Capital flows and the risk-taking channel of monetary policy

Valentina Bruno[a,*], Hyun Song Shin[b†]

[a] American University, United States; [b] Princeton University, United States

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Abstract

We study the dynamics linking monetary policy with bank leverage and show that adjustments in leverage act as the linchpin in the monetary transmission mechanism that works through fluctuations in risk-taking. In an international dimension, we find evidence of monetary policy spillovers on cross-border capital flows through the banking sector. A contractionary shock to US monetary policy leads to a decrease in the cross-border banking capital flows through a decline in the leverage of international banks.

Keywords: Bank leverage, monetary policy, capital flows, risk-taking channel

JEL classification: F32, F33, F34

*Corresponding author: hsshin@princeton.edu

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1. Introduction

Low interest rates maintained by advanced economy central banks have led to a lively debate on cross-border monetary policy spillovers and the possible transmission channels. We examine one such channel: the banking sector. Banks are intermediaries whose financing costs are closely tied to the policy rate chosen by the central bank. If funding costs affect decisions on how much exposures to take on, monetary policy will then affect the economy through greater risk-taking by the banking sector.

Borio and Zhu (2012) coined the term "risk-taking channel" of monetary policy to denote the impact of monetary policy on the willingness of market participants to take on risk exposures, thereby influencing financial conditions and ultimately influencing real economic decisions. Our focus in this paper is on the operation of the risk-taking channel through the banking sector. We ask how banking sector leverage fluctuates in the face of changing financial conditions and track the consequences domestically and internationally.

Comovement of exchange rates and leverage connect the domestic and global impact of risk taking. 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. Lund-Jensen (2012) presents similar evidence. These findings hold both for emerging and advanced economies. Schularick and Taylor (2012) similarly highlight the historical evidence on financial vulnerability, especially that associated with the size of the banking sector. Thus, one way to frame the debate on international monetary policy spillovers is to ask how monetary policy influences bank leverage, cross border flows and the exchange rate.

In answering this question, we tie together two strands in the empirical literature. In a domestic context, Bekaert, Hoerova and Lo Duca (2013) conduct a vector autoregression (VAR) study that shows a close 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. In particular, they show that a cut in the Fed Funds rate is followed by a dampening of the VIX index.

Meanwhile, in an international context, an earlier paper by Eichenbaum and Evans (1995)

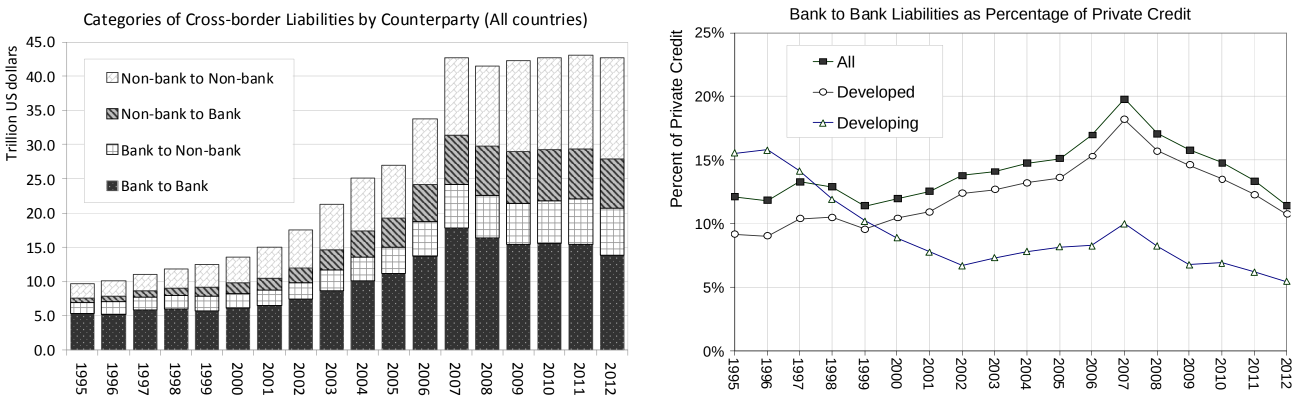

Figure 1: **Cross-border liabilities by type of counterparty.** Left panel shows cross-border debt liabilities by pairwise classification of borrower and lender. "Bank to bank" refers to cross-border claims of banks on other banks (BIS banking statistics table 7A minus 7B). "Bank to non-bank" refers to cross-border claims of banks on non-banks (BIS table 7B). Claims of non-banks are from BIS international debt security statistics, tables 11A and 11B). The right panel shows cross-border bank-to-bank debt liabilities as percentage of total private credit in recipient economy. GDP and private credit data are from the World Bank.

found that a contractionary shock to US monetary policy leads to persistent appreciation in the US dollar both in nominal and real terms, with a maximum impact that does not occur until at least 24 months after the shock. This finding has been dubbed the *delayed overshooting puzzle* due to its apparent contradiction with the instantaneous appreciation implied by uncovered interest parity (UIP).

Our contribution is to show that the findings of Bekaert et al. (2013) and Eichenbaum and Evans (1995) may be seen as two sides of the same coin. We highlight banking sector leverage as the linchpin that connects these two sets of results. By tying together these two sets of findings under a common framework, we thereby shed light on the links between the domestic and international dimensions of monetary policy transmission.

The investigation is guided by the model of cross-border banking developed in our earlier paper on global liquidity (Bruno and Shin (2014)), where we incorporate known institutional features of cross-border banking to construct a "double-decker" model of global banks. In this setting, regional banks borrow in US dollars from global banks in order to lend to local corporate borrowers. Thus, bank-to-bank credit plays a key role in propagating capital flows. The regional banks could either be the regional branches or subsidiaries of the global banks or locally owned banks. In turn, the global banks finance cross-border lending to regional banks by tapping US dollar money market funds in financial centers.

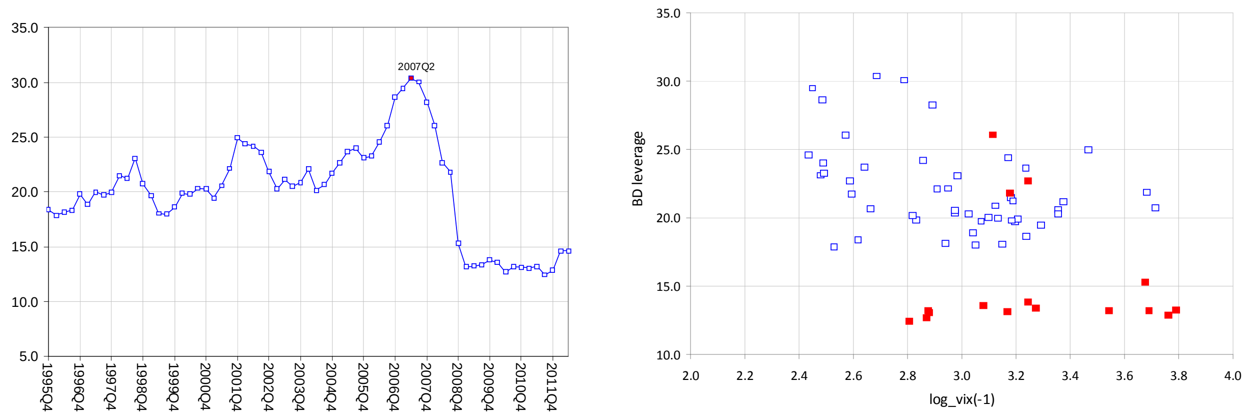

Figure 2: The left panel plots the leverage of the US broker dealer sector from the Federal Reserve's Flow of Funds series (1995Q4 - 2012Q2). Leverage is defined as (equity + total liabilities)/equity. The right panel plots the scatter chart of US broker dealer leverage against the log VIX index lagged one quarter. The dark shaded squares are the post-crisis observations after 2007Q4 (Source: Federal Reserve and CBOE)

In our model, when the US dollar interest rate falls, the spread between the local lending rate and the US dollar funding rate increases. Such lower dollar funding costs have spillover effects on global financial conditions because it leads to greater cross-border liabilities and consequently more permissive credit conditions in recipient economies.

Figure 1 shows evidence of the acceleration of bank capital flows through the bank leverage channel. The left panel of Figure 1 plots cross-border debt liabilities classified by type of counterparty. We see that cross-border liabilities where both the creditor and debtor are banks grew rapidly in the years before the 2008 crisis. The amounts involved were economically significant before the crisis. The right hand panel of Figure 1 shows cross-border bank-to-bank liabilities as a proportion of all private credit. At the peak in 2007, bank-to-bank cross-border liabilities accounted for 20% of total private credit.

In this paper, we conduct VAR exercises to shed light on the domestic and international transmission channels of monetary policy through the bank-to-bank lending explained in Bruno and Shin (2014) and illustrated in Figure 1. We show two sets of results that trace the interactions of the domestic and international channels of monetary policy transmission.

In the domestic dimension, we find that a decline in US dollar bank funding costs results in an increase in bank leverage. At the same time, we show that banking sector leverage is closely tied to risk measures, such as the VIX index as also illustrated in Figure 2. The left hand panel of Figure 2 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 2 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 2007 associated with the crisis and its aftermath. The scatter chart adds weight to theories of bank leverage based on measured risk, such as Value-at-Risk presented in Adrian and Shin (2010, 2014). The close relationship between leverage and the VIX Index also provides a point of contact between Gourinchas and Obstfeld (2012) who point to the importance of leverage and Forbes and Warnock (2012) who have highlighted the explanatory power of the VIX index for gross capital flows.

In the international dimension, we find evidence of monetary policy spillovers in cross-border capital flows through the banking sector. We find that an expansionary shock to US monetary policy increases cross-border banking capital through higher leverage of international banks. Such an increase in cross-border flows is associated with a depreciation of the US dollar over a prolonged period of time. Consistent with the earlier findings in Eichenbaum and Evans (1995), we find that a decline in the Fed Funds rate leads to a depreciation in the U.S. dollar after about 14 quarters, while an increase in leverage is followed by a depreciation of the US dollar from 3 quarters but which persists for 20 quarters or more.

Taken together, the key contribution of our results is to show that banking sector leverage is a candidate channel for the transmission of monetary policy to exchange rate changes. Given the close relationship between leverage and measured risks, our findings bridge the domestic channel of monetary policy studied by Bekaert et al. (2013) and the international channel of monetary policy in Eichenbaum and Evans (1995).

Further corroboration on the importance and relevance of the banking channel in monetary transmission comes from the strength of the empirical results during our sample period (1995 - 2007) chosen to coincide with the era of global banking expansion. When we examine the same VAR exercises for the sample period 1986 to 1995 that excludes the period of rapid banking sector growth, we find that the key impulse response relationships that drive our main conclusions no longer hold. This difference in findings across the two periods provides further evidence in support of the bank-to-bank transmission mechanism during the period running up to the 2008 crisis.

Our VAR exercises complement micro studies of the risk-taking channel, showing how credit standards are influenced by the central bank policy rate. For instance, Jiménez, Ongena, Peydró and Saurina (2012) using data from Europe find that a low policy rate induces thinly capitalized banks to grant more loans to ex ante riskier firms. Maddaloni and Peydró (2011) find that low rates erode lending standards for both firms and households. Using US survey data, Dell'Ariccia, Laeven and Suarez (2013) find that low interest rates are associated with riskier lending according to the internal ratings used by the banks themselves. Compared to these micro studies on lending standards, our complementary approach provides a backdrop to the individual loan decisions by showing how risk-taking overall is affected by monetary policy.

Our VAR exercise also complements the study of investor portfolio flows in Froot and Ramadori (2005), who use VAR methods to decompose the transitory price impact of flows from the permanent component of price impact in an asset pricing model. In contrast, our risk-taking channel is not well suited for asset pricing exercises. In addition, the risk-taking channel stands in contrast to models of monetary economics that have traditionally been used at central banks, which tend to downplay the importance of short-term interest rates as price variables in their own right. 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 findings in this paper 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 hope that policy debates on the global spillover effects of monetary policy may gain a firmer footing. The BIS report on global liquidity (BIS (2011)) 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 this report.

2. Evidence from VARs

2.1. Data

Our empirical investigation consists of recursive vector autoregressions (VAR) examining the dynamic relationship between the CBOE VIX index of implied volatility on the S&P index options, the real Feds Funds target rate of the US Federal Reserve, and a proxy for the leverage of global banks. The real Fed Funds target rate is computed for the end of the quarter as the target Fed Funds rate minus the CPI inflation rate.

We use the leverage of the US broker dealer sector from the US Flow of Funds series published by the Federal Reserve as our empirical proxy for global bank leverage.[1] Since we are ultimately interested in investigating spillover effects on cross-border bank-lending, our empirical counterpart for global bank leverage should ideally be measured as the leverage of the broker dealer subsidiaries of the global banks that facilitate cross-border lending. Shin (2012) shows that the European global banks were central in banking sector capital flows in the years before the crisis of 2008. However, the reported balance sheet data for European banks are the consolidated numbers for the holding company 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, 2014), broker dealers and commercial banks will differ in important ways in balance sheet management. 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.

In the VAR model, we also include the US dollar exchange rate (in log differences) as a prelude to our more detailed examination of the international dimension of the risk-taking channel and cross-border effects. The US dollar exchange rate is measured by the Real Effective Exchange Rate (REER) of 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.

We use quarterly data from the fourth quarter of 1995 to the last quarter of 2007 in order to examine the workings of the risk-taking channel on the up-swing of the global liquidity cycle. The fourth quarter of 2007 marks the beginning of the financial crisis, and our empirical results turn out to be sensitive to the zero lower bound on the policy rate after the crisis, as we explain below.

Our chosen sample period coincides with the period when banking sector growth was strong in the run-up to the 2008 crisis, and conforms most closely to the model of Bruno and Shin (2014) where the transmission of financial conditions occurs through the fluctuations in lending across the global banking system.

[1] Leverage is obtained from (1) "total liabilities" (FL664190005.Q) and (2) "total liabilities and equity" (FL664194005.Q) of the US broker dealer sector from the Flow of Funds. Leverage is defined as $2/(2-1)$.

2.2. Set-up

The selection of the number of variables carefully considers 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 the interaction between measured risks and banking sector leverage. Our interest is focused especially on the way that monetary policy interacts with measured risks and the risk-taking behavior of banks. By including both the VIX index and the broker-dealer leverage variable, we aim to capture the core mechanisms that involve financial intermediaries.

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

$$A(L)y_t = \varepsilon_t \tag{1}$$

where $A(L)$ is a matrix of polynomial in the lag operator L, and ε_t is a vector of orthogonalized disturbances. 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:

$$A = \begin{bmatrix} a_{11} & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \tag{2}$$

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 fast moving variables like REER and the VIX Index, which adjust instantaneously to news.[2] The Fed Funds target rate reflects the periodic decision making process at the Federal Reserve and the slowly evolving implementation of monetary policy. The order of our VAR model is also consistent with the mechanism in Bruno and Shin (2014), where a decrease in the cost of borrowing or other risk measures is reflected in banks' balance sheet management. Specifically, the adjustment of broker dealer (book) leverage will reflect the speed of the balance adjustment of market-based intermediaries and so we may see them as being of intermediate sluggishness.

Formal lag selection procedures (Hannan and Quinn information criterion (HQIC) and the Bayesian information criterion (BIC)) suggest one lag. However, the Lagrange multiplier test for autocorrelation in the residuals of the VAR shows that a 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. We display bootstrapped bias-corrected confidence intervals based on 1000 replications and make a small-sample degree-of-freedom adjustment when estimating the error variance-covariance matrix.

2.3. Evidence from Impulse Response Functions

Figures 3 presents the impulse response functions from our 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 3 is organized so that the rows of the matrix indicate 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 graphs the impulse responses over 20 quarters to a one-standard-deviation variable shock identified in the first column.

Figure 4 groups the key panels for the narrative. Consider 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 leverage of the US broker dealer sector. We see from the right panel of Figure 4 that a positive Fed Funds target rate shock leads to a decline in leverage after a fairly long lag of around 10 quarters and remains significant until quarter 17. The impact

[2]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.

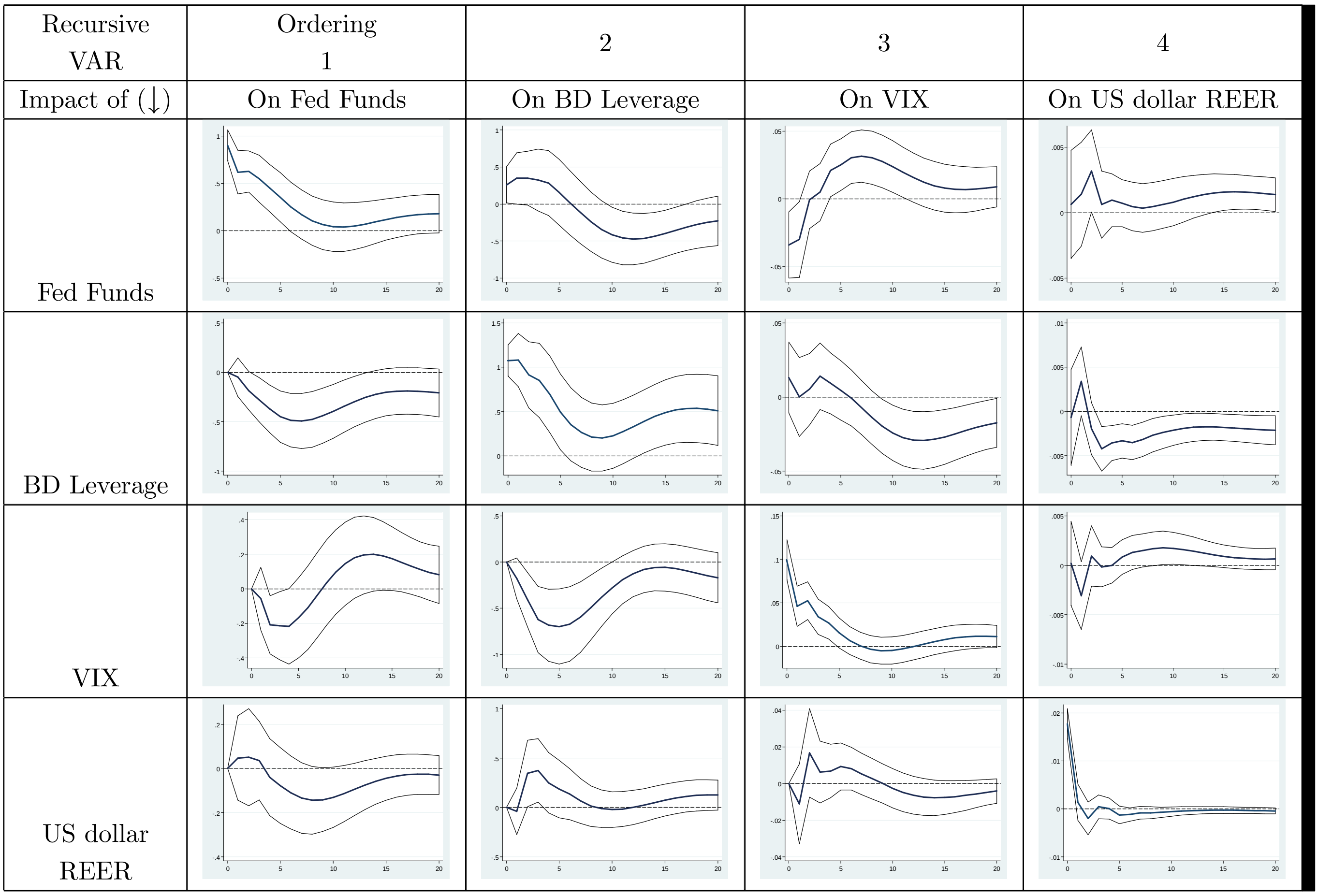

Figure 3: **Impulse response functions in recursive VAR.** This figure presents estimated impulse-response functions for the four variable recursive VAR (Fed Funds, BD leverage, VIX and REER) and 90 percent bootstrapped confidence intervals for the model with two lags, based on 1000 replications.

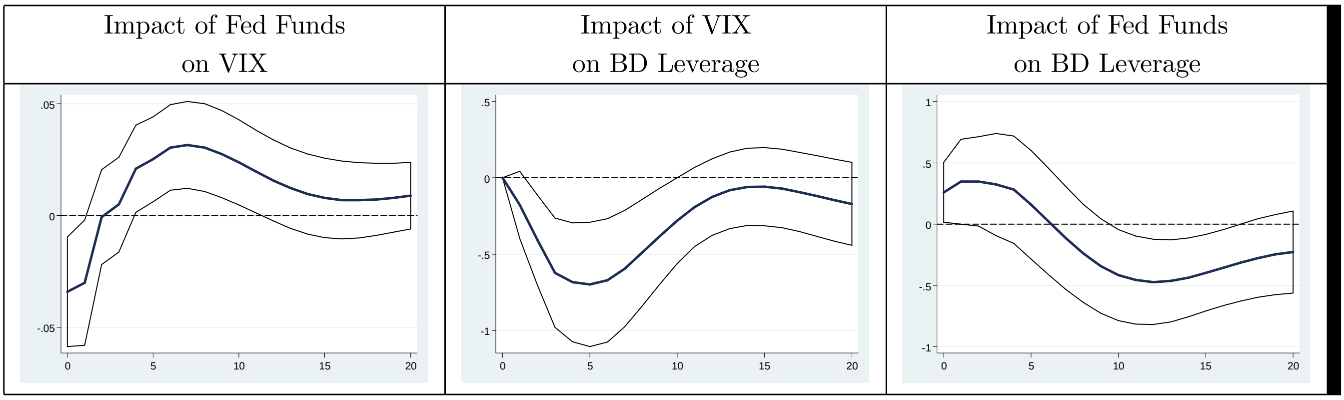

Figure 4: **Impulse response functions in recursive VAR.** This figure presents three panels from the impulse response functions of the four variable VAR (Fed Funds, BD leverage, VIX and REER) illustrating the impact of a Fed Funds target rate shock on the leverage of the US broker dealer sector. A positive Fed Funds target rate shock leads to a decline in broker dealer leverage, via the fall in the VIX index. The panels show 90 percent bootstrapped confidence intervals for the model with two lags, based on 1000 replications.

reaches a maximum response of -0.47 at quarter 12. When measured against the sample average of 21.94 for leverage, a one standard deviation shock to the Fed Funds rate entails a decline in leverage to around 21.5.

The other panels reveal related aspects of the mechanism. The left panel of Figure 4 shows that tighter monetary policy raises the VIX Index from quarter 4, which corroborates the finding in Bekaert et al. (2013) who find a similar effect on the VIX Index starting between months 9 and 11.

Our distinctive finding is the middle panel in Figure 4, which shows that an increase in the VIX index lowers bank leverage. This panel provides indirect support for the proposition that the banking sector's balance sheet management is driven by risk measures such as Value-at-Risk, as argued by Adrian and Shin (2010, 2014). Thus, the conjunction of the first two panels tells the story underlying the final panel - of how an increase in the US dollar bank funding costs results in a decline in bank leverage.

Finally, in anticipation of our examination of the international dimension to the risk-taking channel, we see from Figure 3 that a positive Fed Funds target rate shock leads to an appreciation of the US dollar after a fairly long lag. This result is consistent with the "delayed overshooting puzzle" found in Eichenbaum and Evans (1995) who find that a contractionary shock to US monetary policy leads to persistent appreciation in nominal and real US dollar exchange rates, with an impact that does not occur contemporaneously but which comes between 24 and 39 months after the initial shock depending on the currency pair considered. We will return to this aspect in Section 3.

Our sample period stops in 2007 due to the crisis, a structural break. 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 Liu, Waggoner and Zha (2011) and 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. Bekaert et al (2013) also find a similar structural break, suggesting that shifts in the autoregressive slope parameters may also have offsetting effects on the impulse response functions. For this reason, the results reported in this paper should be seen as applying mainly for the boom period preceding the onset of the crisis.

By using the VXO index, which is a precursor of the VIX index, it is possible to extend the sample back to 1986. The VARs using this earlier sample show much smaller impact of banking sector leverage, and the impulse responses are not statistically significant. In the context of banking sector developments at the relevant time, we interpret our findings as confirmation that the bank-to-bank transmission mechanism was operating strongly only during the period running up to the 2008 crisis. The earlier sample period of 1986 - 1995 does not show a similarly active role for the global banking system in the cross-border transmission of monetary policy. Results are reported in Figure A.1 of the online Appendix.

Overall, our initial evidence shows that during the 1995 - 2007 period, the risk-taking channel of monetary policy was operating strongly in a domestic context whereby permissive monetary policy is followed by a period of lower measured risks and expanded bank lending risk-capacity. In the next section, we will investigate the international dimension of the spillover effects of US monetary policy and how such a lower dollar funding cost results in higher cross-border bank flows through the internal capital markets of global banks.

2.3.1. Variance Decompositions

We have seen that monetary policy has a medium-run (two to three years) impact on broker leverage and VIX, and that broker dealer leverage has a statistically significant effect on the US dollar exchange rate. The effects are not only statistically significant, but also economically significant. Figure 5 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 Index and between 10% and 20% of the variance of BD leverage at horizons longer than 10 quarters. In contrast, 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 Funds 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 points to the importance of the leverage cycle of the global banks as being a key determinant of the transmission of monetary policy shocks.

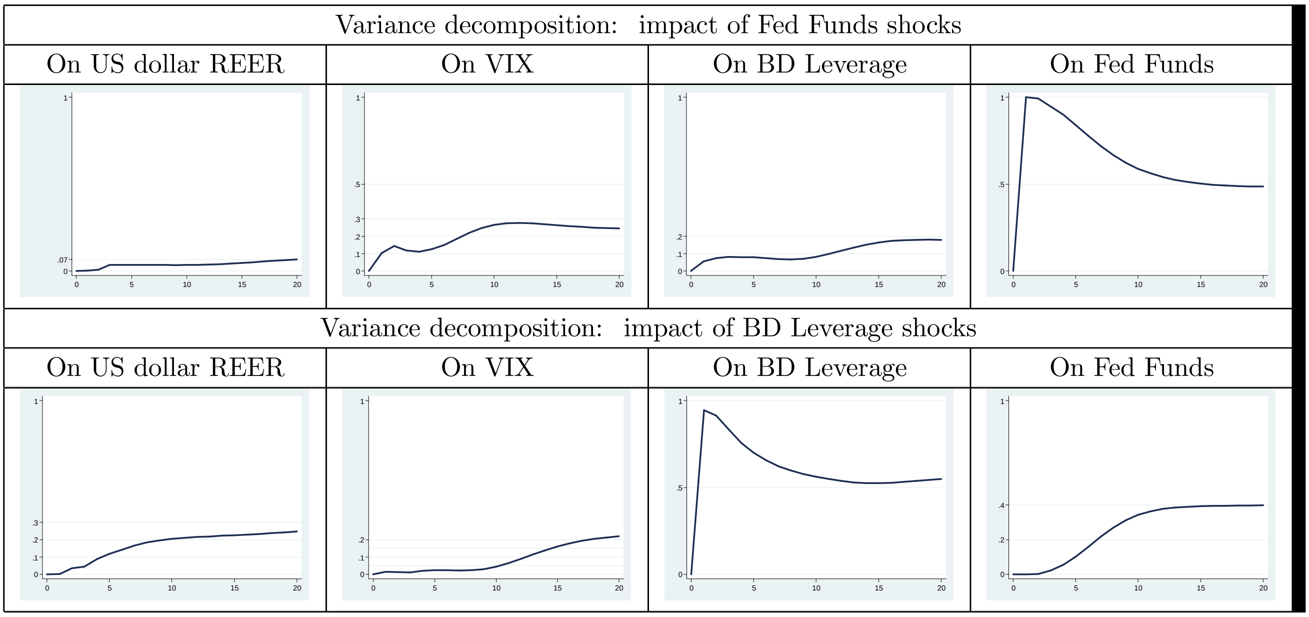

Figure 5: **Variance Decomposition.** This figure presents variance decompositions from the four variable VAR giving the fractions of the structural variance due to Fed Fund or Leverage shocks for the four variables REER, VIX, BD Leverage and Fed Fund (model with 2 lags).

2.3.2. Alternative Measures of Monetary Policy Shocks

Figure 6 shows the impulse-response functions for alternative measures of monetary policy 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, M1 growth and nominal effective Fed Funds rate.

The first alternative measure of monetary policy stance is the difference between the nominal Fed Funds target rate and the Fed Funds rate implied by a backward looking Taylor rule. The Taylor rule rate we use assumes the natural real Fed funds 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 6, we see that our qualitative conclusions when 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 relation 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.

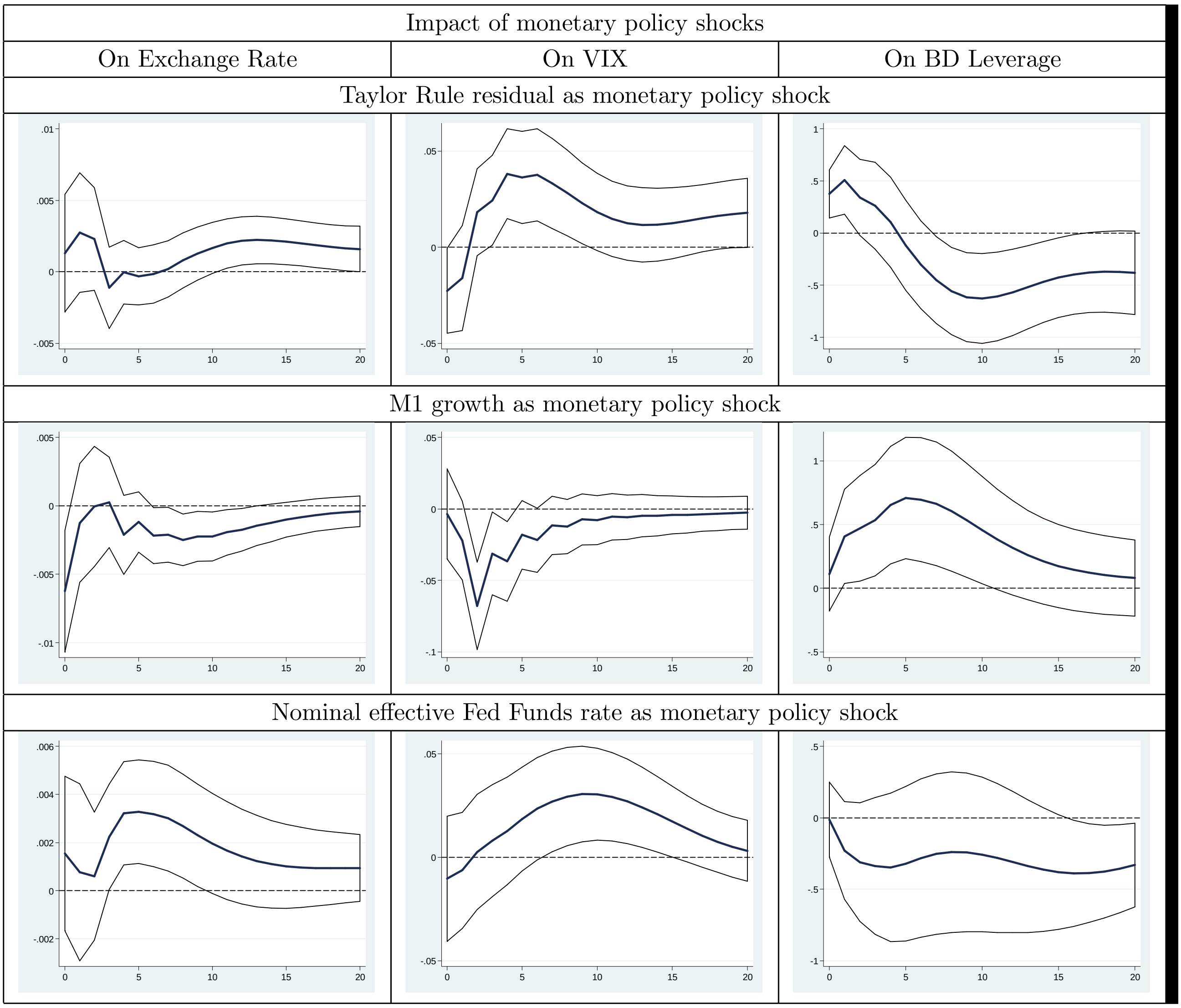

Figure 6: **Alternative definitions of monetary policy shocks.** This figure shows the impulse-response functions and 90 percent confidence bands for alternative monetary policy shocks on REER, VIX and BD-leverage in the four-variable model with two lags and 1000 bootstrapped standard errors. Monetary policy shocks considered are residuals from a Taylor rule, M1 growth and nominal effective Fed Funds rate.

We consider two further alternative measure of monetary policy shocks, shown in the second and third rows of Figure 6. One alternative measure is the growth rate of the US M1 money stock, where a positive shock to M1 corresponds 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 of 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.

Our third measure of monetary policy shock is the nominal 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 robust to this variation. 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.

2.3.3. Additional Robustness Checks

We conduct a series of robustness exercises for our VARs, which are reported in the separate online appendix of the paper. The sensitivity of the recursive VAR to alternative orderings of the variables is a perennial theme in VAR analysis. The selection and ordering of the variables in our VAR follows the bank-to-bank mechanism outlined in Bruno and Shin (2014). Furthermore, the different degrees of inertia inherent in our selected variables give some basis for the specification of our VAR analysis (see Kilian (2011) for discussion of this point). In the separate appendix to our paper, we conduct various robustness exercises. In Figure A.2 of the appendix, we examine the alternative ordering: (1) Fed Funds target rate (2) broker dealer leverage (3) REER and (4) VIX, where the two price variables REER and VIX are switched. Our key findings on the risk-taking channel remain unchanged to such a change.

Figure A.3 in the appendix also reports the impulse responses for the VAR when the Fed Funds rate is ordered last to investigate within-quarter policy responses of the Fed Funds rate to VIX or bank leverage.[3] In the VAR with the ordering: (1) broker dealer leverage

[3] We thank Chris Sims for suggesting this alternative ordering for our robustness tests.

(2) VIX (3) REER and (4) Fed Funds target rate, our key results on the risk-taking channel are again qualitatively unchanged.

Our results remain unchanged if we use the *nominal* effective exchange rate (NEER) instead of the real effective exchange rate (REER), as shown in Figure A.4 in the appendix.

We also examine one specification that includes the growth of US industrial production in the VAR to examine the impact of macroeconomic conditions as a backdrop to monetary policy. Our results reported in Figure A.5 in the appendix indicate that including industrial production does not alter the main conclusions on the mechanism of the risk-taking channel through the leverage of the broker dealer sector.

3. International Dimension

3.1. Another look at the evidence

We turn our attention to the international dimension of the transmission mechanism of monetary policy. Taylor (2013) argued that the potential for monetary policy spillovers operating through divergent policy interest rates has led to an enforced coordination of interest rate policy among central banks who fear that failure to follow suit in lowering rates would undermine other macro objectives. The role of global banks that channel wholesale funding across borders is perhaps the most important channel for such transmission of financial conditions. For instance, Cetorelli and Goldberg (2012) have found that global banks respond to changes in US monetary policy by reallocating funds between the head office and its foreign offices, thus contributing to the international propagation of domestic liquidity shocks.

Figure 7 uses data from the BIS locational banking statistics to plot the foreign currency assets and liabilities of BIS-reporting banks, classified according to currency. The top plot represents the US dollar-denominated assets of BIS-reporting banks in foreign currency, and hence gives the US dollar assets of banks outside the United States. The bottom plot in Figure 7 gives the corresponding US dollar-denominated liabilities of banks outside the United States. It is clear from Figure 7 that the US dollar plays a much more prominent role in cross-border banking than does the euro, sterling or yen.

To gain some perspective on the size of the US dollar assets in Figure 7, we can plot

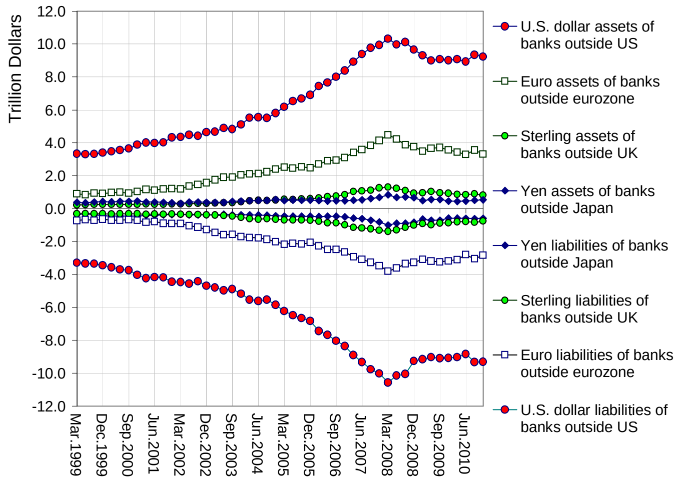

Figure 7: Foreign currency assets and liabilities of BIS reporting banks by currency (Source: BIS locational banking statistics, Table 5A)

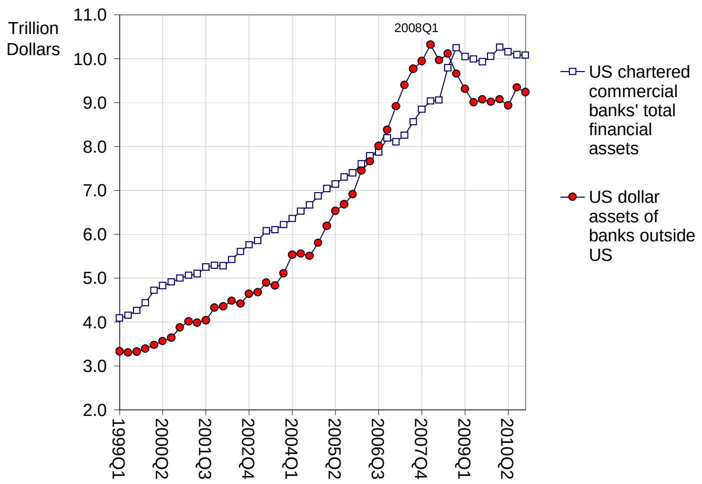

Figure 8: US dollar foreign currency claims of BIS-reporting banks and US commercial bank total assets (Source: Flow of Funds, Federal Reserve and BIS locational banking statistics, Table 5A)

the total assets series next to the aggregate commercial banking sector in the United States, which is given in Figure 8. We see that US dollar assets of banks outside the US exceeded $10 trillion in 2008Q1, briefly overtaking the US chartered commercial banking sector in terms of total assets. So, the sums are substantial. It is as if an offshore banking sector of comparable size to the US commercial banking sector is intermediating US dollar claims and obligations. Shin (2012) shows that the European global banks account for a large fraction of the US dollar intermediation activity that takes place outside the United States.[4]

As we have seen already in Figure 1, capital flows through the international banking system was a very substantial proportion of total cross-border debt flows. Such banking flows have also played a major role in the expansion of domestic lending. At the peak in 2007, for instance, bank-to-bank cross-border liabilities accounted for 20% of total private credit and for over 30% of the percentage of global GDP. The large weight of the banking sector prior to 2008 lends weight to the bank-to-bank mechanism in Bruno and Shin (2014). Rey (2013) also documents the rapid increase in credit flows relative to FDI and portfolio equity flows.

3.2. Structural VAR Analysis of Cross-Border Banking Flows

We now turn out attention to the cross-border dimension. In order to address the international dimension of monetary policy spillovers, we augment our list of VAR variables by adding a measure of cross-border banking sector flows into our existing VAR analysis that is consistent with the model in Bruno and Shin (2014). In particular, we focus on the cross-border lending by banks to other banks, as given by the BIS banking statistics.

The choice of our capital flow variable conforms to the mechanism in Bruno and Shin (2014) which builds on the institutional features underpinning the international banking system. In particular, global and local banks operate in a "double-decker" model of banking where regional banks borrow in US dollars from global banks in order to lend to local corporate borrowers. In turn, the global banks finance cross-border lending to regional banks by tapping US dollar money market funds in financial centers.

[4]A BIS (2010) study describes how the branches and subsidiaries of foreign banks in the United States borrow from money market funds and then channel the funds to their headquarters. See also Baba, McCauley and Ramaswamy (2009), McGuire and von Peter (2009), IMF (2011) and Shin (2012), who note that in the run-up to the crisis, roughly 50% of the assets of U.S. prime money market funds were obligations of European banks.

In this setting, when the US dollar risk-free rate interest rate falls, the spread between the local lending rate and the U.S. dollar funding rate increases. The resulting lower dollar funding costs leads to an acceleration of bank capital flows and more permissive credit conditions in recipient economies. An implication of the model is that the loosening of US monetary policy will result in greater cross-border liabilities, with spillover effects on global financial conditions through the bank leverage channel.

We measure international banking flows as the growth (log difference) in cross-border loans of BIS-reporting banks on banking sector counterparties, as measured by the difference between Table 7A (all borrowers) and Table 7B (non-bank borrowers) from the BIS Locational Bank Statistics. Global banks account for most of the international exposures. Since European banks have a pivotal role in the transmission of global liquidity (see Shin (2012)) and the US dollar is the currency underpinning the global banking system, this variable is a good proxy for banking claims of global banks that use US dollar wholesale funding. This measure fits our objective to capture the activities of the internationally active banks that were instrumental in channeling dollar funding globally.

We use the following Cholesky ordering: (1) Fed Funds target rate (2) broker dealer leverage (3) BIS banking flows (4) VIX and (5) US dollar REER. Capital flows reflect the speed of balance adjustment of the intermediaries so we order them between the Fed Funds rate and the market variables, but after the broker dealer leverage. Figure 9 presents the impulse responses together with bootstrapped bias-corrected 90% confidence bands for the model with two lags. As before, Figure 9 is organized so that the rows of the matrix indicate 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.

Figure 9 reveals how capital flows through the banking sector are an important element of the narrative of the risk-taking channel. Figure 10 gathers six of the panels for a more succinct summary of the relationships. The top two left panels of Figure 10 show the impact of lower cost of borrowing (Fed Funds rate) and Value-at-Risk measures (VIX) on banking sector leverage, as already documented in Figure 3. The other panels in Figure 10 show the mechanism of how the risk taking channel of monetary policy impact capital flows and the US dollar exchange rate through the banking sector.

The top right panel in Figure 10 shows that an increase in broker dealer leverage leads

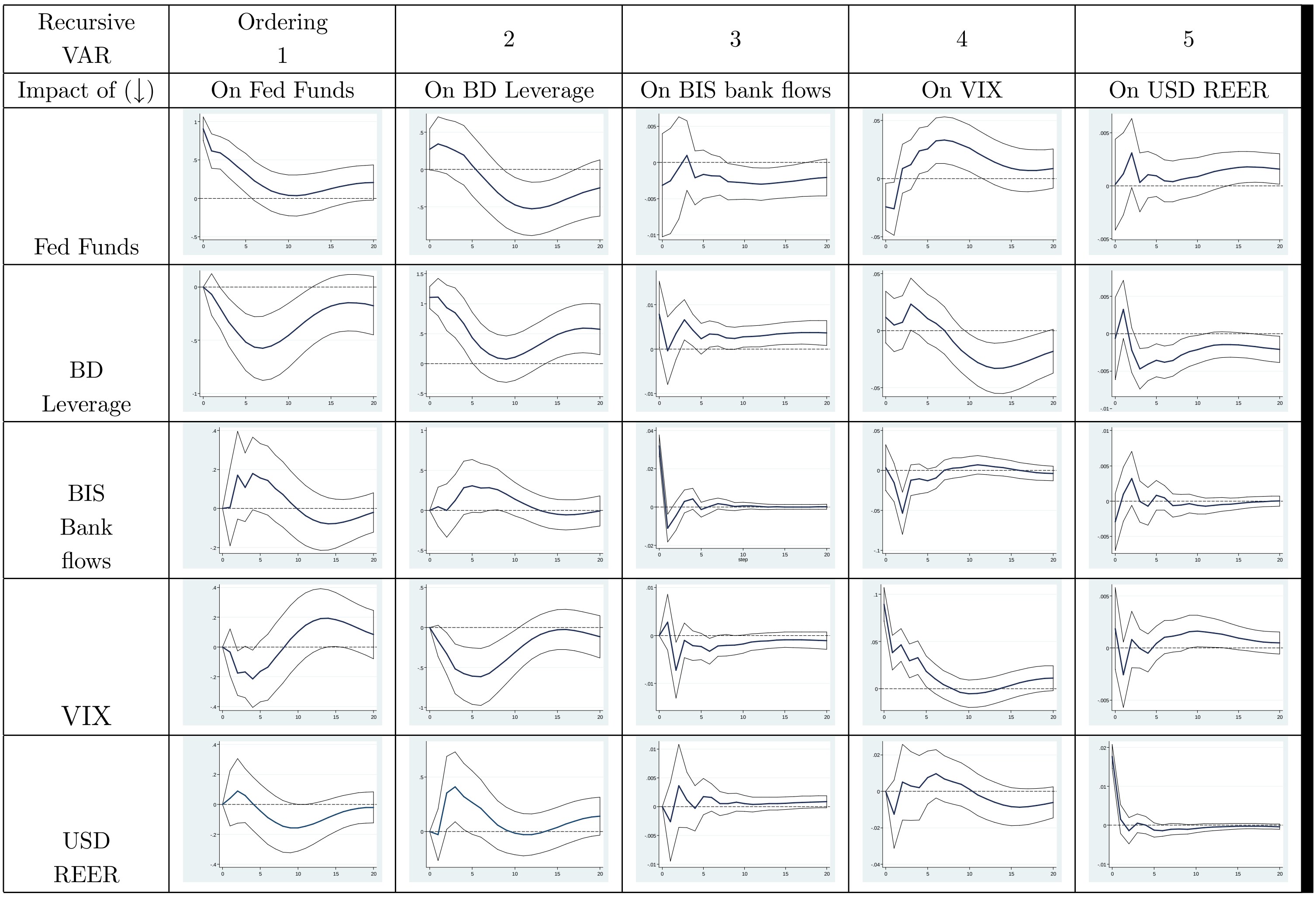

Figure 9: **Impulse response functions in recursive VAR.** This figure presents estimated impulse-response functions for the five variable structual VAR (Fed Funds, BD leverage, BIS bank flows, VIX and REER) and 90 percent bootstrapped confidence intervals for the model with two lags, based on 1000 replications.

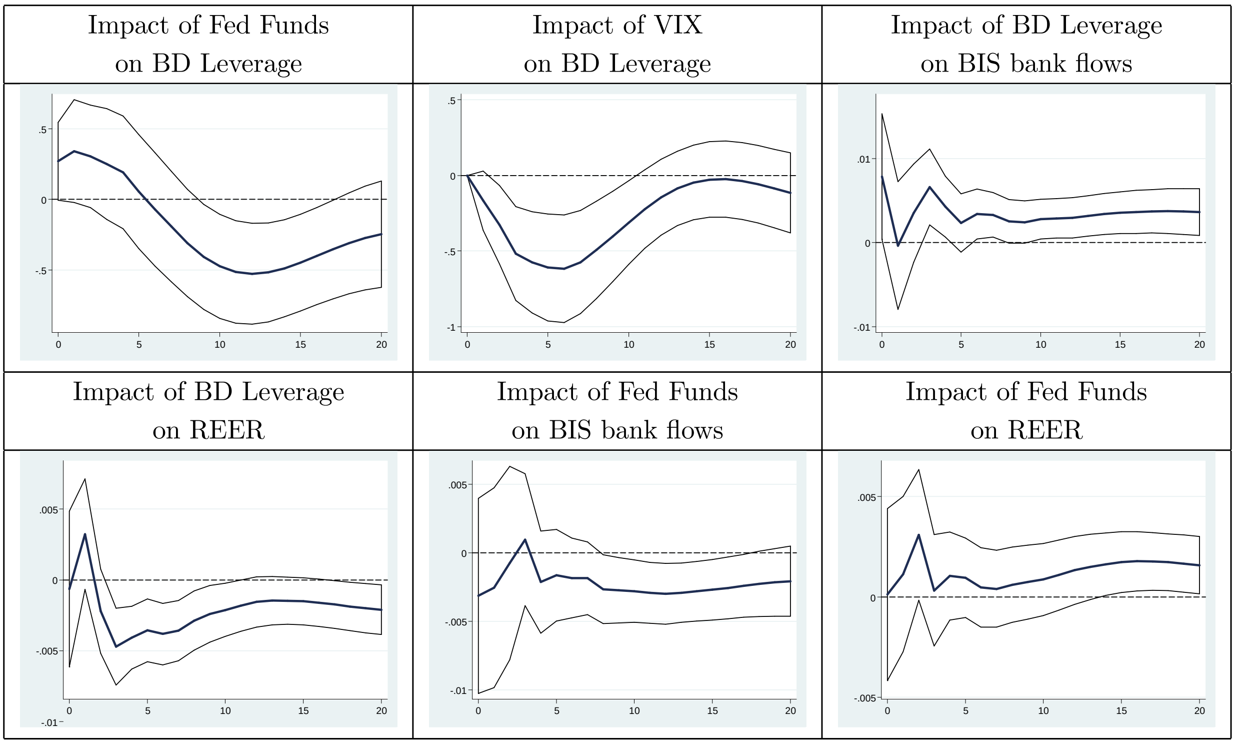

Figure 10: **Impulse response functions in recursive VAR.** This figure presents six panels from the impulse response functions of the five variable VAR (Fed Funds, BD leverage, BIS bank flows, VIX and REER) illustrating the impact of a Fed Funds target rate shock on BIS bank capital flows and REER. 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.

to an immediate marked increase in cross-border bank flows and a long term increase after 3 quarters, persisting over the entire 20 quarters. Such a vehement increase in cross-border flows is associated with US currency depreciation that starts at quarter 3 and lasts until quarter 11 and starts again after quarter 17 (bottom left panel). The last two panels together show that monetary policy eventually leaves its mark on the US dollar exchange rate and the capital flows funded by the US dollar. Figure A.6 presented in the appendix confirms the our results are robust to an alternative ordering of the variables.

Overall, the empirical regularities uncovered in our VAR results show the risk-taking channel of monetary policy and its impact on financial and real variables through bank leverage. Bank leverage is thus the linchpin that translates lower measures of risk (lower cost of borrowing and Value-at-Risk) into greater cross-border banking flows and local currency appreciation. Such empirical features corroborate the finding in Eichenbaum and Evans (1995) that the US dollar tends to depreciate over a protracted period when the US dollar funding cost declines. Our complementary evidence shows that the impact of monetary policy works through the bank leverage channel.

Our results are also consistent with the findings in Gourinchas and Obstfeld, who conduct an empirical study using data from 1973 to 2010 and 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. Shularick and Taylor (2012) similarly highlight the role of leverage in financial vulnerability, especially that associated with the banking sector.

4. Concluding Remarks

The main contribution of our paper relative to earlier studies has been to highlight the role of the banking sector in the cross-border transmission of monetary policy. Our findings underline the role of banks as intermediaries whose financing costs are closely tied to the policy rate chosen by the central bank. If funding costs affect decisions on how much exposures to take on, monetary policy will then affect the economy through greater risk-taking by the banking sector. Given the pre-eminent role of the U.S. dollar as the currency that underpins the global banking system, our findings suggest that the impact of the policy rate chosen by the Federal Reserve has an international dimension, as well as a domestic one.

The role played by the US dollar in the global banking system suggests that the value of the US dollar may thus be 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. In a financial system with interlocking claims and obligations, one party's obligation is another party's asset. When global banks apply more lenient conditions on local banks, the more lenient credit conditions are transmitted to the recipient economy. In this way, more permissive liquidity conditions in the sense of greater availability of credit will be transmitted across borders through the interactions of global and local banks. 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. Eickmeier, Gambacorta and Hofmann (2013) and Chen et al. (2012) are two papers in a recent literature that has attempted to elucidate the concept of "global liquidity" that was first formally studied by the official sector in the BIS study on global liquidity (BIS (2011)). Conversely, during times of crises, the deleveraging of the global banks is associated with "dollar shortages" as documented by Baba, McCauley and Ramaswamy (2009) and McGuire and von Peter (2009).

The results in our paper suggest that further research on the impact of the risk-taking channel of monetary policy may yield insights into the transmission of global liquidity conditions across borders. One key question is to what extent future episodes of cross-border financial spillovers will resemble the banking sector-led model examined in this paper. The fact that banking sector leverage has been subdued since the crisis suggests that the future channels of transmission will not be bank-driven, but instead involve alternative mechanisms - perhaps through the market for debt securities (Shin (2013)). One contribution of our paper has been to establish a benchmark for comparison during a period when banking sector activity was particularly strong, alternative channels can be gauged relative to such a benchmark.

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