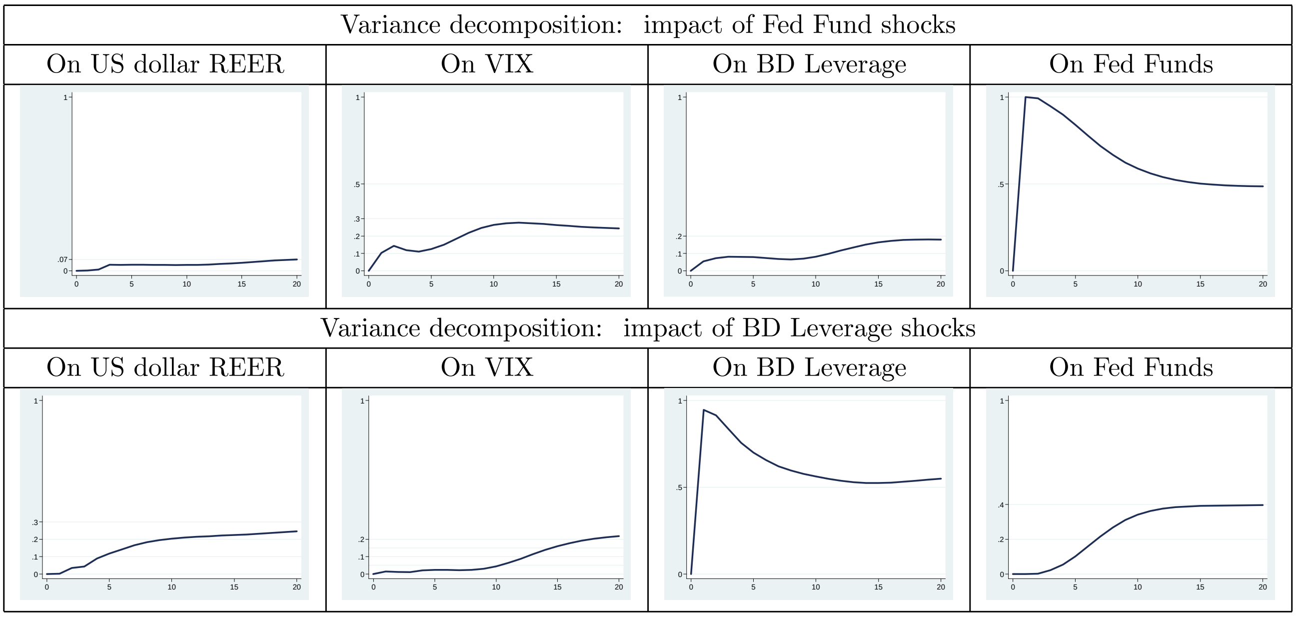


Figure 13. **Variance Decomposition.** This figure presents variance decompositions from the four variable VAR giving the fractions of the structural variance due to Fed Fund or Leverage shocks for the four variables REER, VIX, BD Leverage and Fed Fund (model with 2 lags).

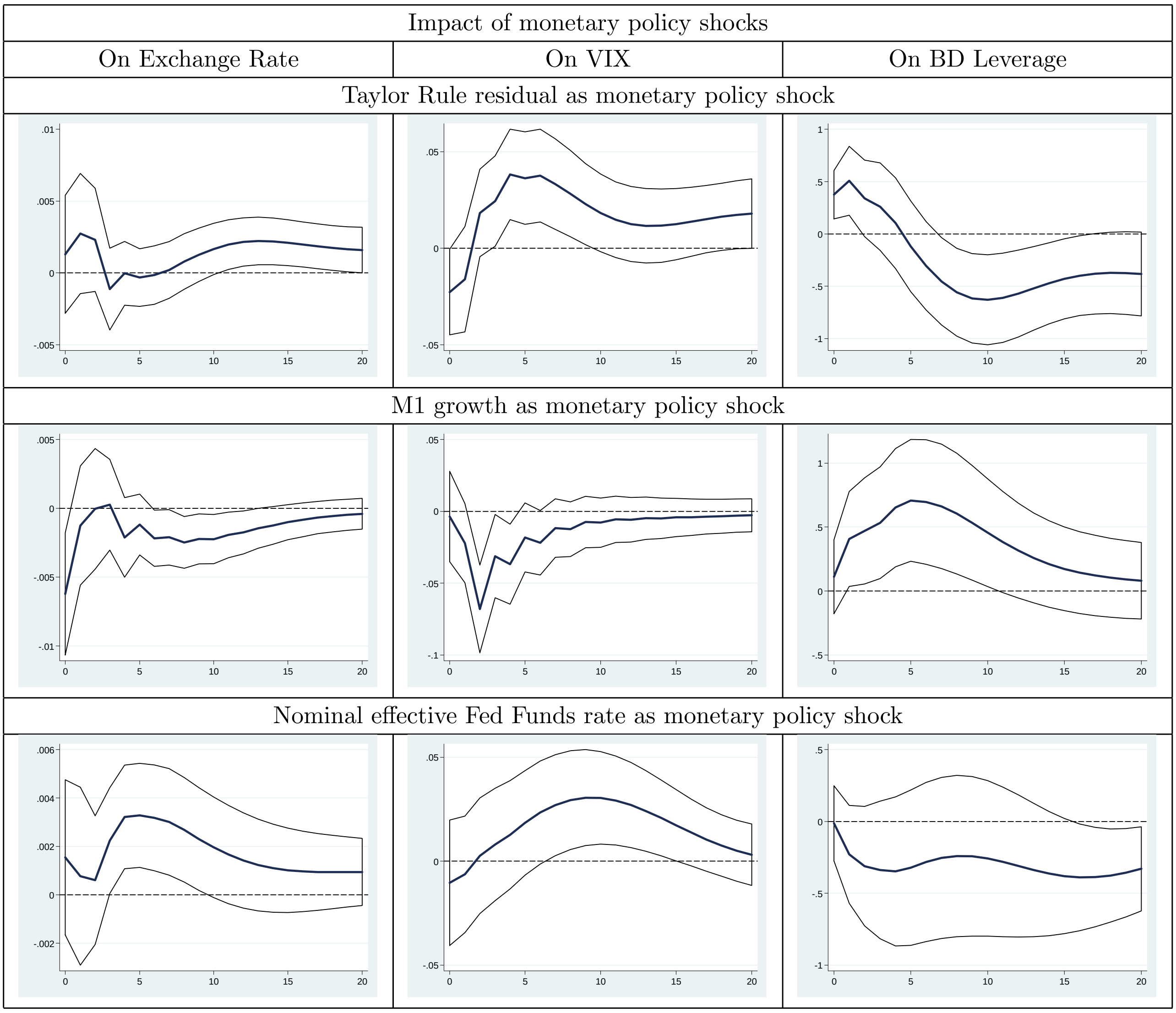


Figure 14. **Alternative definitions of monetary policy shocks.** This figure shows the impulse-response functions and 90 percent confidence bands for alternative monetary policy shocks on REER, VIX and BD-leverage in the four-variable model with two lags and 1000 bootstrapped standard errors. Monetary policy shocks considered are residuals from a Taylor rule, M1 growth and nominal effective Fed Funds rate.

Taylor rule we use assumes the natural real Fed funds rate and the target inflation rate to be 2%, while the output gap is computed as the percentage deviation of real GDP (from the IFS) from potential GDP (from the Congressional Budget Office). In the top row of Figure 15, we see that our qualitative conclusions using the Fed Funds target rate as the monetary policy shock remain unchanged. A positive interest rate shock leads to an appreciation of the US dollar after a lag of 10 quarters, and the mechanism is consistent with a decline in banking sector leverage after around 7 quarters. In turn, the "risk-taking channel" is clearly evident in the middle cell of the top row, where a monetary policy shock is associated with greater measured risks after two quarters.

We consider two further alternative measure of monetary policy shocks, shown in the second and third rows of Figure 15. One is the growth rate of the US M1 money stock, where a positive shock to M1 corresponding to monetary policy loosening. We see that the qualitative conclusions are borne out in the impulse responses for the exchange rate and the banking sector leverage. The impact on the VIX dissipates more quickly than for the other monetary shock measures. One reason for the qualitative difference for the M1 variable may be the greater search for safe assets during periods when markets become turbulent, as investors seek out bank deposits rather than riskier claims. Further empirical investigations may reveal more the reasons for the differences.

Our third measure of monetary policy shock is the effective Federal Funds rate, which measures actual transactions prices used in the Fed Funds market of interbank lending, rather than the Fed Funds target rate itself. Our earlier conclusions using the Fed Funds target rate are confirmed. To the extent that the difference between the Fed Funds target rate and the effective Fed Funds rate are small, high frequency deviations, our results are perhaps not surprising.

4.3.3 Capital Flows in Five Variable VAR

We now turn to the pattern of banking sector capital flows by adding the growth in loans of BIS-reporting banks to our VAR. The ordering of the five variables is (1) Fed Funds target rate (2) broker dealer leverage (3) BIS banking flows (4) VIX and (5) US dollar REER. Figure 16 presents the impulse responses together with the 90% confidence bands. As before, Figure 16 is organized so that the rows of the matrix indicates the variable whose shock we are following and the columns of the matrix indicate the variable whose response we are tracking. Each cell of the tables gives the impulse responses over 20 quarters to a one-standard-deviation variable shock identified in the first column.

As well as showing the impact of the risk-taking channel of monetary policy on the US dollar exchange rate as before, Figure 16 also reveals how capital flows through the banking sector is an important element of the narrative of the risk-taking channel. Figure 17 gathers three of the panels for a more succinct summary of the relationships. The left panel of Figure 17 shows the impact of a Fed Funds shock on banking sector leverage, showing very clearly the risk-taking channel of monetary policy associated with the leverage cycle of global banks. A positive shock in the Fed Funds rate reduces leverage markedly from after around eight quarters or so reaching its maximum impact at round twelve quarters.

The other two panels in Figure 17 shows the impact of the risk taking channel on capital flows through the banking sector. The middle panel in Figure 17 shows that an increase in broker dealer leverage leads to a marked increase in BIS bank flows, although the initial impact is uneven until around nine quarters. The right panel in Figure 17 shows the consequence of the chain reaction where the monetary policy shock works through leverage leading to a decrease in the capital flows in the banking sector.

Figures 16 and 17 together show the risk-taking channel in action, where the monetary policy and measured risks determine the leverage cycle of the banking sector, eventually leaving its mark on the US dollar exchange rate and the capital flows funded by the US dollar. The empirical regularities uncovered in our VAR results lend considerable weight to the model sketched in our theory section. All the main predictions of our theory are verified in the VAR results, namely

- Uncovered Interest Parity fails in a strong sense. When the US dollar bank funding rate declines, there follows a depreciation of the US dollar, not an appreciation as predicted by

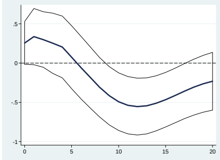
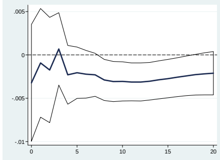
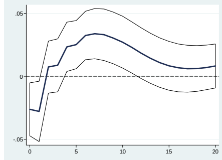
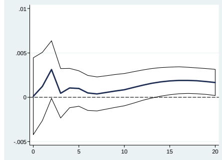
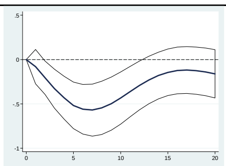
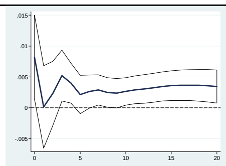
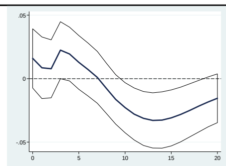
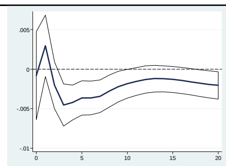
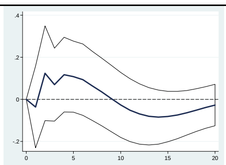
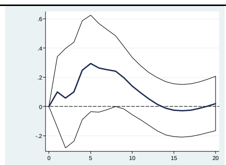
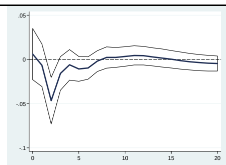
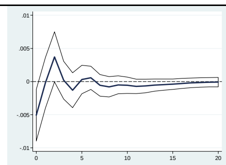
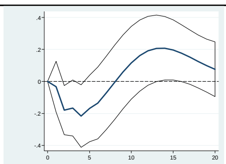
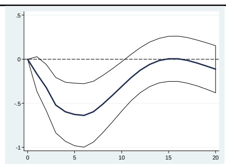
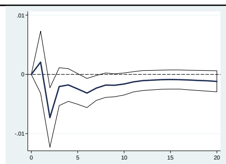
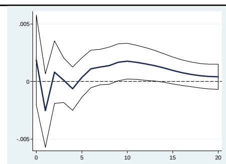
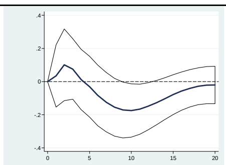
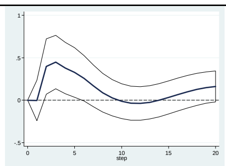
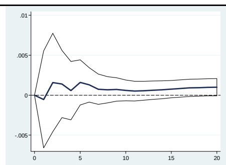
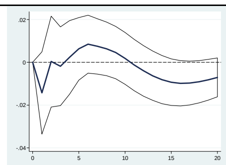
Recursive VAR	Ordering 1	2	3	4	5
Impact of (↓)	On Fed Funds	On BD Leverage	On BIS bank flows	On VIX	On USD REER
Fed Funds					
BD Leverage					
BIS Bank flows					
VIX					
USD REER					

Figure 15. **Impulse response functions in recursive VAR.** This figure presents estimated impulse-response functions for the five variable structual VAR (Fed Funds, BD leverage, BIS bank flows, VIX and REER) and 90 percent bootstrapped confidence intervals for the model with two lags, based on 1000 replications.

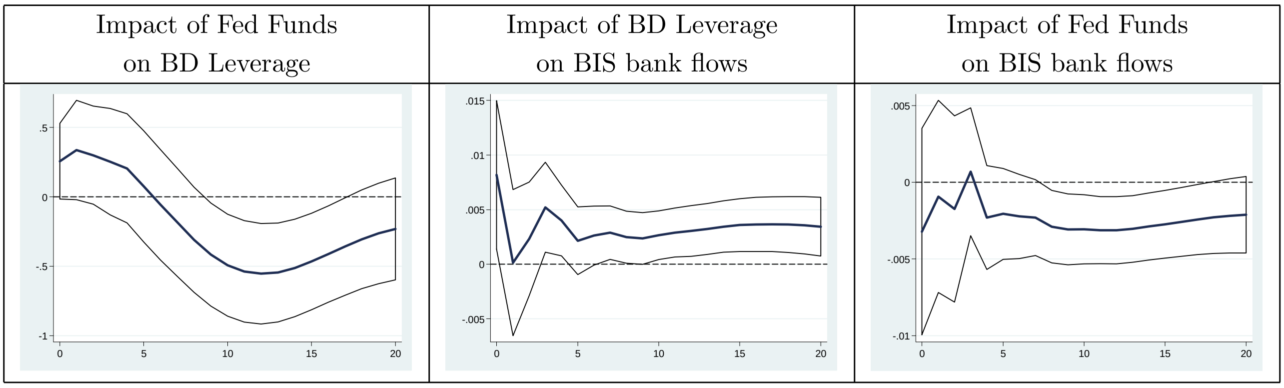


Figure 16. **Impulse response functions in recursive VAR.** This figure presents three panels from the impulse response functions of the five variable VAR (Fed Funds, BD leverage, BIS bank flows, VIX and REER) illustrating the impact of a Fed Funds target rate shock on BIS bank capital flows. A positive Fed Funds target rate shock leads to decline in bank capital flows, via the fall in the leverage of the banking sector. The panels show 90 percent bootstrapped confidence intervals for the model with two lags, based on 1000 replications.

UIP. This result echoes earlier empirical findings (e.g. Fama (1984)) and lends empirical support to our result on the strong failure of UIP.

- When the US dollar bank funding rate declines, there follows an increase in the leverage of the banking sector and increased capital flows as measured by the BIS banking statistics. This result lends empirical support to our model of capital flows driven by the risk-taking channel of monetary policy that operates through banking sector leverage.
- The dynamics of the VIX index corroborates the risk-taking channel of monetary policy. A loosening of monetary policy manages to quell the VIX measure of risk and thereby facilitate the greater leverage of the banking sector. The role of the VIX in determining the leverage of the banking sector strongly suggests behavior that is related to the Value-at-Risk driven leverage cycles developed in our theory section.

4.3.4 Additional Robustness Checks

Our interpretation of a shock in the Fed Funds target rate as a monetary policy shock needs to be taken in the context of the business cycle and the endogenous nature of monetary policy. We used alternative definitions of the monetary policy shocks to take account of the endogeneity. We also conducted additional exercises to examine the impact of macroeconomic conditions on monetary policy policy. In one specification, we included a measure of growth of industrial production (defined as the log difference of the US industrial production index) and added it to our four-variable VAR model. The ordering was such that the growth in industrial production was placed first in the new five variable VAR. Our results (not reported here) indicate that the addition of the growth of industrial production does not alter the main conclusions of our VAR. Our earlier results on the impact of the risk-taking channel of monetary policy on the US dollar exchange rate and capital flows remain unchanged.

Sensitivity of the recursive VAR to alternative ordering of the variables is a perennial theme in VAR analysis. The selection of our variables has been motivated by the risk-taking channel of monetary policy driven by the leverage cycle of global banks. The theory-based selection of variables and the different degrees of inertia inherent in our selected variables give some firm foundations to our VAR analysis. Kilian (2011) argues that if the ordering of the recursive VAR has strong theory foundations, robustness to alternative orderings have less rationale. Monetary policy through the choice of the Fed Funds target rate makes it reasonable to order the variables so that monetary policy has contemporaneous effects on bank leverage decisions (especially the broker dealers, who hold marketable claims) and other financial variables. In turn, our ordering assumes that banks' leverage decisions have a contemporaneous impact on financial price variables such as the VIX and exchange rates because their leverage behavior will impact the price of volatility in the market and the exchange rate. The relative ordering between the two price variables - VIX versus REER is more difficult, as both are prices that react instantaneously to shocks to the market. An alternative to our ordering of putting REER last would have been to put VIX last. We examined this alternative ordering in a VAR. In untabulated results from these additional VARs we verified that our earlier results remain qualitatively unchanged.

Our sample period stops in 2007. The crisis period presents special challenges in the VAR estimation, especially since the post-crisis period is associated with the Fed Funds rate pressed against the zero lower bound (see Kilian (2011)). The VAR using an extended sample period that encompasses the zero lower bound period show markedly weaker VAR impulse responses, and many of the impulse response functions associated with shifts in the Fed Funds target rate fail to show significant effects. All the evidence points to a structural break in the relationships driving our key macro variables. Existing literature reflects the structural change associated with the crisis. The sample period in Bekaert et al (2012) also stops in 2007, before the crisis erupts in earnest. Structural breaks in the autoregressive slope parameters may also have offsetting effects on the impulse response functions. For these reasons we exclude the post-2008 period from our analysis.

4.3.5 Cross-Correlogram

The relationship between the major macro variables used in our analysis show the consistent pattern due to the risk-taking channel of monetary policy. The patterns seen in the impulse response functions can be seen also in the cross-correlograms that show the pairwise correlations between the variables used in our analysis across time. Table 2 presents the pairwise correlations between the first-listed variable and the second-listed variable t quarters ahead. The length of horizontal lines indicate level of the cross-correlation between the two variables.

We see all the key patterns from the impulse response functions appearing in the correlogram. In the top left panel, we see the strong negative relationship between the Fed Funds rate and the leverage of the broker dealer sector. The negative relationship strengths over time, and reaches its peak after thirteen quarters. The correlation between the Fed Funds rate and broker dealer leverage 13 quarters ahead is -0.534.

Looking across the top row in Table 2 to the third cell, we see the cross correlation between BD leverage and future values of the US dollar REER. We see the strongly negative relationship between the two at all horizons, but especially around eight quarters. The correlation between BD leverage and REER eight quarters ahead is -0.326. These features support the narrative of the risk-taking channel of monetary policy being driven by the leverage cycle of the global banks. The strong failure of Uncovered Interest Parity stems from the observed behavior of the

Table 2. **Cross-correlogram.** This table shows the pairwise correlations between the first-listed variable and the second-listed variable t quarters ahead. The length of horizontal lines indicate level of the cross-correlation between the two variables.

t	Fed Fund, BD Leverage $(+t)$	BD Leverage, Fed Fund $(+t)$	BD Leverage, REER $(+t)$	REER, BD Leverage $(+t)$
0	-0.1116	-0.2402	-0.1436	-0.0636
1	-0.1333	-0.2653	-0.1527	-0.0341
2	-0.1603	-0.2972	-0.1762	-0.0503
3	-0.2052	-0.3053	-0.2009	-0.0668
4	-0.2555	-0.2500	-0.2241	-0.0788
5	-0.2957	-0.2166	-0.2649	-0.1092
6	-0.3274	-0.1564	-0.2830	-0.1170
7	-0.3830	-0.1263	-0.3171	-0.1125
8	-0.4228	-0.1486	-0.3258	-0.1008
9	-0.4473	-0.1150	-0.2977	-0.0388
10	-0.4763	-0.0869	-0.2563	0.0359
11	-0.5082	-0.0481	-0.2187	0.1519
12	-0.5261	0.0391	-0.1962	0.2541
13	-0.5340	0.0926	-0.1736	0.3183
14	-0.5212	0.1173	-0.1699	0.3699
15	-0.5023	0.1709	-0.1539	0.4234
16	-0.4488	0.2107	-0.1750	0.4569
17	-0.3898	0.2291	-0.2095	0.4803
18	-0.3374	0.2761	-0.2377	0.4956
19	-0.2811	0.2778	-0.2744	0.4765
20	-0.2513	0.2537	-0.2810	0.4569

t	Fed Fund, VIX $(+t)$	VIX, Fed Fund $(+t)$	BD Leverage, VIX $(+t)$	VIX, BD Leverage $(+t)$
0	0.1650	-0.0445	-0.1822	-0.3332
1	0.2978	-0.1173	-0.1080	-0.4181
2	0.3583	-0.1100	-0.0898	-0.4475
3	0.4036	-0.1301	-0.1068	-0.4628
4	0.4636	-0.1935	-0.1632	-0.4731
5	0.4814	-0.2594	-0.2374	-0.4538
6	0.5750	-0.2871	-0.2363	-0.4560
7	0.6265	-0.2967	-0.2688	-0.4292
8	0.6479	-0.2837	-0.2456	-0.3602
9	0.6815	-0.2930	-0.2369	-0.2753
10	0.6912	-0.3102	-0.2660	-0.2059
11	0.6297	-0.3044	-0.2006	-0.0861
12	0.5998	-0.2650	-0.2299	0.0214
13	0.5466	-0.1976	-0.2060	0.0880
14	0.5013	-0.1844	-0.1624	0.2157
15	0.4083	-0.2052	-0.0945	0.2999
16	0.3445	-0.1827	-0.0635	0.3331
17	0.2982	-0.2177	-0.0424	0.3414
18	0.2210	-0.2536	-0.0593	0.3627
19	0.1619	-0.1705	-0.0364	0.2874
20	0.0999	-0.2244	-0.0064	0.2383

t	Fed Fund, REER $(+t)$	REER, Fed Fund $(+t)$	REER, VIX $(+t)$	VIX, REER $(+t)$
0	-0.2635	-0.3835	0.5031	0.5698
1	-0.1558	-0.4710	0.4740	0.5884
2	-0.0545	-0.5427	0.3497	0.5452
3	0.0571	-0.5989	0.2247	0.5129
4	0.1719	-0.6646	0.1519	0.4591
5	0.2990	-0.6989	0.0838	0.3918
6	0.3878	-0.7245	-0.0377	0.3861
7	0.4989	-0.7320	-0.1460	0.3466
8	0.5861	-0.6823	-0.2232	0.2775
9	0.5996	-0.6286	-0.3132	0.2581
10	0.6418	-0.5813	-0.4312	0.2804
11	0.6696	-0.5164	-0.3785	0.2651
12	0.6861	-0.4648	-0.4257	0.2400
13	0.6962	-0.3850	-0.4623	0.2007
14	0.6617	-0.2419	-0.5073	0.1009
15	0.6273	-0.1647	-0.4927	0.0276
16	0.5752	-0.0915	-0.4793	-0.0121
17	0.5184	-0.0076	-0.4448	-0.0779
18	0.4688	0.0424	-0.4858	-0.1800
19	0.3823	0.1056	-0.4971	-0.2097
20	0.3014	0.1708	-0.4718	-0.2678

leverage cycle of the global banks that appear to be driven by the measures of risk such as the VIX, rather than the intertemporal portfolio choice logic inherent in the UIP.

The cross-correlograms also reveal insights on the reaction function used by the Federal Reserve in its monetary policy. In the second row of Table 2, we see that there is a mutual dependence between the Fed Funds rate and the VIX. The second panel in row 2 of Table 2 shows that the Fed Funds target ten quarters ahead has a correlation of -0.31 with the current value of the VIX. Conversely, the first panel of row 2 shows that there is a positive correlation of 0.69 between Fed Funds and the VIX index ten quarters ahead. These features suggest that monetary policy both *reacts to* but also *has an impact on* the volatility in the capital markets. A high value of VIX is associated with lower Fed Funds rates in the future, while a lower Fed Funds rate is associated with lower VIX rates in the future. The interpretation is that monetary policy is loosened in response to market distress, which is a feature that would be familiar to observers of market events. The evidence on the relationship between risk and monetary policy in Table 2 corroborate the findings of Bekaert et al. (2012) 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.

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) and Obstfeld (2012a, 2012b) 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.[8]

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

Our empirical results also highlight the role played by the US dollar as the currency that underpins the global banking system, even if the intermediaries are non-US intermediaries. Shin (2012) emphasizes the combination of the US dollar as the currency of global banking, but the role of the European banks as the conduit for the transmission of financial conditions. The focus on the US dollar as the currency underpinning global banking lends support to studies that have emphasized the US dollar as a bellwether for global financial conditions, as recently suggested by Lustig, Roussanov and Verdelhan (2012) and Maggiori (2010).

More broadly, the role of the US dollar in the global banking system opens up important questions on the transmission of financial conditions across borders. Calvo, Leiderman and Reinhart (1993, 1996) famously distinguished the global "push" factors for capital flows from the country-specific "pull" factors, and emphasized the importance of external push factors in explaining capital flows to emerging economies in the 1990s. Our earlier paper (Bruno and Shin (2011)) has verified the role of global factors associated with the leverage of the banking sector as being a key determinant of cross-border capital flows in panel regressions of capital flows to emerging and advanced economies. The results here suggest that further research on the impact of global factors may yield insights into the transmission of global financial conditions across borders.

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.

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

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

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

and

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

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

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