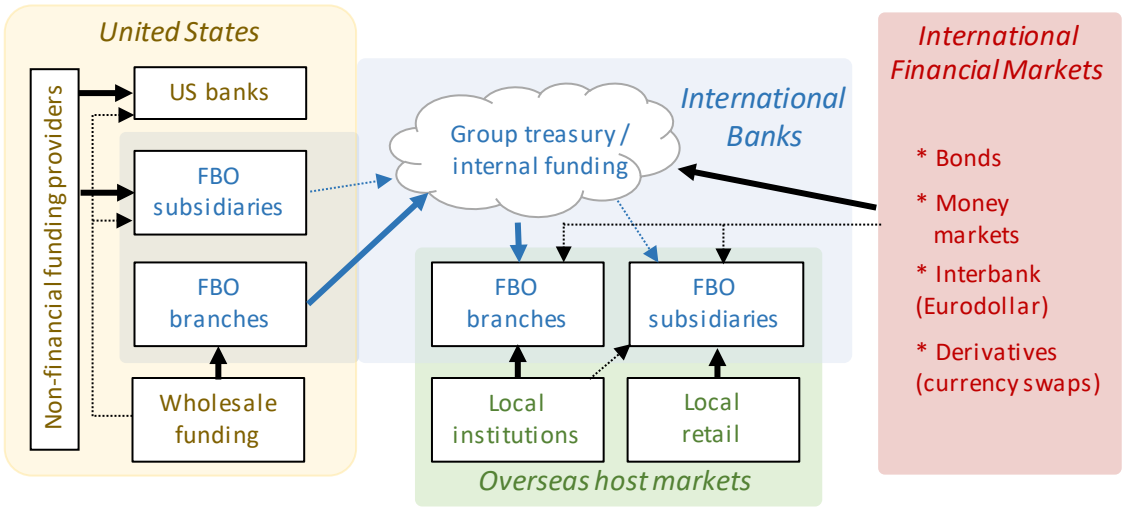
ONLINE ANNEX 5.1. NON-US BANKS' USD FUNDING: MECHANICS AND STABILITY IMPLICATIONS

Chapter 5 of the October 2019 Global Financial Stability Report (GFSR) documents rising US dollar intermediation by non-US banks (see Figure 5.1). This phenomenon appears rooted in both demand and supply drivers. Corporate borrowers may prefer to borrow in dollars since the bulk of international trade, and therefore of trade finance, is denominated in dollars. Non-US international banks collectively dominate bank intermediation of US dollar credit outside the United States because, for many, international dollar lending is more profitable than their low-margin domestic businesses. The chapter documents how international banks' US dollar funding stress has been related to broader financial system stress.

This annex attempts to explain how stress episodes relate to the 'plumbing' that generates dollar funding for non-US banks' dollar-denominated business outside the United States. This plumbing is broadly illustrated in Online Annex Figure 5.1.1.

Stable dollar-denominated savings (persistent and relatively insensitive to financial risk and return signals) reside mainly in the United States, and mainly in households. These savings are in principle adequate to meet the international demand for dollars. However, the bulk of these savings are in practice confined to the United States by regulation.[1]

Online Annex Figure 5.1.1. International Non-US Banks' Dollar Funding Channels



Note: Black arrows indicate 'open market' funding sources; blue arrows are intra-group flows. Thick solid arrows indicate major channels; dotted arrows are smaller and less significant. Channels FBO = Foreign Banking Organization.
Source: IMF staff analysis.

[1] Regulation Q prevents banks from deploying insured deposits outside the United States. Almost every jurisdiction similarly 'ring-fences' insured deposits in this way.

Non-US banks therefore either tap international market instruments or seek to fund their operations locally in the economy where the loan is booked. The latter is often difficult due to insufficient foreign currency savings and the international banks' limited local funding relationships.

Banks seeking dollars outside the United States therefore rely heavily on international financial markets. This funding—interbank markets, money markets, debt capital markets and derivative markets—is either expensive (for example, long-tenor bonds) or is short-tenor and requires frequent refinancing. Refinancing (rollover) risk is particularly concerning since these instruments are chronically susceptible to fluctuations in international investors' investment preferences and risk appetite. When yields in the US rise or international risk appetite diminishes, these sources become more expensive and their supply highly inelastic, with volumes well below international banks' funding demands.

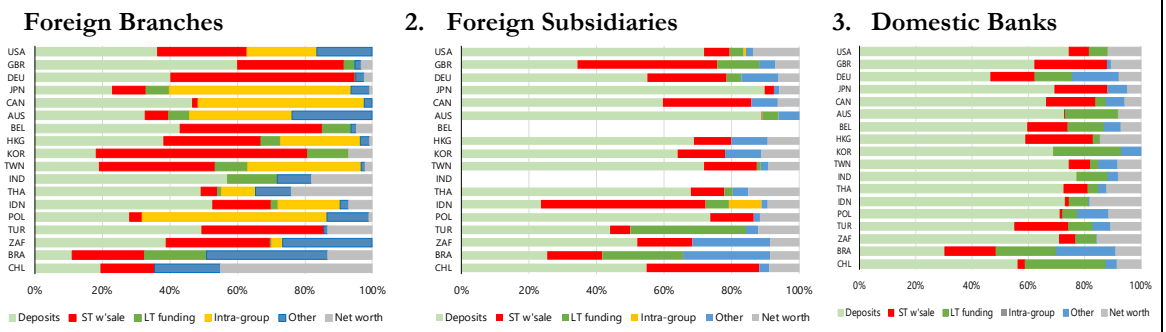
As wholesale markets for on-balance sheet foreign currency funding are exhausted, non-US banks turn increasingly to the least attractive and most 'marginal' funding source—cross-currency swaps. These swap contracts, mainly at short-tenors, are in most cases priced at premium cost to interbank cash in the same currency and of equivalent tenor. This premium, which gauges willingness to pay for marginal funding and therefore reflects tightness in overall funding conditions, is captured by the 'cross-currency basis', which serves as a proxy for marginal US dollar funding costs throughout the chapter.

Banks can obtain wholesale funding in the economy where it is needed in one of two ways. The local operation can in principle tap international markets directly. In practice, though, international investors often prefer to lend to legal entities in the bank's headquarters economy or other large financial centers. In these cases, the international bank transfers liquidity through intra-group treasury operations and cross-border transactions (represented by the orange segments of the bars in Online Annex Figure 5.1.2).

International banks' operations in economies around the world can assume one of two forms—branches or subsidiaries. Branch offices, which are legally subsumed within an overseas parent, more readily transact with overseas affiliates and therefore better provide the flexibility needed in wholesale and corporate banking operations, including the bulk of foreign currency intermediation. However, these branches are generally prevented from tapping insured retail and so are heavily dependent on uninsured (wholesale or corporate) deposits, short-term wholesale funding sourced direct from market instruments (the red segment in the bars below) or funding raised by the overseas banking group and transferred intra-group into the branch (the orange segment). The latter two sources together represent a high proportion of foreign branches' total funding in most economies—the bulk of foreign currency intermediation rests on stress-prone funding mechanisms (Online Annex Figure 5.1.2, panel 1). Subsidiaries, local legal entities able to tap insured deposits but restricted from transferring funding across borders, fund themselves more like local banks (Online Annex Figure 5.1.2, panels 2 and 3).

Online Annex Figure 5.1.2. Liabilities Structure: Average by Booking Economy (Locational Basis), by Category of Institution

(Percent of total liabilities, end-2018)



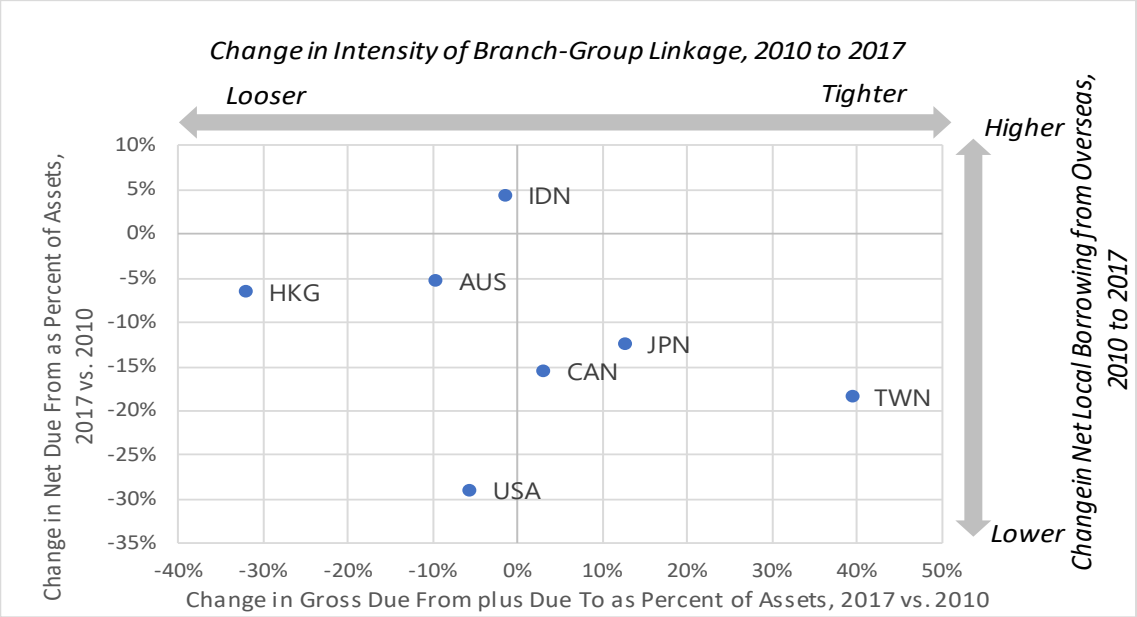
Note: Booking economy is the domicile of the operation, whether a branch or subsidiary, where balances are booked. Data on intra-group assets and liabilities is unavailable for the United Kingdom, Germany, Belgium, Korea, India, Turkey, Brazil and Chile.
Sources: National Central Banks and Supervisory Authorities; Haver Analytics; CEIC; and IMF staff estimates and analysis. ST=short-term; LT=long-term

Over the past few years, bank managers responsible for international cash management and funding have become increasingly concerned that branch operations' access to intra-group liquidity management may become more restricted. This creeping 'subsidiarization' may follow from regulators' desire to shield entities under their supervision from cross-border spillovers should a bank's overseas operations fail. Global standard-setters, particularly the Basel Committee for Banking Supervision, and national regulators and supervisors may be gradually tightening intra-group channels through liquidity regulations, insolvency regimes and other (formal or informal) mechanisms intended to protect the viability of operations in each jurisdiction (Beck and others 2015; BOE 2016; Federal Reserve 2014 and 2019; FSB 2014; Gambacorta and van Rixtel 2013; Goldberg and Gupta 2013; IIF 2019; Quarles 2018; The Economist 2013; and United Nations 2014;).

Increasing restrictions on intra-group channels would be reflected in the admittedly sparse data on international banks' national branch 'due from' and 'due to' accounts. The evidence weakly supports these concerns. Branch operations are generally shifting toward higher net borrowing (lower net 'due from' or higher net 'due to') from their related parties overseas[2]. (Vertical axis of Online Annex Figure 5.1.3) This may reflect either a reduction in branches' access to market sources of liquidity relative to their funding needs and consequent need to borrow more internally. Alternatively, it may indicate that host supervisors are enjoying some success in their reported objective reduce branches' exposure to potential default by international banks' operations outside the host economy.

[2] 'Net due from' indicates the branch's net lending position (i.e., lending to overseas affiliates, less borrowing from overseas affiliates). A negative value indicates that a branch borrows more from than it lends to overseas affiliates. A negative value in the change of net due from position, therefore, indicates an increase in the branch's level of net borrowing from overseas affiliates, expressed as a percentage of assets.

Online Annex Figure 5.1.3. Change in the Characteristics of Intragroup Relationships–Branches in Selected Host Economies (Locational Basis), 2017 vs. 2010



Sources: National Central Banks and Supervisory Authorities; Haver Analytics; CEIC; and IMF staff estimates and analysis.

Banks' concern that regulators are shrinking overall cross-border intra-group cash management channels is less obvious from available data. This would appear as a decline in the gross (absolute) value of branches' due from and due to balances, relative to branches' total assets (Online Annex Figure 5.1.3, horizontal axis). However, in Japan and, most notably, in Taiwan Province of China branch connectedness with overseas related parties has risen, contrary to the postulated fragmentation of banks' international cash management networks. However, any 'subsidiarization' is nascent in most economies and so may be difficult to detect. The recent decline in gross net due from and due to positions by foreign banks' in the United States (generally regarded as a proponent of stricter supervision) may be a leading indicator of future developments.

Either restriction on intragroup channels—economic branches' greater net borrowing from overseas or shrinking overall cross-border funding —would suggest that branches must in the future maintain more 'precautionary' US dollar liquidity relative to their funding commitments—a development consistent with the rising estimated US dollar liquidity ratios.[3] While this push for greater US dollar liquidity in non-US banks' operations outside the United States is generally positive for global financial stability, it also increases banks' effective demand for US dollar funding and therefore further pressures the dollar supply-demand balance. Non-US banks are in effect accumulating greater persistent US dollar liquidity on the balance sheets of individual foreign bank offices to compensate for reductions in the mobility of dollar funding across economies.

[3] As documented in this chapter and in Chapter 2 of the October 2018 *Global Financial Stability Report.*

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ONLINE ANNEX 5.2. ECONOMETRIC METHODOLOGY

1. DEFINITION AND DRIVERS OF THE CROSS-CURRENCY BASIS (CCB)

a. Definition

Following Du and others (2018), $y^{\$}_{t,t+n}$ and $y_{t,t+n}$denote the continuously compounded risk-free interest rates quoted at date *t* in U.S. dollars and home currency, respectively. S_t is defined as the spot exchange rate and defined such that an increase denotes a depreciation of the home currency and an appreciation of the U.S. dollar. $\mathrm{F_{t,t+n}}$ denotes the *n*-year forward exchange rate in home currency per U.S. dollar at time *t*. The following condition should then hold under covered interest parity (CIP):

$$e^{ny^{\$}_{t,t+n}} = e^{ny_{t,t+n}} \frac{S_t}{F_{t,t+n}} \qquad (1)$$

In logs:

$$\rho_{t,t+n} \equiv \frac{1}{n}\left(f_{t,t+n} - s_t\right) = y_{t,t+n} - y^{\$}_{t,t+n} \qquad (2)$$

Where $\rho_{t,t+n}$ is the continuously compounded forward premium. The relation implies that in the absence of currency and counterparty risk, an investor should be indifferent between investing US dollars at time *t* for *n* years and exchanging US dollars to invest in foreign currency and swapping back in US dollars *n* years later. The cross-currency basis (CCB) can be considered therefore a measure of violation of CIP, the price difference between funding directly in US dollar and funding synthetically in US dollars using currency forward contracts. It is calculated as follows:

$$CCB_{t,t+n} = y^{\$}_{t,t+n} - \left(y_{t,t+n} - \rho_{t,t+n}\right) \qquad (3)$$

The 3-month Libor basis tenor is used throughout the chapter as it represents the main benchmark in market practice and for a large part of the literature. The US dollar basis can be positive against currencies with high interest rates. Spot, forward and LIBOR rates used to construct the CCB for different currencies are obtained from Bloomberg. The sample of currencies included in panel 1 of Figure 5.3 are: Australian dollar, Brazilian real, Canadian dollar, Swiss franc, Danish krone, euro, British pound, Hong Kong dollar, Japanese yen, South Korean won, Indian rupee, Mexican peso, Malaysian ringgit, Norwegian krone, New Zealand dollar, Philippine peso, Russian ruble, Swedish krona, Thai baht, Turkish lira, and the South African rand.

b. Drivers and Amplification Effect of the Crosso-Currency Funding Ratio (CCFR)

This exercise aims to understand which major factors have been driving the CCB and whether the CCFR serves as an amplifier. The sample period is from 01/01/2000 to 03/01/2018.

Because of data availability, the sample of currencies for this exercise is restricted to: Australian dollar, Canadian dollar, Swiss franc, euro, British pound, Hong Kong dollar, Japanese yen, Indian rupee, Malaysian ringgit, Swedish krona. The analysis estimates the following level regression:

$$CCB_{i,t} = \alpha_i + \beta' X_{i,t} + + \epsilon_{i,t} \qquad (4)$$

Where α_i are currency fixed effects, $X_{i,t}$ represents the set of drivers and ϵ_t is the error term. The set of drivers includes: VIX, US dollar index, home economy default probability, FX implied volatility, bid-ask spread, term-spread differential, Libor-OIS spread and the cross-currency funding ratio (CCFR)[4]. The term spread differential is defined as the difference between the term spread in the home economy and the term spread in US. Home economy default probability is measured with the expected-default frequency (EDF)[5] over 1-year time horizon. The term spread is defined as the 10-year government bond yield – 3-month government bond yield for both US and the home economy. All regressors are standardized.

Values shown in panel 2 of Figure 5.3 refer to the aggregate effect of the baseline coefficient (β') of x_j ($\in X$) and estimated cross-term coefficients (λ') conditioning on "high" and "low" values of CCFR. "High" and "low" levels of CCFR are defined as the fourth and first quintiles,[6] respectively, of the historical distribution of the CCFR. Regressors are standardized prior to estimation. The absence of panel unit roots has been tested with Im–Pesaran–Shin test. Robust standard errors are used for estimations. Results are robust with Newey-West standard errors.

c. Effects of Regulation and Reserve Holding

A variant of Eq. (4) is also estimated to test the effects of the introduction of different regulatory changes on the coefficients on $CCFR_{i,t}$, as follows:

$$CCB_{i,t} = \beta' X_{i,t} + \alpha_m + \epsilon_{i,t} \qquad (5)$$

Where the set of drivers $X_{i,t}$ are the same as in the baseline model, and regressors are standardized. The regression includes month fixed effects α_m to control for quarter- and year-end effects. The sample period is from 01/01/2012 to 12/31/2016. The exercise focuses on the currencies mainly affected by the regulatory changes: Australian dollar, Canadian dollar, Swiss franc, euro, British pound, Japanese yen, Swedish krona. Regulatory reforms considered in the analysis are coded as follows:

[4] Since VIX and US dollar index do not vary across country by construction, we tested an alternative specification including only the remaining variables with a country-specific variation. Results are in line with the baseline specification and robust to the inclusion of time-fixed effects.

[5] The banking sector EDF (expected default frequency) is constructed by taking an average of all listed banks' EDF. Expected default frequency is a measure of the probability that a firm will default over a specific period (typically one year). We use the EDF estimation from Moody's Analytics based on their EDF model. More details can be found here: https://www.moodysanalytics.com/-/media/products/edf-expected-default-frequency-overview.pdf.

[6] Throughout the chapter, "high" versus "low" comparisons refer to the fourth and first quintiles of the distribution, which may be sample-wide or within an economy, depending on the exercise.

Regulatory reform	Dummy = 1 in the period
Stress-VaR	01/01/2013 – 12/31/2013
Supplementary leverage ratio	01/01/2014 – 12/31/2014
Liquidity coverage ratio	01/01/2015 – 12/31/2015
Money market mutual fund reform (MMMF)	01/01/2016 – 12/31/2016

Values shown in panel 2 of Figure 5.4 refer to the effect of the baseline coefficient (β') and each cross-term coefficient (λ') with the dummy for the time of each regulation change.

2. USD FUNDING COSTS AND HOME COUNTRY FINANCIAL STRESS

The analysis aims to answer the following questions:

- How do banking sector stability and domestic financial conditions in home economies of global non-US banks respond to changes in US dollar funding costs? To what extent does this relationship depend on non-US banks' share of US dollar business?
- To what extent does it depend on USD funding fragility?
- What policy-related variables serve to mitigate the association of variations in the US dollar funding cost and banking sector stress/domestic financial conditions in home economies of global non-US banks?

a. Baseline Regression

The model specification relates changes in the US dollar funding costs of economy *i* to a measure of banking sector stability $Y_{i,t}$ in country *i* in quarter *t*. The equation and variables are defined as follows:

$$\Delta_1 Y_{i,t} = \alpha_i + \beta \Delta_1 Cost_{i,t} + \gamma' Controls_{i,t} + \varepsilon_{i,t} \qquad (6)$$

- $Y_{i,t}$ is country-level financial stress, captured by taking the average 1-year ahead bank probability of default $PD_{i,t}$[7], or the financial conditions index $FCI_{i,t}$[8]
- α_i is an economy fixed effect
- $Cost_{i,t}$ is the US dollar funding cost, the negative of the $CCB_{i,t}$
- $Controls_{i,t}$ is a vector including several macro variables, as in Avdjiev and others (forthcoming), and banking sector control variables, as in Samaniego-Medina and others (2016). Macro controls include interest rate differentials, inflation, logarithm of nominal

[7] Banking sector *PD* is defined as logarithm of the one-year-ahead probability of default for all publicly listed banks, which is compiled by the Risk Management Institute. It also includes dead firms which helps to reduce survivorship bias. Probability of default is constructed on a forward intensity function, whose inputs include the state of economy (four macro-financial risk factors), and the vulnerability of individual banks (twelve bank-specific attributes). For each economy, a quarterly average across these listed banks is taken.

[8] Alternatively, bank CDS spreads could be used to measure home economy financial stress, but this would limit the sample to only half of the economies.

effective exchange rate (NEER), logarithm of VIX, volatility of logarithm of VIX, and real GDP growth, and bank controls include bank capital to assets ratio, cash to assets ratio, return to assets ratio, deposit to assets ratio, net loan to assets ratio, and cost to income ratio. All controls are moving averages from quarter *t*-4 to *t*-1.

In order to understand how the association of the variations in the US dollar funding cost and the change in financial stress changes over time, dummies are included for four different periods as are their interactions with the change in the USD funding cost. More specifically, the estimated model is the following:

$$\Delta_1 Y_{i,t} = \cdots + \sum_{j=1}^{4} \delta_j D_j + \sum_{j=1}^{4} \beta_j D_j \Delta_1 Cost_{i,t} + \varepsilon_{i,t}{}^{9} \qquad (7)$$

- D_1 to D_4 correspond to four different dummies in five periods, $D_1(2007 \leq Year \leq 2009)$, $D_2(2011 \leq Year \leq 2012)$, $D_3(Year \geq 2013)$, and $D_4(Year = Rest)$.

Panel 1 of Figure 5.5 shows the association between the change in the probability of default (ΔPD) or financial conditions (ΔFCI) of the home economy banking sector with a contemporaneous increase in the change of the US dollar funding cost by 50 basis points, comparing this association for the entire sample period, and by different subperiods. Standard errors used for estimations are clustered at the economy level.

A similar exercise investigates the spillover impact on banking sector stress and domestic financial conditions in recipient economies, those that receive cross-border dollar credit flows from the global non-US banks, by shocks to USD funding conditions in home economies of these banks. Panel 2 of Figure 5.5 shows the association between a 50 basis point increase in US dollar funding costs across a recipient economy's top 10 lending economies and the probability of default of 38 recipient economies (borrowers), and compares the results for each lender's top 10 main borrowers to those of the rest of borrowers.

b. Amplification Efects of the Share of USD Assets and Funding Fragility

- An augmented specification of equation (6) is used which includes the share of US dollar assets to total assets (*S*) and its interaction with the change in US dollar funding cost. The asset share is calculated as the average for economy *i* between quarter *t*-4 and quarter *t*-1.

$$\Delta_1 Y_{i,t} = \cdots + \beta_1 \Delta_1 Cost_{i,t} + \beta_2 S_{i,t-1\sim-4} + \beta_3 \Delta_1 Cost_{i,t} S_{i,t-1\sim-4} + \varepsilon_{i,t} \qquad (8)$$

Figure 5.7 shows the association between a 50 basis point increase in US dollar funding costs and the change in the probability of default in home economies of global non-US banks. Panel 1 compares the effect on the probability of default when the share of US dollar business in quarter t-4 to quarter t-1 is low versus when it is high within the full-sample distribution of US dollar assets to total assets.

[9] To save space, "…" represents the same control variables and country fixed effects.

A variant model specification, shown in equation (9), uses USD funding fragility (*F*) instead. The analysis considers three types of US dollar funding fragility, as measured by either the CCFR, the US dollar liquidity ratio (LR), or the US dollar stable funding ratio (SFR). As with the US dollar share, each fragility measure is taken as an average between quarter *t*-4 and quarter *t*-1.

$$\Delta_1 Y_{i,t} = \cdots + \beta_1 \Delta_1 Cost_{i,t} + \beta_2 F_{i,t-1\sim-4} + \beta_3 \Delta_1 Cost_{i,t} F_{i,t-1\sim-4} + \varepsilon_{i,t} \qquad (9)$$

Asymmetry is introduced in the response of financial stress to funding costs by differentiating when the funding gap is positive or negative:

$$\Delta_1 Y_{i,t} = \cdots + \beta_0 i.D[CCFR > 0] + \beta_1 \Delta_1 Cost_{i,t} i.D[CCFR > 0] + \beta_2 CCFR_{i,t-1\sim-4} i.D[CCFR > 0] + \beta_3 \Delta_1 Cost_{i,t} CCFR_{i,t-1\sim-4} i.D[CCFR > 0] + \varepsilon_{i,t} \qquad (9')$$

Panel 2 of Figure 5.7 compares this effect when the cross-currency funding ratio (CCFR) or the ratio of cross-currency funding gap (CCFG) to US dollar assets in quarter t-4 to quarter t-1 is low versus when it is high within the distribution of positive-value CCFGs. Panel 3 compares the effect when the US dollar liquidity ratio (LR), or US dollar stable funding ratio (SFR) in quarter t-4 to quarter t-1 is low and high relative to the historical distribution for each economy.

c. Policy-Related Variables as Mitigators:

- First, a bank health variable (BH) is introduced along with its interaction with US dollar funding costs. It is also averaged over *t-4* to *t-1*.

$$\Delta_1 Y_{i,t} = \cdots + \beta_1 \Delta_1 Cost_{i,t} + \beta_2 BH_{i,t-1\sim-4} + \beta_3 \Delta_1 Cost_{i,t} BH_{i,t-1\sim-4} + \varepsilon_{i,t} \qquad (10)$$

Panel 1 of Figure 5.9 shows the association between a 50 basis point increase in the change of US dollar funding costs and the change in the probability of default. The figure compares these associations when the capital-asset ratio (capital), cash-assets ratio (liquidity), or return on assets (ROA) in quarter *t*-4 to quarter *t*-1 is low or high within the full sample distribution.

- Second, to explore the effectiveness of swap lines with the U.S. Federal Reserve, the following model is estimated:

$$\Delta_1 Y_{i,t} = \cdots + \delta Swap_{it} + \beta_{10} \Delta_1 Cost_{i,t}(Swap_{it} = 0) + \beta_{11} \Delta_1 Cost_{i,t}(Swap_{it} = 1) + \varepsilon_{i,t} \qquad (11)$$

- $Swap_{i,t}$ is a dummy indicating if there is a swap liquidity agreement between central bank in economy *i* and the Federal Reserve in quarter *t*. Thus, it varies both across economies and time.

- Third, to explore the impact of holdings of international reserves by the home economy central banks, the variable *R* and its interactions with US dollar funding costs and US dollar funding fragility are introduced. International reserve holdings are also averaged over *t-4* to *t-1*.

$$\Delta_1 Y_{i,t} = \cdots + \beta_1 \Delta_1 Cost_{i,t} + \beta_2 F_{i,t-1\sim-4} + \beta_3 R_{i,t-1\sim-4} + \beta_4 \Delta_1 Cost_{i,t} F_{i,t-1\sim-4} + \beta_5 F_{i,t-1\sim-4} R_{i,t-1\sim-4} + \beta_6 \Delta_1 Cost_{i,t} R_{i,t-1\sim-4} + \beta_7 \Delta_1 Cost_{i,t} F_{i,t-1\sim-4} R_{i,t-1\sim-4} + \varepsilon_{i,t} \qquad (12)$$

- Panel 2 of Figure 5.10 shows the association between a 50 basis point increase in US dollar funding costs and the change in the home economy probability of default, comparing when a swap line arrangement is in effect versus when it is not. Panel 3 shows the transmission effect of US dollar funding fragility—with LR or SFR evaluated at their median—on the change in the probability of default when the home central bank's international reserve holding is low or high by historical standards. Standard errors are clustered at the economy level in all regressions.

3. USD FUNDING COSTS AND CROSS-BORDER LENDING

The analysis aims to answer the following questions:

- How large is the spillover impact on cross-border US dollar lending of shocks to US dollar funding conditions? Do EM lenders cut cross-border lending by more when the US dollar funding cost increases? Are EM recipients more vulnerable to their lending partners' US dollar funding shocks? Do we observe non-linear relations in the transmission channel?
- Can recipient countries fully substitute US dollar credit across different sources (i.e. other lending countries, local position US dollar credit, or other currency cross-border lending) after their cross-border US dollar lenders experience funding cost shocks?
- Do US dollar funding fragilities amplify of the cross-border spillover transmission channel? Do bank conditions in home economies bank conditions act as mitigators or amplifiers?
- Are home countries' central bank swap line arrangements and international reserve holdings effective in mitigating the negative impact of USD funding shocks?
- Are recipient countries with higher historical corporate, sovereign, or bank risks more vulnerable?

a. Baseline Regression

The following baseline specification is used to estimate the spillover impact of US dollar funding cost increases on cross-border US dollar lending:

$$\log\left(L^{USD}_{i,j,t+1,t+4}\right) \times 100 = \alpha_{j,t} + \rho_{i,j} + \beta \Delta_4 Cost_{i,t} + \eta' Controls_{i,t} + \varepsilon_{i,j,t+4} \qquad (13)$$

Where $L^{USD}_{i,j,t+1,t+4}$ is the average cross-border US dollar bilateral lending during t+1 to t+4 from home economy *i* to recipient economy *j*. $\Delta_4 Cost_{i,t}$ is the one-year cumulative change in US dollar funding costs (the negative of the CCB), and $Controls_{i,t}$ is a vector of control variables, which include:

- Home country macro controls: Domestic credit growth rate: $\Delta \frac{Domestic\ Credit}{GDP}$, real GDP growth rate: $\%\Delta RGDP$, the logarithm of nominal exchange rate: $\log(FX)$
- Home country banking sector controls: the log of total banking sector assets, average equity-asset ratio, deposit-assets ratio, cash-assets ratio, return on assets (ROA).

If $\beta < 0$, then shocks to USD funding costs have a disruptive impact on cross-border USD lending (panel 1 of Figure 5.6). The baseline specification is further modified by interacting

$\Delta Cost_{i,t,t+4}$ with an EM lender dummy or an EM recipient dummy. The following specification is used:

$$\log\left(L^{USD}_{i,j,t+1,t+4}\right) \times 100 = \alpha_{j,t} + \rho_{i,j} + \beta_1 \Delta_4 Cost_{i,t} + \beta_2 \Delta_4 Cost_{i,t}\text{EM} + \eta' Controls_{i,t} + \varepsilon_{i,j,t+4} \quad (14)$$

Where EM_i is an EM lender dummy, and $\beta_2 < 0$ if EM lenders cut cross-border US dollar lending by more than do other lenders when their USD funding cost increases, and EM_j is an EM recipient dummy and $\beta_2 < 0$ indicates a more adverse impact on EM recipients than on other US dollar recipients (both in panel 1 of Figure 5.6).

In addition, the following two specifications are used to test for nonlinear effects (results will be presented in the forthcoming working paper):

$$\log\left(L^{USD}_{i,j,t+1,t+4}\right) \times 100 = \alpha_{j,t} + \rho_{i,j} + \beta_1 \Delta_4 Cost_{i,t} + \beta_2 \left(\Delta_4 Cost_{i,t}\right)^2 + \eta' Controls_{i,t} + \varepsilon_{i,j,t+4} \quad (15)$$

$$\log\left(L^{USD}_{i,j,t+1,t+4}\right) \times 100 = \alpha_{j,t} + \rho_{i,j} + \beta_1 \Delta_4 Cost_{i,t} + \beta_2 \Delta_4 Cost_{i,t} \times \left[CCB_{i,t-1} < p - pctile\right] + \beta_3 \left[CCB_{i,t-1} < p - pctile\right] + \eta' Controls_{i,t} + \varepsilon_{i,j,t+4} \quad (16)$$

If $\beta_2 \neq 0$ in specification (15) then there are non-linear effects of US dollar funding cost shocks, and if $\beta_2 < 0$ in specification (16), this would reflect that higher initial funding costs (i.e. lower initial CCB level) lead to larger effects on cross-border lending following the same size of funding cost shocks.

b. Substitutability

The test consists of investigating whether (i) a recipient country can substitute US dollar cross-border lending across different lending partners when, ceteris paribus, one lending partner experiences an additional increase in US dollar funding costs, and whether (ii) a recipient country can switch to local position (domestic) US dollar borrowing or other currency cross-border borrowing when the weighted average of all cross-border lending partners' US dollar funding cost increases.

For test (i), we follow the following specification

$$\log\left(Amount_{-i,j,t+1,t+4}\right) = \beta_1 \Delta_4 Cost_{i,t} + \beta_2 \sum_{-i} S_{-i,j,t} \Delta_4 Cost_{-i,t} + \eta' Controls_{i,t} + \gamma_{j,t} + \gamma_{i,j} + \varepsilon_{i,j,t+4} \quad (17)$$

Where $Amount_{-i,j,t+1,t+4}$ is the average total cross-border US dollar borrowing by recipient economy *j* during $t+1$ to $t+4$ from all other lending partners except for economy i, $S_{-i,j,t}$ is the share of cross-border US dollar borrowing from a lending partner $-i$ in the total US dollar borrowing from all lending partners in quarter t. It is expected that $\beta_1 > 0$ if the substitution effect exists across US dollar lending partners for cross-border credit. In addition, a new measure is proposed for the degree of substitution $\theta = -\frac{\beta_1}{\beta}$, where β is the estimate in specification (13). If $\theta = 1$, then there is full substitution, while partial substitution is indicated by positive values less than 1. The value of θ, the degree of substitution from one cross-border lender to all others, is presented in panel 2 of Figure 5.6.

For test (ii), the following two specifications are used

$$\frac{\Delta(CB+LP)_{j,t+4}}{CB_{j,t}+LP_{j,t}} = \beta_1 \sum_i S_{i,j,t}\Delta_4 Cost_{i,t} + \eta' Controls_{j,t} + \gamma_j + \gamma_{t+4} + \varepsilon_{j,t+4} \quad (18)$$

$$\frac{\Delta AllCurr_{t+4}}{AllCurr_t} = \beta_1 \sum_i S_{i,j,t}\Delta_4 Cost_{i,t} + \eta' Controls_{j,t} + \gamma_j + \gamma_{t+4} + \varepsilon_{j,t+4} \quad (19)$$

Where $CB_{j,t}$ is total cross-border US dollar lending to recipient j in quarter t, $LP_{j,t}$ is total local position US dollar lending to recipient j in quarter t, and $AllCurr_t$ is total all currency cross-border lending to recipient j in quarter t. If $\beta_1 < 0$ then a recipient j cannot fully compensate the loss in cross-border US dollar borrowing by local position US dollar borrowing, or other currency cross-border borrowing. Again, the degree of substitutions is computed in each case. For the degree of substitutions between cross-border USD credit and local position USD credit, the left-hand side of equation (18) is replaced as $\frac{\Delta CB_{j,t+4}}{CB_{j,t}+LP_{j,t}}$ and $\frac{\Delta LP_{j,t+4}}{CB_{j,t}+LP_{j,t}}$ individually to yield β_1^{CB} and β_1^{LP}. The degree of substitution is thus computed as $\theta = -\frac{\beta_1^{LP}}{\beta_1^{CB}}$. For the degree of substitution between USD cross-border credit and all other currency cross-border credit, the left-hand side variable of equation (19) is replaced as $\frac{\Delta USD_{t+4}}{AllCurr_t}$ and $\frac{\Delta OtherCurr_{t+4}}{AllCurr_t}$ individually to yield β_1^{USD} and $\beta_1^{OtherCurr}$. The degree of substitution is $\theta = -\frac{\beta_1^{OtherCurr}}{\beta_1^{USD}}$. Both estimates of the degree of substitution are presented in panel 2 of Figure 5.6. Moreover, panel 3 of Figure 5.6 shows the degree of substitution estimates for the EM recipients.

c. Amplifiers and Mitigators of Effects on Cross-Border Lending

To test whether US dollar funding fragilities are amplifiers of the cross-border lending spillover effects, the following specifications are used:

$$\log\left(L_{i,j,t+4}^{USD}\right) \times 100 = \alpha_{j,t} + \rho_{i,j} + \beta_1 \Delta Cost_{i,t+3,t+4} + \beta_2 \Delta_1 Cost_{i,t+3} F_{i,t-1} + \beta_3 F_{i,t-1} + \eta' Controls_{i,t} + \varepsilon_{i,j,t+4} \quad (20)$$

where $F_{i,t-1}$ is the funding fragility measure (CCFR, LCR, and SFR) expressed as quintiles across each country's historical levels. To mitigate endogeneity concerns, 4-quarter lags are introduced between shocks and fragility measures. It is expected that $\beta_2 < 0$ for amplifiers (i.e. CCFR) and $\beta_2 > 0$ for mitigators (i.e., LCR, SFR, and HQLA ratio). The results are presented in panel 4 of Figure 5.7.

Furthermore, banking sector health works as a mitigator of the USD funding cost shocks. We use the following specification to test this hypothesis.

$$\log\left(L_{i,j,t+4}^{USD}\right) \times 100 = \alpha_{j,t} + \rho_{i,j} + \beta_1 \Delta Cost_{i,t+3,t+4} + \beta_2 \Delta_1 Cost_{i,t+3} BH_{i,t-1} + \beta_3 BH_{i,t-1} + \eta' Controls_{i,t} + \varepsilon_{i,j,t+4} \quad (21)$$

where $BH_{i,t-1}$ is the bank health measure (i.e., capital ratio, deposit to asset ratio, liquidity ratio, and ROA) expressed as quintiles across each country's historical levels. It is expected that $\beta_2 > 0$ if bank health serves as a mitigator for US dollar funding cost shocks. Results are shown in panel 2 of Figure 5.9.

d. Policy-Related Variables as Mitigators:

The following specification tests whether central bank swap line arrangement or international reserve holdings mitigate the disruptive effect of US dollar funding cost shocks.

$$\log\left(L^{USD}_{i,j,t+1,t+4}\right) \times 100 = \alpha_{j,t} + \rho_{i,j} + \beta_1 \Delta_4 Cost_{i,t} + \beta_2 \Delta_4 Cost_{i,t} P_{i,t-1} + \beta_3 P_{i,t-1} + \eta' Controls_{i,t} + \varepsilon_{i,j,t+4} \quad (22)$$

Where $P_{i,t-1}$ is a dummy for the existence of a swap line arrangement between lending economy *i* and the Fed at t-1, or expresses quintiles of the ratio of international reserves to GDP across lending country *i*'s historical levels. If $\beta_2 > 0$ then swap lines and/or international reserve holdings mitigate the disruptive effects of the US dollar funding shocks. See panel 4 of Figure 5.10 for the results.

e. Testing for Differences Across Economy Groups and for Recipient Economy Risk

To examine whether recipient economies' historical risk matters for the transmission of USD funding shocks, the following specification is used:

$$\log\left(L^{USD}_{i,j,t+1,t+4}\right) \times 100 = \alpha_{j,t} + \rho_{i,j} + \beta_1 \Delta_4 Cost_{i,t} + \beta_2 \Delta_4 Cost_{i,t} Risk_{j,t-1} + \eta' Controls_{i,t} + \varepsilon_{i,j,t+4} \quad (23)$$

Where $Risk_{j,t-1}$ is the historical average of the risk measure (corporate spreads, sovereign spreads, and banking sector EDF) from 2000Q1 up to t-1, and all risk measures are expressed as dummies with a value equal to 1 if its higher than the top 20 percentile across all economies in the same quarter.[10] It is expected that $\beta_2 < 0$ if recipients' risk is to amplify the negative impact of USD funding shocks. There is also horse race of all three risk measures, with the following specification:

$$\log\left(L^{USD}_{i,j,t+1,t+4}\right) \times 100 = \alpha_{j,t} + \rho_{i,j} + \beta_1 \Delta_4 Cost_{i,t} + \sum_{r=1}^{3} \beta_r \Delta_4 Cost_{i,t} \times Risk^r_{j,t-1} + \eta' Controls_{i,t} + \varepsilon_{i,j,t+4} \quad (24)$$

Where $Risk^r_{j,t-1}$ is one of the three risk measures. The results will be presented in the forthcoming working paper.

4. MARGINAL AND TOTAL US DOLLAR FUNDING COST

The exercise aims to explore whether the CCB, in addition to be a reasonable proxy for the marginal US dollar funding cost, is also related to *total* US dollar funding costs. To shed light on this issue, the analysis examines end-of-month portfolios of US money market mutual funds, as provided by CRANE data from Jan 2012 to Dec 2018. The sample of issuers is limited to 73 non-US banks who finance roughly one trillion of their US dollar activities in US dollar money markets, using Certificates of Deposits, Commercial Paper, and Repurchase Agreements, funded by 461 funds managed by 81 fund families. Since the dataset is based on regulatory filings, it includes the universe of US money market mutual funds and as such provides a comprehensive overview of US dollar wholesale funding for non-US banks.[11] The level of observation is an individual contract (e.g. a repo). The baseline specification is:

[10] The results are unchanged in signs if we use deciles of risk measures, with slightly lower significance levels. This might be due to non-linearity of the recipient country risk impact.

[11] US MMFs however are not the sole provider of USD wholesale funding to non-US banks. These banks can also fund themselves in the Eurodollar interbank market. For a more thorough overview of funding channels the reader is referred to the Online Annex 3.1 on "Non-US Banks' USD Funding: Mechanics and Stability Implications."

$$Yield_{ijct} = \gamma_1 \cdot CCB_{it} + \gamma_2 \cdot CCB_{it-1} + \gamma_3 Rem.maturity_{ijct} + \gamma_4 \log(value_{ijct}) + \beta \cdot \boldsymbol{X_{i,t}} + \delta_i \times \nu_t + IsRepo_c \times \nu_t + \mu_i + \epsilon_{ijct} \quad (25)$$

Where *i* denotes the bank, *j* stands for the fund, *c* represents the contract, and *t* is the month. The dependent variable $Yield_{ijct}$ is the yield to maturity of the particular contract as reported by the MMFs to the SEC, $Rem.maturity_{ijct}$ is the remaining maturity in days and $\log(value_{ijct})$ is the natural logarithm of the total face value of the contract in USD. $\boldsymbol{X_{i,t}}$ is a vector of bank, currency and country controls.

IsRepo is a dummy for repo contracts, $\delta_i \times \nu_t, \mu_i, IsRepo_c \times \nu_t$ are fund × month, bank and Repo × time fixed effects and ϵ_{ijct} is the error term. Fund × month fixed effects allow to control for unobserved supply side effects. Repo × time fixed effects control for changes of the (average) funding costs for secured and unsecured debt across time. Time fixed effects allow to control for any unobserved shock that affects all funding instruments similarly in a given month, for instance, a general increase in funding costs driven by an increase in economic policy uncertainty. This allows for a cleaner identification of the effect of the marginal US dollar funding costs (CCB) on the total funding costs (yields in money markets). The standard-errors are clustered on currency and time (since the variation is driven by changes in the CCB).

The regression is in spirit similar to the main specification in Aldasoro and others (2019). The analysis suggests that a ten-bp widening of the CCB is associated with an increase in wholesale funding costs by one basis point in the following month in the baseline specification[12]. The results are robust to including bank × fund fixed effects, banks 1-year expected default frequency (which limits the sample to listed banks) and country controls, such as the country's baseline interest rate and CCFR of the country's banking system).

5. ROBUSTNESS ANALYSIS

Recognizing the potential simultaneity/reverse causality bias from the CCFR and the CCB, on the one hand, and from CCB and financial stress in the home economy, on the other hand, a number of additional exercises were run to address this issue. While direct identification is not fully possible, these robustness exercises support the documented evidence and that results are not overall confounded by omitted variables. Furthermore, the core objective of the econometric analysis—to measure the possible amplification or mitigation effect of US dollar funding fragility and other factors—is tackled through a difference-in-difference strategy that is not affected by possible simultaneity. The additional exercises are described below.

First, the analysis of the CCB drivers in the chapter mainly treats the CCFR as an independent driver of the basis, whereas movements in the basis could also have effects on the CCFR per se. By using an unrestricted panel VAR framework that treats the variables as endogenous and

[12] That is, γ_2 is negative and statistically significant and $\gamma_1$is not significant. Since the basis is negative for most currencies a decrease in the CCB is to be interpreted as a widening of the basis. The baseline test therefore limits the sample to currencies with a negative basis throughout the sample period (effectively excluding AUD, CNY, SGD, KRW).

interdependent, Impulse Response Functions (IRFs) were estimated to corroborate the finding that the basis responds to shocks to the CCFR.

Second, a separate set of regressions was run using measures of US monetary policy shocks as an instrument for the basis in determining the home country probability of default. This yields a positive and significant relationship between the (instrumented) basis and the probability of default in the home economy.

Third, to deal with the reverse causality concern in the specification of the effect of the CCB on home economy financial stress, a separate set of regressions was run only for Euro area countries. Euro Area countries share the same basis but have different probabilities of banking default or domestic financial conditions, thereby this is a natural design to solve the concern of reverse causality, as it is not obvious that the probability default of a small Euro Area country can move the basis for the Euro Area as a whole. The positive and significant effect of increases in US dollar funding costs on financial stress persists in this exercise, even restricting to the sample to small Euro Area countries by excluding the two largest Euro Area countries (Germany and France) that could drive the probability of default of the area.

Regarding the use of time fixed effects (TFE) in the regressions for home economy financial stress, the chapter reports regressions which include various time-varying macroeconomic variables (as described in the specifications of the different exercises in this Annex) to ensure that the results are not driven by aggregate trends. A full set of robustness tests was run including TFEs, and a key message of this chapter was confirmed: conditional on US dollar funding fragility, tightening in US dollar funding conditions will be transmitted to stress in home economy of non-US global banks.

Finally, to take care of one potential source of omitted variable bias, a separate set of regressions for home country financial stress was run, which control for non-banking financial stress, as measured by sovereign CDS spreads. The results are broadly robust as well.

6. DATA AND SOURCES

The table below summarizes the main data used in the chapter's empirical analysis with the exception of the fragility indicators, for which the sources and construction methodology are described in detail in Annex 5.2.3.

Online Annex Figure 5.2.1. Data Sources and Transformations

Variable	Description	Source
BID-Ask Spread	Unit point difference between ask price and bid price.	Bloomberg. IMF staff estimates
Cross-Currency Basis	Difference between the direct dollar funding and the synthetic dollar funding.	Bloomberg, IMF staff estimates
Default Probability	Country average expected default frequency (EDF) over 1-year	Bloomberg. IMF staff estimates
Financial Conditions Index	For methodology and variables included in the FCI, refer to Annex 3.2 of the October 2017 Global Financial Stability Report. Positive values of the FCI indicate tighter-than-average financial conditions.	IMF staff estimates
LIBOR-OIS spread	Unit point difference between LIBOR and OIS rates.	Bloomberg, IMF staff estimates
Term spread differential	Difference between 10-year government bond yield and the 3-month government bond yield	Haver Analytics
US dollar index	Trade Weighted U.S. Dollar Index: Broad	Haver Analytics
VIX	Chicago Board Options Exchange Volatility Index	Haver Analytics
US dollar bilateral lending (cross-border)	Amount of US dollar bilateral cross-border lending from locational banking statistics (national basis)	BIS
US dollar bilateral lending (local position)	Amount of US dollar bilateral lending in local positions from locational banking statistics (national basis)	BIS
Other currency bilateral lending (cross-border)	Amount of bilateral cross-border lending denominated in all other currencies from locational banking statistics (national basis)	BIS
Swap line arrangement	Dummy when the central bank swap line with the Fed is available	Board of Governors of the Federal Reserve System
International Reserves	Reserve Assets (Includes reserve position in the Fund and SDR holdings)	International Financial Statistics.
Probaility of Default of Banking Sector	Banking sector expected default frequency (EDF) over 1-year ahead at country level.	The National University of Singapore Risk Management Institute (RMI)
Interest rate differentials	(Home - US) 1-year government bond yield difference	International Financial Statistics.
Inflation differentials	(Home - US) inflation difference based on quarterly consumer price index (period average)	International Financial Statistics.
Norminal Effective Exchange Rate	Nominal effective exchange rate of United States in logarithm	International Financial Statistics.
Real GDP	Gross domestic product, constant prices in national currency in logarithm	International Financial Statistics.
Capital ratio	Capital to assets ratio of banking sector at nationality level	Fitchconnect, Bankscope, IMF staff estimates
Liquidity ratio	Cash to assets ratio of banking sector at nationality level	Fitchconnect, Bankscope, IMF staff estimates
ROA	Return over assets ratio of banking sector at nationality level	Fitchconnect, Bankscope, IMF staff estimates
Deposit ratio	Deposit to assets ratio of banking sector at nationality level	Fitchconnect, Bankscope, IMF staff estimates
Cost ratio	Cost to income ratio of banking sector at nationality level	Fitchconnect, Bankscope, IMF staff estimates
Net loan ratio	Net loan to assets ratio of banking sector at nationality level	Fitchconnect, Bankscope, IMF staff estimates
EM	Dummy if the country belongs to the emerging market country list	Brauning and Ivashina (2019)

Source: IMF staff.

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ONLINE ANNEX 5.3. NON-US BANKS' US DOLLAR BALANCE SHEET AND THE FUNDING FRAGILITY MEASURES: METHODOLOGY

Building on the Online Annex 1.2 of April 2018 *Global Financial Stability Report* (GFSR) Chapter 1[13], this annex describes the methodology and concepts behind the US dollar funding fragility measures of non-US banks estimated for the analysis.

Inspired by the Basel framework's liquidity coverage ratio (LCR), the chapter computes a US dollar (USD) liquidity ratio (LR), as a measure of USD-denominated short-term liquidity metrics funding needs of non-US banks. Also inspired by the Basel framework's net stable funding ratio (NSFR), a USD stable funding ratio (SFR) is computed, as a measure of USD-denominated long-term stable funding metrics. In addition to these two measures, the chapter calculates the USD cross-currency funding ratio (CCFR), defined as USD assets minus USD liabilities and presented as a ratio of US dollar assets. The main focus of this annex is to explain the methodology behind the LR and SFR estimations.

DATA AND CONCEPTS

The jurisdictions (i.e., economies) are defined at banking system-level based on where the banks are headquartered, as opposed to the domicile/residency basis, given that the analysis aims to measure the US dollar funding fragilities of non-US banks at a consolidated level. The sample of economies is shown in Online Annex Table 5.3.1.

Online Annex Table 5.3.1. Sample Coverage

Panel A: sample with all three funding fragility measures	
Australia	Japan
Austria	Korea
Canada	Netherlands
France	Spain
Germany	Sweden
India	Switzerland
Italy	United Kingdom
Panel B: sample with CCFR only	
Brazil	Mexico
China	Norway
Cyprus	Russia
Hong Kong SAR	Singapore
Luxembourg	South Africa
Malaysia	Turkey

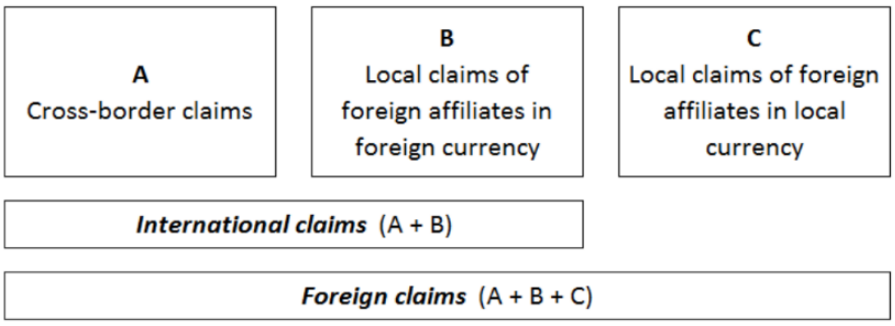
[13] Link to Online Annex 1.2 of Chapter 1 of the April 2018 GFSR—https://www.imf.org/~/media/Files/Publications/GFSR/2018/April/ch1/pdf/annex1-2.ashx?la=en

The USD balance sheets are constructed to capture:

- The International Position (IP): USD operations outside the United States, which capture the USD cross-border positions of non-US banks and the US dollar local positions of non-US banks outside the United States (i.e., local positions in foreign currency).
- Branch operations in the United States.
- The aggregate encompassing both of the above is termed International Position plus Branches in the United States (IP+B).
- The Foreign Position (FP) balance sheets are constructed by adding subsidiary operations in the United States.[14]

Thus, USD funding fragility can also be estimated at the foreign position level. A graphical representation of the different aggregates is shown in Online Annex Figure 5.3.1, and averages of the estimated ratios are shown in Online Annex Figure 5.3.2.

Online Annex Figure 5.3.1. International Position vs. Foreign Position



Source: Cerutti, Claessens, and McGuire (2012).
Note: In our analysis A corresponds to US dollar cross-border claims; B refers to US dollar local positions outside the US (hence US dollar is the foreign currency of the jurisdiction); C refers to the local positions in the US (i.e., non-U.S. banks' branches and subsidiaries in the US) Due to data limitations, this component is sourced from FFIEC002 filings for non-US banks' US branches and from call reports (i.e., FFIEC 031/041) for non-US banks' US subsidiaries when the balance sheets are constructed.

Due to data limitations on bank-level USD dollar balance sheets outside the United States, the analysis is performed at the jurisdiction level rather than at the bank-level. BIS international banking statistics are used to capture the USD operations outside the United States. While BIS consolidated statistics would be better suited, they do not contain the granularity required including the currency composition and the counterparty sectors. Therefore, the analysis uses USD-denominated claims and liabilities with appropriate granularity from the BIS confidential database on nationality basis locational statistics.[15] This dataset includes the parent jurisdictions for each reporting residency jurisdiction and the counterparty; hence, USD-denominated series can be constructed based on the headquartered jurisdictions that are needed. One limitation

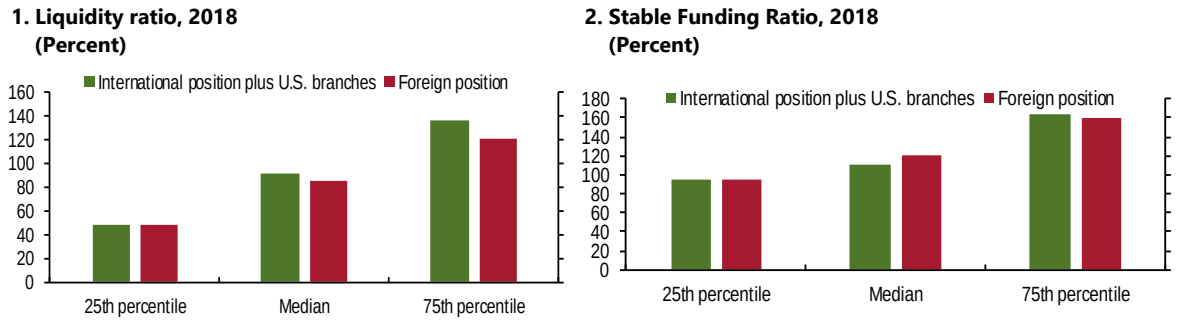
[14] This balance sheet was not constructed for the April 2018 GFSR and is used to run robustness tests in the present chapter.

[15] A subset of BIS locational statistics on nationality basis is publicly available as well; however, the data with the granularity required for this analysis is only available through the BIS confidential database.

encountered is related to capturing non-U.S. banks' operations within the United States, given that the United States does not report the non-US banks' operations within the United States (i.e., BIS local positions) to the BIS locational international banking statistics. Thus, data for branch operations in the United States are constructed through a bottom-up aggregation, (based on nationality) of balance sheet information available in FFIEC 002 regulatory filings. Data for subsidiary operations in the United States are similarly constructed using data from the call report filings (FFIEC 031/041 filings) for non-US-owned subsidiaries, obtained via the S&P Global Market Intelligence platform.

Online Annex Figure 5.3.2. US Dollar Liquidity and Stable Funding Ratios-Inclusion of US Subsidiaries of Non-US Banks

A comparison of the liquidity and stable funding ratios estimated across the IP+B and FR concepts broadly suggests that the inclusion of US subsidiaries of non-US banks does not affect the analysis.



Sources: Bank for International Settlements, locational banking statistics (nationality basis); Federal Financial Institutions Examination Council; S&P Global, Market Intelligence; IMF staff calculations.

CONSTRUCTION OF THE US DOLLAR LIQUIDITY AND THE STABLE FUNDING RATIOS

Liquidity (LR) and stable funding (SFR) ratios are constructed by following the methodology developed in Chapter 1 of the April 2018 GFSR (see Online Annex 1.2 of that chapter for a description). Due to the lack of granularity in BIS statistics the analysis is constrained by the same restrictions incurred by the April 2018 analysis when constructing US dollar balance sheets. Therefore, additional estimates of the LR—using several alternative outflow assumptions—are estimated for robustness (see Online Annex Figure 5.3.3).

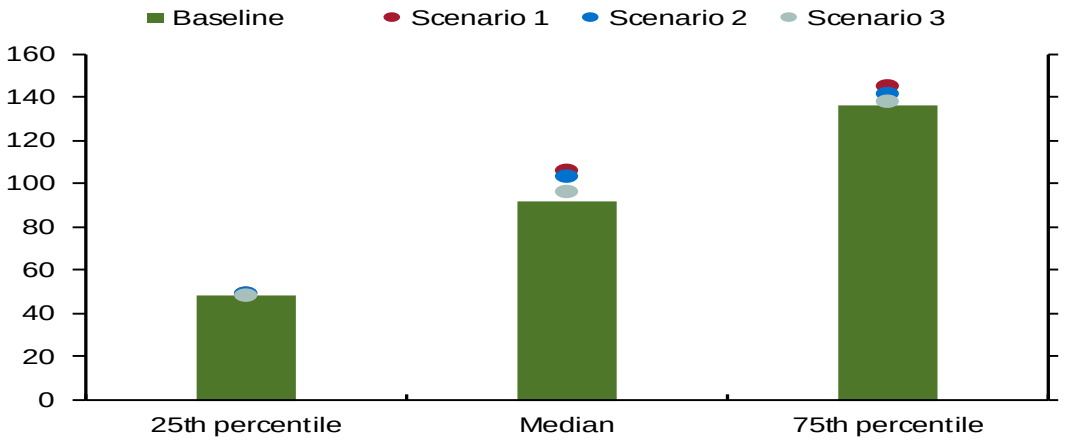
Moreover, a few minor modifications are made to the balance sheet components constructed, with the objective of further refining the estimated ratios. One such adjustment relates to the estimation of the *deposit* component:

- The April 2018 analysis estimated this component by subtracting USD-denominated bonds and short-term debt securities issued by banks from liabilities to nonbanks in BIS locational banking statistics. As a further refinement, only a fraction of US dollar-denominated bonds and short-term debt securities issued by banks is subtracted.

- This fraction corresponds to an estimate of the portion that is held by the nonbank sector. Due to the lack of data on holders of USD-denominated bonds and ST securities issued by banks, several assumptions are made:
- First, if the counterparty breakdown of USD-denominated debt securities is available on a residency basis in BIS locational banking statistics, it is assumed that the nationality basis ratio of debt securities held by the nonbank sector to debt securities held by all sectors is the same as in residency basis.
- When the counterparty sector breakdown is not available even on a residency basis, it is assumed that the nationality basis ratio of debt securities held by the nonbank sector to debt securities held by all sectors is same as the nationality basis liabilities to the non-bank sector as a ratio of liabilities to all sectors.[16]

Online Annex Figure 5.3.3. Sensitivity of the US Dollar Liquidity Ratios to Different Assumptions for Deposits

The median liquidity ratios estimated using less stringent alternative assumptions varies by about fifteen percentage points from the baseline



Sources: Bank for International Settlements, locational banking statistics (nationality basis); Federal Financial Institutions Examination Council; S&P Global, Market Intelligence; IMF staff calculations.
Note: The figure corresponds to the international position plus US branches concept. Scenario 1-3 uses different run-off factors for transaction and non-transactional deposits at branch-level (3 and 5, 5 and 10, and 5 and 25).

[16] When the residency basis series exists as a shorter series, we use the nationality basis liabilities to nonbanks as a ratio of liabilities to all sectors to splice the former series.

Another adjustment made is related to the foreign exchange swaps included in the stable funding ratio estimations. In addition to foreign exchange swap payables defined in the April 2018 chapter as the net position when US dollar claims are greater than the liabilities and included in the numerator, an estimate of foreign exchange swap receivables are now included in the denominator. The latter is the net position when USD liabilities are greater than the claims.

The full balance sheet construction is illustrated in Online Annex Table 5.3.2 for the IP+B balance sheet, and in Online Annex Table 5.3.3 for the FP balance sheet.[17]

Based on the balance sheets presented in Online Annex Tables 5.3.2 and 5.3.3, the liquidity ratio (LR) and the stable funding ratio (SFR) are estimated as follows:

$$LR = \frac{High\ Quality\ Liquid\ Assets}{Net\ cash\ outflows} * 100$$

$$Net\ cash\ outflows^{18} = Cash\ outflows - \min(cash\ inflows, 0.75 * cash\ outflows)$$

$$SFR^{19} = \frac{Deposits + long\ term\ securities + FX\ swaps\ payable}{Loans + FX\ swaps\ receivable} * 100$$

[17] Using the same methodology, the balance sheet for non-US banks' operations in all currency denomination was also constructed. The comparison between the all-currency LR and USD LR is discussed in the main text of the chapter.

[18] Cash outflows refer to interbank liabilities, other short-term liabilities, and deposits. Cash inflows refer to interbank assets. Cash outflows and inflows also incorporate applicable run-off factors.

[19] Also incorporates applicable run-off factors.

Online Annex Table 5.3.2. US Dollar Balance Sheet Construction—Non-US Banks' Operations Outside the United States and in US Branches

Balance Sheet Item	Data Series from Source	Data Sources
Assets		
A1. HQLA	Claims on US official sector, ultimate risk basis	BIS consolidated banking statistics, Table B4 for USA
	minus HQLA position from US subsidiaries	Call report filings, via S&P Global Market Intelligence
A2. Interbank assets	Claims on banks	BIS locational banking statsitics (Nationality basis)
	minus Intragroup claims	BIS locational banking statsitics (Nationality basis)
	plus US branches' Interbank assets	FFIEC 002
A3. Intragroup assets	Intragroup claims	BIS locational banking statsitics (Nationality basis)
	plus US branches' intragroup claims	FFIEC 002
A4. Loans	Claims on nonbanks	BIS locational banking statsitics (Nationality basis)
	plus US branches' loans	FFIEC 002
	minus A1. HQLA	see section A1
	minus Claims on central bank	BIS locational banking statsitics (Nationality basis)
A5. Other claims	Claims on banks	BIS locational banking statsitics (Nationality basis)
	plus Claims on nonbanks	BIS locational banking statsitics (Nationality basis)
	minus A1. HQLA	see section A1
	minus A2. Interbank assets	see section A2
	minus A3. Intragroup assets	see section A3
	minus A4. Loans	see section A4
	plus US branches' other claims	FFIEC 002
Liabilities		
L1. Interbank liabilities	Liabilities to banks	BIS locational banking statsitics (Nationality basis)
	minus Intragroup liabilities	BIS locational banking statsitics (Nationality basis)
	plus US branches' interbank liabilities	FFIEC 002
	minus Long-term debt securities (held by banks)	BIS debt securities statistics, BIS locational banking statsitics (Nationality basis), BIS locational banking statsitics (Residency basis)
	minus Short-term debt securities (held by banks)	BIS debt securities statistics, BIS locational banking statsitics (Nationality basis), BIS locational banking statsitics (Residency basis)
L2. Intragroup liabilities	Intragroup liabilities	BIS locational banking statsitics (Nationality basis)
	plus US branches' intragroup liabilities	FFIEC 002
	minus Long-term debt securities (intragroup portion)	BIS debt securities statistics, BIS locational banking statsitics (Nationality basis), BIS locational banking statsitics (Residency basis)
	minus Short-term debt securities (intragroup portion)	BIS debt securities statistics, BIS locational banking statsitics (Nationality basis), BIS locational banking statsitics (Residency basis)
L3. Bonds	Long-term debt securities issued by banks	BIS debt securities statistics, BIS locational banking statsitics (Nationality basis)
	plus US branches' long-term securities	FFIEC 002
L4. Other short-term liabilities	Short-term debt securities issued by banks	BIS debt securities statistics, BIS locational banking statsitics (Nationality basis)
	plus US branches' short-term securities	FFIEC 002
L5. Deposits	Liabilities to nonbanks	BIS locational banking statsitics (Nationality basis)
	minus Long-term debt securities (held by nonbanks)	BIS debt securities statistics, BIS locational banking statsitics (Nationality basis), BIS locational banking statsitics (Residency basis)
	minus Short-term debt securities (held by nonbanks)	BIS debt securities statistics, BIS locational banking statsitics (Nationality basis), BIS locational banking statsitics (Residency basis)
L6. FX swaps	Claims on banks	BIS locational banking statsitics (Nationality basis)
	plus Claims on nonbanks	BIS locational banking statsitics (Nationality basis)
	minus Liabilities on banks	BIS locational banking statsitics (Nationality basis)
	minus Liabilities on nonbanks	BIS locational banking statsitics (Nationality basis)
	plus US branches' FX swaps	FFIEC 002

Note: BIS = Bank for International Settlements; FFIEC = Federal Financial Institutions Examination Council; FX = foreign exchange; HQLA = high-quality liquid assets.

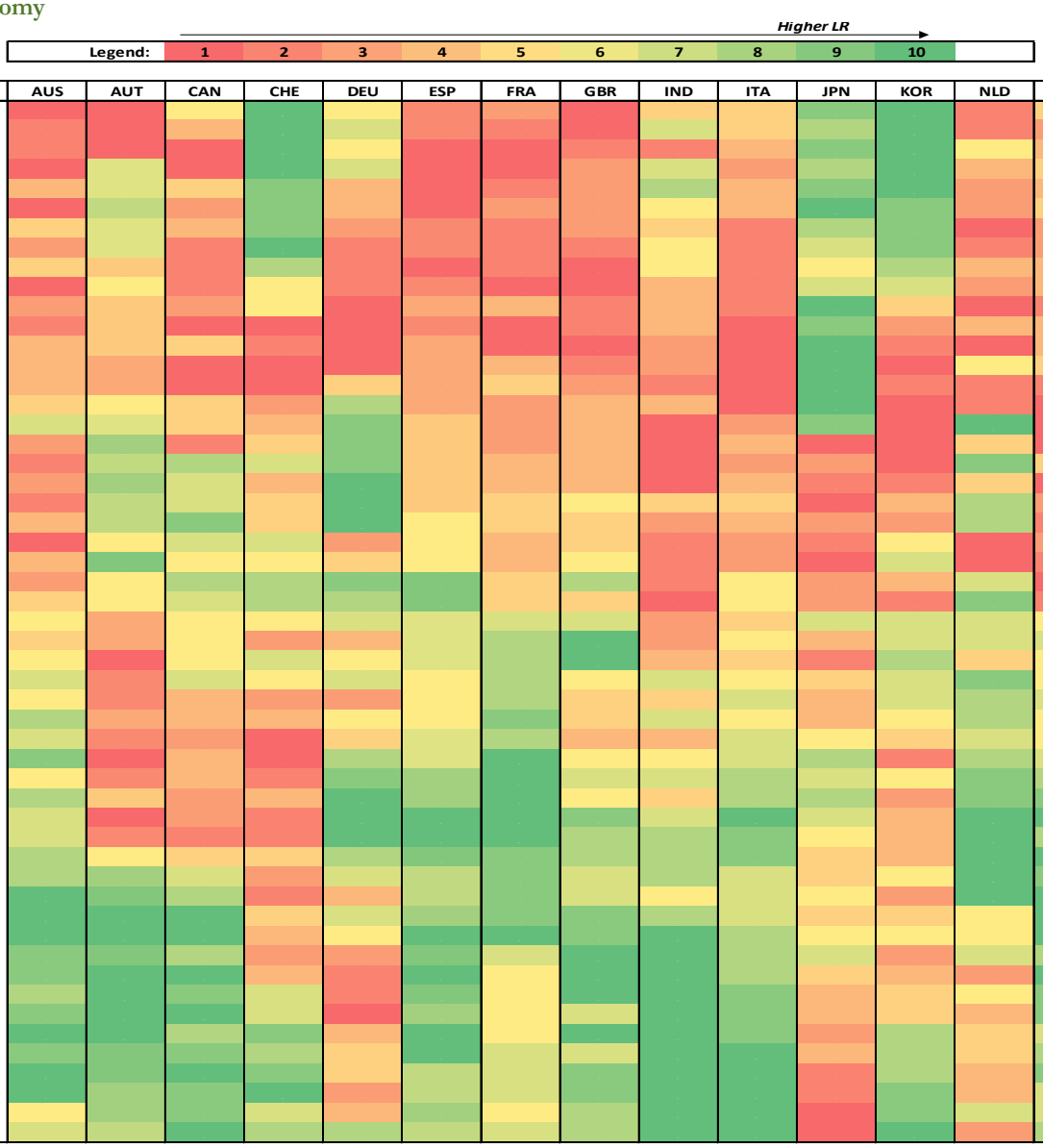
Online Annex Table 5.3.3. US Dollar Balance Sheet Construction—Non-US Banks' Operations Outside the United States and in US Branches and Subsidiaries

Balance Sheet Item	Data Series from Source	Data Sources
Assets		
A1. HQLA	Claims on US official sector, ultimate risk basis	BIS consolidated banking statistics, Table B4 for USA
A2. Interbank assets	Claims on banks	BIS locational banking statsitics (Nationality basis)
	minus Intragroup claims	BIS locational banking statsitics (Nationality basis)
	plus US branches' Interbank assets	FFIEC 002
	plus US subsidiaries' Interbank assets	Call report filings, via S&P Global Market Intelligence
A3. Intragroup assets	Intragroup claims	BIS locational banking statsitics (Nationality basis)
	plus US branches' intragroup claims	FFIEC 002
	plus US subsidiaries' intragroup claims	Call report filings, via S&P Global Market Intelligence
A4. Loans	Claims on nonbanks	BIS locational banking statsitics (Nationality basis)
	plus US branches' loans	FFIEC 002
	plus US subsidiaries' loans	Call report filings, via S&P Global Market Intelligence
	minus A1. HQLA	see section A1
	minus Claims on central bank	BIS locational banking statsitics (Nationality basis)
A5. Other claims	Claims on banks	BIS locational banking statsitics (Nationality basis)
	plus Claims on nonbanks	BIS locational banking statsitics (Nationality basis)
	minus A1. HQLA	see section A1
	minus A2. Interbank assets	see section A2
	minus A3. Intragroup assets	see section A3
	minus A4. Loans	see section A4
	plus US branches' other claims	FFIEC 002
	plus US subsidiaries' other claims	Call report filings, via S&P Global Market Intelligence
Liabilities		
L1. Interbank liabilities	Liabilities to banks	BIS locational banking statsitics (Nationality basis)
	minus Intragroup liabilities	BIS locational banking statsitics (Nationality basis)
	plus US branches' interbank liabilities	FFIEC 002
	plus US subsidiaries' interbank liabilities	Call report filings, via S&P Global Market Intelligence
	minus Long-term debt securities (held by banks)	BIS debt securities statistics, BIS locational banking statsitics (Nationality basis), BIS locational banking statsitics (Residency basis)
	minus Short-term debt securities (held by banks)	BIS debt securities statistics, BIS locational banking statsitics (Nationality basis), BIS locational banking statsitics (Residency basis)
L2. Intragroup liabilities	Intragroup liabilities	BIS locational banking statsitics (Nationality basis)
	plus US branches' intragroup liabilities	FFIEC 002
	plus US subsidiaries' intragroup liabilities	Call report filings, via S&P Global Market Intelligence
	minus Long-term debt securities (intragroup portion)	BIS debt securities statistics, BIS locational banking statsitics (Nationality basis), BIS locational banking statsitics (Residency basis)
	minus Short-term debt securities (intragroup portion)	BIS debt securities statistics, BIS locational banking statsitics (Nationality basis), BIS locational banking statsitics (Residency basis)
L3. Bonds	Long-term debt securities issued by banks	BIS debt securities statistics, BIS locational banking statsitics (Nationality basis)
	plus US branches' long-term securities	FFIEC 002
	plus US subsidiaries' long-term securities	Call report filings, via S&P Global Market Intelligence
L4. Other short-term liabilities	Short-term debt securities issued by banks	BIS debt securities statistics, BIS locational banking statsitics (Nationality basis)
	plus US branches' short-term securities	FFIEC 002
	plus US subsidiaries' short-term securities	Call report filings, via S&P Global Market Intelligence
L5. Deposits	Liabilities to nonbanks	BIS locational banking statsitics (Nationality basis)
	minus Long-term debt securities (held by nonbanks)	BIS debt securities statistics, BIS locational banking statsitics (Nationality basis), BIS locational banking statsitics (Residency basis)
	minus Short-term debt securities (held by nonbanks)	BIS debt securities statistics, BIS locational banking statsitics (Nationality basis), BIS locational banking statsitics (Residency basis)
L6. FX swaps	Claims on banks	BIS locational banking statsitics (Nationality basis)
	plus Claims on nonbanks	BIS locational banking statsitics (Nationality basis)
	minus Liabilities on banks	BIS locational banking statsitics (Nationality basis)
	minus Liabilities on nonbanks	BIS locational banking statsitics (Nationality basis)
	plus US branches' FX swaps	FFIEC 002
	plus US subsidiaries' FX swaps	Call report filings, via S&P Global Market Intelligence

Note: BIS = Bank for International Settlements; FFIEC = Federal Financial Institutions Examination Council; FX = foreign exchange; HQLA = high-quality liquid assets.

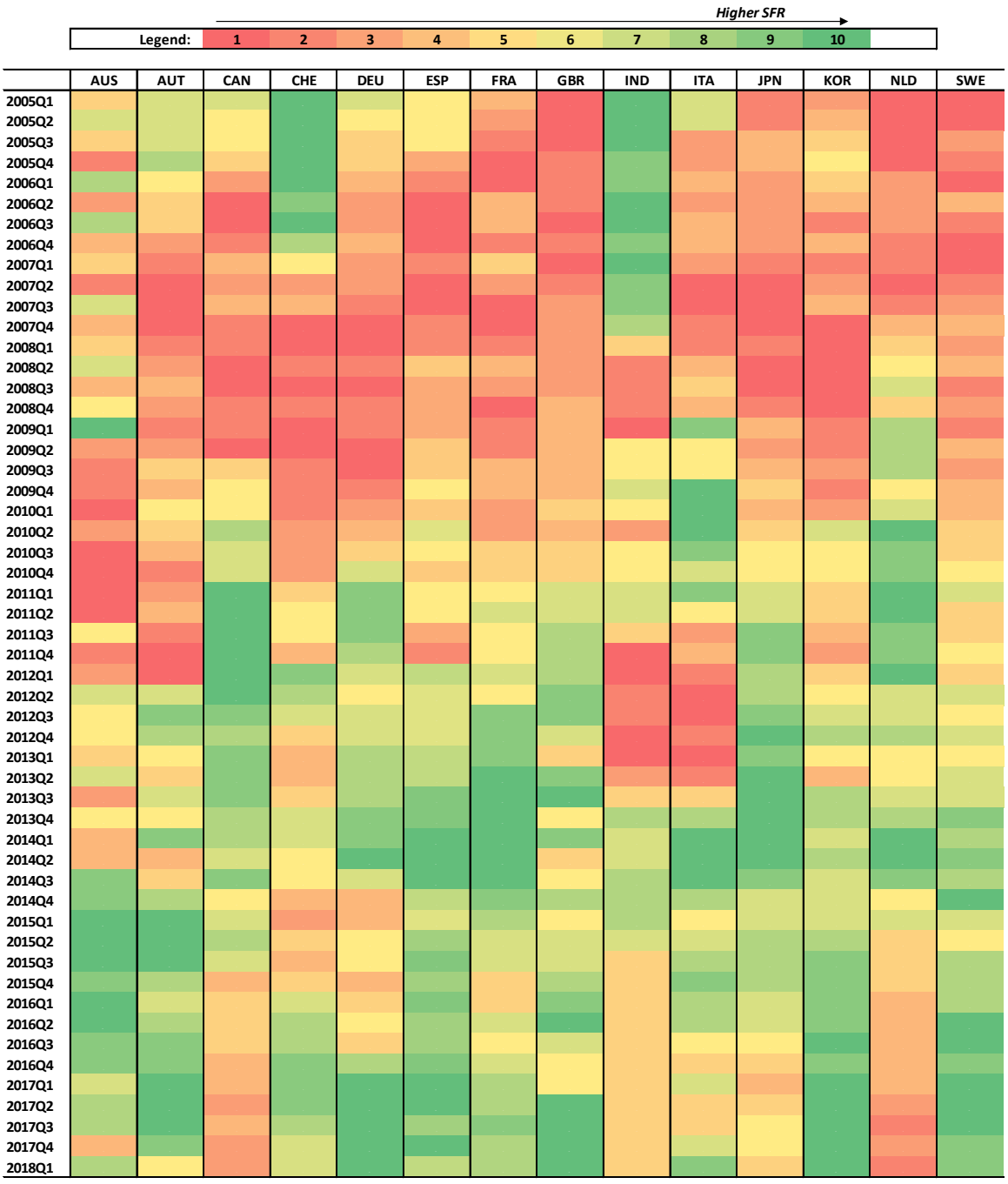
Online Annex Tables 5.3.4 and 5.3.5 illustrate the evolution of the estimated LR and SFR within each of the economies included in our sample. The results are presented in terms of deciles within the country.

Online Annex Table 5.3.4. US Dollar Liquidity Ratio—Heatmap Based on the Deciles Within Each Economy



Bank for International Settlements, locational banking statistics (nationality basis); Federal Financial Institutions Examination Council; S&P Global, Market Intelligence; IMF staff calculations.

Online Annex Table 5.3.5. US Dollar Stable Funding Ratio—Heatmap Based on the Deciles Within Each Economy



Bank for International Settlements, locational banking statistics (nationality basis); Federal Financial Institutions Examination Council; S&P Global, Market Intelligence; IMF staff calculations.

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Cerutti, Eugenio, Stijn Claessens, and Patrick McGuire. 2012. "Systemic Risks in Global Banking: What Available Data can tell us and What More Data are Needed?" NBER Working Paper No. 18531, National Bureau of Economic Research, Cambridge, MA.

Online Box 5.1. Analysis of US Dollar Funding Fragility in Recent Financial Sector Assessment Programs (FSAPs)[1]

Several recent FSAPs have assessed the adequacy of the banking system's liquidity in US dollars.[2] This was facilitated by the introduction of Basel liquidity requirements by significant currency as a monitoring metric in major jurisdictions.[3] Analysis covered structural liquidity ratios such as Liquidity Coverage Ratio and Net Stable Funding Ratio, asset encumbrance, and cash-flow based IMF top-down liquidity stress tests.

LCR in US dollars is used to identify potential currency mismatches under stressed conditions. While LCR by currency is monitored by authorities to identify liquidity needs in foreign currency, there is no requirement to reach a predefined LCR target in US dollars, and for some major banks the ratio falls below 100 percent. In cases when the LCR in US dollars exceeds 100 percent, it is common for banks to extend maturities of outflows above 30 days or to use collateral swap facilities to meet end-of-month LCR reporting.

To analyse USD maturity mismatches over different time horizons, some FSAPs conducted top-down cash-flow based USD liquidity stress tests. Scenarios included assumptions about closure of unsecured and/or secured funding markets, including wholesale US dollar deposit outflow rates in line with those observed during the global financial crisis and the US dollar funding crisis in Europe. Results reveal that some major banks are vulnerable to these shocks, mainly due to: (i) mismatches between repo and reverse repo outflows/inflows; (ii) concentrated US dollar wholesale funding, that is, a limited number of counterparties and small share of retail funding; and (iii) limited transferability of excess liquidity and collateral between jurisdictions during a crisis.

FSAPs concluded that, although under current market conditions banks with US dollar funding gaps had excess liquidity in domestic currency and relied on well-functioning FX swap markets or central bank facilities to fill the US dollar funding gap, they needed to ensure that they had available US dollar liquidity in market- and firm-specific stress situations. Although some authorities have started to address US dollar liquidity risk through supervisory action, additional actions can further mitigate risk: (i) collect granular cash flow liquidity data by currency, entity and jurisdiction; (ii) monitor US dollar funding patterns and liquidity metrics for various maturity buckets; (iii) simulate the impact of specific liquidity scenarios for additional time horizons; (iv) ensure that banks engaged in US dollar liquidity transformation have adequate US dollar liquidity buffers to cover wholesale cash outflows for at least a one-week horizon; and (v) assess risks related to US dollar liquidity trapping in foreign jurisdictions.

[1] This box was prepared by Laura Valderrama and Mindaugas Leika.

[2] FSAPs include Japan (2017), Euro Area (2018), Switzerland (2019), and France (2019) (see IMF 2017; 2018; 2019a and 2019b).

[3] BCBS (2013), "Basel III—The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools".

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