ADBI Working Paper Series

DIVERGENT MONETARY POLICIES AND INTERNATIONAL DOLLAR CREDIT: EVIDENCE FROM BANK-LEVEL DATA

Dong He, Eric Wong,
Kelvin Ho, and Andrew Tsang

No. 741
May 2017

Asian Development Bank Institute

Dong He is deputy director of the Monetary and Capital Markets Department at the International Monetary Fund. Eric Wong is senior manager and Kelvin Ho is manager at the Research Department of the Hong Kong Monetary Authority. Andrew Tsang is manager at the Hong Kong Institute for Monetary Research.

Suggested citation:

He, D., E. Wong, K. Ho, and A. Tsang. 2017. Divergent Monetary Policies and International Dollar Credit: Evidence from Bank-Level Data. ADBI Working Paper 741. Tokyo: Asian Development Bank Institute. Available: https://www.adb.org/publications/divergent-monetary-policies-and-international-dollar-credit

Please contact the authors for information about this paper.

Email: dhe@imf.org; etcwong@hkma.gov.hk; kkwho@hkma.gov.hk;
ahctsang@hkma.gov.hk

Asian Development Bank Institute
Kasumigaseki Building, 8th Floor
3-2-5 Kasumigaseki, Chiyoda-ku
Tokyo 100-6008, Japan

Tel: +81-3-3593-5500
Fax: +81-3-3593-5571
URL: www.adbi.org
E-mail: info@adbi.org

Abstract

This paper uses a comprehensive and detailed bank-level data set to study how the divergence of central bank balance sheet policy in the US vis-à-vis the euro area and Japan affects the supply of international US dollar loans by global banks. Our empirical findings support the view that the contractionary effect of US monetary normalization on global dollar liquidity would be offset by an expansionary effect from a continued supply of US dollar loans by euro area and Japanese banks. The net effect, however, is crucially dependent on the stability of global foreign exchange markets and investor perceptions of the default risks of global banks. The analysis shows that US monetary policy shocks are one of the most important explanatory variables for the deviations from the covered interest rate parity (CIP) in the major foreign exchange (FX) markets. We also demonstrate a tail risk scenario of the contraction of the supply of international US dollar loans if and when the US monetary normalization coincides with a dislocation of the FX swap market and a rise of bank default risks. Our results are robust to alternative model specifications and different data sets.

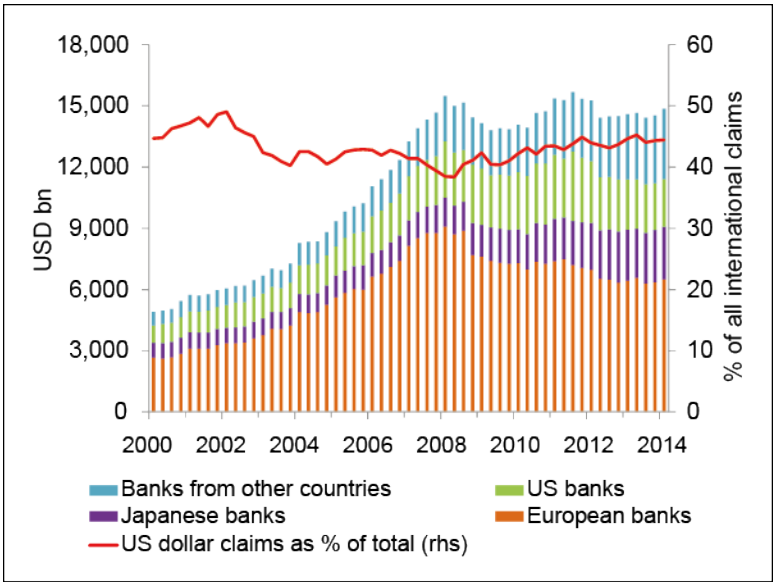
JEL Classification: E44, E52, E58, E63

Contents

1. INTRODUCTION

The US dollar is the premier currency for international trade and investment. According to statistics from the Bank for International Settlements (BIS), around half of international claims by banks were US dollar denominated at the end of 2015 (Figure 1). The supply of international dollar credit[1] is largely influenced by the behavior of non-US international banks, particularly those headquartered in Europe and Japan (McCauley, McGuire and Sushko 2015; Ivashina, Scharfstein and Stein 2015), as they provide the lion's share of international dollar credit.

Figure 1: US Dollar International Claims by Nationality of Banks



Notes:

1. The claims are vis-à-vis all sectors and include interoffice bank claims.
2. US dollar international claims include US dollar cross-border claims and local credit extended in US dollars in countries other than the US.
3. European banks include those headquartered in Belgium, France, Germany, Italy, the Netherlands, Spain, Sweden, Switzerland, and the UK.

Source: BIS locational banking statistics (by nationality).

The strong presence of European and Japanese banks in the international dollar loan market raises interesting questions about the role of their respective home central banks relative to that of the US Federal Reserve (Fed) in influencing global dollar liquidity. For example, how does a divergence of central bank balance sheet policies (BSPs) in the US vis-à-vis the euro area and Japan affect the supply of international dollar credit? Policymakers are particularly concerned about the potential disruption of global liquidity arising from the Fed's monetary normalization. Indeed, as evidenced during the 2007–08 Global Financial Crisis (GFC), a global shortage of US dollar liquidity contributed to a significant tightening of global financial conditions, hampering economic activities not only for advanced economies but also for emerging market economies where the dollar is used extensively to finance domestic economic activities. More recently, the expected tapering of the Fed's large-scale asset purchase

[1] Throughout this paper, "international dollar credit" refers to US dollar-denominated credit by banks to nonbanks outside the US.

program in 2013 also induced instability at the global level (Aizenman, Mahir and Hutchison 2014; Eichengreen and Gupta 2014; Mishra et al. 2014).

However, there is a counterargument that the Fed's monetary normalization will not necessarily lead to a significant contraction in the supply of international dollar loans if the Bank of Japan (BOJ) and the European Central Bank (ECB) continue to expand their balance sheets through asset purchase programs. At the heart of this argument is that with the ample home-currency liquidity provided by their respective central banks, Japanese and euro area banks can fund their international dollar loans continuously through foreign exchange (FX) or cross-currency swaps. In principle, this can narrow or close the US dollar liquidity gap arising from the Fed's monetary normalization.

This paper attempts to answer this important policy question by empirically investigating the net impact of the divergence of central bank BSPs on the supply of international dollar loans through the bank lending channel. Drawing on the theoretical work by Ivashina, Scharfstein and Stein (2015), we specify our empirical models to study how a global bank's supply of international dollar loans would be affected by central bank BSPs in the US and its home country, the functioning of the FX swap market, the bank's default risk, and balance sheet characteristics. Since our primary objective is to understand how these factors affect the supply of international dollar loans, we apply the fixed-effects approach advocated by Khwaja and Mian (2008)[2] to disentangle the demand-side effect. We carry out the empirical study using a unique confidential panel data set from the Hong Kong Monetary Authority (HKMA) of US dollar loans of foreign banks in Hong Kong, China. We conduct various robustness checks, including re-estimating the empirical models using an alternative confidential data set from the BIS.

Our empirical findings suggest that from a global bank's perspective, the expansion of central bank balance sheets in the US and in the home country would produce expansionary effects on its supply of international dollar loans. This finding is consistent with the evidence of monetary policy spillovers on cross-border bank capital flows through a risk-taking channel provided by Bruno and Shin (2015). The functioning of the FX swap market and bank default risk are also found to be significant determinants of the supply of international dollar loans, which is in line with the findings of Baba and Packer (2009) and McGuire and von Peter (2009) that the impairment of the FX swap market and heightened default risk of global banks contributed to a prolonged global US dollar shortage during the GFC. Finally, we find that global banks' risk-taking attitude, credit risk exposure, and the business model of their overseas branches matter for how central banks' BSPs are transmitted internationally. This finding echoes the conclusion of Brunnermeier et al. (2012) that the financial and organizational structure of global banks plays a vital role in transmitting imbalances of cross-border funding flows.

On the net impact of divergent central bank BSPs on the supply of international dollar loans, we find that the expansionary effect of continued asset purchases by the ECB and BOJ would offset the contractionary effect of US monetary normalization. The net effect, however, is crucially dependent on whether normalization of monetary policy in the US coincides with risk aversion by global investors and serious dislocation of the foreign exchange markets. Specifically, our tail risk analysis shows that the supply of

[2] This approach identifies the supply effect using a special data set that contains loan data on multiple-bank firms. By using firm-specific fixed effects to control for the change in loans of a firm from the pre- and post-event periods of liquidity shocks, any differences in loans provided to the same firm by different banks are attributable to the supply effect. See recent studies by Cetorelli and Goldberg (2011) and Aiyar et al. (2014).

international US dollar credit could decline sharply if FX swap market dislocation leads to a sharp spike in the deviation from CIP conditions and the perceived banks' default risks increase significantly. Indeed, estimates for the sample period show that US monetary policy shocks were one of the most important explanatory variables for the deviations from the CIP conditions in the markets that trade yen and euro against the US dollar.

This paper contributes to the literature on the international transmission of financial shocks through the bank lending channel. Early studies include Peek and Rosengren (2000), who examine the effect of the bursting of the asset bubble in Japan in the early 1990s on the loan supply of Japanese banks in the US commercial real estate market. Chava and Purnanandam (2011) and Schnabl (2012) examine the effect of the 1998 Russian crisis on the supply of bank loans in the US and Peru, respectively. More recent studies focus on the transmission of funding stress during the GFC through the balance sheets of global banks (Cornett et al. 2011; Cetorelli and Goldberg 2011, 2012a, and 2012b; Buch and Goldberg 2015; Ivashina, Scharfstein and Stein 2015). A few recent studies examine how unconventional monetary policies (UMPs) are transmitted through the bank lending channel. However, they mainly focus on the impact on the domestic economy (Bowman et al. 2011; Joyce and Spaltro 2014). Cross-border transmission of UMPs through the banking channel remains an underexplored research topic (McCauley, McGuire and Sushko 2015).[3]

The rest of the paper is organized as follows. We first specify one channel through which central bank BSPs affect the supply of international dollar loans of global banks in Section 2 to support our regression specifications. Section 3 specifies the empirical models and describes the HKMA data set. Section 4 presents the empirical findings, while Section 5 conducts robustness checks. Section 6 concludes.

2. THEORETICAL DISCUSSIONS

This section discusses the transmission of central bank BSPs to global banks' supply of international dollar loans. Starting with a similar theoretical framework by Ivashina, Scharfstein and Stein (2015), we take the position of a global bank that provides home-country currency loans (L) in the local market and US dollar loans (L^*) in the international market, with decreasing marginal returns for both L and L^*. The bank has an initial amount of costless home-currency funding denoted by D and dollar funding denoted by D^*. The bank can raise additional home-currency and dollar funding in the respective markets by any amount denoted by F and F^*, respectively, but incurring increasing marginal costs. The bank cannot take any FX risk. So, for any level of L^* exceeding D^*, the bank needs to acquire dollar funding in the US (i.e. F^*) or convert its home-currency funding into US dollars in the FX swap market by paying a swap cost (w). We denote the amount of swap funding by S. Following Ivashina, Scharfstein and Stein (2015), it is assumed that the bank has a default probability p and that it cannot pay off all its debt if it defaults. We further assume that only home-currency funding is insured. As a result, fund providers in the US will demand a risk premium equivalent to p to compensate the bank's default risk.

[3] See also He and McCauley (2013). There is another stand of literature focusing on the impact of UMPs on financial markets. D'Amico and King (2013) study the stock and flow effects of the Fed's 2009 asset purchase program on the yield curve. Chen et al. (2012 and 2016) find that expansionary central bank balance sheet policies affect a broad range of asset prices in emerging markets. Fratzscher, Duca and Straub (2013) find that the Fed's UMP has a significant spillover effect on financial markets in EMEs through a portfolio balancing channel. Neely (2015) and Bauer and Neely (2014) find sizable effects of the Fed's UMP on sovereign yields in advanced economies.

Based on the above setting, we can identify one channel through which central bank BSPs affect global banks' supply of international dollar loans. Using the BOJ's quantitative and qualitative program as an example to illustrate, when the BOJ purchases Japanese government bonds from a firm that has a bank account in a Japanese bank, the proceeds of the purchase will be reflected initially in the Japanese bank's liability side as "current deposits," while its asset side also expands by the same amount in "reserves at the central bank."

From the vantage point of the Japanese bank, the BOJ's bond purchase could be taken as an exogenous positive shock on D. On the funding side, the bank will react by selecting less expensive home-currency funding by substituting some costly home-currency funding F with D, leading to a lower marginal cost of F. On the asset side, the lower marginal cost of F induces the bank to increase its home-currency loans (L) until the marginal return of L equates to the marginal cost of F (which is lower now). Since F can alternatively finance dollar loans through the FX swap market, the lower marginal cost of F also implies that the bank increases its L^* in equilibrium. Finally, the lower marginal cost of F leads the bank to substitute part of F^* with S to finance L^*. By the same logic, an expansion of the Fed's balance sheet (i.e. a positive shock on D^*) can be shown to produce an expansionary effect on both L and L^*. It can also be shown that a higher w and p, which implies a higher US dollar funding cost, would reduce the supply of L^* (see Appendix 1 for details).

The above example shows that a global bank transmits central bank BSPs internationally driven by its profit-maximization decisions on cross-border loan allocations, which is consistent with the evidence of monetary policy spillovers on cross-border bank capital flows through a risk-taking channel demonstrated by Bruno and Shin (2015).

More broadly, the mechanism described above is consistent with the consensus view that monetary policy affects the supply of credit by financial intermediaries through both the funding channel and the risk-taking channel (IMF 2015, 2016). It is true that excess reserves held with the central bank are an asset item on the balance sheet of the banking system, and do not affect the liability structure of the banks directly. However, the change in excess reserves as a result of asset purchases by the central bank would lead to changes in both the term and risk premiums, thereby affecting the broader funding conditions and the risk-bearing capacity of financial intermediaries. Therefore, a monetary policy shock as measured by an exogenous change in the size of the central bank balance sheet can be interpreted as an exogenous shock to the bank's funding cost.

3. EMPIRICAL MODELS AND DATA

3.1 The Baseline Model

We follow the discussion in the previous section to specify a baseline regression model by equation (1). The model will be estimated using the confidential panel data set from the HKMA, which records quarterly flows of US dollar-denominated loans of foreign bank branches in Hong Kong, China vis-à-vis more than 70 destination countries.

$$\Delta L^*_{ijt} = \beta_1 \Delta HCB_{jt} + \beta_2 \Delta FED_t * \mathrm{USF}_j + \beta_3 \Delta CDS_{jt} + \beta_4 \Delta CIP_{jt-1} + \beta_5 \Delta GDP_{jt} + \mu_{it} + \varepsilon_{ijt} \quad (1)$$

where ΔL^*_{ijt} is the quarterly growth rate of US dollar-denominated loans to nonbank sectors in destination country *i* by the Hong Kong, China branch of a global bank *j* from *t-1* to *t*. ΔL^*_{ijt} is posited to be affected by the central bank BSP in the home country of bank *j*, which is proxied by the quarterly growth rate of the central bank's balance sheet (in US dollars) in the home country of bank *j* (ΔHCB_{jt}).

Similarly, the Fed's BSP is measured by the quarterly growth rate of the Fed's balance sheet (ΔFED_t). We further assume that the transmission of the Fed's BSP differs across global banks, with the effect being more pronounced for those banks that raise more US dollar funding in the US market.[4] To capture this intuition, we include the product term of ΔFED_t and bank *j*'s reliance on dollar funding from the US market (USF_j) in the regression equation. USF_j is defined as the ratio of total funding (excluding the amount due to interoffice and trading liabilities) raised by bank *j*'s branches in the US to the total consolidated assets of bank *j*.

The change in the default risk of bank *j* is proxied by the quarterly change in the credit default swap (*CDS*) spread of bank *j* (ΔCDS_{jt}). We measure the swap cost by the spread between the FX swap-implied dollar interest rate from the home currency of bank *j* and US dollar LIBOR, and use its quarterly change (ΔCIP_{jt-1}) in the regression model. The lagged term is used to avoid a potential endogeneity problem between ΔCIP and ΔL^*. The growth rate of nominal GDP forecast for the home country of bank *j* (ΔGDP_{jt}) is also included to control for the demand for home-currency loans.[5]

Finally and importantly, destination country-time fixed effects (μ_{it}) are included in the model to account for a change in the demand for US dollar loans in country *i*. μ_{it} is the analogue of the borrower fixed effects adopted by Khwaja and Mian (2008) to absorb changes in demand for loans by borrowers. Since the comparison is across banks for the same destination country in a given quarter *t*, destination country-specific demand shocks at *t* are fully absorbed by μ_{it}. As such, the specification is conducive to a clean identification of the supply-side effect.

3.2 Extended Models

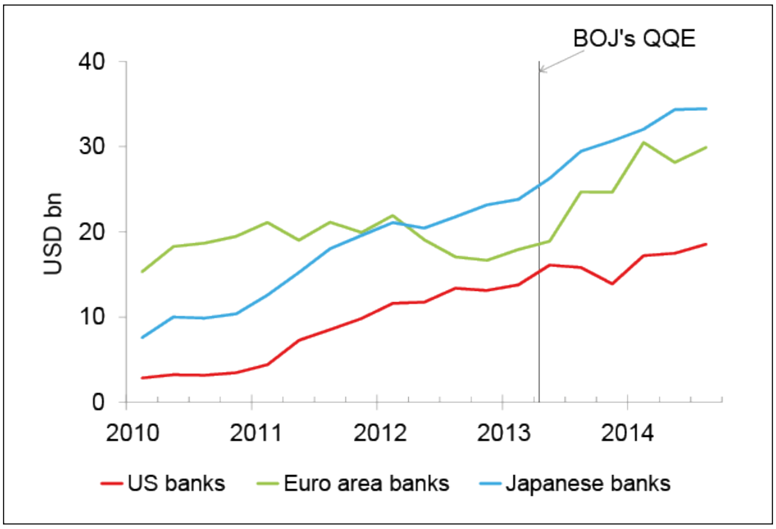
One advantage of the HKMA data set is that the granular bank-level information allows us to consider bank-specific balance sheet factors in estimations. We follow recent development in the literature (Cornett et al. 2011; Buch and Goldberg 2015) to argue that global banks' balance sheet characteristics are important factors affecting the extent of international transmission of central bank BSPs.

[4] Although it may be argued that ΔFED may be sufficient to capture the pure effect of dollar liquidity without interacting with *USF*, technicallyΔFED cannot be included in the regression equation as a single explanatory variable due to perfect multicollinearity between ΔFED and the destination country-time fixed effect, μ_{it}.

[5] We use the GDP forecast made at time *t* instead of the actual GDP at *t* to capture the demand shock for home-currency loans, as the former in theory contains all publicly known information that may influence the future state of the economy, which should be more relevant to loan demand (see Peek, Rosengren and Tootell 2003).

This hypothesis is supported by anecdotal evidence of different developments in respect of US dollar loans for the euro area and Japanese bank branches in Hong Kong, China (Figure 2). In particular, US dollar loans of Japanese bank branches exhibited a clear upward trend amid the expansion of the Fed's balance sheet, while those of euro area banks were much less responsive prior to 2013, which may be partly due to euro area banks' weak balance sheet conditions amid the euro sovereign-debt crisis.

Figure 2: US Dollar Loans of Foreign Bank Branches in Hong Kong, China by Selected Nationalities



Source: HKMA.

In order to understand how far cross-sectional differences in balance sheet characteristics explain the different loan responses to the Fed's BSP as observed in Figure 2, we modify the baseline model as follows:

$$\Delta L^*_{ijt} = \beta_1 \Delta HCB_{jt} + (\beta_2 + \alpha_1\ BSF_{jt})\Delta FED_t{}^*USF_j + \beta_3 \Delta CDS_{jt} + \beta_4 \Delta CIP_{jt-1} + \beta_5 \Delta GDP_{jt} + \alpha_2\ BSF_{jt} + \mu_{it} + \varepsilon_{ijt} \quad (2)$$

where *BSF* is a vector of bank-specific balance sheet factors. *BSF* is also added in equation (2) separately (i.e. $\alpha_2 BSF$) to control for the differences in bank balance sheet structures. We consider four balance sheet variables to proxy for global banks' differences in attitude towards risk taking, asset quality, funding structure, and business model.

We gauge the attitude towards risk taking by looking at the parent bank's capital adequacy ratio (CAR) before the GFC. A dummy variable for a low CAR in 2006,[6] *Dum(low CAR)*, is therefore included in the model. A highly leveraged bank (i.e. a lower CAR) before the GFC may suggest that dollar loans of the bank may increase more rapidly amid the expansion of the Fed's balance sheet. The asset quality is proxied by the ratio of impaired loans to equity (*PLR*) of the parent bank. Theoretically, a higher

[6] Defined as one for banks whose average capital adequacy ratio in 2006 was lower than the 25th percentile, and zero otherwise.

level of loan impairments (i.e. a higher *PLR*) would constrain the bank's lending capacity, leading to a lower sensitivity of ΔL^* to central bank BSPs.

We further conjecture that the funding structure and business model of Hong Kong, China branches are important determinants of the sensitivity of ΔL^* to the Fed's BSP. For the funding structure, we add a deposit-to-asset ratio of the branch (*DTA*). Theoretically, if a branch finances its loan business mainly by taking retail deposits from the host country, its sensitivity of ΔL^* is likely to be more moderate than a bank that finances its loan book by other less stable funding. We also consider a loan-to-asset ratio of the branch (*LTA*) and posit that if a branch is positioned as a lending unit, the branch's dollar loans may be more responsive to the Fed's BSP.

3.3 The HKMA Data Set

The operation of foreign bank branches in Hong Kong, China provides a natural experiment setting to study the international transmission of central bank BSP through the bank lending channel, as most global banks have branches in Hong Kong, China: 44 of the top 50 global banking organizations had branch operations in Hong Kong, China at the end of 2013. Many of these branches act as regional headquarters to provide US dollar loans to borrowers in Asia, and their loan books are generally funded by overseas offices, including their headquarters. These characteristics mean that their dollar loans might be sensitive to external funding conditions, particularly in the home country and the US.

We build the HKMA data set based primarily on the *return of external positions*, which all banks in Hong Kong, China are required to file with the HKMA. Our data set only includes foreign bank branches in Hong Kong, China and their data reflect the sole position of the Hong Kong, China branch's external loans vis-à-vis destination countries. The data set covers the period from 2007Q1 to 2014Q2.

The estimation sample consists of 37 non-US foreign bank branches in Hong Kong, China. They are selected using the following criteria. We include all non-US foreign bank branches in Hong Kong, China that belong to global systemically important banks,[7] as they are presumably important vehicles for the propagation of shocks internationally. Branches with a significant scale of operations in Hong Kong, China (that is, with an average size accounting for at least 0.5% of the total assets of all foreign branches in Hong Kong, China) are added. We exclude branches that did not operate over the full sample period. The aggregate assets of the estimation sample account for an average of 60% of the total assets of foreign bank branches in Hong Kong, China in the sample period.

Table 1 provides summary statistics for key variables for the data set. Parent-bank balance sheet variables are constructed using data from *Bankscope*,[8] while branch balance sheet variables are constructed using data from the *return of assets and liabilities* filed by foreign bank branches to the HKMA. Appendix 2 details the definition of variables.

[7] See Financial Stability Board (2013).

[8] Parent-level variables are based on consolidated data on their ultimate parents from *Bankscope*. We identify parent banks using information on the organization structure of banking groups available at *Bankscope* and regulatory information.

Table 1: Summary Statistics for Key Variables

Summary statistics of variables for model using the HKMA data set

Variable	Unit	Mean	SD	25th Percentile	Median	75th Percentile
$\Delta Loan_{ijt}$		0.109	0.442	–0.044	0.000	0.145
ΔHCB_{jt}		0.034	0.092	–0.017	0.022	0.069
ΔFED_t	decimal point	0.051	0.105	–0.005	0.033	0.071
USF_j	decimal point	0.045	0.033	0.021	0.040	0.068
ΔFED_t*USF_j		0.002	0.006	0.000	0.001	0.003
ΔCDS_{jt}	decimal point	0.000	0.004	–0.001	0.000	0.001
ΔCIP_{jt-1}	decimal point	0.000	0.004	–0.001	0.000	0.001
ΔGDP_{jt}	decimal point	0.038	0.032	0.020	0.028	0.042
Dum(low CAR)$^P{}_j$		0.247	0.431	0.000	0.000	0.000
$PLR^P{}_{jt-1}$	decimal point	0.254	0.164	0.116	0.218	0.366
$DTA^B{}_{jt-1}$	decimal point	0.295	0.148	0.174	0.282	0.405
$LTA^B{}_{jt-1}$	decimal point	0.308	0.254	0.104	0.224	0.492

Notes:

1. Sample period: 2007Q1–2014Q2.
2. Dum(low CAR) = 1 for banks with CAR at 25th percentile or below in 2006, high leverage.

4. EMPIRICAL FINDINGS

4.1 Estimation results

We start the analysis by estimating equation (1). The estimation results are presented in Model 1 in Table 2. The empirical results are broadly in line with the intuitions discussed in Section 2, although *ΔCIP* is found to be statistically insignificant. We modify the baseline model by adding an interaction term between *ΔCIP* and a crisis dummy variable,[9] *Dum(Crisis)*, and conjecture that *ΔL** is responsive to the functioning of the swap market in a crisis mode. The estimation results are consistent with this conjecture (see Model 2).

In terms of the effect of central bank BSPs, the estimation results for Model 2 suggest that central bank BSPs in the US and home country have expansionary effects on the supply of international dollar loans of global banks. This finding supports the hypothesis of international transmission of central bank BSPs through the bank lending channel. Taking Japanese banks as an example, an expansion of the BOJ's balance sheet by one standard deviation (i.e. 4.3%) would increase the supply of international dollar loans of their Hong Kong, China branches by 1.33%, while an expansion of Fed's balance sheet by one standard deviation (i.e. 10.5%, see Table 1) would increase the supply of international dollar loans of the same branches by 1.28%.[10]

[9] Defined as one for observations for 2008Q3–2009Q1 and 2010Q2–2012Q1, and zero otherwise.

[10] We arrive at the estimate based on the average *USF* for Japanese banks (=0.04) and the estimated coefficient on *FED*USF* of 3.05. An expansion of the Fed's balance sheet would increase the supply of international dollar loans of Hong Kong, China branches of Japanese banks by 0.105*0.04*3.05=1.28%.

Table 2: Estimation Result for the HKMA Data Set

Model	Model 1 Base Case	Model 2 with a Crisis Dummy for $\Delta CIP_{j,t-1}$	Model 3 with Parents' Characteristics	Model 4 Full Model
ΔHCB_{jt}	0.30**	0.31**	0.31**	0.32**
	(2.48)	(2.52)	(2.33)	(2.25)
ΔFED_t*USF_j	3.15*	3.05*	6.53***	10.40***
	(1.70)	(1.73)	(3.48)	(3.77)
ΔCDS_{jt}	–9.13**	–9.42***	–9.73**	–10.10**
	(–2.71)	(–2.85)	(–2.54)	(–2.55)
ΔCIP_{jt-1}	0.88	4.78	5.38	4.99
	(0.34)	(1.38)	(1.57)	(1.41)
$\Delta CIP_{jt-1}*Dum(Crisis)_t$		–13.42*	–13.60**	–12.75*
		(–2.02)	(–2.03)	(–1.88)
ΔGDP_{jt}	–0.31	–0.33	–0.51	–0.42
	(–0.78)	(–0.84)	(–1.25)	(–1.29)
$\Delta FED_t*USF_j*Dum(low\ CAR)^P_j$			7.07*	6.71**
			(1.99)	(2.06)
$\Delta FED_t*USF_j*PLR^P_{jt-1}$			–31.57*	–33.35**
			(–1.94)	(–2.30)
$\Delta FED_t*USF_j*DTA^B_{jt-1}$				–22.13**
				(–2.13)
$\Delta FED_t*USF_j*LTA^B_{jt-1}$				6.65
				(0.71)
Control variables				
$Dum(low\ CAR)^P_j$			–0.01	–0.01
			(–0.23)	(–0.32)
PLR^P_{jt-1}			–0.01	–0.05
			(–0.09)	(–0.58)
DTA^B_{jt-1}				0.04
				(0.78)
LTA^B_{jt-1}				–0.23***
				(–3.02)
Country-time fixed effects for destination country i				
	Yes	**Yes**	**Yes**	**Yes**
R-squared	0.2802	0.2811	0.2830	0.2881
RMSE	0.4414	0.4413	0.4477	0.4465
No. of observations	2,637	2,637	2,547	2,547

Notes:

1. Some outliers of dependent variable are dropped.
2. j = home country j.
3. Dum(low CAR) = 1 for banks with CAR at 25th percentile or below in 2006, high leverage.
4. Figures in parentheses are t-statistics.
5. Standard errors are clustered by home country and destination country.
6. ***, **, and * respectively indicate significance at the 1%, 5%, and 10% level.

For other factors, an increase in the spread between the FX-implied dollar interest rate and the US dollar LIBOR (i.e. the swap cost) of one standard deviation (i.e. 40 basis points, see Table 1) would reduce the supply of international dollar loans by around 3.47%, suggesting that the functioning of the swap market is an important factor. The default risk of banks is also found to affect the supply of international dollar loans significantly, as an increase in the CDS spread of one standard deviation (i.e. 40 basis points, see Table 1) would reduce the supply of international dollar loans by 3.77%.

Models 3 and 4 present the estimation results for the extended models specified by equation (2). Model 3 considers how the parent bank's attitude towards risk taking and asset quality affects the transmission of the Fed's BSP. To this end, we include *Dum(low CAR)* and *PLR,* respectively, in *BSF* in equation (2). The estimation results for Model 3 suggest that parent-bank balance sheet characteristics play a significant role in determining the sensitivity of the supply of dollar loans of foreign bank branches in Hong Kong, China to the Fed's BSP. Specifically, a bank with a greater willingness to take risks and with a better asset quality tends to supply more dollar loans through its Hong Kong, China branches in response to an expansion of the Fed's balance sheet.

In Model 4, we add two branch-level balance sheet factors (i.e. *DTA* and *LTA*) to Model 3 to study whether the funding structure and business model of Hong Kong, China branches matter for the transmission of central bank BSPs. Model 4 shows a negative and significant estimated coefficient on the interaction term between *ΔFED *USF* and *DTA*, suggesting that branches financing their loans primarily by taking retail deposits from the host country tend to be less responsive to the Fed's BSP. This finding supports the hypothesis that the funding structure is a significant factor affecting the transmission of central bank BSPs. However, the interaction term between *ΔFED *USF* and *LTA* is found to be statistically insignificant despite the expected sign of the estimated coefficient, indicating that whether a branch is initially positioned as a lending unit or not would not significantly affect its loan response to the Fed's BSP. We show that the differences in the sensitivity of *ΔL** to the Fed's BSP arising from banks' balance sheet characteristics are economically significant based on the estimation results for Model 4 (Appendix 3).

4.1 The Net Impact of Divergence of BSPs on the Supply of International Dollar Loans

This section analyzes the net impact of divergence of central bank BSPs on the supply of international dollar loans. We focus on euro area and Japanese banks, as these two groups of banks are major providers of international dollar loans and they would be mostly affected by the current divergence of central bank BSPs in the US vis-à-vis the euro area and Japan.

Although the estimation results in Table 2 support the hypothesis of international spillover of central bank BSPs through the bank lending channel, they cannot be directly employed to conduct the analysis in this section for two reasons. First, the two central bank BSP variables in the models (i.e. *ΔFED* and *ΔHCB*) are not exogenous shocks of central bank BSPs. Estimating the impact of central bank BSPs on international dollar loans requires identification of the exogenous component of central bank BSPs from endogenous responses of central bank BSPs to financial and macroeconomic risks. Second, *ΔCDS* and *ΔCIP* may be responsive to central bank BSPs. Failing to incorporate their responses to central bank BSP shocks would produce biased estimation results. For example, the current divergence of BSPs between the Fed and the BOJ is likely to increase the cost of swapping yen for US dollars. Ignoring this potential impact on the swap cost would overestimate the supply of international dollar loans.

We employ vector autoregressive (VAR) analysis to estimate first-order VAR models for two country pairs (i.e. US-Japan and US-euro area) to aid the identification of exogenous shocks of central bank BSPs in the US, the euro area, and Japan, and the empirical responses of ΔCDS and ΔCIP to the central bank BSP shocks.

Each VAR model includes ten variables. Taking the US-Japan pair as an example, each country contains two macroeconomic variables (real industrial outputs and the consumer price index) and the central bank balance sheet. Their first differences of log seasonally adjusted time series are used in the estimations (denoted respectively by Δy_t^{US}, $\Delta \pi_t^{US}$, and ΔFED_t for the US; and Δy_t^{JP}, $\Delta \pi_t^{JP}$, and ΔHCB_t^{JP} for Japan). We follow Gambacorta, Hofmann and Peersman (2014) to include the change in the VIX index (ΔVIX_t) in the model, arguing that central bank BSPs may react to financial market risks. The remaining three variables are financial market variables, namely the change in the cost of swapping yen for US dollars (ΔCIP_t^{JP}), the change in the average CDS spread for major Japanese banks (ΔCDS_t^{JP}), and the change in the spot exchange rate of yen per US dollar (ΔEXR_t^{JP}). These variables are separated into US and Japanese blocks with the following ordering: $\{\Delta y_t^{US}, \Delta \pi_t^{US}, \Delta VIX_t, \Delta FED_t\}$ and $\{\Delta y_t^{JP}, \Delta \pi_t^{JP}, \Delta CIP_t^{JP}, \Delta CDS_t^{JP}, \Delta EXR_t^{JP}, \Delta HCB_t^{JP}\}$. The ordering of variables is largely consistent with the literature on monetary policy shock identification.[11]

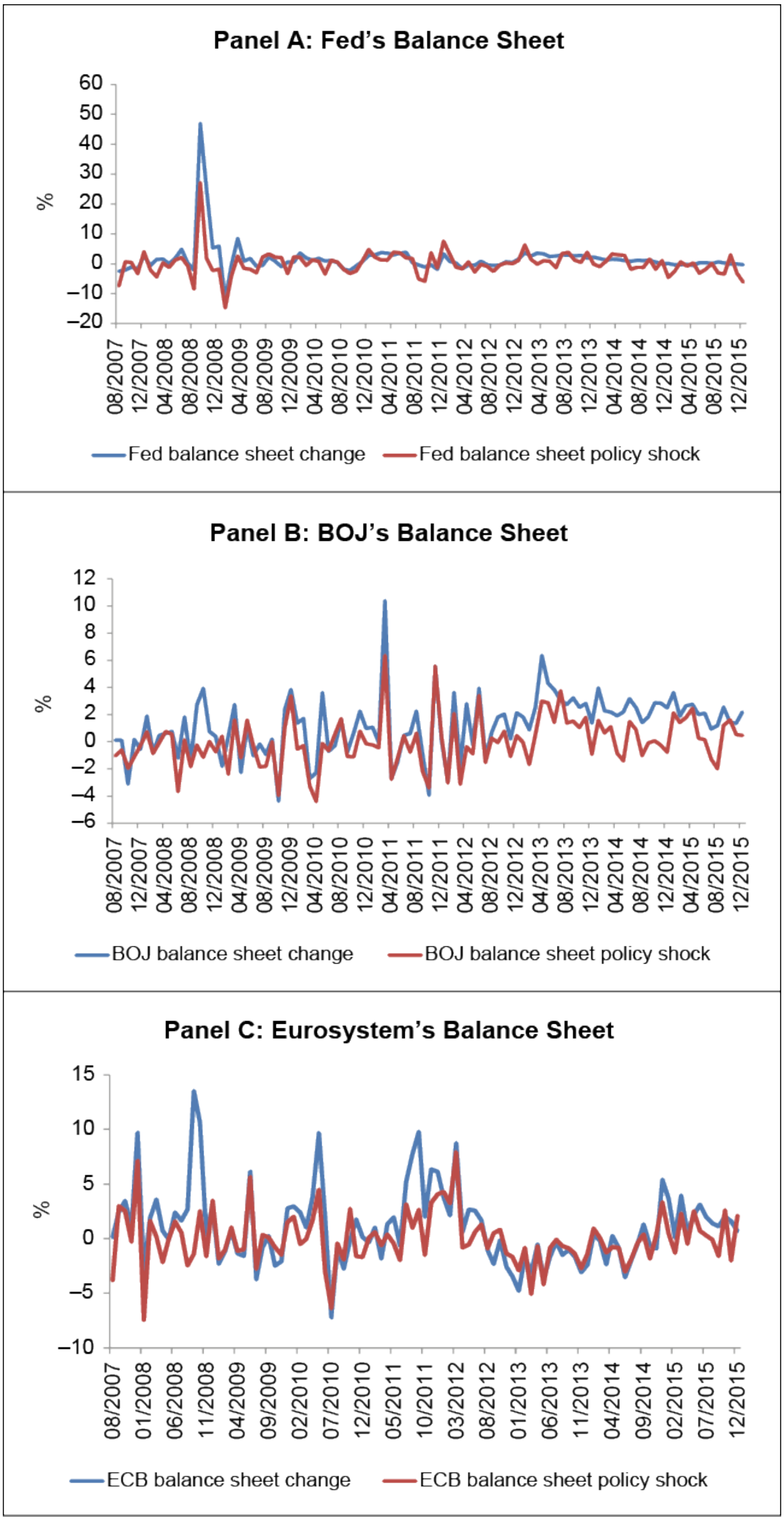
To reduce the number of parameters needed to estimate, we follow Cushman and Zha (1997) to impose block exogeneity restrictions in the estimation such that shocks in the US block are assumed to have effects on variables in the Japanese block but any shock from Japan has no effects on the US. Apart from this statistical consideration, imposing the exogeneity restrictions can allow us to obtain an identical identification of US monetary policy shocks in the US-Japan and US-euro area models so that our estimates are self-consistent. We also conduct a robustness check by relaxing the exogeneity restrictions (see the next section).

The model is estimated using the seemingly unrelated regression method with monthly data from August 2007 to December 2015. Once the model is estimated, the recursive identification scheme (i.e. the Cholesky decomposition of the variance-covariance matrix of the reduced-form disturbances) is adopted to identify the central bank BSP shocks with the mentioned ordering of the variables. The US-euro area model is also specified and estimated in a similar fashion.

Figure 3 presents the estimated central bank BSP shocks for the Fed, the BOJ, and the ECB (in Panels A to C, respectively). The sizes of the BSP shocks measured by the one-year standard deviation are estimated to be 14.4%, 6.3%, and 8.5% for the Fed, the BOJ, and the ECB, respectively. These compare with 26.1%, 18.3%, and 13.3% for their respective average annual growth rate of balance sheets since the implementation of their BSPs after the GFC. This indicates a significant difference between the changes in central banks' balance sheets observed and the exogenous central bank BSP shocks.

[11] See Gambacorta, Hofmann and Peersman (2014) and Chen et al. (2016).

Figure 3: Changes on Central Bank Balance Sheets and Identified BSP Shocks



Sources: Board of Governors of the Federal Reserve System, Bank of Japan, the European Central Bank, IMF International Financial Statistics, and authors' estimates.

Our VAR estimations also show that financial market variables are responsive to central bank BSPs. In particular, Table 3 summarizes the variance decompositions for ΔCIP_t for the US-Japan and US-euro area models. The US central bank BSP shock is found to be the most important factor in explaining the forecast error variance for ΔCIP_t, followed by its own shocks. Home-country central bank BSP shocks, however, are found to give little explanatory power. Both models show a similar picture.

Table 3: Variance Decomposition Analysis for ∆CIP

Decomposition of total variance of the forecast error for ∆CIP
for the US-Japan VAR model

Period	ΔVIX_t	ΔFED_t	ΔCIP_t^{JP}	ΔHCB_t^{JP}	*Others*
1	8.4	28.2	53.0	0.0	10.4
2	12.0	35.7	38.9	0.0	13.3
3	11.2	38.5	35.2	0.9	14.2
4	11.1	38.0	34.8	0.9	15.3
5	11.0	38.3	34.4	1.0	15.4
6	11.0	38.3	34.3	1.0	15.4
7	11.0	38.3	34.3	1.0	15.4
8	11.0	38.3	34.3	1.0	15.4
9	11.0	38.3	34.3	1.0	15.4
10	11.0	38.3	34.3	1.0	15.4
11	11.0	38.3	34.3	1.0	15.4
12	11.0	38.3	34.3	1.0	15.4

Note: Figures represent the percentage share of the total variance of the forecast error for ∆CIP attributable to the variance of each structural shock.

Decomposition of total variance of the forecast error for ∆CIP
for the US-euro area VAR model

Period	ΔVIX_t	ΔFED_t	ΔCIP_t^{EU}	ΔHCB_t^{EU}	*Others*
1	24.0	40.0	29.6	0.0	6.4
2	19.3	32.9	26.6	3.7	17.5
3	16.5	37.4	22.5	3.4	20.3
4	15.6	37.1	21.5	3.5	22.3
5	15.4	36.6	21.2	3.8	23.0
6	15.3	36.5	21.2	3.8	23.2
7	15.3	36.5	21.1	3.9	23.2
8	15.3	36.5	21.1	3.9	23.3
9	15.3	36.4	21.1	3.9	23.3
10	15.3	36.4	21.1	3.9	23.3
11	15.3	36.4	21.1	3.9	23.3
12	15.3	36.4	21.1	3.9	23.3

Note: Figures represent the percentage share of the total variance of the forecast error for ∆CIP attributable to the variance of each structural shock.

The finding that a significant part of the forecast error variance of ΔCIP_t can be explained by its own shocks is consistent with the finding by Sushko et al. (2016) that there remains a significant part of the CIP deviation that cannot be explained by factors identified in the literature (e.g. crisis and banks' default risks).

In order to estimate the net impact of divergence of central bank BSPs on the supply of international dollar loans of the euro area and Japanese banks, we conduct Monte Carlo (MC) simulations based on the estimated VAR models and the identified central bank BSP shocks. Appendix 4 details the procedure of the MC simulations.

For the case of Japanese banks, we impose divergent central bank BSP shocks in the VAR model by considering simultaneously negative shocks to the Fed's balance sheet and positive shocks to the BOJ's balance sheet. We then simulate the distributions for the four determinants of the supply of international dollar loans (i.e. ΔHCB_{jt}, ΔFED_t, ΔCIP_{jt-1}, and ΔCDS_{jt}). Table 4 presents their distributional statistics for the cumulative 12-month changes from December 2015 based on 10,000 simulation trials. Although we impose negative shocks on ΔFED_t, the simulation results show that the Fed's balance sheet may expand or contract, depending on the simulated movements of other factors. By contrast, the balance sheet of the BOJ would be more likely to increase with an average growth rate of 17.7%. For the cost of swapping yen for US dollars (ΔCIP_{jt-1}), the simulated distribution shows that it is more likely to increase than decrease, which is consistent with research findings that the current divergent monetary policy environment could push up the dollar funding cost in cross-currency funding markets (Iida, Kimura and Sudo 2016; Sushko et al. 2016). Finally, the direction of change in the default risk of Japanese banks is somewhat uncertain based on the simulated distribution for ΔCDS_{jt}.

Table 4: Distributions of Simulated Changes for Key Variables that Affect the Supply of International Dollar Loans of Japanese Bank Branches under the Scenario of Divergence of Central Bank BSP Shocks

Distributional Statistics	ΔFED_t (%)	ΔHCB_t (%)	ΔCDS_{jt} (bps)	ΔCIP_{jt-1} (bps)
90th percentile	31.7	28.3	72.2	76.3
75th percentile (upper quartile)	19.8	23.2	43.6	55.7
Median	6.5	17.7	12.2	32.0
25th percentile (lower quartile)	–6.3	12.3	–18.2	8.6
10th percentile	–17.7	7.0	–46.5	–12.7
Mean	6.6	17.7	12.7	32.1
S.d.	19.3	8.3	46.2	34.4

We further decompose the contribution of these factors to the supply of ΔL^*_{ijt} of Japanese banks by using the estimation results for Model 4 in Table 2. The decomposition results are presented in the upper panel of Table 5. We first focus on the lower and upper quartile estimates in order to reveal the expected range of contributions to the growth of international dollar loans of different factors. For the contribution of ΔFED_t, the lower and upper quartile estimates are found to be –1.3 and 4 percentage points respectively, suggesting that ΔFED may increase or reduce the supply of ΔL^* of Japanese banks. The possible contractionary effect of the Fed's BSP on the supply of ΔL^*, however, would be offset by the expansionary effect of the BOJ's BSP, as the contribution of ΔHCB to the supply of ΔL^* is found to be positive for both the lower and upper quartile estimates (i.e. 3.9 and 7.4 percentage points, respectively). It is worth pointing out that the net impact would be largely dependent on financial market responses, particularly in the FX swap market. Specifically, the swap cost could contribute to a significant decline in the supply of dollar loans of Japanese banks, as both lower and upper quartile estimates are negative (i.e. –0.7 and –4.3 percentage points). Indeed, the last column of the upper panel of Table 5, which shows the estimates for the combined contributions of the four factors to changes in international dollar loans,[12] confirms this conjecture, as the estimated distribution shows that the supply of *ΔL** of Japanese banks could increase or decrease.

Table 5: Distributions of Estimated Contribution of Factors to the Growth of International Dollar Loans of Japanese Bank Branches and Tail Risk Estimates under the Scenario of Divergence of Central Bank BSP Shocks

Contribution to the Growth of Japanese Banks' Dollar Loans	ΔFED_t*USF_j (%)	ΔHCB_{jt} (%)	ΔCDS_{jt} (%)	ΔCIP_{jt-1} (%)	$\Delta Loan_{ijt}$ (%)
Upper panel					
90th percentile	6.3	9.1	4.7	1.0	12.2
75th percentile (upper quartile)	4.0	7.4	1.8	–0.7	8.0
Median	1.3	5.7	–1.2	–2.5	3.3
25th percentile (lower quartile)	–1.3	3.9	–4.4	–4.3	–1.6
10th percentile	–3.6	2.3	–7.3	–5.9	–5.9
Mean	1.3	5.7	–1.3	–2.5	3.2
S.d.	3.9	2.6	4.7	2.7	7.1
Lower panel					
Tail risk estimate	–3.3	3.5	–4.6	–4.2	–8.6

We also analyze the tail risk by estimating how these factors might contribute to an extreme decline in the supply of *ΔL** of Japanese bank branches in Hong Kong, China. We measure the tail risk by an expected shortfall estimate defined as the average estimated credit growth in the worst 10% of the 10,000 simulation trials. Among the worst 10% of trials, we compute the average changes of the factors and their contributions to the supply of *ΔL** of Japanese banks. We present the expected shortfall estimate in the lower panel of Table 5, which shows that the supply of dollar loans of Japanese banks could fall by 8.6%. Although the contractionary effect of the Fed's BSP would be offset by the expansionary effect of the BOJ's BSP (i.e. –3.3% vs 3.5%), the rising default risks for Japanese banks and the swap cost would lead to a significant decline in the supply of international dollar loans of Japanese bank branches in Hong Kong, China. We repeat the same analysis for euro area bank branches and report the results in Tables 6 and 7. The results are qualitatively similar to those for Japanese bank branches reported in Tables 4 and 5.

[12] For the distributional statistics for the combined contribution estimates, we first drive a combined contribution estimate for each simulation trial by adding up the contributions of the four factors to dollar loan growth in that trial. We then use the 10,000 combined contribution estimates to obtain the distributional statistics.

Table 6: Distributions of Simulated Changes for Key Variables that Affect the Supply of International Dollar Loans of Euro Area Bank Branches under the Scenario of Divergence of Central Bank BSP Shocks

Distributional Statistics	ΔFED_t (%)	ΔHCB_t (%)	ΔCDS_{jt} (bps)	ΔCIP_{jt-1} (bps)
90th percentile	31.7	29.0	61.9	64.0
75th percentile (upper quartile)	19.8	22.6	32.2	38.4
Median	6.5	16.0	–1.6	9.0
25th percentile (lower quartile)	–6.3	9.5	–35.5	–19.1
10th percentile	–17.7	3.5	–66.1	–44.9
Mean	6.6	16.1	–1.7	9.5
S.d.	19.3	9.9	50.1	42.4

Table 7: Distributions of Estimated Contribution of Factors to the Growth of International Dollar Loans of Euro Area Bank Branches and Tail Risk Estimates under the Scenario of Divergence of Central Bank BSP Shocks

Factor Contribution	ΔFED_t*USF_j (%)	ΔHCB_{jt} (%)	ΔCDS_{jt} (%)	ΔCIP_{jt-1} (%)	$\Delta Loan_{ijt}$ (%)
Upper panel					
90th percentile	4.8	9.3	6.7	3.5	14.3
75th percentile (upper quartile)	3.0	7.2	3.6	1.5	10.2
Median	1.0	5.1	0.2	–0.7	5.5
25th percentile (lower quartile)	–1.0	3.0	–3.2	–3.0	0.9
10th percentile	–2.7	1.1	–6.3	–5.0	–3.1
Mean	1.0	5.1	0.2	–0.7	5.6
S.d.	2.9	3.2	5.1	3.3	6.8
Lower panel					
Tail risk estimate	–0.3	5.6	–4.4	–5.1	–4.2

Taken together, the empirical findings in this section point to the same conclusion: The contractionary effect of US monetary normalization on global liquidity would be offset by an effect of central bank balance sheet expansion in Japan and the euro area. The net effect, however, is crucially dependent on whether the US monetary normalization coincides with risk aversion by global investors and leads to serious financial market dislocations. Specifically, our tail risk analysis shows that there remains a small risk that the supply of international US dollar credit will decline sharply if dislocations in FX swap markets occur and banks' default risks increase as the US normalizes its monetary policy.

5. ROBUSTNESS ANALYSIS

5.1 Robustness Analysis using the BIS Data Set

Our first robustness test re-estimates the baseline model using a confidential data set from the BIS. Based on the estimation results for the BIS data set, we then obtain the tail risk estimates for Japanese and euro area banks to assess the extent to which the main conclusion drawn in the final paragraph of the previous section is sensitive to an alternative data set.

The BIS data set is constructed from the locational banking statistics by nationality. The BIS recently refined the data collection exercise and as a result, since June 2012, a breakdown of the statistics by 12 core global bank nationalities has been available for the BIS quarterly data on dollar-denominated external claims vis-à-vis 76 counterparty countries. The breakdown by reporting bank nationality makes it possible to identify the effect of central bank BSP in the home country on the supply of cross-border dollar credit by global banks.

One advantage of the BIS data set is that it covers a major part of the aggregate position of reporting banks for the BIS location statistics, which is by far the most comprehensive data set available for analyzing international dollar loans. However, there are some caveats for the analysis using the BIS data set. First, the sample period of the BIS data set is short (i.e. our sample period covers seven time points only from June 2012 to March 2014), although there are a sufficiently large number of observations (more than 4,000). Second, we cannot analyze precisely international flows of dollar-denominated cross-border loans as we did in the previous section, as the exact variable is not available from the BIS data set. Only dollar-denominated cross-border claims that contain much broader assets than loans are available from the BIS data set. Finally, since the BIS data set is only available at the aggregate level by nationality of banks, we cannot consider bank-specific balance sheets as determinants of the transmission of central bank BSPs. Therefore we can only estimate the baseline model specified in equation (1) for the BIS data set. These caveats together suggest that the estimation results using the BIS data set could be significantly different from those using the HKMA data set.

Table 8 presents the estimation results using the BIS data set, which are broadly in line with the discussion in Section 2, as the estimated coefficients are statistically significant and with the expected signs. This suggests that the baseline model specification has adequate explanatory power on the aggregate flow of international dollar loans.

Table 8: Estimation Result for the BIS Data Set

Variable	
ΔHCB_{it}	0.48***
	(3.21)
ΔFED_t*USF_i	4.10***
	(2.67)
ΔCDS_{it}	–9.12*
	(–1.86)
ΔCIP_{it-1}	–23.97**
	(–2.11)
ΔGDP_{it}	–1.00*
	(–1.80)
Country-time fixed effects for destination country *i*	
	Yes
R-squared	0.13
RMSE	0.58
No. of observations	9,161

Notes:

1. j = home country j, i = destination country i.
2. Figures in parentheses are t-statistics.
3. Standard errors are clustered by home country and destination country.
4. ***, **, and * respectively indicate significance at the 1%, 5%, and 10% level.

Based on the results presented in Table 8, we obtain the tail risk estimates of credit growth for euro area and Japanese banks with the same procedure described in the previous section. The estimation results are presented in Table 9. The results are found to be qualitatively similar to those reported in the previous section, and the conclusion that there remains a tail risk that financial market responses to the divergence of central bank BSPs could lead to a sharp decline in the supply of international dollar loans remains. However, quantitatively, the FX swap cost is found to become an even more important contributor to the tail risk for the estimations using the BIS data set than for those using the HKMA data set.

Table 9: Tail Risk Estimates based on Estimation Results from the BIS Data Set

Tail Risk Estimates	**ΔFED_t*USF_j** (%)	**ΔHCB_{jt}** (%)	**ΔCDS_{jt}** (%)	**ΔCIP_{jt-1}** (%)	**$\Delta Loan_{ijt}$** (%)
Japanese banks	–15.2	4.3	–0.6	–13.5	–25.1
Euro area banks	–2.5	8.1	–4.0	–15.2	–13.5

5.2 Other Robustness Checks

Apart from the above robustness analysis using the BIS data set, we also conduct the following analysis using the HKMA data set. First, we add shadow policy rates to the VAR models, arguing that shadow policy rates may contain different information from central banks' balance sheets in respect of the unconventional monetary policy stance. We obtain our shadow policy rate estimates from Lombardi and Zhu (2014). More specifically, we employ updated Lombardi-Zhu shadow rate estimates for the US and preliminary estimates for the euro area and Japan from the authors to conduct the analysis. Panel A of Table 10 presents the tail risk estimates, which are found to be similar to those presented in Tables 5 and 7. Second, we relax the block exogeneity restrictions in the VAR models using the same recursive scheme with the same ordering of variables to identify monetary policy shocks. The tail risk estimates (see Panel B of Table 10) turn out to be qualitatively similar to those presented in the previous section.

Table 10: Robustness Tests: Tail Risk Estimates for Alternative Model Specifications

Tail Risk Estimates	**ΔFED_t*USF_j** (%)	**ΔHCB_{jt}** (%)	**ΔCDS_{jt}** (%)	**ΔCIP_{jt-1}** (%)	**$\Delta Loan_{ijt}$** (%)
Panel A (inclusion of shadow policy rates in the VAR models)					
Japanese banks	–2.9	4.6	–4.2	–4.2	–6.7
Euro area banks	–1.8	4.3	–9.1	–4.6	–11.1
Panel B (relaxing block exogeneity restrictions in the VAR models)					
Japanese banks	–0.4	6.4	–4.8	–5.3	–4.2
Euro area banks	–2.8	4.8	–5.5	–5.1	–8.6

6. CONCLUSION

Our findings show that although continued asset purchases by the ECB and BOJ are expected to cushion the negative impact of US monetary policy normalization on the supply of international dollar credit, the Fed's monetary policy shocks are found to be the principal factor driving the tail risks. In particular, we show a tail risk scenario in which the US monetary normalization could widen the CIP in the major FX swap markets (i.e. the yen and euro against the US dollar), leading to a sharp decline in the supply of international dollar liquidity. Similarly to findings by Stefan et al. (2016),[13] our empirical findings point to an unmatched role of the US dollar in driving global financial stability through its impacts on cross-currency funding markets and thus international bank lending.

[13] Stefan et al. (2016) documented that a stronger dollar goes hand in hand with larger deviations from CIP and lower growth of cross-border dollar-denominated lending. The paper attributes this triangular relationship to the role of the dollar as a proxy for the shadow price of bank leverage.

REFERENCES

Aiyar, S., C. W. Calomiris, J. Hooley, Y. Korniyenko and T. Wieladek (2014), "The International Transmission of Bank Capital Requirements: Evidence from the UK?" *Journal of Financial Economics*, 113(3): 368–82.

Aizenman, J., B. Mahir and M. Hutchison (2014), "The Transmission of Federal Reserve Tapering News to Emerging Financial Markets," NBER Working Paper No.19980.

Baba, N. and F. Packer (2009), "From Turmoil to Crisis: Dislocations in the FX Swap Market Before and After the Failure of Lehman Brothers", *Journal of International Money and Finance*, 28(8): 1350–74.

Bauer, M. and C. Neely (2014), "International Channels of the Fed's Unconventional Monetary Policy," *Journal of International Money and Finance*, 44: 24–46.

Bowman, D., F. Cai, S. Davies and S. Kamin (2011), "Quantitative Easing and Bank Lending: Evidence from Japan," Board of Governors of the Federal Reserve System, International Finance Discussion Papers, No. 1018.

Brunnermeier, M., J. Gregorio, B. Eichengreen, M. El-Erian, A. Fraga, T. Ito, P. Lane, J. Pisani-Ferry, E. Prasad, R. Rajan, M. Ramos, H. Rey, D. Rodrik, K. Rogoff, H. Shin, A. Velasco, B. Mauro, and Y. Yu (2012), "Banks and Cross-Border Capital Flows: Policy Challenges and Regulatory Responses," Washington DC: Brookings Institutions.

Bruno, V. and H. S. Shin (2015), "Capital Flows and the Risk-taking Channel of Monetary Policy," *Journal of Monetary Economics*, 71: 119–132.

Buch, C. M. and L. S. Goldberg (2015), "International Banking and Liquidity Risk Transmission: Lessons from across Countries," *IMF Economic Review,* 63: 377–410.

Cetorelli, N. and L. S. Goldberg (2011), "Global Banks and International Shock Transmission: Evidence from the Crisis," *IMF Economic Review,* 59: 41–76.

Cetorelli, N. and L. S. Goldberg (2012a), "Follow the Money: Quantifying Domestic Effects of Foreign Bank Shocks in the Great Recession," *American Economic Review*, 102(3): 213–8.

Cetorelli, N. and L. S. Goldberg (2012b), "Liquidity Management of US Global Banks: Internal Capital Markets in the Great Recession," *Journal of International Economics*, 88: 299–311.

Chava, S. and A. Purnanandam (2011), "The Effect of Banking Crisis on Bank-dependent Borrowers," *Journal Financial Economics*, 99: 116–135.

Chen, Q., A. Filardo, D. He and F. Zhu (2012), "International Spillovers of Central Bank Balance Sheet Policies," BIS Paper No. 66p.

Chen, Q., A. Filardo, D. He and F. Zhu (2016), "Financial Crisis, Unconventional Monetary Policy and International Spillovers," *Journal of International Money and Finance*, 67: 62–81.

Cornett, M. M., J. J. McNutt, P. E. Strahan and H. Tehranian (2011), "Liquidity Risk Management and Credit Supply in the Financial Crisis," *Journal of Financial Economics*, 101: 297–312.

Cushman, D. and T. Zha (1997), "Identifying Monetary Policy in a Small Open Economy under Flexible Exchange Rates," *Journal of Monetary Economics*, 39(3): 433–448.

D'Amico, S. and T. B. King (2013), "Flow and Stock Effects of Large-Scale Treasury Purchases: Evidence on the Importance of Local Supply," *Journal of Financial Economics*, 108(2): 425–48.

Eichengreen, B. and P. Gupta (2014), "Tapering Talk: The Impact of Expectations of Reduced Federal Reserve Security Purchases on Emerging Markets," World Bank Policy Research Working Paper, No. 6754.

Financial Stability Board (2013), "2013 Update of Group of Global Systemically Important Banks," 11 November 2013.

Fratzscher, M., M. Duca and R. Straub (2013), "On the International Spillovers of U.S. Quantitative Easing," ECB Working Paper Series, No. 1557.

Gambacorta, L., B. Hofmann and G. Peersman (2014), "The Effectiveness of Unconventional Monetary Policy at the Zero Lower Bound: A Cross-Country Analysis," *Journal of Money, Credit and Banking*, 46(4): 615–642.

He, D. and R. N. McCauley (2013), "Transmitting Global Liquidity to East Asia: Policy Rates, Bond Yields, Currencies and Dollar Credit," BIS Working Paper, No. 431.

Iida, T., T. Kimura and N. Sudo (2016), "An Upsurge in a CIP Deviation During the Noncrisis Period and the Role of Divergence in Monetary Policy," Bank of Japan Working Paper Series, no 16-E-14, August.

International Monetary Fund (2015), "Market Liquidity—Resilience or Fleeting?" *Global Financial Stability Report*, October 2015.

International Monetary Fund (2016), "Monetary Policy and the Rise of Nonbank Finance" *Global Financial Stability Report*, October 2016.

Ivashina, V., D. S. Scharfstein and J. C. Stein (2015), "Dollar Funding and the Lending Behavior of Global Banks," *Quarterly Journal of Economics*, 130(3): 1241–1281.

Joyce, M. and M. Spaltro (2014), "Quantitative Easing and Bank Lending: A Panel Data Approach," Bank of England Working Paper No. 504.

Khwaja, A. and A. Mian (2008), "Tracing the Effect of Bank Liquidity Shocks: Evidence from an Emerging Market," *American Economic Review*, 98: 1413–42.

Lombardi, M. J. and F. Zhu (2014), "A Shadow Policy Rate to Calibrate US Monetary Policy at the Zero Lower Bound," BIS Working Papers No. 452.

McCauley, R. N., P. McGuire and V. Sushko (2015), "Global Dollar Credit: Links to US Monetary Policy and Leverage," *Economic Policy*, 30(82): 187–229.

McGuire, P. and G. von Peter (2009), "The US Dollar Shortage in Global Banking and the International Policy Response," BIS Working Papers No. 291.

Mishra, P., K. Moriyama, P. N'Diaye and N. Lam (2014), "The Impact of Fed Tapering Announcements on Emerging Markets," IMF Working Paper, WP/14/109.

Neely, C. (2015), "Unconventional Monetary Policy had Large International Effects," *Journal of Banking and Finance*, 52: 101–11.

Peek, J. and E. Rosengren (2000), "Collateral Damage: Effects of the Japanese Bank Crisis on Real Activity in the United States," *American Economic Review*, 90: 30–45.

Peek, J., E. Rosengren and G. Tootell (2003), "Identifying the Macroeconomic Effect of Loan Supply Shocks," *Journal of Money, Credit and Banking*, 35(6): 931–46.

Schnabl, P. (2012), "The International Transmission of Bank Liquidity Shocks: Evidence from an Emerging Market," *Journal of Finance*, 67: 897–932.

Stefan, A., W. Du, C. Koch and S. S. Hyun (2016), "The Dollar, Bank Leverage and the Deviation from Covered Interest Parity," BIS Working Paper No. 592, November 2016.

Sushko, V., C. Borio, R. McCauley and P. McGuire (2016), "The Failure of Covered Interest Parity: FX Hedging Demand and Costly Balance Sheets," BIS Working Paper No. 590, October 2016.

APPENDIX 1: DETAILS FOR THE THEORETICAL DISCUSSIONS

Using the same setting as that discussed in the main text, we further make the following assumptions. The bank is assumed to earn returns $h(L) = \theta L - \beta L^2/2$ for L and $g(L^*) = \theta^* L^* - \beta^* L^{*2}/2$ for L^*, where θ and θ^* are demand shock parameters and β and β^* denote the change in marginal loan return with respect to loan volume in the two markets. We assume θ, θ^*, β, and $\beta^*>0$. The marginal loan returns in the two markets are decreasing functions with respect to loan volume given by $h'(L) = \theta - \beta L$ and $g'(L^*) = \theta^* - \beta^* L^*$. For the cost functions in the domestic and US markets, we assume $c(F) = \alpha F^2/2$ and $l(F^*) = \alpha^* F^{*2}/2$ respectively, where α and $\alpha^* > 0$.

The global bank's profit maximization problem can be written as follows:

$$Max\{L^*, L, F^*, F, S\}: h(L) - c(F) + g(L^*) - l(F^*) - pF^* - wS \quad \text{(A1)}$$

subject to two constraints:

$$L^* = D^* + F^* + S \quad \text{(A2)}$$

$$L = D + F - S \quad \text{(A3)}$$

The last two terms in equation (A1), i.e. pF^* and wS, are the total risk premiums paid to fund providers in the US and total swap costs, respectively. It can be shown that in equilibrium the following conditions must hold:

$$h'(L) = c'(F) \quad \text{(A4)}$$

$$g'(L^*) = h'(L) + w \quad \text{(A5)}$$

$$g'(L^*) = l'(F^*) + p \quad \text{(A6)}$$

Equation (A4) simply states that the bank extends home-currency loans up to a level where the marginal return of home-currency loans is equal to the marginal cost of home-currency funding. Equation (A5) follows from the fact that since the bank can convert its home-currency funding into US dollars by paying a swap cost w to fund dollar loans, in equilibrium the marginal return of home-currency loans is equal to the marginal return of US dollar loans minus the swap cost. Finally, equation (A6) states that the marginal return of US dollar loans must be equal to the marginal cost of US dollar funding, which includes the default risk premium demanded by fund providers in the US. Solving for the equilibrium, the equilibrium dollar loan can be expressed as:

$$L^* = \frac{1}{\Omega}D + \frac{1}{\Omega}D^* - \frac{1}{\Omega\alpha^*}p - \frac{\alpha+\beta}{\Omega\alpha\beta}w - \frac{1}{\Omega\beta}\theta + \frac{1}{\Omega}\left(\frac{\alpha+\beta}{\alpha\beta} + \frac{1}{\alpha^*}\right)\theta^* \quad \text{(A7)}$$

where $\Omega = \left(\frac{\alpha^* + \beta^*}{\alpha^*}\right) + \left(\frac{\alpha + \beta}{\alpha}\right)\frac{\beta^*}{\beta} > 0$; or L^* can be represented by

$$L^* = \beta_1 D + \beta_2 D^* + \beta_3 p + \beta_4 w + \beta_5 \theta + \beta_6 \theta^* \quad \text{(A8)}$$

where β_1, β_2, and $\beta_6 > 0$; β_3, β_4, and $\beta_5 < 0$.

The model predicts that, other things being equal, more abundant liquidity either in the home or the US market (i.e. larger D and D^*, respectively) reduces the funding costs and therefore increases dollar loans L^*. A higher default risk (higher p) or higher swap costs (higher w) increases the bank's dollar funding cost, thereby reducing its dollar loans. An increase in the demand for home-currency loans (i.e. larger θ) leads the bank to cut its supply of dollar loans.

APPENDIX 2: DESCRIPTION OF VARIABLES

Variable	Description	Source
ΔL_{ijt}	The quarterly growth rate of external loans to nonbank sector denominated in the US dollar to a destination country *i* by the Hong Kong, China branch of global bank *j*. The data are from *the return of external positions*.	HKMA
USF_j	The ratio of total funding raised by US branch of global bank *j* to total assets of bank *j* in 2012Q2.	Federal Financial Institutions Examination Council (FFIEC) and Bankscope
ΔFED_t	The growth rate of the Fed's balance sheet (ΔFED_t).	IMF International Financial Statistics
ΔHCB_{jt}	The growth rate of the central bank's balance sheet in country *j* to proxy liquidity shocks in country *j*.	IMF International Financial Statistics and national central banks
ΔCDS_{jt}	For the models using the HKMA data set, the change in the CDS spread for bank *j* to proxy the default risk of bank *j*.	Bloomberg
ΔCIP_{jt-1}	The change in the deviation from covered interest parity for converting country *j*'s currency (the country of headquarters of bank *j*) into the US dollar in *t-1* to gauge the change of swap cost.	Bloomberg and author's calculations
ΔGDP_{jt}	Forecast of nominal GDP growth rate from WEO for country *j* to control for changes in the demand for local-currency loans in country *j*.	IMF WEO
μ_{it}	Destination country-time fixed effect to account for changes in the demand for US dollar loans in country *i* (Proxy for θ^*).	Author's calculations
$Dum(Crisis)_t$	Dummy variable for crisis period. Defined as one for observations for 2008Q3-2009Q1 and 2010Q2-2012Q1, and zero otherwise.	
$Dum(LowCAR)_{jt}^P$	Dummy variable for a high capital adequacy ratio in 2006. This ratio is the total capital adequacy ratio under the Basel rules. It measures Tier 1 + Tier 2 capital, which includes subordinated debt, hybrid capital, loan loss reserves, and the valuation reserves as a percentage of risk-weighted assets and off balance sheet risks. This ratio should be at least 8%. The dummy variable is defined as one for banks whose average capital adequacy ratio in 2006 was lower than the 25th percentile, and zero otherwise.	Bankscope
PLR_{jt}^P	A ratio of impaired loans to equity, which is defined as impaired or problem loans as a percentage of the bank's equity. This indicates the weakness of the loan portfolio relative to the bank's capital. If this is a high percentage this would be cause for concern.	Bankscope
DTA_{jt}^B	Hong Kong, China branch's customer deposits divided by Hong Kong, China branch's total assets. The data are from the return of external positions.	HKMA
LTA_{jt}^B	Hong Kong, China branch's loans and advances to customers divided by Hong Kong, China branch's total assets. The data are from the return of external positions.	HKMA

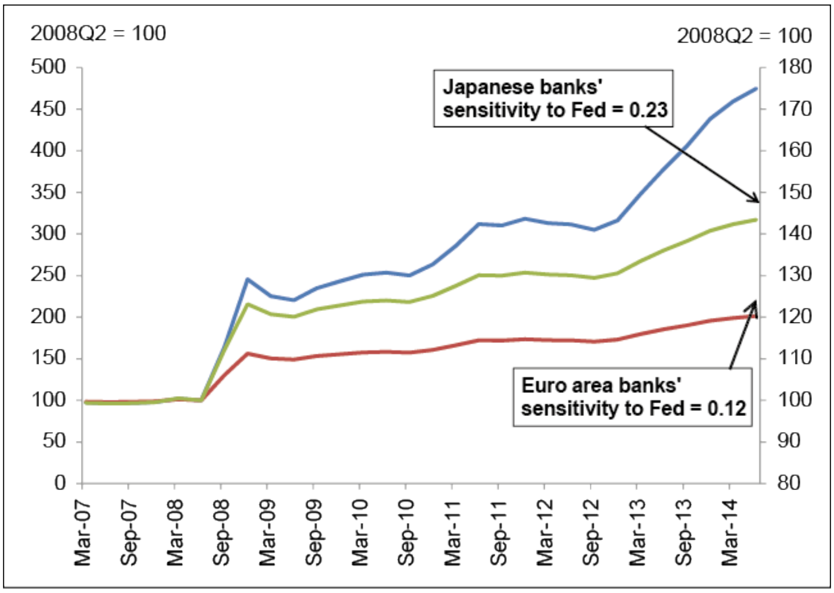
APPENDIX 3: ECONOMIC SIGNIFICANCE OF THE IMPACT OF BALANCE SHEET FACTORS ON ΔL^*

To assess the economic significance of the differences in the sensitivity of ΔL^* to the Fed's BSP arising from banks' balance sheet characteristics, we conduct a simple exercise based on the estimation result for Model 4. Specifically, two hypothetical banks are created by taking the characteristics of typical euro area banks and Japanese banks, respectively. We compute the median for each bank characteristic for euro area banks and for Japanese banks using our estimation sample in 2014 (Table A1). As shown in Table A1, the two groups of banks have very different balance sheet characteristics. For instance, the hypothetical euro area bank has a higher impaired loan ratio than the hypothetical Japanese bank, pointing to a lower sensitivity to the US's central bank BSP for the euro area bank. The variables *CAR* and *DTA* together, however, point to higher sensitivity for the euro area bank than the Japanese bank. To reveal a clearer picture, we compute the elasticity of ΔL with respect to ΔFED using the estimation result for Model 4 for the two hypothetical banks. The euro area bank is found to have a lower elasticity (at 0.12) than the Japanese bank (at 0.23). The difference has economic significance, as it would imply that US dollar loans of the Japanese bank would increase by around 50% from the start of the expansion of the Fed's BSP compared to around 20% for the euro area bank (Figure A1).

Table A1: Median Value of Bank Characteristics for Euro Area Banks and Japanese Banks based on Estimation Sample in 2014

	USF	Dum(low CAR)	PLR	DTA	LTA
Euro area bank	0.048	0.518	0.340	0.067	0.208
Japanese bank	0.040	0.000	0.130	0.137	0.403

Figure A1: Differences in the Sensitivity to the Fed's Unconventional Monetary Policy between Japan's Banks and Euro Area Banks



APPENDIX 4: DETAILED DESCRIPTION OF THE MONTE CARLO SIMULATIONS

The procedure is illustrated using the case of Japanese banks. We first impose divergent central bank BSP shocks in the VAR model by considering simultaneously negative shocks to the Fed's balance sheet and positive shocks to the BOJ's balance sheet. Specifically, for the ΔFED_t and ΔHCB_t^{JP} equations, their innovation terms in each of the consecutive 12 months starting from January 2016 are assumed to be –1.2% and 0.53%, respectively. The central bank BSP shocks are set thus as the sum of innovation terms for the 12 months is consistent with the one-year standard deviation of the BSP shocks as identified in Figure 3. Innovation terms for other variables in the VAR model are obtained by the MC simulation method. Hence, in each simulation trial a 12-month simulated path for each of the ten variables of the VAR model can be obtained. We focus on the simulated paths for ΔFED_t,ΔHCB_t^{JP}, ΔCIP_t^{JP},ΔCDS_t^{JP}, and ΔEXR_t^{JP}, as these paths, together with the estimation results in Table 2, allow us to decompose the contribution of different factors to the supply of international dollar loans by Japanese banks under the divergence of BSP shocks of the Fed and BOJ. Based on the 10,000 simulation trials, we can compute the distributions for the four key variables in equation (1) that affect the supply of international dollar loans (i.e. ΔHCB_{jt}, ΔFED_t, ΔCIP_{jt-1}, and ΔCDS_{jt}) for Japanese banks.

We can further decompose the contribution of these factors to the supply of ΔL^*_{ijt} of Japanese banks by using the estimation results for Model 4 in Table 2. The contribution of a factor is obtained by multiplying the estimates in Table 4 by the corresponding estimated coefficients from Model 4 in Table 2 except for that of ΔFED_t.[14] Since the specification for Model 4 assumes that bank-specific balance sheet characteristics affect the transmission of central bank BSPs, the decomposition analysis needs assumptions on the value for the balance sheet characteristics for Japanese banks. We hence assume a hypothetical Japanese bank whose balance sheet characteristics are the average values of Japanese banks in the estimation sample for the period Q12014 to Q42014.

[14] The contribution of ΔFED_t is derived by multiplying the estimated coefficient on ΔFED_t *USF_j and the value of USF_j.