Online Appendix

Dollar Funding Liquidity and non-US Global Banks

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This Online Appendix has 6 sections. Section A derives the period 2 net worth of the bank (equation (13) of the text). Section B derives the optimal swap market position (equation (21) of the text) and the optimal euro and dollar loan portfolios (equations (22) and (23) of the text). Section C derives the analytical results in Table 1 of the paper. Section D discusses other equilibria of the model than the equilibrium focused on in the text. Section E discusses the data used to calibrate the representative G-SIB bank balance sheet and the responses of bank balance sheet variables to a shock to dollar funding in Figure 2 of the paper. Section F discusses sensitivity analysis.

A Period 2 Net Worth

We can write the period 2 net worth as

$$\begin{aligned} W_2 \;\; = \;\; & \left(1+i_0^{€,l}-d_2^{€}\right)L_1^{€}+\frac{1}{E_2}\left(1+i_0^{\$,l}-d_2^{\$}\right)L_1^{\$}-(1+i^s)B^{€}-(1+i_1^{€})B_1^{€,w} \\ & -\frac{1}{E_2}(1+i_1^{\$})B_1^{\$,w}+S_1\left(1-\frac{F_1}{E_2}\right) \qquad \text{(A.1)} \end{aligned}$$

The first two terms capture the gross returns on euro and dollar loans, the latter multiplied by $1/E_2$ to convert to euros. The last two terms on the first line subtract the gross return on retail euro liabilities and wholesale euro liabilities. The second line subtracts the gross return on wholesale dollar liabilities, converted to euros and adds the period profit from the swap market position.

We have

$$B_1^{\$,w}=L_1^{\$}-S_1 \qquad \text{(A.2)}$$

$$B_1^{€,w}=-W_1+L_1^{€}-B^{€}+S_1 \qquad \text{(A.3)}$$

Substituting these into (A.1), we have

$$\begin{aligned} W_2 &= \left(i_0^{€,l} - d_2^{€} - i_1^{€}\right) L_1^{€} + (i_1^{€} - i^s)B^{€} + (1 + i_1^{€})W_1 \qquad (A.4) \\ &+\frac{1}{E_2}\left(i_0^{\$,l} - d_2^{\$} - i_1^{\$}\right) L_1^{\$} + \left(-1 - i_1^{€} + \frac{1}{E_2}(1 + i_1^{\$}) + 1 - \frac{F_1}{E_2}\right) S_1 \end{aligned}$$

The first term on the second line becomes $\left(i_0^{\$,l} - d_2^{\$} - i_1^{\$}\right) L_1^{\$}$ when linearizing around $e_2 = ln(E_2) = 0$ and an excess return $i_0^{\$,l} - d_2^{\$} - i_1^{\$}$ of zero. The second term on the second line becomes $(i_1^{\$} - i_1^{€} + e_1 - f_1)S_1$ when linearizing around $e_2 = i_1^{\$} = f_1 = 0$ and using that $e_1 = 0$.

This gives

$$\begin{aligned} W_2 &= \left(i_0^{€,l} - d_2^{€} - i_1^{€}\right) L_1^{€} + (i_1^{€} - i^s)B^{€} + (1 + i_1^{€})W_1 \\ &+ \left(i_0^{\$,l} - d_2^{\$} - i_1^{\$}\right) L_1^{\$} + \left(e_1 - f_1 + i_1^{\$} - i_1^{€}\right) S_1 \qquad (A.5) \end{aligned}$$

Substituting

$$W_1 = W_0 - (1 - p_1^{\$})(L_0^{\$} - L_1^{\$}) - (1 - p_1^{€})(L_0^{€} - L_1^{€}) \qquad (A.6)$$

we have

$$\begin{aligned} W_2 &= \left(i_0^{€,l} - i_1^{€} - d_2^{€}\right) L_1^{€} + \left(i_0^{\$,l} - i_1^{\$} - d_2^{\$}\right) L_1^{\$} + (1 + i_1^{€})W_0 + (i_1^{€} - i^s)B^{€} \\ &+ \left(i_1^{\$} - i_1^{€} + e_1 - f_1\right) S_1 \\ &-(1 + i_1^{€})(1 - p_1^{\$})(L_0^{\$} - L_1^{\$}) - (1 + i_1^{€})(1 - p_1^{€})(L_0^{€} - L_1^{€}) \qquad (A.7) \end{aligned}$$

Linearizing the last line at $i_1^{€} = L_0^{\$} - L_1^{\$} = L_0^{€} - L_1^{€} = 0$, we have

$$\begin{aligned} W_2 &= \left(i_0^{€,l} - i_1^{€} - d_2^{€}\right) L_1^{€} + \left(i_0^{\$,l} - i_1^{\$} - d_2^{\$}\right) L_1^{\$} + (1 + i_1^{€})W_0 + (i_1^{€} - i^s)B^{€} \\ &+ \left(i_1^{\$} - i_1^{€} + e_1 - f_1\right) S_1 - (1 - p_1^{\$})(L_0^{\$} - L_1^{\$}) - (1 - p_1^{€})(L_0^{€} - L_1^{€}) \qquad (A.8) \end{aligned}$$

This is equation (13) in the text.

B Optimal Decisions by Bank

The bank maximizes the Lagrangian

$$\begin{aligned} &ER_2^p - 0.5\gamma var(R_2^p) - 0.5\frac{1}{W_1}\eta S_1^2 \qquad (B.1) \\ &-\frac{l_e}{W_1}\left(B_1^{€,w} - \bar{B}^{€}\right) - \frac{l_d}{W_1}\left(B_1^{\$,w} - \bar{B}^{\$}\right) - \frac{\mu_e}{W_1}\left(L_1^{€} - L_0^{€}\right) - \frac{\mu_d}{W_1}\left(L_1^{\$} - L_0^{\$}\right) \end{aligned}$$

Since $R_2^p = W_2/W_1$, we have $ER_2^p - 0.5\gamma var(R_2^p) = (1/W_1)E(W_2) - 0.5\gamma(1/W_1^2)var(W_2)$. It then follows from (B.1) that the bank maximizes

$$
\begin{aligned}
&E(W_2) - 0.5\gamma\frac{1}{W_1}var(W_2) - 0.5\eta S_1^2 \\
&-l_e\left(B_1^{€,w} - \bar{B}^{€}\right) - l_d\left(B_1^{\$,w} - \bar{B}^{\$}\right) - \mu_e\left(L_1^{€} - L_0^{€}\right) - \mu_d\left(L_1^{\$} - L_0^{\$}\right)
\end{aligned}
\tag{B.2}
$$

Next substitute the expression (13) for W_2 as well as (A.2)-(A.3) and (A.6). Omitting terms that do not depend on $L_1^{\$}$, $L_1^{€}$ or S_1, the bank maximizes

$$
\begin{aligned}
&\left(i_0^{€,l} - i_1^{€} - d\right)L_1^{€} + \left(i_0^{\$,l} - i_1^{\$} - d\right)L_1^{\$} \\
&+\left(i_1^{\$} - i_1^{€} + e_1 - f_1\right)S_1 - (1-p_1^{\$})(L_0^{\$} - L_1^{\$}) - (1-p_1^{€})(L_0^{€} - L_1^{€}) \\
&-0.5\gamma\frac{1}{W_1}\sigma^2\left(L_1^{€}\right)^2 - 0.5\gamma\frac{1}{W_1}\sigma^2\left(L_1^{\$}\right)^2 - 0.5\eta S_1^2 \\
&-l_e\left(L_1^{€} + S_1 - \bar{B}^{€}\right) - l_d\left(L_1^{\$} - S_1 - \bar{B}^{\$}\right) \\
&-l_e(1-p_1^{€})(L_0^{€} - L_1^{€}) - l_e(1-p_1^{\$})(L_0^{\$} - L_1^{\$}) \\
&-\mu_e\left(L_1^{€} - L_0^{€}\right) - \mu_d\left(L_1^{\$} - L_0^{\$}\right)
\end{aligned}
\tag{B.3}
$$

The first-order condition with respect to S_1 is

$$
S_1 = \frac{\left(i_1^{\$} + l_d\right) - \left(i_1^{€} + l_e + f_1 - e_1\right)}{\eta} \tag{B.4}
$$

This corresponds to equation (21) in the text.

The first-order conditions with respect to $L_1^{€}$ and $L_1^{\$}$ are

$$
L_1^{€} = \frac{i_0^{€,l} - d - i_1^{€} + 1 - p_1^{€} - p_1^{€}l_e - \mu_e}{\gamma\sigma^2}W_1 \tag{B.5}
$$

$$
L_1^{\$} = \frac{i_0^{\$,l} - d - i_1^{\$} + 1 - p_1^{\$} - l_d + l_e(1-p_1^{\$}) - \mu_d}{\gamma\sigma^2}W_1 \tag{B.6}
$$

Next substitute the expressions for $p_1^{€}$ and $p_1^{\$}$. This gives

$$
L_1^{€} = \frac{i_0^{€,l} - d - i_1^{€} - l_e - \mu_e + (1+l_e)\nu_e L_0^{€}}{\gamma\sigma^2 + (1+l_e)\nu_e W_1}W_1 \tag{B.7}
$$

$$
L_1^{\$} = \frac{i_0^{\$,l} - d - i_1^{\$} - l_d - \mu_d + (1+l_e)\nu_d L_0^{\$}}{\gamma\sigma^2 + (1+l_e)\nu_d W_1}W_1 \tag{B.8}
$$

C Analytical Results

C.1 Probability of Default

We start by showing that $\Delta p_D = 0$ to the first order when linearizing at the pre-shock equilibrium. The most important part of the argument is that $\Delta W_1 = 0$ when differentiating at the pre-shock equilibrium:

$$\Delta W_1 = (1 - p_1^{\$})\Delta L_1^{\$} + (L_0^{\$} - L_1^{\$})\Delta p_1^{\$} + (1 - p_1^{€})\Delta L_1^{€} + (L_0^{€} - L_1^{€})\Delta p_1^{€} \tag{C.1}$$

This is zero at the pre-shock equilibrium, where the asset prices are 1 and period 0 and 1 loans are the same.

We have

$$p_D = Prob(W_2 < 0) = Prob\left(d_2^{€} L_1^{€} + d_2^{\$} L_1^{\$} > C\right) \tag{C.2}$$

where the second equality follows from (13) and

$$\begin{aligned} C \;\; = \;\; & \left(i_0^{€,l} - i_1^{€}\right) L_1^{€} + \left(i_0^{\$,l} - i_1^{\$}\right) L_1^{\$} + (1 + i_1^{€})W_0 + (i_1^{€} - i^s)B^{€} \\ & + \left(i_1^{\$} - i_1^{€} + e_1 - f_1\right) S_1 - (1 - p_1^{\$})(L_0^{\$} - L_1^{\$}) - (1 - p_1^{€})(L_0^{€} - L_1^{€}) \end{aligned} \tag{C.3}$$

Linearizing $d_2^{€} L_1^{€} + d_2^{\$} L_1^{\$}$ at pre-shock loan levels and $d_2^{€} = d_2^{\$} = d$, we can write the probability of default as

$$p_D = Prob\left(\left(d_2^{€} - d\right) L_0^{€} + \left(d_2^{\$} - d\right) L_0^{\$} > C - dL_1^{€} - dL_1^{\$}\right) \tag{C.4}$$

The left hand side has an exogenous stochastic distribution that is unaffected by the shock. It therefore follows that this probability depends on $C - dL_1^{€} - dL_1^{\$}$. This is equal to

$$\begin{aligned} & \left(i_0^{€,l} - d - i_1^{€}\right) L_1^{€} + \left(i_0^{\$,l} - d - i_1^{\$}\right) L_1^{\$} + (1 + i_1^{€})W_0 + (i_1^{€} - i^s)B^{€} \\ & + \left(i_1^{\$} - i_1^{€} + e_1 - f_1\right) S_1 - (1 - p_1^{\$})(L_0^{\$} - L_1^{\$}) - (1 - p_1^{€})(L_0^{€} - L_1^{€}) \end{aligned} \tag{C.5}$$

This term does not change to the first-order due to the shock, so that $\Delta p_D = 0$. We have already discussed that the last two terms, associated with the change in W_1, do not change to the first-order. Also, when $\Delta p_D = 0$, the euro and dollar borrowing rates do not change to the first order. Now consider changes in euro and dollar lending. For example, for euro lending this term is

$$\left(i_0^{€,l} - d - i_0^{€}\right) \Delta L_1^{€} = \gamma \sigma^2 L_0^{€} \frac{1}{W_0} \Delta L_1^{€} \tag{C.6}$$

This term is third-order as $\Delta L_1^{€}$ is multiplied by σ^2. So we ignore this. The only term left is the one involving synthetic dollar borrowing. Its first-order change is

$$-\left(f_0 - e_0\right)\Delta S_1 - S_0 \Delta\left(f_1 - e_1\right) \tag{C.7}$$

But this is also zero since the pre-shock CIP deviation $f_0 - e_0$ is zero and also $S_0 = 0$. It follows that $\Delta p_D = 0$, so that also $\Delta i_1^{€} = \Delta i_1^{\$} = 0$.

C.2 Linearization

Differentiating (22)-(23) at the pre-shock equilibrium, using that $\Delta i_1^{€} = \Delta i_1^{\$} = 0$, we have

$$\Delta L_1^{€} = \frac{W_0}{\gamma\sigma^2 + \nu W_0}\left(-\Delta l_e - \Delta\mu_e\right) \tag{C.8}$$

$$\Delta L_1^{\$} = \frac{W_0}{\gamma\sigma^2 + \nu W_0}\left(-\Delta l_d - \Delta\mu_d\right) \tag{C.9}$$

From the swap market clearing condition we have

$$\Delta(f_1 - e_1) = 0.5\eta\epsilon^u + 0.5\left(\Delta l_d - \Delta l_e\right) \tag{C.10}$$

$$\Delta S_1 = -0.5\epsilon^u + 0.5\frac{1}{\eta}\left(\Delta l_d - \Delta l_e\right) \tag{C.11}$$

where $\epsilon^u = \Delta u$.

Using that $\Delta W_1 = 0$, we have

$$\Delta B_1^{€,w} = \Delta L_1^{€} + \Delta S_1 \tag{C.12}$$

$$\Delta B_1^{\$,w} = \Delta L_1^{\$} - \Delta S_1 \tag{C.13}$$

We consider 4 scenarios: dollar liquidity shocks without and with slackness in the euro borrowing constraint and u-shocks without and with slackness in the dollar borrowing constraint. In all the equilibria $\Delta\mu_e = \Delta\mu_d = 0$ as banks do not wish to increase lending.

C.3 Dollar Liquidity Shock without Euro Slackness

In the equilibrium derived below both dollar and euro lending drop, so that $\Delta L_1^{€}$ and $\Delta L_1^{\$}$ are negative. Dollar and euro borrowing constraints hold with equality.

Therefore $\Delta B_1^{€,w} = 0$ and $\Delta B_1^{\$,w} = -\epsilon^b$. These constraints bind, so that Δl_e and Δl_d are positive. We must compute $\Delta L_1^{€}$ and $\Delta L_1^{\$}$ as well as Δl_e and Δl_d.

We solve Δl_e and Δl_d by setting $\Delta B_1^{€,w} = 0$ and $\Delta B_1^{\$,w} = -\epsilon^b$. This implies

$$\Delta L_1^{€} + \Delta S_1 = 0 \tag{C.14}$$

$$\Delta L_1^{\$} - \Delta S_1 = -\epsilon^b \tag{C.15}$$

It is convenient to add and subtract these equations:

$$\Delta L_1^{€} + \Delta L_1^{\$} = -\epsilon^b \tag{C.16}$$

$$\Delta L_1^{€} - \Delta L_1^{\$} + 2\Delta S_1 = \epsilon^b \tag{C.17}$$

These two equations imply

$$\Delta l_d + \Delta l_e = \frac{\gamma\sigma^2 + \nu W_0}{W_0}\epsilon^b \tag{C.18}$$

$$\Delta l_d - \Delta l_e = \frac{\gamma\sigma^2 + \nu W_0}{W_0 + \frac{1}{\eta}(\gamma\sigma^2 + \nu W_0)}\epsilon^b \tag{C.19}$$

Adding and subtracting gives

$$\Delta l_d = 0.5(\gamma\sigma^2 + \nu W_0)\left(\frac{1}{W_0} + \frac{1}{W_0 + \frac{1}{\eta}(\gamma\sigma^2 + \nu W_0)}\right)\epsilon^b \tag{C.20}$$

$$\Delta l_e = 0.5(\gamma\sigma^2 + \nu W_0)\left(\frac{1}{W_0} - \frac{1}{W_0 + \frac{1}{\eta}(\gamma\sigma^2 + \nu W_0)}\right)\epsilon^b \tag{C.21}$$

It follows that

$$\Delta L_1^{€} = -\frac{0.5(\gamma\sigma^2 + \nu W_0)}{\eta W_0 + (\gamma\sigma^2 + \nu W_0)}\epsilon^b \tag{C.22}$$

$$\Delta L_1^{\$} = -\frac{\eta W_0 + 0.5(\gamma\sigma^2 + \nu W_0)}{\eta W_0 + (\gamma\sigma^2 + \nu W_0)}\epsilon^b \tag{C.23}$$

These results also imply that

$$\Delta(f_1 - e_1) = \frac{0.5\eta(\gamma\sigma^2 + \nu W_0)}{\eta W_0 + (\gamma\sigma^2 + \nu W_0)}\epsilon^b \tag{C.24}$$

$$\Delta S_1 = \frac{0.5(\gamma\sigma^2 + \nu W_0)}{\eta W_0 + (\gamma\sigma^2 + \nu W_0)}\epsilon^b \tag{C.25}$$

C.4 Dollar Liquidity Shock with Euro Slackness

In the equilibrium with euro slackness we have $\Delta l_e = 0$ and $\Delta B_1^{€,w} > 0$. In the equilibrium derived below the dollar borrowing constraint still holds with an equality, so that $\Delta B_1^{\$,w} = -\epsilon^b$ and $\Delta l_d > 0$.

We solve for $\Delta l_d > 0$ by imposing the dollar borrowing constraint with an equality. This implies $\Delta L_1^{\$} - \Delta S_1 = -\epsilon^b$, so that

$$\frac{-W_0}{\gamma\sigma^2 + \nu W_0}\Delta l_d - 0.5\frac{1}{\eta}\Delta l_d = -\epsilon^b \tag{C.26}$$

and

$$\Delta l_d = \frac{\eta(\gamma\sigma^2 + \nu W_0)}{\eta W_0 + 0.5(\gamma\sigma^2 + \nu W_0)}\epsilon^b \tag{C.27}$$

We have

$$\Delta L_1^{\$} = -\frac{\eta W_0}{\eta W_0 + 0.5(\gamma\sigma^2 + \nu W_0)}\epsilon^b \tag{C.28}$$

$$\Delta S_1 = \frac{0.5(\gamma\sigma^2 + \nu W_0)}{\eta W_0 + 0.5(\gamma\sigma^2 + \nu W_0)}\epsilon^b \tag{C.29}$$

We also have

$$\Delta L_1^{€} = 0 \tag{C.30}$$

$$\Delta B_1^{€,w} = \frac{0.5(\gamma\sigma^2 + \nu W_0)}{\eta W_0 + 0.5(\gamma\sigma^2 + \nu W_0)}\epsilon^b \tag{C.31}$$

The CIP deviation is

$$\Delta(f_1 - e_1) = \frac{0.5\eta(\gamma\sigma^2 + \nu W_0)}{\eta W_0 + 0.5(\gamma\sigma^2 + \nu W_0)}\epsilon^b \tag{C.32}$$

C.5 u-shock without Dollar Slackness

In the equilibrium below wholesale euro borrowing drops, so that $\Delta l_e = 0$. The dollar borrowing constraint binds, so that $\Delta l_d > 0$ needs to be solved.

We solve Δl_d by setting $\Delta B_1^{\$} = 0$. This implies

$$\Delta L_1^{\$} - \Delta S_1 = 0 \tag{C.33}$$

This implies

$$-\frac{W_0}{\gamma\sigma^2 + \nu W_0}\Delta l_d + 0.5\epsilon^u - 0.5\frac{1}{\eta}\Delta l_d = 0 \tag{C.34}$$

This implies

$$\Delta l_d = \frac{0.5\eta(\gamma\sigma^2 + \nu W_0)}{\eta W_0 + 0.5(\gamma\sigma^2 + \nu W_0)}\epsilon^u \tag{C.35}$$

We then have

$$\Delta L_1^{\$} = -\frac{0.5\eta W_0}{\eta W_0 + 0.5(\gamma\sigma^2 + \nu W_0)}\epsilon^u \tag{C.36}$$

We have

$$\Delta L_1^{€} = 0 \tag{C.37}$$

$$\Delta B_1^{\$,w} = 0 \tag{C.38}$$

$$\Delta B_1^{€,w} = \Delta S_1 = -\frac{0.5\eta W_0}{\eta W_0 + 0.5(\gamma\sigma^2 + \nu W_0)}\epsilon^u \tag{C.39}$$

The change in the CIP deviation is

$$\Delta(f_1 - e_1) = 0.5\eta\epsilon^u + 0.5\Delta l_d = 0.5\eta\frac{\eta W_0 + (\gamma\sigma^2 + \nu W_0)}{\eta W_0 + 0.5(\gamma\sigma^2 + \nu W_0)}\epsilon^u \tag{C.40}$$

C.6 u-shock with Dollar Slackness

When there is dollar slackness we have $\Delta l_d = 0$. It still remains the case that $\Delta l_e = 0$ as euro borrowing falls. Is it easily checked that with no changes in Lagrange multipliers, $\Delta L_1^{€} = \Delta L_1^{\$} = 0$.

We have $\Delta S_1 = -0.5\epsilon^u$, $\Delta B_1^{€,w} = -0.5\epsilon^u$ and $\Delta B_1^{\$,w} = 0.5\epsilon^u$. The CIP deviation rises by $\Delta(f_1 - e_1) = 0.5\eta\epsilon^u$.

D Other Equilibria

Other equilibria, beyond the one we focus on in the paper, can exist. For the benchmark parameterization in the paper, Figure A1 shows a mapping of the probability of default p_D into itself. The value of p_D on the horizontal axis is the assumed value of p_D by the wholesale lenders. This determines the interest rates on wholesale dollar and euro funding. The implied actual default probability is on the vertical axis. These must be equal in order for an equilibrium to exist. Figure A1 is drawn assuming that neither of the two shocks analyzed in the paper apply, so that $\bar{B}^{\$} = B_0^{\$,w}$, $\bar{B}^{€} = B_0^{€,w}$ and $u = 0$.

There are two solutions. We focus on the equilibrium with a low value of p_D, which is 0.005 or 50 basis points. We refer to this as the pre-shock equilibrium.

But there is a second equilibrium with high value of $p_D = 0.107$. This means that without either of the shocks considered in the paper, it is possible to have a self-fulfilling shock that raises the probability of default. Intuitively, a higher probability of default raises wholesale dollar and euro interest rates, which lowers net worth at time 2, which indeed raises the probability of default. However, the higher default equilibrium is unstable. Raising the assumed default probability slightly beyond that of the higher default equilibrium implies that the actual default probability is even higher. Similarly, lowering the assumed default probability slightly implies that the actual default probability is even lower.

But other equilibria can exist as well, where none of the wholesale lending is rolled over. These equilibria can take one of two forms. One is what we will refer to as a bank run equilibrium. This type of equilibrium is familiar from the ban krun literature. If wholesale funding is not rolled over, the bank is forced to liquidate assets. When the losses from liquidation are high enough that the bank is unable to pay the period 0 wholesale lenders, the bank defaults in period 1. In that case, we do not even reach period 2. The other case is where it is possible for the bank to liquidate enough assets in period 1 to pay the period 0 wholesale lenders, but there is a significant drop in net worth and $W_1 < 0$. This also lowers W_2. If it is the case that $W_2 < 0$ even under the most favorable scenario, where $d_2^{\$} = d_2^{€} = 0$, period 2 default is certain. In that case $p_D = 1$ and it is indeed not optimal for wholesale lenders to provide any funding in period 1. We refer to this as a delayed bank run equilibrium. Bank default is delayed to period 2.

D.1 Bank run Equilibrium

First consider a regular bank run equilibrium. Assume that wholesale lenders do not roll over their lending, so that $B_1^{\$,w} = B_1^{€,w} = 0$. In order to pay the period 0 wholesale lenders, the bank must sell enough loans to pay the principal $B_0 = B_0^{\$,w} + B_0^{€,w}$. Note that the interest has already been deducted to pay dividends to bank shareholders. So it must be the case that

$$p_1^{\$}\left(L_0^{\$} - L_1^{\$}\right) + p_1^{€}\left(L_0^{€} - L_1^{€}\right) = B_0 \tag{D.1}$$

If the bank is unable to sell enough loans to satisfy this, there exists a self-fulfilling bankrun equilibrium. So consider if it is possible for the bank to satisfy (D.1).

The bank takes $p_1^{\$}$ and $p_1^{€}$ as given. Assume that the bank will sell loans in a way that maximizes W_1, while satisfying (D.1). From (D.1) we have

$$L_1^{€} = -\frac{p_1^{\$}}{p_1^{€}} L_1^{\$} + \frac{1}{p_1^{€}} \left(p_1^{\$} L_0^{\$} + p_1^{€} L_0^{€} - B_0 \right) \tag{D.2}$$

From (A.6), maximizing W_1 implies maximizing

$$(1 - p_1^{\$}) L_1^{\$} + (1 - p_1^{€}) L_1^{€} = \frac{p_1^{€} - p_1^{\$}}{p_1^{€}} L_1^{\$} + \frac{1 - p_1^{€}}{p_1^{€}} \left(p_1^{\$} L_0^{\$} + p_1^{€} L_0^{€} - B_0 \right) \tag{D.3}$$

The right hand side substitutes (D.2).

When $p_1^{€} > p_1^{\$}$, it is clear that the bank wants to set $L_1^{\$}$ as high as possible. In that case $L_1^{\$} = L_0^{\$}$. But when all banks do this, it implies that $p_1^{\$} = 1$, so that this cannot be an equilibrium.

When $p_1^{€} = p_1^{\$}$, the bank is indifferent about how many dollar loans versus euro loans to sell. Based on the expressions for the asset prices, it follows that $L_0^{\$} - L_1^{\$} = L_0^{€} - L_1^{€}$. Referring to this selloff of both euro and dollar loans as x, we then have $p_1^{\$} = p_1^{€} = 1 - \nu x$. To satisfy (D.1), we must then have

$$\nu x^2 - x + 0.5 B_0 = 0 \tag{D.4}$$

At the same time $x < L_0^{\$}$ as the bank cannot sell more than $L_0^{\$}$ dollar loans. Assuming that $L_0^{€} > L_0^{\$}$, this automatically also implies that $x < L_0^{€}$. In order for a solution to the quadratic to exist, it must be the case that

$$2\nu B_0 < 1 \tag{D.5}$$

In that case we have

$$x = \frac{0.5}{\nu} \left(1 - \sqrt{1 - 2\nu B_0} \right) \tag{D.6}$$

Here we pick the lower solution for x to make it more likely that $x < L_0^{\$}$ is satisfied. It can be checked that when we pick the higher solution to x, $x < L_0^{\$}$ will not be satisfied. Note that since $x < 0.5/\nu$, the loan prices $1 - \nu x$ are larger than 0.5.

Note that $\sqrt{1 - 2\nu B_0} < 1 - \nu B_0$, so that $x > 0.5 B_0$. A sufficient condition for $x < L_0^{\$}$ not to be satisfied is therefore $B_0 > 2L_0^{\$}$. This is certainly the case for our parameterization. For any parameterization where $S_0 = 0$, it is satisfied as long as there are larger euro than dollar wholesale liabilities. I will assume that this is the case. Therefore (D.1) cannot be satisfied with $p_1^{€} = p_1^{\$}$.

This leaves only one way that (D.1) may be satisfied, which is an equilibrium where $p_1^{€} < p_1^{\$}$. In that case the bank wants to set $L_1^{\$}$ as low as possible, which is 0.

Let $x = L_0^{€} - L_1^{€}$. It must then be the case that $L_0^{\$} < x < L_0^{€}$. The first inequality is to have higher euro loan sales then dollar loans sales in order to have a lower euro than dollar asset price. The second inequality says that the bank cannot sell more euro loans than its time zero euro loans.

To satisfy (D.1), it must be the case that

$$\nu x^2 - x + B_0 - (1 - \nu L_0^{\$})L_0^{\$} = 0 \tag{D.7}$$

This can only have a solution when

$$1 - 4\nu(B_0 - (1 - \nu L_0^{\$})L_0^{\$}) > 0 \tag{D.8}$$

and x satisfies the bounds stated above.

The bank is unable to satisfy (D.1) when (D.8) does not hold, which is the case when

$$\left(L_0^{\$}\right)^2 \nu^2 + (B_0 - L_0^{\$})\nu - 0.25 > 0$$

This is the case when

$$\nu > \frac{-(B_0 - L_0^{\$}) + \sqrt{(B_0 - L_0^{\$})^2 + \left(L_0^{\$}\right)^2}}{2\left(L_0^{\$}\right)^2} \tag{D.9}$$

It is easily checked that this is satisfied when $\nu > 1/[4(B_0 - L_0^{\$})]$, which is 0.0215 for our parameterization. But the precise cutoff in (D.9) is 0.0195. When $\nu > 0.0195$, there is no equilibrium where (D.1) is satisfied, so there is a bank run equilibrium.

D.2 Delayed Bank Run Equilibrium

Now consider a delayed bank run equilibrium. In this equilibrium again none of the wholesale lending is rolled over in period 1, so that $B_1^{\$,w} = B_1^{€,w} = 0$. But a regular bank run equilibrium does not exist. The bank is able to satisfy (D.1). This occurs when

$$\nu < \frac{-(B_0 - L_0^{\$}) + \sqrt{(B_0 - L_0^{\$})^2 + \left(L_0^{\$}\right)^2}}{2\left(L_0^{\$}\right)^2} \tag{D.10}$$

and x satisfies the bounds $L_0^{\$} < x < L_0^{€}$. Define the cutoff on the right hand side of (D.10) as $\bar{\nu}$.

To evaluate these bounds, we must solve x from (D.7). We have

$$x = \frac{1 \pm \sqrt{1 - 4\nu \left(B_0 - (1 - \nu L_0^{\$}) L_0^{\$}\right)}}{2\nu} \tag{D.11}$$

For our assumed parameters, x always satisfies the bounds $L_0^{\$} < x < L_0^{€}$ when using the lower value of x, but not when using the upper value. So assume the lower value.

In the delayed bank run equilibrium, both euro and dollar wholesale funding are not rolled over since $p_D = 1$. In this case the bank continues to operate until period 2, but default is guaranteed in period 2. This means that $W_2 < 0$ even in the most favorable scenario where there is no default on loans, so that $d_2^{\$} = d_2^{€} = 0$. We then have

$$W_2 = (1 + i_0^{€,l}) L_1^{€} - (1 + i^s) B^{€} \tag{D.12}$$

Note that $S_1 = 0$ as both dollar assets and liabilities are zero in this scenario.

Using that $L_1^{€} = L_0^{€} - x$, it follows that there exists a delayed bank run equilibrium when $\nu < \bar{\nu}$ and

$$x > L_0^{€} - \frac{1 + i^s}{1 + i_0^{€,l}} B^{€} \tag{D.13}$$

First consider the upper end of the range for ν, $\nu = \bar{\nu}$. In that case $x = 1/(2\bar{\nu})$. As discussed, a very close approximation for $\bar{\nu}$ is $\bar{\nu} = 1/[4(B_0 - L_0^{\$})]$. Under this approximation, (D.13) becomes

$$2(B_0 - L_0^{\$}) > L_0^{€} - \frac{1 + i^s}{1 + i_0^{€,l}} B^{€} \tag{D.14}$$

The ratio involving the interest rates is close to 1. Therefore we can further approximate the condition as

$$2(B_0 - L_0^{\$}) > L_0^{€} - B^{€} \tag{D.15}$$

Assuming $S_0 = 0$, so that $B_0 - L_0^{\$} = B_0^{€,w}$, this becomes $2B_0^{€,w} + B^{€} > L_0^{€}$. When there are larger euro than dollar wholesale deposits, the left hand side is larger than the sum of all liabilities, excluding net worth. Therefore it is larger than $L_0^{€} + L_0^{\$} - W_0$. The condition then becomes $L_0^{\$} > W_0$. This holds easily and certainly for our parameterization of G-SIB banks. Therefore a delayed bank run exists when ν is less than, but close to the cutoff $\bar{\nu}$. While we made a couple of approximations, without doing so this will be the case for the parameters assumed in the paper.

But for this type of equilibrium to exist, ν will need to be above some minimum cutoff. To see this, consider $\nu \to 0$. In that case it follows from (D.7) that $x \to B_0 - L_0^{\$}$. In that case we can rewrite (D.13) as

$$L_0^{€} + L_0^{\$} < B_0 + \frac{1+i^s}{1+i_0^{€,l}} B^{€} \tag{D.16}$$

This is clearly not satisfied as the left hand side is the sum of all bank assets and the right hand side is less than the sum of all bank liabilities. This means that a delayed bankrun equilibrium does not exist when ν is close to zero. This makes sense as in that case the losses from selling assets are negligible.

Figure A2 provides a numerical illustration based on the parameterization in the paper. It shows for ν from 0 to $\bar{\nu} = 0.0195$ the value of W_2 conditional on zero default on bank loans in period 2, as well as the values of W_1, $L_1^{\$}$, $L_1^{€}$, $p_1^{\$}$ and $p_1^{€}$. We need $W_2 < 0$ for a delayed bankrun equilibrium to exist. This is the case for ν in between 0.0126 and 0.0195. There is a small range of values of ν from 0.0098 to 0.0126 where $W_1 < 0$ but $W_2 > 0$. At the upperbound where $\nu = \bar{\nu} = 0.0195$, the balance sheet of the bank looks as follows. The value of remaining euro loans has dropped from the original 39.5 to 13.8. The net worth is -11.5 and retail deposits remain 25.3. The price of the dollar loans has dropped to 0.844, while the price of euro loans has dropped to 0.5. When ν is larger than 0.0195, the bank losses are even larger and the bank is unable to repay the period 0 wholesale lenders. In that case a regular bank run equilibrium exists.

E Bank balance sheets and event study

We discuss some details behind the construction of bank balance sheets, which are used for the calibration exercise in Section 4 of the paper and for the event study in Figure 2 of the paper.

E.1 Balance Sheet Data

We collect balance sheet data from 40 non-US and non-Chinese G-SIB banks. As part of the BIS annual G-SIB assessment that has been conducted every year since

2013, the BIS collects data from a set of the largest banks in the world. These 40 banks are the non-US and non-Chinese banks that have been included in the BIS G-SIB Main Sample every year from 2013 to 2022.[1] These 40 banks are headquartered in 14 countries.

Define $D_{B,c,t}$ as deposits at G-SIB banks in county c, where $D_{B,c,t} = \sum_{i=1}^{I} D_{i,c,t}$ and $D_{i,c,t}$ are deposits at G-SIB bank i in country c and I is the total number of G-SIB banks headquartered in country c. These deposit data are taken from the S&P Capital IQ data.

$C^{USD}_{B,c,t}$ and $L^{USD}_{B,c,t}$ are the USD denominated claims and liabilities for the G-SIB banks in country c, where $C^{USD}_{B,c,t} = m_c C^{USD}_{c,t}$ and $L^{USD}_{B,c,t} = m_c L^{USD}_{c,t}$. $C^{USD}_{c,t}$ and $L^{USD}_{c,t}$ are the dollar denominated claims and liabilities for all banks in country c from the BIS, and m_c is the share that is held by the G-SIB banks.

The USD denominated claims and liabilities at the country-level, $C^{USD}_{c,t}$ and $L^{USD}_{c,t}$, are calculated from the BIS International Banking Statistics following the method described in Aldsoro and Ehlers (2018). From the Locational Banking Statistics by Nationality we can observe the USD claims and liabilities of banks headquartered in country c. This includes both local and cross-border holdings by the bank in the headquarter country as well as local USD claims and liabilities of

[1]The names of these banks, along with the stock exchange and ticker for the publicly traded ones are: ANZ Group Holdings Limited (ASX:ANZ), Banco Bilbao Vizcaya Argentaria, S.A. (BME:BBVA), Banco Santander, S.A. (BME:SAN), Bank of Montreal (TSX:BMO), Barclays PLC (LSE:BARC), BNP Paribas SA (ENXTPA:BNP), CaixaBank, S.A. (BME:CABK), Canadian Imperial Bank of Commerce (TSX:CM), Commerzbank AG (XTRA:CBK), Commonwealth Bank of Australia (ASX:CBA), Coöperatieve Rabobank U.A., Crédit Agricole S.A. (ENXTPA:ACA), Crédit Mutuel Group, Credit Suisse Group AG (SWX:CSGN), Danske Bank A/S (CPSE:DANSKE), DBS Group Holdings Ltd (SGX:D05), Deutsche Bank Aktiengesellschaft (XTRA:DBK), DZ BANK AG, Deutsche Zentral-Genossenschaftsbank Frankfurt am Main , Groupe BPCE, HSBC Holdings plc (LSE:HSBA), ING Groep N.V. (ENXTAM:INGA), Intesa Sanpaolo S.p.A. (BIT:ISP), Lloyds Banking Group plc (LSE:LLOY), Mitsubishi UFJ Financial Group, Inc. (TSE:8306), Mizuho Financial Group, Inc. (TSE:8411), National Australia Bank Limited (ASX:NAB), NatWest Group plc (LSE:NWG), Nordea Bank Abp (HLSE:NDA FI), Royal Bank of Canada (TSX:RY), Société Générale Société anonyme (ENXTPA:GLE), Standard Chartered PLC (LSE:STAN), State Bank of India (NSEI:SBIN), Sumitomo Mitsui Financial Group, Inc. (TSE:8316), Sumitomo Mitsui Trust Group, Inc. (TSE:8309), The Bank of Nova Scotia (TSX:BNS), The Norinchukin Bank, The Toronto-Dominion Bank (TSX:TD), UBS Group AG (SWX:UBSG), UniCredit S.p.A. (BIT:UCG), Westpac Banking Corporation (ASX:WBC)

foreign affiliates, and excludes intragroup holdings. This however does not include the local USD claims and liabilities of affiliates in the United States. So to this data from the Local Banking Statistics by Nationality we add local claims and liabilities in the local currency by the bank's affiliates in the United States from the BIS Consolidated Banking Statistics.

The shares m_c are calculated as follows. Let $C^F_{i,c,t}$ and $L^F_{i,c,t}$ be cross-jurisdictional claims and liabilities of G-SIB bank i in country c. We observe these data for every year from 2013 to 2022. Summing these across the G-SIB banks in a country, we have $C^F_{B,c,t} = \sum_{i=1}^{I} C^F_{i,c,t}$ and $L^F_{B,c,t} = \sum_{i=1}^{I} L^F_{i,c,t}$. We can observe foreign claims and liabilities at the country level from the BIS (denominated in all currencies), $C^F_{c,t}$ and $L^F_{c,t}$. When observing these foreign claims and liabilities from the BIS, we can observe if a claim or liability is with a domestic counterparty, foreign counterparty, or unallocated. We assume that the claims and liabilities with an unallocated counterparty are 50% foreign and 50% domestic.

From this we can calculate $m^C_{c,t} = \frac{C^F_{B,c,t}}{C^F_{c,t}}$ and $m^L_{c,t} = \frac{L^F_{B,c,t}}{L^F_{c,t}}$ for every year 2013-2022. Our shares are $m_c = \frac{1}{2}\frac{1}{10}\sum_{t=2013}^{2022}\left(m^C_{c,t} + m^L_{c,t}\right)$.[2]

$C^{nonUSD}_{B,c,t}$ are non-USD denominated claims for the G-SIB banks in country c. It is computed as a residual: $C^{nonUSD}_{B,c,t} = A_{B,c,t} - C^{USD}_{B,c,t}$. Total assets of G-SIB banks in country c are $A_{B,c,t} = \sum_{i=1}^{I} A_{i,c,t}$, where $A_{i,c,t}$ is the total assets of G-SIB bank i.

$L^{nonUSD}_{B,c,t}$ are non-USD denominated wholesale liabilities for the G-SIB banks in country c. It is also computed as a residual: $L^{nonUSD}_{B,c,t} = L_{B,c,t} - D_{B,c,t} - L^{USD}_{B,c,t}$. Total bank liabilities of G-SIB banks in country c are $L_{B,c,t} = \sum_{i=1}^{I} L_{i,c,t}$, where $L_{i,c,t}$ is total liabilities of G-SIB bank i.

The net worth of G-SIB banks in country c is then $N_{B,c,t} = A_{B,c,t} - L_{B,c,t}$. FX swaps/bank assets are $S_{B,c,t} = \frac{C^{USD}_{B,c,t} - L^{USD}_{B,c,t}}{A_{B,c,t}}$.

[2]We can compute these shares every year from 2013 to 2022. They do not show and upward or downward trend over time, so we simply compute one share and apply it throughout our sample.

E.2 Event Study Figure 2

The event study graphs in Figure 2 present the responses of seven bank balance sheet variables: deposits, USD claims, USD liabilities, non-USD claims, non-USD liabilities, net worth, and FX swaps/bank assets. The figure also presents the CIP deviation and the probability of default (EDF).

The CIP deviation is the 3-month OIS CIP deviation from Bloomberg. The graph of in Figure 2 reports the average of these CIP deviations across our 22 events.

The EDF (expected default frequency) is observed at the bank level and is obtained from Moody's Analytics. The EDF series $EDF_{B,c,t}$ at the country level is the average EDF across the G-SIB banks in the country. The EDF graph in Figure 2 is the average of these country-level EDFs across our 22 events.

We calculate $\frac{s_c D_{B,c,t}}{hp\left(s_c D_{B,c,t}\right)}$, where s_c is the nominal exchange rate in local currency per USD and hp refers to the HP trend. We normalize this series to have a value of zero in the quarter T=0 of an event in country c. The graph of retail deposits in Figure 2 is the average of these normalized $\frac{s_c D_{B,c,t}}{hp\left(s_c D_{B,c,t}\right)}$ across our 22 events. The same is done for USD claims and liabilities, non-USD claims and wholesale liabilities, and net worth. USD assets and liabilities and net worth are not converted to the local currency.

For FX swaps/bank assets, we do not scale by the HP trend. We do normalize the series to have a value of zero in the quarter T=0 of an event in country c. The graph of FX swaps/bank assets in Figure 2 is the average of these normalized $S_{B,c,t}$ across our 22 events.

F Sensitivity Analysis and Extensions

We now consider sensitivity analysis and extensions. Figures A3 through A10 illustrate how changing these affect the response of variables to a dollar liquidity shock.

F.1 Role of $\nu_e = \nu_d$

In the paper we set $\nu = \nu_e = \nu_d = 0.2$. In Figure A3 we vary ν from 0 to 0.3. Unless we lower ν below 0.01, this has very little effect on the results. The only variable that is affected substantially for values above 0.01 is the probability of default. When the euro borrowing constraint is binding, it rises in response to the dollar liquidity shock as we raise ν. This is natural as a higher cost of asset liquidation lowers net worth, which raises the probability of default. At the extreme where ν approaches zero, so that assets can be sold without cost, banks only sell dollar loans and hold the swap market position at zero. Naturally, in that case the CIP deviation is also unaffected. But beyond this rather extreme case where both dollar and euro assets are perfectly liquid, we find that ν mainly affects net worth and the probability of default and only when the euro borrowing constraint binds.

F.2 Role of η

In the paper we set $\eta = 0.0025$. In Figure A4 we vary η from 0 to 0.01. We see that the only variable that is affected is the CIP deviation. Over this range, the increase in the CIP deviation varies from 0 to 51 basis points with a binding euro borrowing constraint and from 0 to 117 basis points without a binding euro borrowing constraint.

F.3 Difference between ν_e and ν_d

So far we have assumed that $\nu_e = \nu_d = 0.2$. We now vary $\nu_d - \nu_e$ while keeping their average value equal to 0.2. Perhaps not surprisingly, this has a significant effect on the results, as shown in Figure A5.

One extreme involves $\nu_d = 0$ and $\nu_e = 0.4$. Then there is no cost to liquidating dollar loans, but a very high cost to liquidating euro loans. The opposite extreme case involves $\nu_d = 0.4$ and $\nu_e = 0$.

Consider the two extremes in turn. When $\nu_d = 0$ and $\nu_e = 0.4$ there is no cost to liquidating dollar loans. Banks then naturally sell dollar loans when faced with a dollar liquidity shock. They do so even when the euro borrowing constraint does not bind. Dollar assets and liabilities then drop equally and the swap market position remains zero. The CIP deviation is therefore also unaffected by the shock.

When $\nu_d = 0.4$ and $\nu_e = 0$, the cost of selling dollar loans is so high that banks will not sell any dollars loans. When the euro borrowing constraint binds they will instead sell euro loans, which they can do without any cost. But this creates a larger net long dollar position on the balance sheet. This leads to a larger demand for dollar swaps and a larger increase in the CIP deviation.

The probability of bank default actually rises most when $\nu_e = \nu_d = 0.2$. This is because in the two extreme cases banks avoid losses associated with selling loans. For example, when $\nu_d = 0.4$ and $\nu_e = 0$, there is no cost associated with selling euro loans, while banks avoid selling dollar loans as this is too costly.

F.4 Pre-shock Synthetic Dollar Position

Next we consider some extensions. We first vary the pre-shock synthetic dollar position of banks. So far we set it equal to zero in the pre-shock equilibrium. Table 2 of the paper shows that in 2022 dollar assets of non-US banks were about \$0.8T higher than dollar liabilities. If this net dollar position is hedged, it implies that non-US banks hold \$0.8T in dollar swaps, which is 1.7% of all bank assets. On average over the 2003-2022 sample the swap position was 1% of bank assets.

Defining δ as the pre-shock ratio of the swap market position relative to assets, we will vary δ from -0.05 to 0.05 (-5 to +5%). We do so by changing $L_0^{\$}$ and $L_0^{€}$ relative to their values in Table 3. Holding $B_0^{\$,w}$ equal to its value in Table 3 of the paper, we set $L_0^{\$} = B_0^{\$,w} + \delta K$ and $L_0^{€} = K - L_0^{\$}$, where K is the size of the balance sheet that we hold constant at 47.5. Figure A6 shows that this has virtually no effect on any of the variables. The drop in dollar and euro lending that occurs when the euro borrowing constraint binds remains the same. Percentage wise they vary with δ as $L_0^{\$}$ is higher and $L_0^{€}$ is lower as we raise δ.

F.5 Risk Aversion Wholesale Dollar and Euro Lenders

We have assumed that wholesale lenders are risk neutral, so that the interest rates on wholesale dollar and euro funding are equal to the safe rate plus the probability of bank default. We now extend the model to make wholesale lenders risk-averse. Consider wholesale euro lenders. Let their wealth be $W^{l,€}$ and let P_2 be the period 2 payment per euro of wholesale lending to the bank. This is equal to $1 + i_1^{€}$ with probability $1 - p_D$ and 0 with probability p_D. They earn an interest of i^s on safe euro assets.

When the euro wholesale lenders allocate $A_1^{€,w}$ to bank lending, the portfolio return is

$$R_2^{p,l} = 1 + i^s + \frac{A_1^{€,w}}{W_1^{l,€}} \left(P_2 - 1 - i^s\right) \tag{F.17}$$

Lenders maximize

$$ER_2^{p,l} - 0.5\gamma_e var(R_2^{p,l}) \tag{F.18}$$

This implies maximizing

$$\frac{A_1^{€,w}}{W_1^l}\left(E(P_2) - 1 - i^s\right) - 0.5\gamma_e\left(\frac{A_1^{€,w}}{W_1^{l,€}}\right)^2 var(P_2) \tag{F.19}$$

This implies

$$A_1^{€,w} = \frac{(E(P_2) - 1 - i^s)W_1^{l,€}}{\gamma_e var(P_2)} \tag{F.20}$$

We have

$$E(P_2) = \left(1 + i_1^{€}\right)(1 - p_D) \tag{F.21}$$

and

$$var(P_2) = E(P_2)^2 - (E(P_2))^2 = (1-p_D)\left(1 + i_1^{€}\right)^2 - (1-p_D)^2\left(1 + i_1^{€}\right)^2 = \left(1 + i_1^{€}\right)^2 p_D(1-p_D) \tag{F.22}$$

To summarize, we have

$$A_1^{€,w} = \frac{\left[\left(1 + i_1^{€}\right)(1 - p_D) - 1 - i^s\right] W^{l,€}}{\gamma_e\left(1 + i_1^{€}\right)^2 p_D(1 - p_D)} \tag{F.23}$$

Analogously for wholesale dollar lenders we have

$$A_1^{\$,w} = \frac{\left[\left(1 + i_1^{\$}\right)(1 - p_D) - 1 - i^s\right] W^{l,\$}}{\gamma_d\left(1 + i_1^{\$}\right)^2 p_D(1 - p_D)} \tag{F.24}$$

In the calibration, we set $W^{l,€} = B_0^{€,w}$ and $W^{l,\$} = B_0^{\$,w}$. The market equilibrium conditions for short-term wholesale funding are $A_1^{€,w} = B_1^{€,w}$ and $A_1^{\$,w} = B_1^{\$,w}$, which can be written as

$$\left(1 + i_1^{€}\right)(1 - p_D) - 1 - i^s = \gamma_e\left(1 + i_1^{€}\right)^2 p_D(1 - p_D)\frac{B_1^{€,w}}{B_0^{€,w}} \tag{F.25}$$

$$\left(1 + i_1^{\$}\right)(1 - p_D) - 1 - i^s = \gamma_d(1 + i_1^{\$})^2 p_D(1 - p_D)\frac{B_1^{\$,w}}{B_0^{\$,w}} \tag{F.26}$$

This replaces the equations $i_1^{€} = i_1^{\$} = i^s + p_D$.

With this extension, both the first and second moments associated with bank default affect the interest rates. We vary risk aversion of these lenders from 0 to 2. Figure A7 shows that this has virtually no effect on the results.

F.6 Bailout of Wholesale Euro Lenders

We consider an extension where there is a partial bailout of euro wholesale lenders in case of bank default. A fraction $bail_e$ of obligations to euro wholesale lenders will be bailed out by the government in period 2 in case of default. Assuming risk neutrality, the lenders then demand an interest rate $i_1^{€} = i^s + p_D(1 - bail_e)$. We vary $bail_e$ from 0 to 1. When it is 1, there is a complete bailout in case of default, so that wholesale euro lending becomes risk-free. Figure A8 shows that this parameter also has no effect on the impact of the dollar liquidity shock on variables.

It does affect the pre-shock CIP deviation. In the main analysis, where $bail_e = 0$, the pre-shock CIP deviation is zero. A higher value of $bail_e$ implies a larger pre-shock CIP deviation. It lowers the wholesale euro borrowing rate for banks. This makes it cheaper to borrow dollars synthetically. The resulting larger demand for dollar swaps by banks raises the pre-shock CIP deviation.

F.7 Binding Pre-shock Dollar Borrowing Constraint

In the main analysis the dollar borrowing constraint does not strictly bind in the pre-shock equilibrium, so that $l_d = 0$. We now consider positive values of l_d by raising $i_0^{\$,l}$. As discussed in Appendix B, there is a one-to-one relationship between l_d and $i_0^{\$,l}$. A higher dollar lending rate makes it more attractive for banks to borrow dollars, which causes the dollar borrowing constraint to bind. By varying $i_0^{\$,l}$ we vary l_d in the pre-shock equilibrium from 0 to 0.02.

Raising l_d raises the effective pre-shock dollar funding rate, which makes it more attractive for banks to borrow dollars synthetically. This raises the pre-shock swap rate and CIP deviation. As we vary l_d from 0 to 0.02 the pre-shock CIP deviation varies from 0 to 100 basis points.[3] Nonetheless, Figure A9 shows that the response of variables to a dollar liquidity shock is again unaffected.

[3] We also raise u in the pre-shock equilibrium (so far set at 0). The higher swap rate causes US banks to sell dollar swaps. To equilibrate the swap market, we raise u, so that non-banks agents buy more dollar swaps. See Appendix B for further details.

F.8 Mixture of Dollar Liquidity Shocks and Synthetic Dollar Borrowing Shocks

In reality, the two types of dollar funding shocks that we have discussed often occur in combination. In Figure A10 we consider the following scenario. We continue to assume a dollar liquidity shock of 15.8%, while at the same time varying ϵ^u from 0 to 2.

We have seen that synthetic dollar borrowing shocks on their own mainly impact the CIP deviation. They have little effect on the balance sheet and the probability of default. It is therefore not surprising that when combining the two shocks, the only variable that is affected is the CIP deviation. The larger the synthetic dollar borrowing shock that we mix with a given dollar liquidity shock, the bigger the rise in the CIP deviation.