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INTERNATIONAL DOLLAR CREDIT**

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Asynchronous Monetary Policies and International Dollar Credit

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Abstract

This paper presents a theoretical model in which the supply of international dollar credit by a global bank is responsive to unconventional monetary policies (UMPs) both in the US and its home country, the functioning of the FX swap market and the bank's default risk. The theoretical model is tested using two unique confidential datasets. The results suggest that the contractionary effect of US monetary normalisation on global liquidity would be partly offset by the expansionary effect of UMPs in Japan and the euro-area. However, a stress testing exercise shows that global liquidity would be seriously disrupted if normalisation of monetary policy in the US leads to financial market dislocation, in particular in the FX swap market. Finally, this study finds that global banks' risk-taking attitude, credit risk exposure, and the business model of their overseas offices are important factors affecting how dollar credit supplied by international banks would respond to UMPs.

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The views expressed in this paper are those of the authors, and do not necessarily reflect those of the International Monetary Fund, the Hong Kong Monetary Authority, Hong Kong Institute for Monetary Research, its Council of Advisers, or the Board of Directors.

1. Introduction

The US dollar is the premier currency for international trade and investment. According to statistics from the Bank for International Settlements (BIS), more than 40% of international claims by banks were denominated in US dollars at the end of June 2014 (Figure 1). The supply of international dollar credit¹ is largely influenced by the behaviour of non-US international banks, particularly those headquartered in Europe and Japan (McCauley et al. 2014; Ivashina et al. 2015), as they intermediate the lion's share of such credit.

The strong presence of European and Japanese banks in the global 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 unconventional monetary policies (UMPs) in the US vis-à-vis the euro-area and Japan affect the supply of international dollar credit? Experience from the 2007-08 global financial crisis (GFC) showed that a global US dollar shortage could result in a drastic contraction of global liquidity, 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 and to hold financial assets.

Indeed, the tapering of the Fed's large-scale asset purchase programme in 2014 sparked concerns over a potential disruption to global liquidity (Aizenman et al., 2014; Eichengreen and Gupta, 2014; Mishra et al., 2014). However, as the Bank of Japan (BOJ) and the European Central Bank (ECB) have continued to expand their balance sheets through asset purchase programmes, there is a counter argument that Japanese and euro-area banks may help cushion US dollar liquidity, and thus the Fed's exit from its UMP would not necessarily lead to a significant contraction in global liquidity.

At the heart of this argument is that with the ample supply of home-currency liquidity provided by the BOJ and the ECB, Japanese and euro-area banks can continue to fund their international dollar credit through foreign exchange (FX) swaps, and this may ease at least partly the contraction in international dollar credit due to the Fed's exit. The net impact on the supply of international dollar credit, therefore, is undetermined in theory. In reality, however, determination of the net impact is much more complicated as factors other than UMPs are likely to play a role. In particular, as experienced during the GFC, the impairment of the FX swap market and heightened default risk of global banks contributed to a prolonged global US dollar shortage (Baba and Parker, 2009; McGuire and von Peter, 2009). More importantly, these factors may be also responsive to UMPs.

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

To broaden our understanding of these issues, this paper, drawing on the theoretical framework by Ivashina et al. (2015), presents a simple model to describe the theoretical linkage between the supply of international dollar credit of global banks, UMPs, the functioning of the FX swap market and banks' default risk. A testable empirical equation is derived from the model to help us answer the question of how asynchronous UMPs in the advanced economies affect the supply of international dollar credit. Our empirical analysis is conducted using two unique confidential datasets of banks' dollar-denominated international credit from the BIS and the Hong Kong Monetary Authority (HKMA). Our empirical approach is carefully chosen so that the effect of UMPs on the supply of international dollar credit can be disentangled from the demand-side effect. Specifically, we follow recent studies by Cetorelli and Goldberg (2011) and Aiyar et al. (2014) to apply the fixed-effects approach advocated by Khwaja and Mian (2008)² on the two datasets.

On the theoretical front, our framework contributes to a better understanding of the international spillover of UMPs through the bank lending channel. In particular, our model highlights that from a global bank's perspective, UMPs both in the US and in the home country measured by the size of the balance sheet of the respective central banks have an expansionary effect on the supply of international dollar credit when the bank deploys the resulting liquidity across countries in search of yield. This is consistent with the observation by Shin (2011) on the international spillover of the Fed's liquidity measures during the GFC through non-US global banks.

On the empirical front, our findings show that the expansionary effect of UMPs in the euro-area and Japan would only offset partially the contractionary effect of US monetary normalisation on global liquidity. The net impact, however, is critically dependent on whether the Fed's exit coincides with a switch to a risk-off regime and triggers financial market dislocation, particularly in the FX swap market. Our stress testing analysis shows that even if we assume that monetary policy paths in the US, the euro-area and Japan follow broadly their existing plans up to the end of 2015, there remains a small risk that the supply of international dollar credit declines especially if liquidity in the FX swap market decreases significantly during US monetary normalisation. Finally, we find that global banks' risk-taking attitude, credit risk exposure, and the business model of their overseas branches are important factors affecting the extent to which UMPs are transmitted internationally. This finding echoes the conclusion of Brunnermeier et al. (2012) that the financial and organisational structure of global banks plays a vital role in transmitting imbalances of cross-border funding flows and therefore requires careful regulatory attention.

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), which 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 Schnabel

² This approach identifies the supply effect using a special dataset 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-periods of liquidity shocks, any differences in loans provided to the same firm among banks are attributable to the supply effect.

(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, 2014; and Ivashina et al, 2015). A few recent studies examine how 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 unexplored research topic (McCauley et al, 2014).³ This paper attempts to broaden the scope of the theoretical and empirical literature.

The rest of the paper is organised as follows. Section 2 presents a theoretical framework. Section 3 discusses the empirical model for testing the theoretical framework and describes the two confidential datasets from the BIS and the HKMA used in estimation. Section 4 and 5 present empirical findings from the BIS and HKMA datasets respectively. Section 6 concludes.

2. The Theoretical Framework

Our model is modified from that developed by Ivashina et al. (2015). Consider a global bank that provides home-country currency loans (L) in the local market and US dollar loans (L^*) in the international market. 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 $g'(L^*) = \theta^* - \beta^* L^*$.

The bank is assumed to have 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 cost functions in the respective markets are assumed to be $c(F) = \alpha F^2/2$ and $l(F^*) = \alpha^* F^{*2}/2$ respectively, where α and $\alpha^* > 0$.

We assume that the bank cannot take any FX risk. So, for any level of dollar loans (L^*) exceeding D^* , the bank needs to raise dollar funding in the US (i.e. F^*) or converting its home-currency funding into US dollars in the FX swap market. For simplicity, we assume that the spot rate of the exchange rate between the home-currency and US dollars is equal to one. Denoting the amount of swaps in US dollars by S , an accounting identity for the bank's dollar loans can be derived: $L^* = D^* + F^* + S$. By the same logic, there is an accounting identity for the bank's home-currency loans: $L = D + F - S$.

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 2014) find that expansionary central bank balance sheet policies affect a broad range of asset prices in emerging markets. Fratzscher et al. (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.

Following Ivashina et al. (2015), we assume two additional cost components for dollar funding. First, the bank is assumed to have a default probability p and that the bank cannot pay off all its debt if it defaults. We further assume that all funding in the US market is not insured, while all home-currency funding is fully insured. As a result, fund providers in the US will demand a risk premium equivalent to p to compensate the bank's default risk. Second, in the FX swap market, if the bank converts its home-currency funding into dollars, a swap cost (w) is incurred.

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

$$\text{Max}\{L^*, L, F^*, F, S\}: h(L) - c(F) + g(L^*) - l(F^*) - pF^* - wS \quad (1)$$

subject to two constraints:

$$L^* = D^* + F^* + S \quad (2)$$

$$L = D + F - S \quad (3)$$

The last two terms in equation (1), 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:

$$h'(L) = c'(F) \quad (4)$$

$$g'(L^*) = h'(L) + w \quad (5)$$

$$g'(L^*) = l'(F^*) + p \quad (6)$$

Equation (4) simply states 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 (5) 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 (6) 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:

$$L^* = \frac{1}{\Omega} D + \frac{1}{\Omega} D^* - \frac{1}{\Omega \alpha^*} p - \frac{\alpha + \beta}{\Omega \alpha \beta} w - \frac{1}{\Omega \beta} \theta + \frac{1}{\Omega} \left(\frac{\alpha + \beta}{\alpha \beta} + \frac{1}{\alpha^*} \right) \theta^* \quad (7)$$

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

$$L^* = \beta_1 D + \beta_2 D^* + \beta_3 p + \beta_4 w + \beta_5 \theta + \beta_6 \theta^* \quad (8)$$

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^* (see further illustration in the next paragraph). This prediction is consistent with the hypothesis that UMPs in the US and the home country are determinants of the supply of dollar loans. Additionally, a higher default risk (higher p) or higher swap costs (higher w) increases the bank's dollar funding cost, thus 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.

The model prediction about how the supply of dollar loans of a global bank would react to UMPs can be described using the BOJ's quantitative and qualitative programme as an example. Suppose the BOJ purchased 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 . The model predicts that on the funding side, the bank will react by substituting part of the costly home-currency funding F by D , leading to a lower marginal cost of home-currency funding, i.e. $c'(F') = \alpha F' < \alpha F$, where F' is the new level of costly home-country funding.

On the asset side, the bank will increase its home-currency loans to L' until $h'(L') = c'(F') < c'(F)$ as implied by equation (4). Since home-currency funding can alternatively finance dollar loans through the FX swap market, and since the marginal return of home-currency loans must be equal to that of dollar loans minus the swap cost in equilibrium as stated by equation (5), the bank will increase its dollar loans to $L^{*'}$ where $g'(L^{*'}) = h'(L') + w < g'(L^*)$. Finally, equation (6) implies that the bank will substitute part of costly US dollar funding (F^*) by swap funding to finance its dollar loans. Specifically, the bank will reduce its costly US dollar funding to $F^{*'}$ until $g'(L^{*'}) = l'(F^{*'}) + p$.

The above example shows that a global bank transmits UMPs internationally through its profit-maximisation decisions on loan allocations. Indeed, the model also predicts that the Japanese bank would react similarly to a positive shock of D^* (i.e. US UMP), which is consistent with the observation by Shin (2011) that non-US global banks drew on dollar funding heavily from the emergency liquidity

provided by the Fed during the GFC through their branches in the US, and such dollar funding was then deployed internationally by their headquarters in search of yield.

3. The Empirical Model and Data

We aim to specify a regression model to test equation (8) using quarterly data on banks' dollar-denominated international credit. Two confidential datasets from the BIS and the HKMA are separately employed in empirical testing. Although these two datasets have a similar data structure, they differ in several ways (will be detailed later). Most notably, the former is only available at an aggregate level by nationality of banks, while the latter is more granular at the bank-level. Because of this, some variables in the regression analysis using the BIS dataset are defined differently from those using the HKMA dataset. The definition of variables for the two datasets are detailed in Appendix 1. Notwithstanding different definitions of variables, a regression model as specified by equation (9) can be estimated for the two datasets. For brevity, we discuss the model specification with reference to variables defined using the HKMA dataset:

$$\Delta L^*_{ijt} = \beta_1 \Delta HCB_{jt} + \beta_2 \Delta FED_t * USF_j + \beta_3 \Delta CDS_{jt} + \beta_4 \Delta CIP_{jt-1} + \beta_5 \Delta GDP_{jt} + \mu_{it} + \varepsilon_{ijt} \quad (9)$$

where ΔL^*_{ijt} is the quarterly growth rate of US dollar denominated loans to non-bank sectors in destination country i by global bank j from $t-1$ to t . Following the prediction of the theoretical model, ΔL^*_{ijt} is posited to be affected by liquidity shocks in the home-country of bank j . We proxy the size of home-country liquidity shocks by the quarterly growth rate of the central bank's balance sheet (in US dollars) in country j (ΔHCB_{jt}).

The size of liquidity shocks in the US (i.e. shock on D^*) is measured by the quarterly growth rate of the Fed's balance sheet (ΔFED_t). In addition, we assume that liquidity shocks in the US are distributed unevenly among global banks, with shocks 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 of 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 in 2012.⁵ 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 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

⁴ Although it may be argued that ΔFED may be sufficient to capture the pure effect of dollar liquidity without interacting with USF , technically ΔFED 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 construct the variable USF using data in 2012 (i.e. before the estimation period) to avoid a potential endogeneity issue between ΔL^* and USF as arguably more US dollar loans require more dollar funding from the US market.

ΔCIP and ΔL^* . To control for a demand shock for home-currency loans (i.e. θ), the growth rate of nominal GDP forecast for the home-country of bank j is included (ΔGDP_{jt}).⁶

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 (i.e. θ^*). μ_{it} is analogue of the borrower fixed effects adopted by Khwaja and Mian (2008) to absorb changes in demand conditions. 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.

3.1 The BIS Dataset

Our BIS dataset is constructed from the locational banking statistics by nationality. The BIS recently refined the data collection exercise; as a result, since the June 2012, a breakdown of the statistics by 12 core global bank nationalities is available for the BIS quarterly data on dollar-denominated external claims vis-à-vis 76 counterparty countries.⁷ The breakdown by nationality of reporting bank makes it possible to identify the effect of liquidity shocks in the home country on the supply of cross-border dollar credit by global banks. Despite the short sample period of this dataset (from June 2012 to March 2014), there are a sufficiently large number of observations (more than 4,000) to obtain reliable statistical results.

For estimations using the BIS dataset, L^* is defined as dollar-denominated cross-border claims on nonbanks. Cross-border claims reflect positions where the counterparty resides in a country that is different from where the banking office which books the claim is located. Claims consist of financial assets such as loans, debt securities, properties, and equities, including equity participation in subsidiaries (BIS, 2003). Breakdowns by types of claims, however, are not available for the BIS dataset.

3.2 The HKMA Dataset

The operation of foreign bank branches in Hong Kong provides a natural experiment setting to test the theoretical model, as most global banks have branches in Hong Kong: 44 of the top 50 global banking organisations had branch operations in Hong Kong 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

⁶ We use 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 et al. 2003).

⁷ The data are only available for central bank staff of the BIS reporting countries. The 12 core global bank nationalities are Belgium, Canada, France, Germany, Italy, Japan, the Netherlands, Spain, Sweden, Switzerland, the UK, and the US.

country and the US. The operation of foreign bank branches in Hong Kong can provide another perspective on how UMPs affect international dollar credit.

We build the HKMA dataset based primarily on data on foreign bank branches in Hong Kong, covering the period of 2007Q1 to 2014Q2. The data are from *the return of external positions*, which all banks in Hong Kong are required to file with the HKMA. Data reported by foreign bank branches reflect the sole position of the Hong Kong office's external claims vis-à-vis counterparty countries.

The analysis using the HKMA dataset complements that using the BIS dataset in three respects. First, the HKMA dataset provides a breakdown by type of claim. In the light of this, we are able to refine the definition of L^* to focus purely on bank loans, which are the most important form of bank intermediation. Specifically, we define L^* as dollar-denominated external loans to nonbanks provided by foreign bank branches in Hong Kong. Second, the HKMA dataset may allow us to capture a fuller effect of UMPs as it has a longer time span covering the period during which UMPs have been implemented. Finally, the granular bank-level information allows us to study how bank specific balance sheet factors, such as capitalisation and asset quality affects the propagation of UMPs. To this end, in the regression analysis we include parent-bank variables constructed using data from *Bankscope*⁸ and branch balance sheet variables.⁹

The estimation sample consists of 37 non-US foreign bank branches in Hong Kong. They are selected using the following criteria. We include all non-US foreign bank branches in Hong Kong that belong to global systemically important banks¹⁰, as they are presumably important vehicles for the propagation of shocks internationally. Branches with a significant scale of operations in Hong Kong (that is with an average size accounting for at least 0.5% of the total assets of all foreign branches in Hong Kong) are added. We exclude branches that did not operate over the full sample period. Branches for which parent-bank balance sheet variables are unavailable are excluded also. The aggregate assets of the estimation sample account for an average of 60% of the total assets of foreign bank branches in Hong Kong in the sample period. Table 1 details summary statistics for key variables for both the BIS and HKMA datasets.

4. Findings from the BIS Dataset

This section aims to answer empirically the core question of this study: how do asynchronous UMPs in the US vis-à-vis the euro-area and Japan affect the supply of international dollar credit? We first

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

⁹ Branch variables are constructed using data from *the return of Assets and liabilities* filed by foreign bank branches to the HKMA.

¹⁰ See Financial Stability Board (2013).

discuss the estimation result for equation (9) using the BIS dataset. A decomposition analysis based on the estimation results is then conducted to shed light on the question.

Table 2 presents the estimation results using the BIS data on dollar-denominated cross-border claims of non-US bank nationalities¹¹, which are broadly in line with the predictions of the theoretical framework.¹² The coefficients are statistically significant and with the expected signs. Most importantly, the results show that UMPs in the US and the home country have an expansionary effect on the supply of international dollar credit of global banks, suggesting there would be a significant international transmission of UMPs through the bank lending channel. Taking Japanese banks as an example, a 1% expansion of the BOJ's balance sheet would induce Japanese banks to increase the supply of cross-border dollar credit by 0.67%, while the same change in the Fed's balance sheet would increase the supply of cross-border dollar credit of Japanese banks by 0.87%.¹³

Regarding the effect of other factors, the results suggest that an increase in the spread between the FX-implied dollar interest rate and the US dollar LIBOR (i.e. the swap cost) by one standard deviation of the estimation sample (i.e. 10 basis points, see Table 1) would reduce the supply international dollar credit by around 2.5%, 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 credit significantly, with an increase in the CDS spread by one standard deviation (i.e. 30 basis points, see Table 1) reducing the supply of international dollar credit by 2.4%.

Based on the estimation results, we analyse how the supply of cross-border dollar credit by Japanese and euro-area banks to the Asia-Pacific region is affected by the asynchronous UMPs. These two groups of banks are selected because they are major providers of international dollar loans and are presumably most affected by the recent UMPs conducted by the BOJ and the ECB.

The objective of our analysis is to decompose the contribution of different factors to the supply of international dollar credit in the Asia-Pacific region for the two groups of banks. By comparing the contribution of UMPs by the Fed and the home-country central bank, we can gauge the net impact of asynchronous UMPs on the supply of international dollar credit. Before we detail the results, it is worth mentioning one caveat. Since our empirical model is estimated using a sample period only covering quantitative easing by major central banks, it is assumed that banks' responses to monetary policy

¹¹ Since the model is specified to identify the effect of the Fed's UMP (ΔFED) and that of home country central bank (ΔHCB), US bank nationality samples are excluded in the estimation as ΔFED and ΔHCB are identical.

¹² An alternative definition of USF is considered when conducting the regression. In particular, we define USF as US dollar external liabilities of global banks headquartered in country j vis-à-vis banks in the US divided by total external claims by country j . The new definition not only captures intragroup dollar funding from branches in the US, but also those from unrelated banks in the US. It should be noted that, however, "claims", by the BIS definition, are much broader than pure intra- and interbank loans. For example, claims include funds received by banks on a trust basis and securities issued by banks in their own names but on behalf of third parties. The estimation result is also consistent with the theoretical predication, except that the variable ΔCDS is found to be statistically insignificant.

¹³ We arrive the estimate based on the average USF for Japanese banks of 17.25% and the estimated coefficient on $FED*USF$ of 5.05. The 1% expansion in the Fed's balance sheet would increase the supply of cross-border dollar credit of Japanese banks by $1\%*0.1725*5.05=0.87\%$.

actions (easing versus tightening) as measured by changes in a central bank's balance sheet are symmetric.

We first estimate the size the balance sheet of the Fed, the BOJ and the ECB up to the end of 2015 based on available information regarding their UMPs. Figure 2, which summarises the results into estimated amounts of US dollars, shows that the Fed's balance sheet is broadly unchanged, while that of the BOJ increases by 80 trillion yen according to the QQE programme, translating into an average growth rate 6% in 2015. The ECB's balance sheet also increases by an amount of 720 billion euro in 2015, contributing to an average quarterly growth rate of 4.5%.

To form our baseline scenario, we further assume other factors follow their trends. The estimated contribution of different factors is shown in Figure 3. For the Japanese and euro-area banks, the Fed's UMP is found to be a major driver of their international dollar credit to the Asia-Pacific region in 2013, but the importance receded after the Fed started the tapering. UMPs in the home country, in turn, are estimated to be the principal factor sustaining the supply of dollar credit from 2014 for Japanese banks and 2015 for euro-area banks. The findings suggest that the contractionary effect of US monetary normalisation on global liquidity may be partly offset by an expansionary effect from a continued supply of US dollar credit from euro-area and Japanese banks.

One clear limitation of the above analysis is that we assume that movements in the swap cost, default risk of banks, and exchange rates follow their respective trends up to the end of 2015. However, it can be argued that theoretically, these factors would be significantly affected by UMPs. Normalisation of US monetary policy may reduce dollar liquidity in the FX swap market leading to higher swap costs. In turn, this could reduce the supply of international dollar credit. Meanwhile, a normalisation in US monetary policy together with an expansion of the balance sheets of home country central banks may lead the home currency to depreciate, partially offsetting the expansionary effect of UMPs in the home country on the supply of dollar credit.¹⁴ Therefore, apart from the direct effect of UMPs on the supply of international dollar credit, there would be significant indirect effects through its impact on swap costs, exchange rates, and possibly the default risk of banks.

In order to examine the significance of the indirect effects, we estimate two sets of first-order vector autoregressive (VAR) models for Japanese and euro-area banks respectively. Each VAR model includes five variables. The model for Japanese banks includes the quarterly growth rate of the BOJ's balance sheet in Japanese yen (ΔBOJ_t), the quarterly change in the average CDS spread for major Japanese banks (ΔCDS_t^{JP}), the quarterly change in the swap cost for converting Japanese yen into US dollars (ΔCIP_t^{JP}), the quarterly change in the spot exchange rate of Japanese yen against the US dollar (ΔJPY_t) and ΔFED_t . We restrict the model structure so that ΔBOJ_t and ΔFED_t are affected only

¹⁴ The exchange rate effect here refers to the impact on the size of liquidity shocks in the home country. Recall that in our empirical model, the size of liquidity shocks in the home country is proxied by the percentage change in size of the balance sheet of the home-country central bank in US dollars. By construction, depreciation of the exchange rate of home-currency against US dollars reduces the size of the liquidity shocks in the home country.

by their own lags, but there are no other restrictions on the other variables. We estimate the model using the seemingly unrelated regression method, which takes into account the contemporaneous correlation of error terms between the variables. Those regressors that are found to be statistically insignificant are dropped from the regression equations for ΔCDS_t^{JP} , ΔCIP_t^{JP} and ΔJPY_t . The model for euro-area banks is estimated in a similar fashion.

Tables 3 and 4 show the estimation results for Japanese and euro-area banks respectively. The estimation results support the conjecture that there would be significant indirect effects of UMPs on the supply of international dollar credit. Most notably, ΔFED_t is found to be negatively correlated with the swap cost for the two models.¹⁵ One implication of the estimation results in Tables 3 and 4 is that the baseline scenario estimates as presented in Figure 3 may be biased towards an overestimation of the supply of international dollar credit, as the estimation results suggest that normalisation of US monetary policy would lead to higher swap costs, which in turn could reduce the supply of international dollar credit.

In the final part of this section, we conduct a stress testing exercise to study how these indirect effects might contribute to the tail risks for the supply of international dollar credit. In essence, the exercise is similar to the baseline analysis, but differs in two respects. First, instead of assuming a deterministic path for the swap cost, default risk of banks and exchange rates, they are endogenously determined by the VAR models. Second, we focus on the tail risk rather than the expected estimate. Specifically, we employ a commonly adopted stress testing approach by central banks (Boss, 2002; Sorge and Virolainen, 2006), which uses Monte Carlo simulations to estimate the tail risk. This paper measures the tail risk by an expected shortfall estimate defined as the average estimated credit growth in the worst 10% of 10,000 trails.

The methodology is detailed in Appendix 2. Here, a brief discussion on the procedure for conducting the stress testing exercise is given using the case of Japanese banks. We impose the same assumption on the size of central bank balance sheets as we did for the baseline scenario. The only difference is that the path for the BOJ's balance sheets is now expressed in terms of Japanese yen instead of US dollars. Based on this assumption, we fix the paths for ΔFED_t and ΔBOJ_t , and using the estimation result for the VAR model presented in Table 3, we simulate 10,000 paths of other variables using the conventional Monte Carlo method.¹⁶ For each trail, we obtain a credit growth estimate by using the simulated values of the variables and the estimated coefficients presented in Table 2. Finally, we obtain the estimated expected shortfall by computing the average estimated credit growth in the worst 10% of 10,000 trails.

¹⁵ Apart from this, exchange rates are also found to be affected by UMPs: an expansion of the Fed's balance sheet would lead the exchange rate of yen against US dollars to appreciate (see Table 3); an expansion of the ECB's balance sheet would exert depreciation pressure on the exchange rate of euro against US dollars (see Table 4).

¹⁶ See Boss (2002) and Sorge and Virolainen (2006).

The estimation results for Japanese banks are presented in Panel A of Figure 4, and those for euro-area banks are presented in Panel B. The results show that mainly due to the indirect effects of UMPs through their impact on the swap cost, the supply of international dollar credit by Japanese and euro-area banks in 2015 would reduce notably, as compared to the baseline scenario estimates. The stress scenario analysis indicates that although UMPs in Japan and the euro-area would cushion the supply of international dollar credit, the net effect is crucially dependent on whether normalisation of liquidity in the US leads to serious financial market dislocation, especially in the FX swap market. A severe global dollar shortage is possible if the Fed's exit coincides with a risk-off phase for global investors. This suggests that funding liquidity risks associated with the flow of international US dollar credit can be high.

5. Empirical Evidence from the HKMA Dataset

In this section, we follow recent findings in the literature (Cornett, et al., 2011; Buch and Goldberg, 2014) to argue that global banks' balance sheet characteristics are an important factor affecting the extent of international transmission of UMPs. 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 (Figure 5). In particular, US dollar loans of Japanese banks branches exhibit a clear upward trend during the period of US UMP, while that of euro-area banks remained broadly unchanged prior to 2013. We hypothesise that the cross-sectional differences in US dollar loans among foreign bank branches in Hong Kong is partly attributable to differences in their parent-bank balance sheet characteristics and heterogeneous business models among branches in Hong Kong.

We start the analysis by estimating equation (9) using the HKMA dataset. The estimation results are presented in Model 1 in Table 5. The empirical results are broadly in line with the predictions of the theoretical model, although ΔCIP is found to be statistically insignificant. We modify the baseline model by adding an interaction term between ΔCIP and a crisis dummy variable¹⁷, $Dum(Crisis)$, and conjecture that ΔL^* is responsive to the functioning of the swap market only in crisis mode. The estimation results, which are presented in Model 2, are consistent with this conjecture.

Unlike Models 1 and 2 which assert a constant sensitivity of ΔL^* to US liquidity shocks across banks, we conjecture that the sensitivity of ΔL^* to US liquidity shocks would likely vary with banks' characteristics. We first investigate how parent-bank characteristics affect the sensitivity by specifying Model 3, which is a modified version of Model 2 and adds two variables.

The first parent-bank variable is constructed to reflect the attitude towards risk-taking. We gauge the attitude by looking at banks' capital adequacy ratios (CAR) before the GFC. A highly leveraged bank before the GFC (i.e. a lower CAR) may indicate that the bank would be more aggressive in making loans than their counterparts in response to US UMP. Thus, we include an interaction term between

¹⁷ Defined as one for observations for 2008Q3-2009Q1 and 2010Q2-2012Q1, and zero otherwise.

$\Delta FED*USF$ and a dummy variable for a low CAR in 2006¹⁸, $Dum(low\ CAR)$ in Model 3. The coefficient of the interaction term is expected to be positive.

The second parent-bank variable reflects the asset quality of the parent bank, which is proxied by a ratio of impaired loans to equity (PLR). Theoretically, a higher level of loan impairments (i.e. a higher PLR) would constrain the bank's lending capacity leading to a lower sensitivity of ΔL^* to US liquidity shocks. To test this hypothesis, we include an interaction term between $\Delta FED*USF$ and PLR in Model 3. We expect a negative estimated coefficient for this variable.

The estimation results for Model 3 suggest that parent-bank balance sheet characteristics play a significant role in determining the sensitivity of dollar loans of Hong Kong branches to US UMP. Specifically, a bank with greater willingness to take risk and with better asset quality tends to be more responsive to US UMP than other banks.

We further conjecture that the funding structure and the business model of Hong Kong branches are important determinants of the sensitivity of ΔL^* to US UMP. Models 4 and 5 are modified from Model 3 to test these conjectures respectively. In Model 4, we add a deposit-to-asset ratio of 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. Thus, the coefficient of the interaction term between $\Delta FED*USF$ and DTA is expected to be negative.

In Model 5, apart from the determinants considered in the previous models, we add an interaction term between $\Delta FED*USF$ and a loan-to-asset ratio of branch (LTA) and posit that if a branch is positioned as a lending unit, the branch's dollar loans may be more responsive to US UMP leading to a positive coefficient on the interaction term.

The estimation results for Models 4 and 5 support the conjecture that branch balance sheet characteristics affect the extent of transmission of UMPs, as the coefficients on the two branch variables are estimated with their expected sign. However, only the DTA is found to be statistically significant.

To assess the economic significance of the differences in the sensitivity of ΔL^* to US UMP, which arise from the balance sheet characteristics, we conduct a simple exercise based on the estimation result for Model 5. 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 6). As shown in Table 4, the two groups of banks have very different characteristics. For instance, the hypothetical euro-area bank has a higher impaired loan ratio than the hypothetical

¹⁸ Defined as one for banks that the average capital adequacy ratio in 2006 is lower than the 25th percentile, and zero otherwise.

Japanese bank, pointing to a lower sensitivity to US UMP 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 5 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 US's UMP compared to around 20% for the euro-area bank (Chart 6).

6. Conclusion

Monetary policy normalisation by the Fed and tighter US dollar liquidity conditions may potentially lead to a disruption of the supply of international US dollar loans. There is, however, a counter argument that when the ECB and the BOJ pursue UMPs, the continued supply of dollar funding from euro-area and Japanese banks through the FX swap market may cushion international US dollar funding liquidity.

This paper provides both theoretical and empirical findings to broaden our understanding on how a divergence of monetary policy paths in the US vis-à-vis the euro-area and Japan and the functioning of FX swap markets would affect the supply of international US dollar loans by global banks. Our findings support the view that the contractionary effect of US monetary normalisation on global liquidity would be partly offset by an expansionary effect from a continued supply of US dollar funding from euro-area and Japanese banks. The net effect, however, is crucially dependent on whether normalisation of liquidity in the US coincides with risk aversion by global investors and leads to serious financial market dislocation, in particular in the FX swap market. Specifically, our stress testing analysis shows that, even if we assume that monetary policy paths in the US, the euro-area and Japan follow broadly their existing plans up to the end of 2015, there remains a small risk that the supply of international US dollar credit declines especially if liquidity in the FX swap market decreases significantly as the US normalises monetary policy.

Finally, we find that global banks' risk-taking attitude, credit risk exposure, and the business model of their overseas branches are important factors affecting the extent to which UMPs are transmitted internationally. This finding echoes the conclusion of Brunnermeier et al. (2012) that the financial and organisational structure of global banks plays a vital role in transmitting imbalances of cross-border funding flows and therefore requires careful regulatory attention.

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Table 1. Summary Statistics for Key Variables

Summary statistics of variables for model using the BIS dataset

Variable	Unit	Mean	SD	25 th percentile	Median	75 th percentile
ΔLoan_{ijt}		0.034	0.640	-0.100	-0.001	0.122
ΔHCB_{jt}		-0.007	0.067	-0.039	0.001	0.016
ΔFED_t		0.056	0.036	0.036	0.071	0.082
USF_j	decimal point	0.136	0.097	0.038	0.096	0.194
$\Delta\text{FED}_t * \text{USF}_j$		0.007	0.008	0.002	0.006	0.013
ΔCDS_{jt}	decimal point	-0.002	0.003	-0.003	-0.001	0.000
ΔCIP_{jt-1}	decimal point	-0.001	0.001	-0.001	-0.001	0.000
ΔGDP_{jt}	decimal point	0.028	0.011	0.020	0.026	0.040

Note: Sample period: 2012Q2 – 2014Q2

Summary statistics of variables for model using the HKMA dataset

Variable	Unit	Mean	SD	25 th percentile	Median	75 th percentile
ΔLoan_{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
$\Delta\text{FED}_t * \text{USF}_j$		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
$\text{Dum}(\text{low CAR})^P_j$		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. $\text{Dum}(\text{low CAR}) = 1$ for banks with CAR at 25th percentile or below in 2006, high leverage.

Table 2. Estimation Result for the BIS Dataset

Variable	
ΔHCB_{jt}	0.67 *** (3.64)
$\Delta FED_t * USF_j$	5.05 *** (2.98)
ΔCDS_{jt}	-8.12 * (-1.81)
ΔCIP_{jt-1}	-24.92 ** (-2.05)
ΔGDP_{jt}	-3.73 *** (-3.79)
Country-time fixed effects for destination country <i>i</i>	Yes
R-squared	0.12
RMSE	0.63
No. of observations	4,577

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.

Table 3. SUR Estimates of Macro-Stress Testing Models for Japanese Banks

Variable	ΔBOJ_t	ΔFED_{t-1}	$\Delta\text{CDS}_t^{\text{JP}}$	$\Delta\text{CIP}_t^{\text{JP}}$	ΔJPY_t
ΔBOJ_{t-1}	-0.18 ** (-2.52)				
ΔFED_{t-1}		0.37 *** (5.69)		-0.03 *** (-8.56)	-10.06 ** (-2.32)
$\Delta\text{CDS}_{t-1}^{\text{JP}}$			-0.16 * (-1.87)		
$\Delta\text{CIP}_{t-1}^{\text{JP}}$				-0.87 *** (-17.56)	
ΔJPY_{t-1}					
Constant	0.01 *** (2.70)	0.01 ** (2.17)	0.00 (0.46)	0.00 *** (2.18)	0.12 (0.56)
R-squared	0.03	0.15	0.01	0.55	0.03
DW statistic	1.95	1.90	1.93	1.96	1.95
No. of observations	190	190	132	178	176

Notes:

1. $\Delta\text{CDS}_t^{\text{JP}}$ refers to the change in the average CDS spread for the major Japanese banks.
2. $\Delta\text{CIP}_t^{\text{JP}}$ refers to the change in the deviation from covered interest parity for converting Japanese Yen into US dollars.
3. ΔJPY_t refers to the change in the yen/USD spot exchange rate.
4. Apart from spot exchange rate, all variables are measured in decimal points.
5. Figures in parentheses are t-statistics.
6. ***, **, and * respectively indicate significance at the 1%, 5%, and 10% level.

Table 4. SUR Estimates of Macro-Stress Testing Model for Euro-Area Banks

Variable	ΔECB_t	ΔFED_{t-1}	ΔCDS_t^{EA}	ΔCIP_t^{EA}	ΔEUR_t
ΔECB_{t-1}	0.10 (1.58)				0.13 *** (2.67)
ΔFED_{t-1}		0.37 *** (5.75)		-0.01 *** (-4.30)	
ΔCDS_{t-1}^{EA}			-0.16 * (-1.94)		
ΔCIP_{t-1}^{EA}				-0.73 *** (-13.41)	
ΔEUR_{t-1}					
Constant	0.01 *** (2.85)	0.01 ** (2.20)	0.00 (0.18)	0.00 (0.96)	0.00 (-1.20)
R-squared	0.01	0.15	0.003	0.26	0.04
DW statistic	1.89	1.90	1.91	1.51	2.00
No. of observations	190	190	132	178	176

Notes:

1. ΔCDS_t^{EA} refers to the change in the average CDS spread for the major euro-area banks.
2. ΔCIP_t^{EA} refers to the change in the deviation from covered interest parity for converting euro into US dollars.
3. ΔEUR_t refers to the change in the EUR/USD spot exchange rate.
4. Apart from spot exchange rate, all variables are measured in decimal points.
5. Figures in parentheses are t-statistics.
6. ***, **, and * respectively indicate significance at the 1%, 5%, and 10% level.

Table 5. Estimation Result for the HKMA Dataset

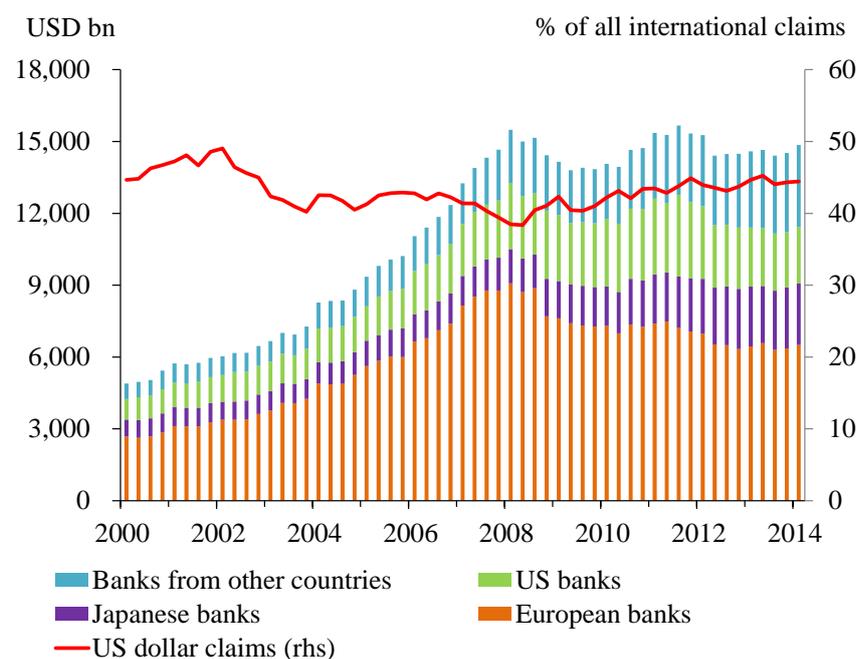
Model	Model 1 Base case	Model 2 with a crisis dummy for $\Delta CIP_{j,t-1}$	Model 3 with parents' characteristics	Model 4 with branches' deposit-to- asset ratios	Model 5 Full model
ΔHCB_{jt}	0.30 ** (2.48)	0.31 ** (2.52)	0.31 ** (2.33)	0.33 ** (2.30)	0.32 ** (2.25)
$\Delta FED_t * USF_j$	3.15 * (1.70)	3.05 * (1.73)	6.53 *** (3.48)	12.89 *** (4.39)	10.40 *** (3.77)
ΔCDS_{jt}	-9.13 ** (-2.71)	-9.42 *** (-2.85)	-9.73 ** (-2.54)	-9.28 ** (-2.32)	-10.10 ** (-2.55)
ΔCIP_{jt-1}	0.88 (0.34)	4.78 (1.38)	5.38 (1.57)	5.04 (1.47)	4.99 (1.41)
$\Delta CIP_{jt-1} * Dum(Crisis)_t$		-13.42 * (-2.02)	-13.60 ** (-2.03)	-12.48 * (-1.84)	-12.75 * (-1.88)
ΔGDP_{jt}	-0.31 (-0.78)	-0.33 (-0.84)	-0.51 (-1.25)	-0.55 (-1.39)	-0.42 (-1.29)
$\Delta FED_t * USF_j * Dum(low CAR)_j^P$			7.07 * (1.99)	7.24 ** (2.10)	6.71 ** (2.06)
$\Delta FED_t * USF_j * PLR_{jt-1}^P$			-31.57 * (-1.94)	-40.29 *** (-2.82)	-33.35 ** (-2.30)
$\Delta FED_t * USF_j * DTA_{jt-1}^B$				-22.71 ** (-2.23)	-22.13 ** (-2.13)
$\Delta FED_t * USF_j * LTA_{jt-1}^B$					6.65 (0.71)
<u>Control variables</u>					
$Dum(low CAR)_j^P$			-0.01 (-0.23)	-0.01 (-0.30)	-0.01 (-0.32)
PLR_{jt-1}^P			-0.01 (-0.09)	0.01 (0.09)	-0.05 (-0.58)
DTA_{jt-1}^B				0.04 (0.73)	0.04 (0.78)
LTA_{jt-1}^B					-0.23 *** (-3.02)
Country-time fixed effects for destination country i					
	Yes	Yes	Yes	Yes	Yes
R-squared	0.2802	0.2811	0.2830	0.2852	0.2881
RMSE	0.4414	0.4413	0.4477	0.4472	0.4465
No. of observations	2,637	2,637	2,547	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.

Table 6. 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

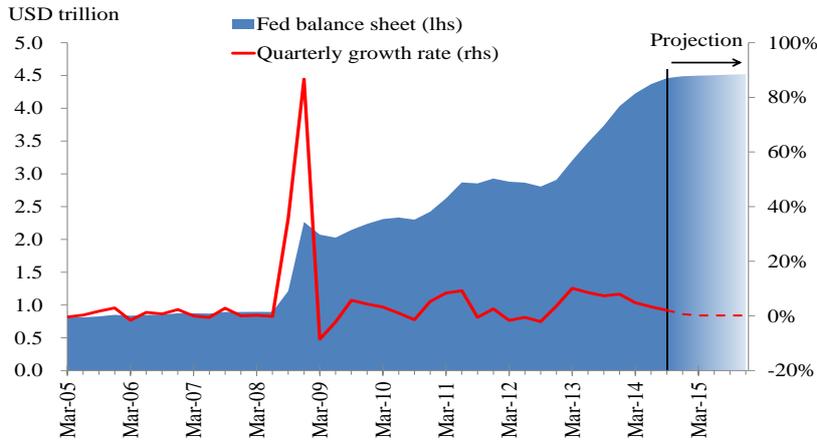
Figure 1. US Dollar International Claims by Nationality of Banks**Notes:**

1. The claims are vis-à-vis all sectors and include interoffice claims of banks.
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.

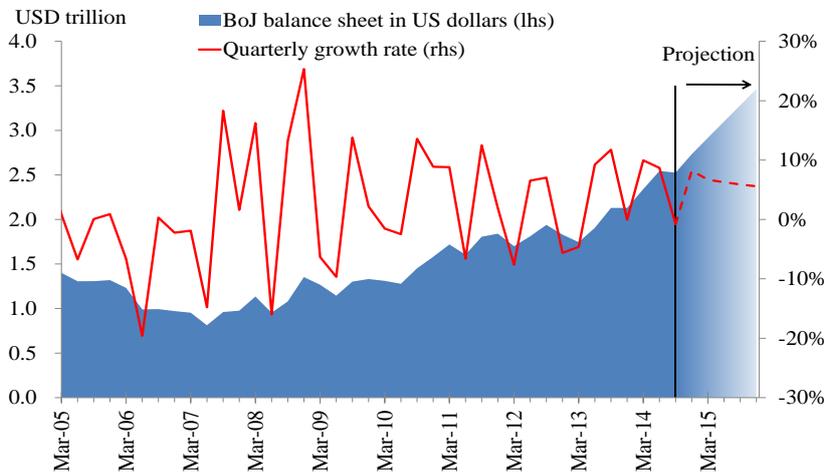
Source: BIS locational banking statistics (by nationality).

Figure 2. Assumptions on Central Bank Balance Sheets

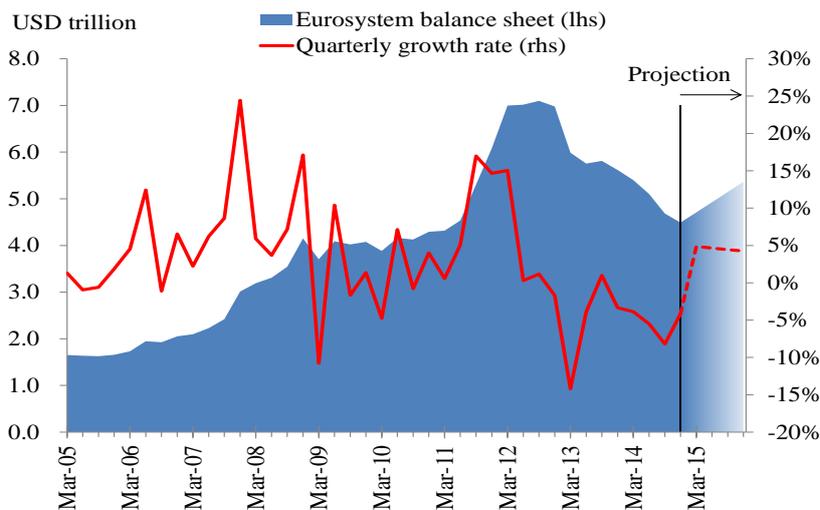
Panel A: Fed's balance sheet



Panel B: BOJ's balance sheet

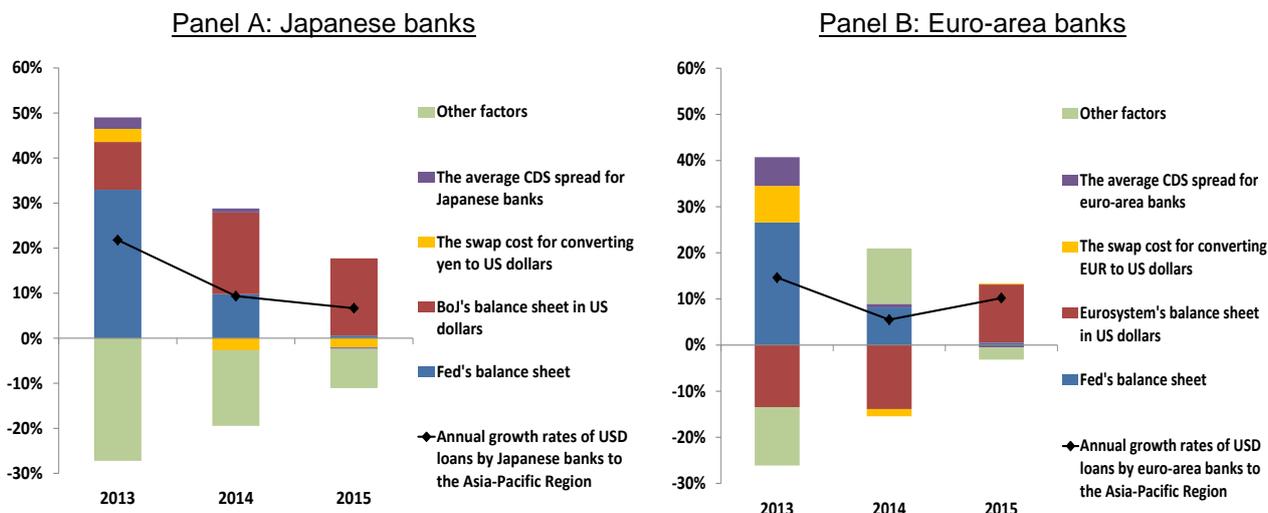


Panel C: Eurosystem's balance sheet



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

Figure 3. Estimated Contribution by Factors to the Growth Rate of US Dollar Loans of Japanese Banks and Euro-Area Banks to the Asia-Pacific Region



Notes:

1. The growth rates of US dollar loans before 2014 Q3 are computed based on actual data, while the results thereafter are generated based on the estimated contribution by the respective factors.
2. The Fed's balance sheet is assumed to increase at the long-run trend rate from 2014 Q4 onwards and financial assets held by the Fed with a remaining maturity below 1 year are assumed to be matured by the end of 2015.
3. The BOJ's balance sheet is assumed to expand at an annual pace of 80 trillion yen from Nov 2014 onwards, consistent with its latest QQE plan introduced in Oct 2014. The size of the BOJ's balance sheet is converted into US dollars in estimation.
4. The exchange rate of yen/USD is assumed to be unchanged since 2014 Q3.
5. The change of swap cost and that of the average CDS spread for Japanese banks since 2014 Q3 are assumed to follow the respective trends in the recent 4 quarters.

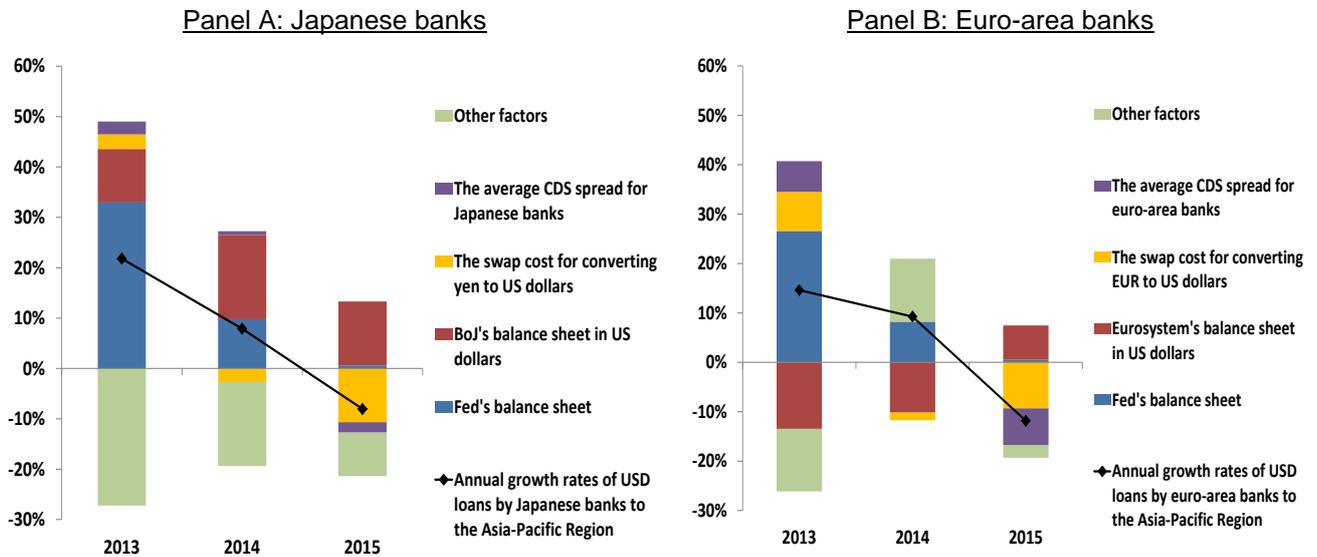
Source: Author estimates.

Notes:

1. The growth rates of US dollar loans before 2014 Q3 are computed based on actual data, while the results thereafter are generated based on the estimated contribution by the respective factors.
2. The Fed's balance sheet is assumed to increase at the long-run trend rate from 2014Q4 onwards and financial assets held by the Fed with a remaining maturity below 1 year are assumed to be matured by the end of 2015.
3. The Eurosystem's balance sheet is assumed to expand at a monthly pace of 60 billion euro from Jan 2015 onwards, consistent with its latest asset purchase programme introduced in Jan 2015. The size of the Eurosystem's balance sheet is converted into US dollars in estimation.
4. The exchange rate of EUR/USD is assumed to be unchanged since 2014 Q4.
5. The change of swap cost and that of the average CDS spread for euro-area banks since 2014 Q3 are assumed to follow the respective trends in the recent 4 quarters.

Source: Author estimates.

Figure 4. Estimated Contribution by Factors to the Growth Rate of US Dollar Loans of Japanese Banks and Euro-Area Banks to the Asia-Pacific Region under a Stress Scenario



Notes:

1. The growth rates of US dollar loans before 2014 Q3 are computed based on actual data, while the results thereafter are generated based on the estimated contribution by the respective factors.
2. For assumptions on the balance sheets of the Fed and BOJ, see footnotes 2 and 3 under Panel A of Figure 3 respectively.
3. From 2014 Q4 onwards, the exchange rate of yen/USD, the change of swap cost for Japan and the average CDS spread for Japanese banks are assumed to follow the stress scenario paths simulated under the macro-stress testing model presented in Table 3. The Monte Carlo simulation method is adopted to generate the stress scenario paths for the respective factors.

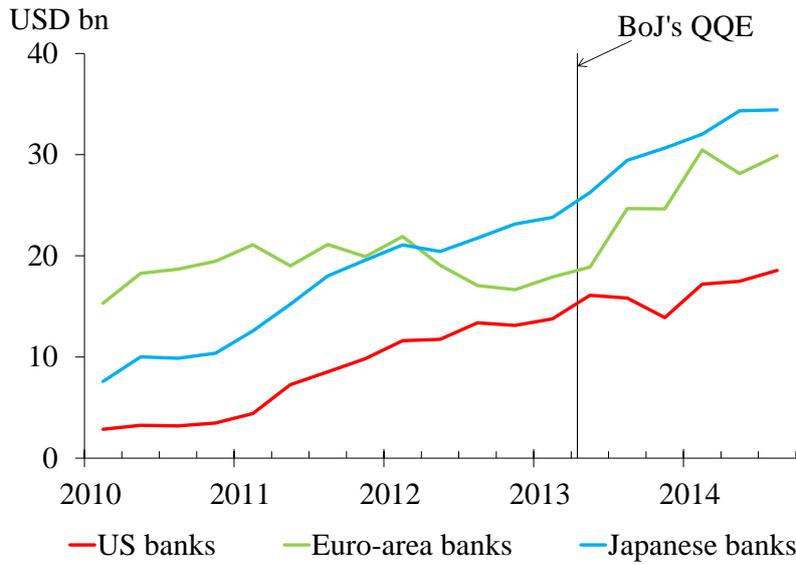
Source: Author estimates.

Notes:

1. The growth rates of US dollar loans before 2014 Q3 are computed based on actual data, while the results thereafter are generated based on the estimated contribution by the respective factors.
2. For assumptions on the balance sheets of the Fed and Eurosystem, see footnotes 2 and 3 under Panel B of Figure 3 respectively.
3. From 2014 Q4 onwards, the exchange rate of EUR/USD, the change of swap cost for euro-area and the average CDS spread for euro-area banks are assumed to follow the stress scenario paths simulated under the macro-stress testing model presented in Table 4. The Monte Carlo simulation method is adopted to generate the stress scenario paths for the respective factors.

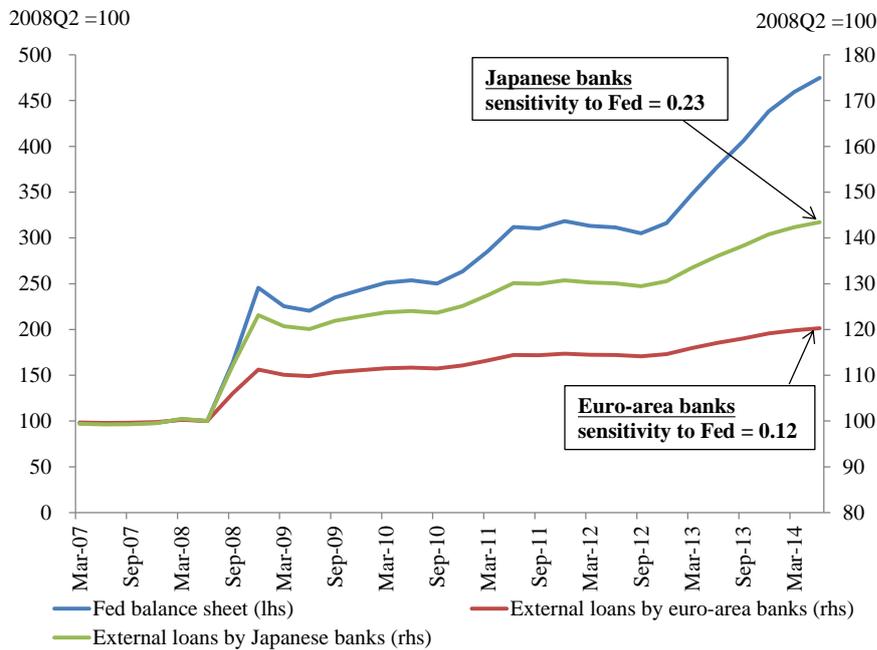
Source: Author estimates.

Figure 5. US Dollar Loans of Foreign Bank Branches in Hong Kong by Selected Nationalities



Source: HKMA.

Figure 6. Differences in the Sensitivity to the Fed's Unconventional Monetary Policy between Japanese Banks and Euro-Area Banks



Source: Author estimates.

Appendix 1. Description of Variables

Variable	Description	Source
$Loan_{ijt}$	For the models using the BIS dataset, the quarterly growth rate of cross-border claims to nonbank denominated in the US dollar to a destination country i by the global banks headquartered in country j . For the models using the HKMA dataset, the quarterly growth rate of external loans to nonbank denominated in the US dollar to a destination country i by the Hong Kong branch of global bank j . The data are from <i>the return of external positions</i> .	BIS locational banking statistics (by nationality) HKMA
USF_j	For the models using the BIS dataset, the ratio of total funding raised by US branch of global banks headquartered in country j to total external claims by country j in 2012Q2. For the models using the HKMA dataset, 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
$\Delta FED_t * USF_j$	The product term of growth rate of the Fed's balance sheet (ΔFED_t) and bank j 's reliance of dollar funding from the US market (USF_j) to proxy liquidity shocks in the US for bank j (Proxy for ΔD_{jt}^*).	Author's calculations
ΔHCB_{jt}	The growth rate of the central bank's balance sheet in country j to proxy liquidity shocks in country j (Proxy for ΔD_{jt})	IMF International Financial Statistics and national central banks
ΔCDS_{jt}	For the models using the BIS dataset, the change in the average CDS spread for the major banks in country j to proxy the default risk of banks headquartered in country j (Proxy for ΔP_{jt})	Bloomberg

	For the models using the HKMA dataset, the change in the CDS spread for bank j to proxy the default risk of bank j (Proxy for ΔP_{jt})	
ΔCIP_{jt-1}	The change in the deviation from covered interest parity for converting country j 's currency (the country of headquarter of bank j) into the US dollar in $t-1$ to gauge the change of swap cost. (Proxy for ΔS_{jt-1})	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 (Proxy for θ)	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 that the average capital adequacy ratio in 2006 is lower than the 25 th 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 branch's customer deposits divided by Hong Kong branch's total assets. The data are from the return of external positions.	HKMA
LTA_{jt}^B	Hong Kong branch's loans and advances to customers divided by Hong Kong branch's total assets. The data are from the return of external positions.	HKMA

Appendix 2. The Methodology for Stress Testing Global Banks' International Dollar Loan Supply

This appendix illustrates the methodology for stress testing global banks' dollar loan supply (ΔL_{ijt}^*) based on the econometric model developed in Section 3 (i.e. eq. (9)). The stress testing framework facilitates the examination of both direct and indirect effects of UMPs (through the interaction with other financial market variables) on global banks' dollar loan supply. The stress testing framework consists of two parts: (1) a system of econometric models for determining ΔL_{ijt}^* and characterising the dynamics of the determinants, and (2) a Monte Carlo simulation for generating distributions of ΔL_{ijt}^* . In essence, the stress testing framework employed in this study is a simplification of the work by Boss (2002) and Sorge and Virolainen (2006).

Similar to their frameworks, we consider five economic variables which are the main determinants of global banks' supply of dollar loans as presented in eq. (9) for the stress testing analysis.¹⁹ For the case of Japanese banks, the five variables are the quarterly growth rate of the BOJ's balance sheet in Japanese yen (ΔBOJ_t), the quarterly change in the average CDS spread for major Japanese banks (ΔCDS_t^{JP}), the quarterly change in the swap cost for converting Japanese yen into the US dollar (ΔCDS_t^{JP}), the quarterly change in the spot exchange rate of Japanese yen against the US dollar (ΔJPY_t)²⁰ and the quarterly growth rate of the Fed's balance sheet (ΔFED_t).²¹

To capture the interdependence of these five variables (henceforth referred to as "risk factors"), it is assumed that they would follow a first-order vector autoregressive (VAR) process:

$$X_t = \Phi_0 + \Phi_1 X_{t-1} + E_t \quad (A1)$$

where

$$X_t = \begin{bmatrix} \Delta BOJ_t \\ \Delta FED_t \\ \Delta CDS_t^{JP} \\ \Delta CIP_t^{JP} \\ \Delta JPY_t \end{bmatrix} \text{ and } E_t \sim N(0, \Sigma)$$

¹⁹ We include all the explanatory variables as shown in eq. (9), with the exception of the growth rate of nominal GDP forecast for country j .

²⁰ In contrast to the assumption of the baseline scenario where the exchange rate of home currency against US dollars is assumed to stay unchanged since 2014 Q3, it is postulated that the spot exchange rate of home currency against US dollars would be affected by UMPs.

²¹ The model for euro-area banks is constructed and estimated in a similar fashion.

X_t is an 5×1 vector of risk factors, Φ_0 is a 5×1 vector of intercepts, Φ_1 are 5×5 coefficient matrices and E_t is a 5×1 vector of error terms. Σ is the variance-covariance matrix of the error terms in which the interdependences of shocks in the risk factors are taken into account.

Eq. (A1) is estimated using the seemingly unrelated regression (SUR) method, which takes into account the contemporaneous correlation of error terms between the risk factors. We also restrict the model structure that ΔBOJ_t and ΔFED_t are affected only by their own lags, but there is no restriction for other variables. Furthermore, those regressors that are found to be statistically insignificant are dropped from the regression equations for ΔCDS_t^{JP} , ΔCIP_t^{JP} and ΔJPY_t . Table 3 shows the estimation result of eq. (A1) for Japanese banks.²²

The estimated VAR model for characterising the dynamics of the risk factors and the resulting Σ , together with the econometric model for determining ΔL_{ijt}^* (shown in Table 2) facilitate the simulation analysis under the assumed path of shocks on ΔBOJ_t and ΔFED_t . As the dependences among individual risk factors are accounted for in the framework through the term Σ , the extent to which shocks on ΔBOJ_t and ΔFED_t affects ΔL_{ijt}^* not only depends on the direct effect but also on the indirect effect of other risk factors due to their responses to the shock. This enables us to examine both direct and indirect effects of UMPs on international dollar credit.

To examine how the direct and indirect effects of UMPs would contribute to the tail risk for the supply of international dollar credit, one would need to compute the paths for other risk factors originated from the shock on UMPs under a stress scenario. In the following, we describe the procedure for computing the simulated future paths of other risk factors under a stress scenario:

1. Based on the estimation result of (A1) and taking the latest values of risk factors as the current states, a Monte Carlo simulation²³ is applied under the assumed deterministic paths of ΔBOJ_t and ΔFED_t to simulate their future values over a one-year horizon.
2. By repeating the simulation for 10,000 trials, 10,000 simulated paths for each of the respective risk factors are obtained under the assumed paths of central banks' balance sheet growth.
3. Using the estimation result of the econometric model for ΔL_{ijt}^* (Table 2), the distributions of the estimated dollar loan growth can be constructed based on the 10,000 simulated paths of various risk factors.

²² The estimation result for euro-area bank is shown in Table 4.

²³ Technical details of the Monte Carlo simulation can be found in Boss (2002) and Sorge and Virolainen (2006).

4. We then define the stress scenario as the simulation of risk factors that would cause the estimated dollar loan growth falling within the worst ten percentile of the distribution. The stress scenario paths for ΔCDS_t^{JP} , ΔCIP_t^{JP} and ΔJPY_t are computed by taking the average of the selected simulated paths for each of the risk factors under the stress scenario.