The Global Network of Liquidity Lines *

Saleem Bahaj UCL

Marie Fuchs LSE

Ricardo Reis LSE

May 2024

Abstract

At the end of 2023, there were 175 cross-border connections between central banks in a global network of liquidity lines that gave access to foreign currency for countries accounting for 79% of world GDP. This paper presents a comprehensive dataset of this network and its characteristics between 2000 and 2023. While the Federal Reserve drove growth in 2007-09, the network expanded as much between 2010 and 2015 through bilateral arrangements involving the ECB and the People's Bank of China. The network structure means that banks without direct access to a source central bank can still have indirect access to its currency. The central intermediaries in the network for all major currencies are the PBoC and the ECB. We find support using cross-country data that the lines reduce CIP deviations at the tails. Liquidity lines are often signed to substitute for a bleeding of FX reserves, but once in place they complement reserves.

JEL codes: E44, F33, G15.

Keywords: swap lines, capital flows, financial crises, IMF, cross-currency basis

*Contacts: s.bahaj@ucl.ac.uk, m.fuchs1@lse.ac.uk, and r.a.reis@lse.ac.uk. We are grateful to Chris Clayton and Arnaud Mehl for comments, to Marina Feliciano, Seyed Mahdi Hosseini, and Xiaotong Wu for research assistance, and to seminar audiences at the ASSA 2024 meetings and the State Bank of Pakistan. This work was supported by the UK Research and Innovation grant number EP/Eo25039/1.

1 Introduction

A central bank cross-border liquidity line is an agreement between two central banks to provide a collateralised loan of currency from one to the other. They have been around for a long time, but have risen in prominence over the last twenty years. Following both the great financial crisis and the pandemic, central banks expanded the number of lines and relied on them to restore financial stability. By 2023, the funds committed to the liquidity lines were well above the lending capacity of the International Monetary Fund (IMF).[1]

These agreements are varied in their signatories and in their characteristics. For instance, while swap lines get most of the attention, there are many repurchase agreements as well. Also, while borrowing from a line usually means money issuance by one of the central banks, some large lines instead lend out existing US dollar reserves. Finally, the People's Bank of China (PBoC) has a large hub-and-spoke network, while the Federal Reserve (Fed)'s lines form a smaller but denser network, and the European Central Bank (ECB)'s network is in between.

This paper provides a comprehensive dataset of central bank cross-border liquidity lines at the agreement level: by date and duration (2000-23), by source currency (USD, EUR, RMB, others), by framework (bilateral or multilateral), by structure (pooled, reciprocal, or unidirectional), by counterparties (central banks), and by some terms (type of collateral and cap on amount). This dataset was collated from public sources, and is freely available for other researchers to use.[2] After explaining the effort to collect the data and the main features of the dataset, we characterise its salient features over four sections.

In section 2, we document the evolution of the lines over time, by central bank, by type and scope, and across different regions. Different lines have different goals. Some, like the ones signed during the financial crisis, provided loans to banks in the jurisdiction of the recipient central bank in order to preserve financial stability. Others, like most of the ones involving the renminbi, pursued a goal of internationalising the currency. During the pandemic in 2020, lines were signed to stabilise debt markets, and more recently central banks in Turkey and Argentina have used them to intervene in foreign exchange markets, returning to their original use during Bretton Woods. This decentralised spontaneous process has led to an uneven spread and composition of liquidity lines in parallel with the other centrally negotiated pillars of the international financial system, like the World

[1]For some history of the lines and their evolution see Bordo, Humpage and Schwartz (2015), McCauley and Schenk (2020), Bahaj and Reis (2022*b*, 2023).

[2]The website `https://r2rsquaredlse.github.io/web-lines/` has the data repository.

Bank and the IMF.

Section 3 shows that the lines form a network. Through this network, a bank can have indirect access to a loan in a foreign currency even when its own central bank does not have a line that directly involves that currency. Our main finding is that the coverage of the network is broader than is commonly appreciated and shared by the three major currencies: the US dollar (USD), the Euro (EUR), and the Renminbi (RMB) networks reach countries covering 79% of world GDP. Moreover, the PBoC has a central role in the network for both USD and EUR.

Section 4 proves that the indirect connections put ceilings on the covered interest parity (CIP) deviations (sometimes also called the cross-currency basis) between two currencies to a much wider set of pairs of currencies than previously thought. Matching CIP data with our network dataset, we find a positive association between the average size of CIP deviations between two currencies and the degree of the connection between the central banks of these currencies.

Section 5 asks whether the liquidity lines complement or substitute for foreign exchange (FX) reserves. Both the reasons that lead countries to hold large stocks of reserves, as well as the actual benefits that they get from them, are open research questions. Insofar as the lines provide some of the same benefits, and their adoption reflects some of the same causes, by studying reserves jointly with lines we can better understand both benefits and causes.

Since both lines and reserves are deliberate joint policy choices, identification is challenging. We propose a two-part strategy to make some progress. First, we study the determinants of signing a liquidity line between two central banks. We find that a rapid drawdown of reserves is a significant predictor. In this sense, the lines work as substitutes for FX reserves. Second, we use the indirect connections in the network of liquidity lines to obtain plausibly exogenous variation in a country's ability to tap into this network for foreign currency. Specifically, we ask what happens to a country's reserves when a counterparty it is connected to improves its position in the network. This improvement in higher-degree connections is not associated with a specific action by the country. Using this source of variation, we find that when a country becomes better connected, this is followed by an increase in FX reserves. In this sense the liquidity lines are complements to FX reserves.

Section 6 concludes.

Relation to the literature. The modern literature on liquidity lines has grown quickly:

see Bahaj and Reis (2022*a*, 2020), Ferrara et al. (2022), Cesa-Bianchi, Erugen-Martin and Ferrero (2022), Goldberg and Ravazzolo (2022), Albrizio, Kataryniuk and Molina (2023), Bohórquez (2023), Horn et al. (2023), Kekre and Lenel (2023), Bacchetta, Davis and van Wincoop (2023), Róldan and Sosa-Padilla (2023), among others. This literature has focussed on individual liquidity lines, as opposed to mapping the whole network as we do. Perks et al. (2021) is closest. We build on its data, but significantly extend the coverage over time, countries, and characteristics.

The empirical part of these studies has used high-frequency data to isolate the micro channels through which the liquidity lines operate. This paper instead focuses on the lower-frequency macro trends. On the relation between liquidity lines and deviations from covered interest parity (CIP), existing research has established causal links in time-series data for a handful of advanced economics. We instead look at correlations in a large cross-section of lines over 72 countries and CIP measures for 42 countries, building on the work of Du and Schreger (2016) and Cerutti and Zhou (2024).

Both theoretically and empirically, the papers listed above have studied the impact of the lines on investment across borders, the currency of cross-border payments, the price of risk associated with the dollar, the supply of dollar liquidity, the incidence of global financial crises. Our study of the connection between lines and reserves is more novel, and was first studied by Obstfeld, Shambaugh and Taylor (2009). We make progress by having a large dataset to systematically study it, and a strategy to deal to achieve identification.

2 The geographic spread and coverage of the lines

We collected information on each agreement by hand after combining multiple sources.

We started by merging the earlier work by Perks et al. (2021), Albrizio, Kataryniuk and Molina (2023), Bahaj and Reis (2023), Horn et al. (2023), Kelly (2023) that had more limited regional and time coverage. Then, we went through the websites, press releases, publications, and central bank annual reports of each central bank since 2000, looking for announcements of any agreement. This provided a first list for which we would find at least one side of a bilateral deal recognising it in some official publication.

Next, we went through websites, press releases, and publications from ministries of finance and embassies. The next step was a general web search, with a focus on the financial and local press. Finally, in several cases, we contacted the central banks.

Often, we were able to cross-check that both sides of the deal reported it, and most of the times they agreed with each other. Just in case, we recorded reciprocal deals as separate line items, so that any discrepancy in the way they are reported is kept for researchers to choose how to deal with those.

Our sample covers active agreements between January 2000 to December 2023, and includes 72 central banks that had an agreement of some sort at some point during this period.

2.1 The dataset

In terms of characteristics, we reported the *start date* if this is explicitly mentioned. If not, we took the date of the press release about the line.

Recording a precise *end date* was harder. Almost all liquidity lines are for a fixed term, with standard choices for length of one or three years, but most of them are regularly renewed. One notable exception is the agreement between the PBoC and the Hong Kong Monetary Authority, which has an unlimited length and requires no extension. Sometimes a renewal comes with a new deal, but often it is the result of a mere extension of the end date. Some central banks do not report these renewals. When an end date was missing and no renewal was announced, we recorded it as so. To be consistent, we recorded renewals as separate line items, allowing future researchers to choose how to merge them, and indicated when we make assumption about the end date. As a result, the dataset has 1,664 line items, which corresponds to significantly fewer country-pair arrangements if they were consolidated by arrangement and by pair. The advantage of recording information at the agreement level is that the dataset explicitly tracks whether an agreement renews, supersedes or supplements prior agreements between the two counterparties.

The next characteristic is the *maximum amount* that can be drawn from the lines. When there is a renewal, if no mention is given of this maximum, we assume it stayed unchanged. Most lines have a cap. An important exception is the sub-network of reciprocal swap lines involving the Fed and five other major central banks (the Bank of Canada, Bank of England, Bank of Japan, Swiss National Bank, and the ECB).

Turning next to *collateral*, for all lines, we were able to ascertain whether they were swap lines, that exchange one currency for another, or instead repurchase agreements, where one central bank receives currency in exchange for giving a security. In the data, 96% of all agreements are swap lines. Repurchase lines are the exception.

We further recorded if the funding for a line is *pooled*. Most attention has been paid to one-to-one lines, where one central bank is the sole source of the liquidity for another. However, only 52% of the recorded deals are one-to-one. The others share a pooled fund of one currency, most often the USD, across several central banks, that is then exchanged for the borrowing central bank's own currency. The most famous pooled fund is the Chiang Mai Initiative (CMI), which grew from the ASEAN Swap Arrangements, involving Singapore, Malaysia, Philippines, Thailand, Indonesia (all since 1977), Brunei, Cambodia, Laos, Myanmar, Vietnam (joining in 2000) and China, Japan, South Korea (joining in 2009). It is a swap line, in which each local central bank exchanges local currency for USD, or occasionally for other local currencies, like the Japanese yen or the Korean won. Another famous, more recent example is the Contingent Reserve Arrangement (CRA) pooling USD reserves from Brazil, Russia, Mexico, China, and South Africa, signed in 2014 (and no end date).

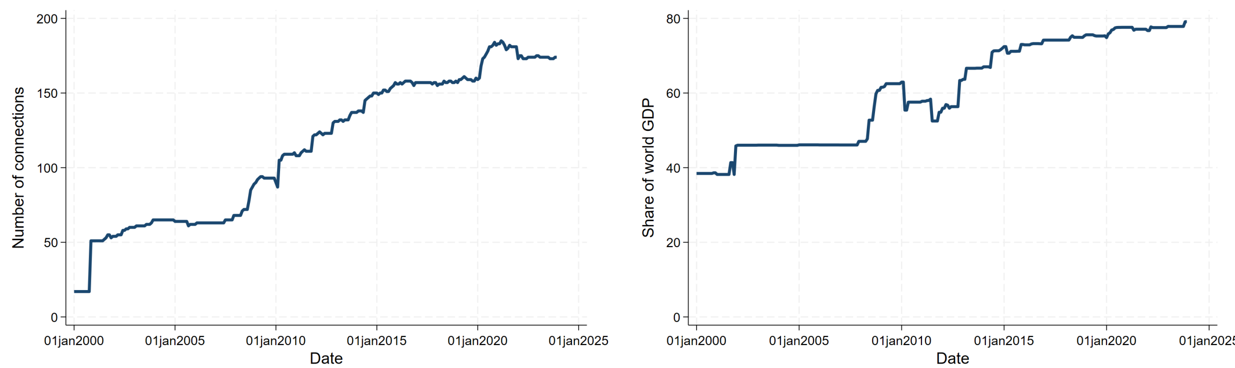
Another characteristic of line is whether it results from a bilateral agreement (43%) or a *multilateral framework* (57%). Multilateral agreements are made between three or more countries, like the CMI. Countries also sometimes form sub-networks of bilateral lines, like the Fed and the five other major banks. What differentiates a multilateral line is its legal structure: all the counterparties in the initiative sign an overarching umbrella agreement. All pooled funds are multilateral agreements, but there are some multilateral frameworks that do not pool funds. Two important multilateral facilities started in 2020 are the Fed's Foreign and International Monetary Authorities (FIMA) Repo Facility and the ECB's Eurosystem Repo Facility for Central Banks (EUREP) via which foreign central banks can obtain USD and EUR, respectively, in a repurchase agreement against their foreign exchange reserves. Most central banks across the globe can seek approval to access FIMA or EUREP, but we include in our data only the countries that received public approval to join.

The next characteristic is *reciprocity*. The *de jure* norm is that non-pooled lines are reciprocal deals (70%), where each country commits to lend to the other. *De facto*, the Fed has not borrowed currency from any of its counterparties, even as many of them have borrowed USD. In fact, the Fed has not even announced the procedure by which banks in its jurisdiction would at any point receive a foreign currency. The alternative are unidirectional lines, whereby only one country has agreed to lend. India's swap lines with other countries in South Asia under the SAARC initiative, as well as the ECB's lines with some Eastern European countries fall under this category.

The final important characteristic is the *currency*. Usually, this is the currency of the

Figure 1: The evolution over time of the liquidity lines

(a) By total number **(b)** By share of world GDP



Note: Panel (a) has the total number of direct connections between central banks, including both bilateral and multilateral connections. It counts one for every pair in an agreement, or the number of edges in the network. For example, four countries signing a reciprocal multilateral agreement would generate six connections. Panel (b) has the share of world GDP in PPP units for countries that have at least one line.

two central banks signing the agreement, but sometimes it is not, as in the case of the agreements that pool USD. Japan, via the Ministry of Finance and not the Bank of Japan, has several bilateral agreements with other Asian countries that swap USD, rather than JPY, for local currency.

2.2 The extent, size, and characteristics of the lines

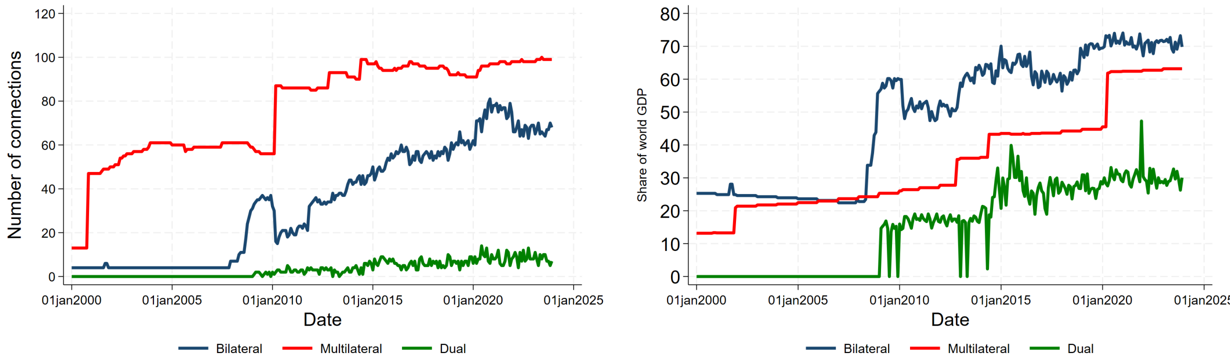
Figure 1 shows the connections between countries with an active line within a given month in our sample. The left-hand panel shows a count of their number, while the right-side panel sums the share of world GDP covered by countries with at least one line.

The figure shows that there were three stages in the expansion of the liquidity lines. First, between 2008 and 2010, there was a jump associated with the global financial crisis. Central banks, led by the Fed, used to swap lines to lend their currency offshore and stabilise turbulent financial markets. Second, between 2010 and 2015, there was a more gradual, but just as large, expansion. After a period of calm between 2015 and 2020, the pandemic led to a third flurry of expansion. This proved to be partly short-lived, as some of the agreements signed then have expired by 2023. By the end of the sample, there were 175 active lines connecting countries covering 79% of the world's output.

Figure 2 breaks the connections between those that arise from agreements involving only two central banks (bilateral), those that involve more than two central banks (multi-

Figure 2: Bilateral versus multilateral liquidity lines, by number

(a) By total number　　　　**(b)** By share of world GDP



Note: Panel (a) splits the connections in figure 1 into those that are strictly bilateral, strictly multilateral, and dual. Dual refers to connections between two countries that are simultaneously linked through a bilateral agreement and a multilateral initiative. Panel (b) shows the share of GDP in PPP units of countries that have at least one bilateral agreement and no multilateral agreement, at least one multilateral agreements and no bilateral agreements, or at least one of each (dual).

lateral), and the connections between two countries that have parallel bilateral and multilateral agreements (dual). The figure provides a stark illustration of a major change in the international financial system in the XXIst century so far: the rise of bilateralism. In a sense, since all liquidity lines involve individual national central banks, their rise is a retreat from Bretton Woods world based on multilateral international institutions. But even within the lines, two central banks signing a bilateral swap line, potentially as part of a broader political agreement between two nation-states, has been the engine of expansion.

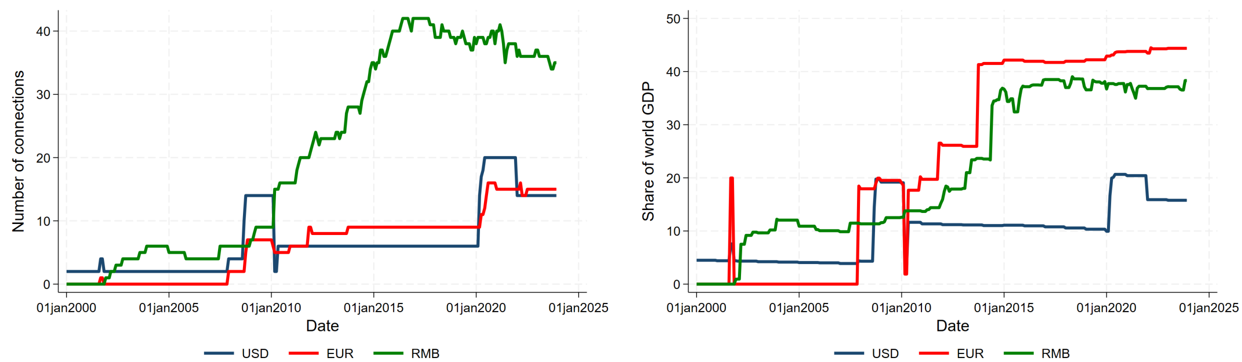
Figure 3 breaks the lines by currency. This shows that in the 2010–15 period, the ECB and the PBoC were the major players signing bilateral agreements and driving the growth in the network. The actions of the PBoC were part of the internationalisation of RMB, while the ECB was both caching up to the Fed as well as creating a sub-network in Eastern Europe. Whereas the EUR grew quickly in its network's share of GDP, the RMB grew especially in the number of agreements. While the ECB's lines contain mostly advanced economies, the ones signed by the PBoC have many more, and on average smaller, economies.

2.3 The geographical coverage of the liquidity lines over time

Figure 4 shows the coverage of the connections in the world map at three key dates in their evolution.

Figure 3: The evolution over time of the liquidity lines, by currency

(a) By total number **(b)** By share of world GDP



Note: Panel (a) shows the number of direct counterparties (borrowing or lending, via both bilateral and multilateral agreements) of the Fed, the ECB, and the PBoC. Panel (b) shows the share of GDP in PPP units of the direct counterparties of each institution.

The network of liquidity lines was regional in 2000. In North America, there was a network of bilateral swap lines connecting the countries in NAFTA. In Asia, the CMI aimed to prevent a repeat of the late 1990s South East Asia financial crisis.

By 2009, the Fed had created a truly global network of liquidity lines. International banks were unable to renew their funding from US money markets during the global financial crises that they had used to buy USD denominated assets. The Fed's swap lines gave these foreign financial institutions access to a lender of last resort through their national central banks, lowering the demand pressure on US money markets, preventing forced sales of the US assets, and avoiding the failure of foreign banks.

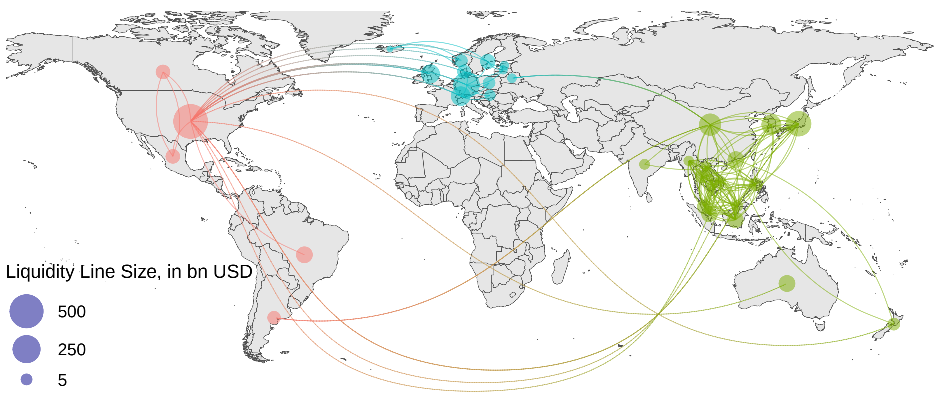
At the end of 2020, the network reached its peak (so far). Relative to 2009, the network by then included both the 2010-15 catch-up of the ECB and the PBoC relative to the Fed, as well as the large expansion in 2020 in response to the pandemic, when the Fed and the ECB expanded their networks to calm financial markets. Several of the lines involving the Fed have expired since then.

Finally, figure 5 splits this geography by connections in the last year in our sample, 2023, focusing only on bilateral connections. The USD network consists primarily of NAFTA and the sub-network with the other five big central banks. The RMB network is wider, and it is the only one to have counterparties in Africa, the middle East, and South America, as well as the only one to include Russia. The EUR network lies in between these two, covering most of non-EUR Europe, and with the singularity of including lines between the ECB and both the Fed and the PBoC.

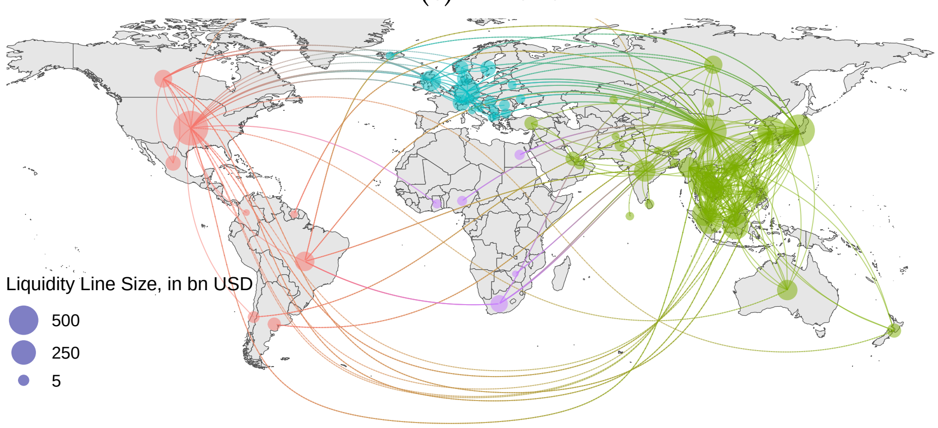
Figure 4: Geographical coverage of the liquidity lines

(a) In 2000

(b) In 2009



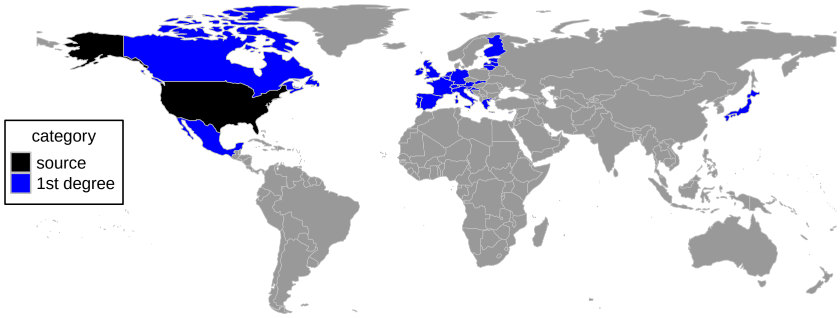
(c) In 2020



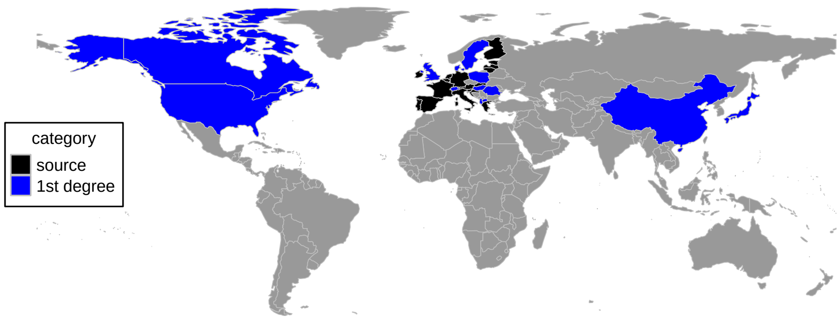
Note: Each map includes both bilateral and multilateral agreements. The liquidity line size for each country is the total amount that country has committed to liquidity lines across all counterparties, averaged across borrowing and lending, and converted to USD using the contemporary exchange rate. When the line is unlimited we use the maximum of (i) any prior cap on the line and (ii) the maximum reported drawing to date.

Figure 5: The world network of direct liquidity lines in 2023 for the three major currencies

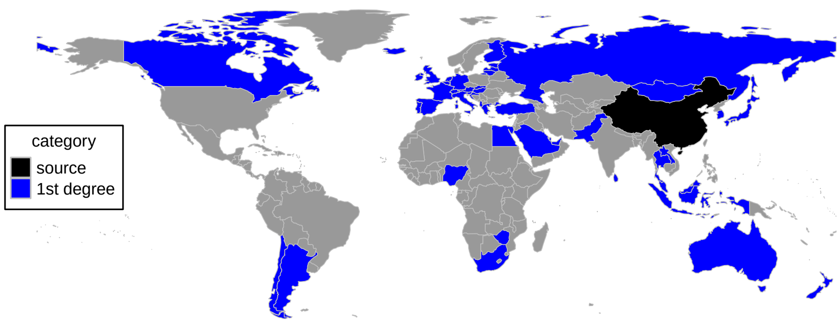
(a) USD (Federal Reserve)



(b) EUR (European Central Bank)



(c) RMB (People's Bank of China)



Note: Highlighted countries had a direct connection through a bilateral agreement with the Fed in panel (a), the ECB in panel (b), or PBoC in panel (c) at any point in 2023.

3 Indirect coverage through the network

When one country has a line with another, and that one has a line with a third country, then there is an indirect connection between the first and the last of the three countries. This section describes the economics of an indirect connection and plots the network of liquidity lines by degree of connection.

3.1 Indirect connections

For concreteness, take the example of a hypothetical bank in Korea. Say this bank had USD funding with which it bought illiquid USD assets. Imagine that funding is not rolled over one day, and unable to sell the assets (or unwilling to take the loss in selling them), the bank turns to the Bank of Korea (BoK) for a loan of last resort.

During the pandemic, in 2020-21, the BoK had a swap line with the Fed. Therefore, it would borrow USD from the Fed, giving Korean won (KRW) in return, and lend these USD out to the Korean bank. When the bank repaid the USD, the Bank of Korea would pay them back to the Fed plus interest, receiving its KRW back, which had never entered circulation. This is how most liquidity lines with a direct connection between two countries work.

In 2022, this liquidity line expired, and was not renewed. Yet, the BoK still had a swap line with the Bank of Japan (BoJ), which in turn had a swap line with the Fed.[3] The BoK could borrow Japanese yen (JPY) from the BoJ and lend them to the Korean bank. This bank could then enter a private forward contract with a private Japanese bank to exchange these JPY for USD, with a commitment to exchange them back at a fixed interest rate and exchange rate at the same date that its loan repayment to the BoK was due. In turn, the Japanese private bank could get the USD in the first place by borrowing them from the BoJ, who in turn could get them from the Fed through its swap line in exchange for JPY collateral.

At the end of this chain of transactions, the Korean bank had the USD it wanted and a commitment for a fixed payment at a fixed date to give them back, and the Fed had created and lent out the USD against collateral, just as before when there was a direct line. The two other currencies, the KRW and the JPY, laid inactive as collateral in someone's balance sheet, so the amount of money in circulation changed in the same way as it did

[3] As it turns out, the BoK can borrow USD directly from the BoJ under a swap agreement signed in 2023.

with a direct line. The interest rate and exchange rate risk borne by all parties was the same as well.

The only significant difference between the direct and indirect way of accessing foreign currency by the local bank is that the latter involves more counterparties. Making the reasonable assumption that none of the three central banks involved will not honor their commitments, the key counterparty risk is the private intermediary (the Japanese bank, in our example) not having capacity to provide the funds or defaulting on the contract. Insofar as there is a liquid market with many of these intermediaries, an indirect connection is almost as good as a direct one in providing the desired lender of last resort.

Replicating this argument, there is indirect access involving not one intermediary currency, bank and central bank, but two, three or more. From now on, we refer to direct lines as providing access of degree one, while the Korean bank in the example would have access of degree two to the USD, and a hypothetical fourth country with a liquidity line with the Bank of Korea (but not with another central bank of degree one) would have access of degree three.

3.2 The network by degree

Figures 6 and 7 update figures 3 and 5 to include also the connections of degree higher than one, for each of the three main international currencies. We take the shortest degree when two countries have multiple connections between them. The highest degree of connectivity we observe to the three major central banks is four. Hence, we encode a disconnected country as taking a value of five.

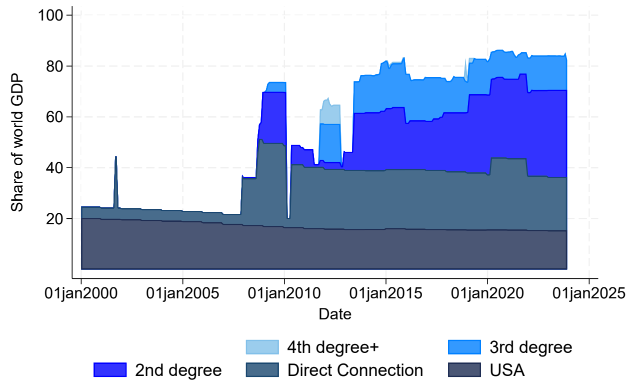
The USD's direct network in 2023, measured on the basis of bilateral connections, was geographically narrow. Yet, indirectly via the ECB, it reached Eastern Europe and China. Through China and the PBoC's sub-network, it then reached countries widely spread throughout the world, including even Russia.

The world network for each of the three major currencies turns out to be similar. For each of them, approximately 80% of world GDP is covered under the umbrella of liquidity provided by the network. This is a consequence of the density of the degree of lines between the Fed, ECB, and PBoC, as well as the BoJ and the Bank of Canada.

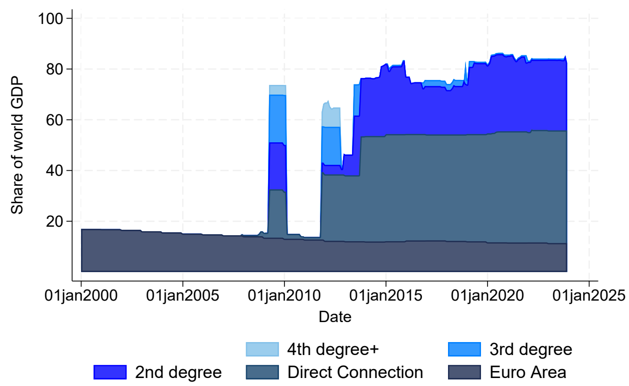
What differs between them is the degree of each line in that global network, and the weight of each degree in their total connections. For the USD, 20% is the size of the US economy, which has domestic access to USD through the domestic liquidity facilities, another 20% are direct lines, and the indirect connections add another 40% of GDP, roughly

Figure 6: Countries connected to each currency, as a share of world GDP

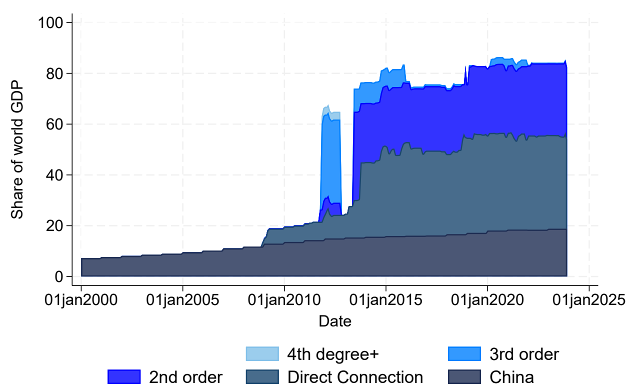
(a) USD (Federal Reserve)



(b) EUR (European Central Bank)



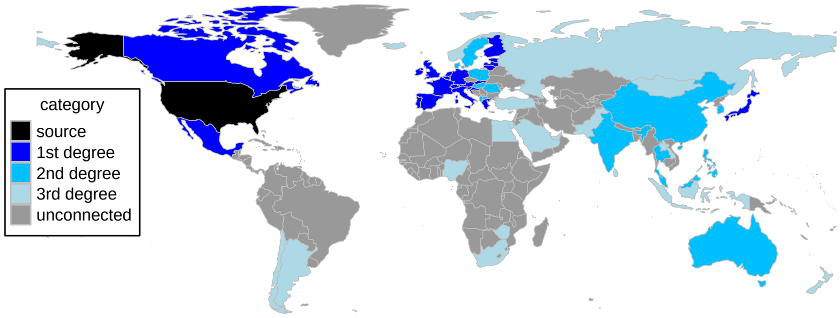
(c) RMB (People's Bank of China)



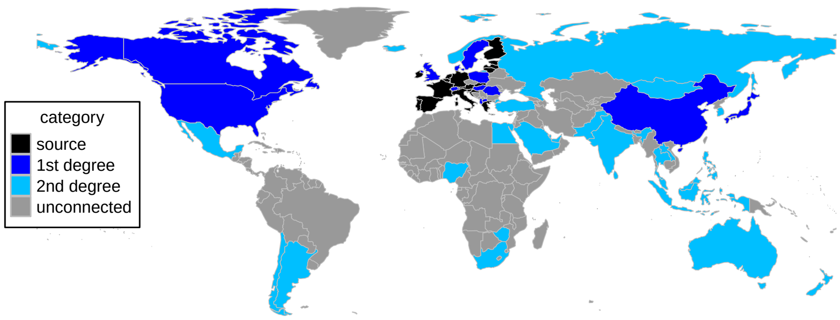
Note: Share of world GDP in PPP covered by the liquidity line network of the Fed in panel (a), the ECB in panel (b), and the PBoC in panel (c), where the coverage is broken down by the degree of connection. Bilateral connections only, excluding multilateral connections.

Figure 7: The world network in 2023 by line degree for the three major currencies

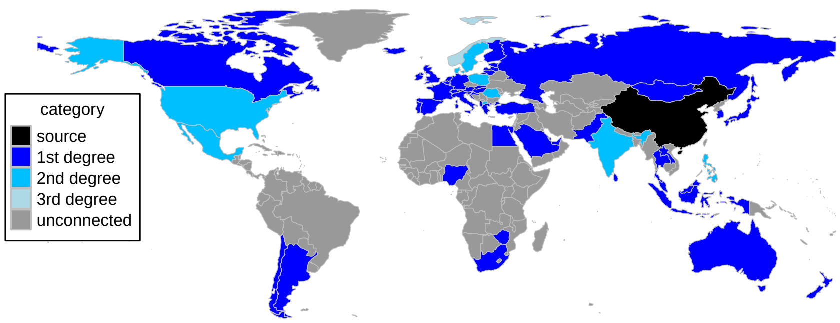
(a) USD (Federal Reserve)



(b) EUR (European Central Bank)



(c) RMB (People's Bank of China)



Note: Connections are measured as in figure 5. Bilateral connections only, excluding multilateral connections.

doubling the reach of its network. Instead, for either the EUR or the RMB, approximately 60% are covered domestically and directly, with indirect connection adding only 20%.

Indirect connections may substitute for direct ones, but they rely on more central banks to keep on renewing past agreement, and on private agents, whether banks or arbitrageurs, doing some of the intermediation. Arguably, indirect connections are more fragile. These two figures then lead to the perhaps surprising conclusion that, in coverage by strength, the USD is behind the other two currencies in the international reach of its network. While the USD lines may the best known ones, the EUR and RMB lines, which grew more gradually and less noticed, were in 2023 wider and more direct.

3.3 Centrality within the network

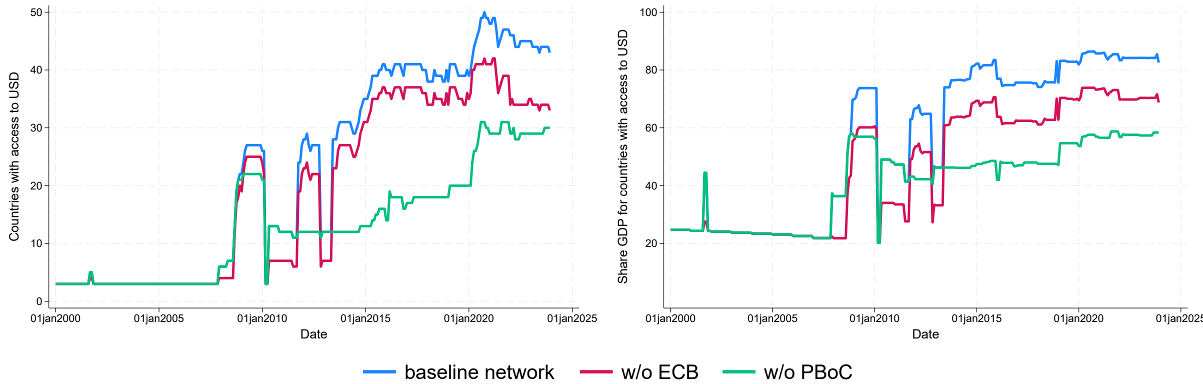
The discussion so far revealed distinct sub-networks for each of the three major currencies. The USD and RMB sub-networks are partly segmented from each other. This suggests that central banks like the ECB of the BoJ, that participate in both of them, as well as in their own sub-networks, may play a connecting role. To analyse this more formally, we now look at different measures of centrality in the network.

The USD is the overwhelming dominant currency in international transactions. We first ask how important are central banks other than the Fed in spreading access to backstop USD central bank funding through the network's indirect connections. Figure 8 counts the number of countries with direct or indirect access to the Fed through the network as well as in two counterfactuals, where we removed the ECB or the PBoC, with all of their respective lines. The PBoC's relevance is clear: without it, 13 countries accounting for 25% of global output would lose access to the USD network. By comparison, the presence of the ECB is essential for countries that produce 12% of global GDP. If, hypothetically one of these major central banks were excluded from USD transactions, this would have a major impact on the coverage of USD backstop liquidity.

Figure 9 goes further by considering the degree of the connections. A lower degree in a connection means either less reliance on private counterparties, or lower deviations from CIP, as we will see in the next section. Panel (a) shows the mean path length to each of the three major currencies. The progress since the start of the sample is clear. Not only there are more direct lines, as we saw before, but the degree of the connections has steadily fallen. Having signed more lines, naturally the PBoC has the lowest average degree of connection.

Panel (b) goes back to the hypothetical scenarios for the safety net if particular central

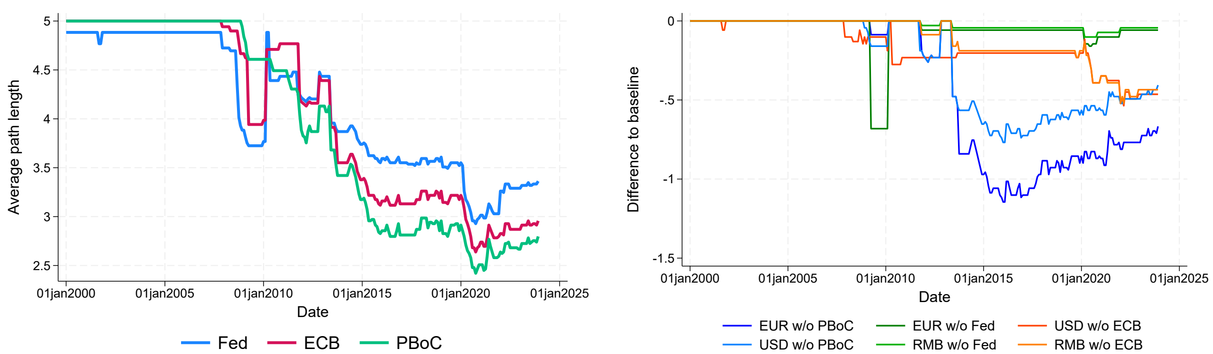
Figure 8: The ECB and PBoC's role in access to the USD



Note: Countries with direct or indirect connections to the Fed to access the USD in baseline bilateral network and in the bilateral network when eliminating selected counterparties. GDP weighted measures use countries' share of PPP annual world GDP.

Figure 9: Average path lengths and the intermediary role of the major central banks

(a) Average path length **(b)** Change from dropping major central banks



Note: Panel (b) shows the difference in average path length from baseline bilateral network when eliminating selected country from network. A difference of -1 indicates the length of the average path to the source is one unit longer upon elimination of the specified node.

banks were excluded. It shows the impact of dropping each of the three major central banks on the length of the path in the network from each country to one of the three major currencies, averaged across all countries. This is an imperfect measure of the importance of each of the three central banks for access to the other central banks' currencies.

Four results stand out. First, the Fed is not particularly important as an intermediary. If the Fed withdrew from the network, this would have a major impact on access to the USD, of course, but a negligible impact on the EUR or the RMB. Second, and confirming the previous figure, if either the PBoC or the ECB left, the impact would be large on the USD. Third, the PBoC has an even more important role for intermediating access to the EUR than it does for intermediating access to the USD. This reflects the coverage of Asian and Middle Eastern countries that is unique to the PBoC sub-network. Fourth, and finally, the numbers are large. The mean path length in the network for the USD in 2023 was 3.3, which without either the ECB or the PBoC would jump to 3.8.

Through the network, banks in a country have several routes through which they can access foreign currency. A central bank that is particularly preponderant in these short connections will have a front role in the networks, even if other central banks in back roles could keep the network going. At one extreme, if for any two nodes in the network, many of the shortest paths went through a particular node, then the central bank in that node would be especially powerful in affecting access to liquidity.

Panel (a) in figure 10 continues to focus on the USD by calculating what share of indirect connections go through the ECB, PBoC, the BoJ or the Swiss National Bank. It turns out that these last two central banks are close to irrelevant. This shows the extent of intermediation being done by the ECB and the PBoC. The importance of the ECB has risen since the pandemic (already visible in figure 9) as it expanded its network (while the Fed let some of its lines expire).

Panel (b) in figure 10 calculates network centrality for the three major central banks and the BoJ. This is a relative measure of the shortest paths between any two countries in the network intermediated by a focussed counterparty. Across currencies, the PBoC has positioned itself in the centre of the vast majority of connections. While the ECB and the Bank of Japan are also relevant, both have less power in this sense.

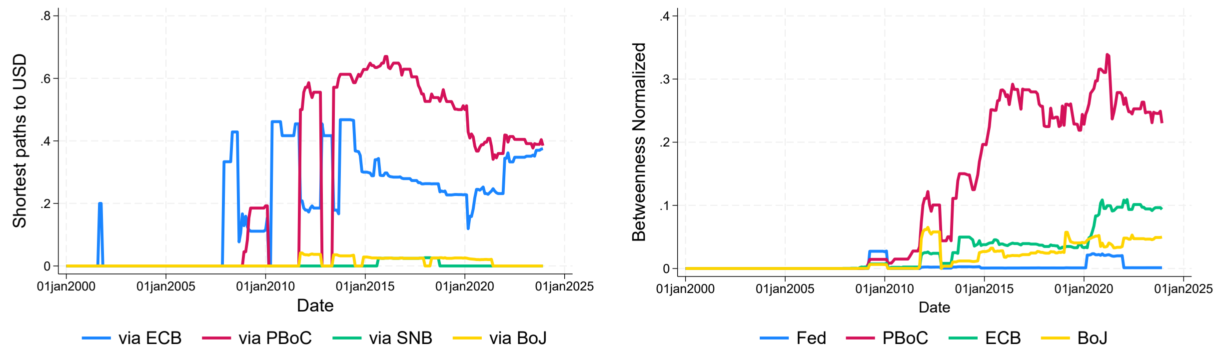
3.4 The role of markets and arbitrageurs

Go back to our discussion of a Korean bank seeking USD and finding it by borrowing JPY from the BOK through its line with the BoJ to then swap them for USD using a private bank in Japan. We suggested that this private bank obtained the USD by borrowing from the BoJ who would get them from its line with the Fed. But, this last operation is not required. The Japanese bank might have had the USD to start with or be able to borrow them in the open market. The original problem facing the Korean bank in a crisis—it could not get private USD funding—need not extend to the Japanese or other banks. Outside of a global meltdown in USD financial markets, it is in fact unlikely that it does.

Continuing with the previous argument, even the Japanese bank could be dispensed

Figure 10: Shortest paths via selected nodes

(a) Shortest path to access USD **(b)** Betweenness centrality of central banks



Note: Panel (a) shows the share of shortest paths to the USD running through each counterparty central bank as a percentage of all paths. Panel (b) shows betweenness centrality $b(c)$ of node c. Letting $k_{s,t}$ be the shortest paths between nodes s and t containing c, and $K_{s,t}$ be the total number of shortest paths from s to t, then betweenness centrality is $b(c) = \sum_{s,t \neq c} k_{s,t}(c)/K_{s,t}$. We normalize it by dividing by 69*68, which is the total number of potential shortest paths among the 72 countries in our network. The measure is calculated for the bilateral connections only.

with. As long as there is an arbitrageur taking advantage of deviations between the KRW-JYP and the JPY-USD CIP deviations, relative to the KRW-USD CIP deviation, and moving to take advantage of it, this arbitrageur would provide the USD to the Korean bank.

This is relevant in light of geopolitical tensions. Imagine that Chinese banks need USD. Perhaps the Fed would be averse to lending them to the ECB, knowing they are making their way to China. Yet, the logic behind indirect connections does not require it. Chinese banks can borrow EUR from the ECB swap line with the PBoC and swap those into USD. Since this puts pressure on the price of a USD-EUR forward or swap contracts, European banks will be motivated by the market prices to trade in the opposite direction, potentially (but not necessarily) using the USD swap lines between the ECB and the Fed. There will be no direct association between the actions of Chinese banks and the credit given by the Fed, and yet the indirect connection in the network of liquidity lines was behind it all.

In this sense, our discussion in the previous section overstated the active role of the various central banks in intermediating access to liquidity in other currencies. More accurately, the network of lines affects credit and prices beyond the actual use of the lines, but through their backstop role as lenders of *last* resort.

4 CIP deviations and indirect connections

This section explain the arbitrage trade in the absence of direct credit by the central banks, and why CIP deviations play a central role.

4.1 Indirect ceilings on CIP deviations

Bahaj and Reis (2022*a*) first derived the following result: imagine a Japanese bank borrowing USD from the BoJ via the swap line with the Fed. The borrowing rate is $i^{\$,l}$, and the USD converts to JPY at the spot exchange rate $S^{¥,\$}$. The bank can convert the USD for JPY, deposit the yen at the BoJ earning the deposit rate $i^{¥,v}$, and sell forward the future JPY return to exchange them back into USD at the forward rate $F^{¥,\$}$. At the end of this operation, the Japanese bank will receive $(S^{¥,\$}/F^{¥,\$})(1+i^{¥,v})$ in USD for sure (neglecting counterparty risk in the forward contract, which should be negligible). The cost in USD of getting the funds for this operation is $(1+i^{\$,l})$. For there to not be an arbitrage opportunity, the cost must be as large as the gain.

Then, let $X^{¥,\$}$ be the deviation from covered interest parity (CIP) between the two currencies, also known as the cross currency basis. By definition: $X^{¥,\$} = (1+i^{\$}) - (S^{¥,\$}/F^{¥,\$})(1+i^{¥})$. Since in our sample $i^{¥} \approx i^{¥,v}$ it then follows that, by no arbitrage, there is a *direct connection ceiling* put by the swap line rate on the deviations from JPY-USD CIP:

$$-X^{¥,\$} \leq i^{l,\$} - i^{\$}. \tag{1}$$

Consider now an indirect connection, and take again the arbitrary example of a Korean bank accessing USD via the network. The private bank can do the same trade involving the KRW and the JPY, from which follows the corresponding ceiling:

$$-X^{₩,¥} \leq i^{l,¥} - i^{¥}. \tag{2}$$

In turn, a standard triangular arbitrage argument involving three currencies states that the sum of the CIP deviation between any two pairs should be the same as the CIP deviation between any two of them:

$$X^{₩,¥} + X^{¥,\$} \approx X^{₩,\$}. \tag{3}$$

Adding up the two equations, one derives an *indirect connection ceiling*, in this case between the KRW and the USD:

$$-X^{₩,\$} \leq (i^{l,\$} - i^{\$}) + (i^{l,¥} - i^{¥}). \tag{4}$$

In short, for an indirect connection, the sum of the ceilings of the direct connections that constitute it provides itself a ceiling. This argument extends to connections of a higher degree.[4]

4.2 Tests of the prediction on ceilings over CIP deviations

Measuring CIP deviations of advanced economies with respect to the USD is relatively straightforward. There are markets for forward contracts with prices that are routinely and consistently quoted, as well as liquid interbank markets with reliable interest rates. The direct ceiling result has been tested and confirmed in the data (for the USD see Bahaj and Reis (2022*a*), Kekre and Lenel (2023), for the EUR see Albrizio, Kataryniuk and Molina (2023), and for the RMB see Bahaj and Reis (2020)).

Extending this work beyond a handful of major economies is difficult. Du and Schreger (2016) calculate CIP deviations for 10 developed countries and 18 emerging markets for 10-year government bonds, while Cerutti and Zhou (2024) complement this work with CIP deviations at 1-month and 3-month tenors using money market rates for the same G-10 countries, as well as 20 emerging markets. Starting from their work, we extend it to have a sample of 42 countries among the 72 that have signed a liquidity line at some point during the sample. Many liquidity line loans are for a one-week maturity, suggesting a one-week tenor would be appropriate to measure CIP, but one-week interest rates are not widely available. We use 3-month and 1-month tenors, as they are available for each country. We build a monthly unbalanced panel running from January 2007 (when CIP deviations started to appear as the global financial crisis started) to August 2023.

The noise in the data makes it hard to trust the precise measures of CIP deviations. This precludes a test that relies on within-month changes, or on the exact numerical value for the ceilings. Instead, we calculate the average CIP deviations within our network by averaging across all existing observations within one month for a particular currency across the available tenors. We test the weaker proposition that the higher is the degree of the connection, on average the higher would be the ceiling. All else equal, connections

[4]Revisiting the arguments in the previous section, when a central bank drops from the network, the effect may not be on loss of access to funding, but rather on the CIP deviations facing investors.

of higher degree should be associated with higher average CIP deviations.

Figure 11 plots, in panel (a), our estimate of the implicit ceilings based on the limited information we have on liquidity line borrowing rates (see Appendix B for more details). We average them over all years and over all pairs of currencies of the same degree of connection with either the USD, the EUR, or the RMB. As expected, the ceiling rises, approximately doubling, with each degree increase in the connection.

Turning to CIP deviations, panel (b) takes individual observations per currency-month relative to the USD and pools them in an empirical cumulative density function by degree of connection. Reflecting our interest in ceilings, the figure zooms in on the left tail.

A ceiling would, strictly speaking, cut these distributions, with zero mass to the left of the ceiling. However, for at least three reasons, we cannot test this sharp prediction in the data. First, for the whole network there is counterparty risk for some currencies that should be included in the ceiling, but we do not have a way to measure it accurately over time, country, and currency. Second, the ceiling will be different for different currencies and different years as the contract changes, so our estimates of its location are noisy. Third, and perhaps most importantly, the significant noise in measuring CIP could easily lead to false rejections of the null hypothesis.

Instead, we ask: is the distribution further to the left when the degree of connection is higher? The evidence in panel (b) supports this prediction.

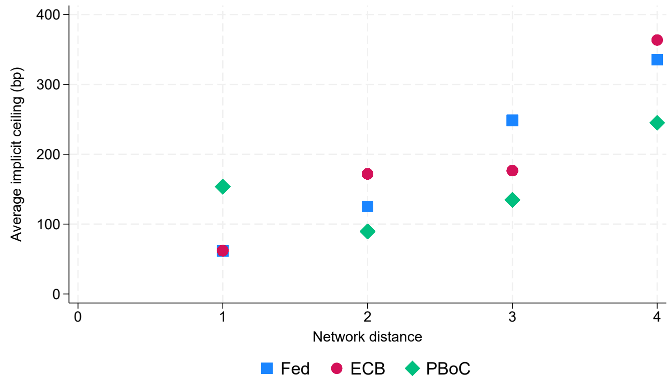
Panel (c) repeats the exercise but after regressing the CIP deviations on year and country fixed effects, to help address the first two of the three problems that affected panel (b), namely country-specific or time-specific variation in CIP deviations driven by counterparty risk and global financial conditions. The result is still there.

Table 1 uses regression models to test more formally the relationship between CIP deviations, as the dependent variable, and the degree of connections, as the independent variable. This lets us judge statistical significance and control for common factors. The independent variables are three dummies that take a value of one if the observation for line i in month t has a second-degree, higher-degree, or no connection with the Fed. The baseline is where there is a direct connection (the omitted dummy). The prediction is that the higher is the degree of the connection, the more likely are we to find larger negative CIP deviations.

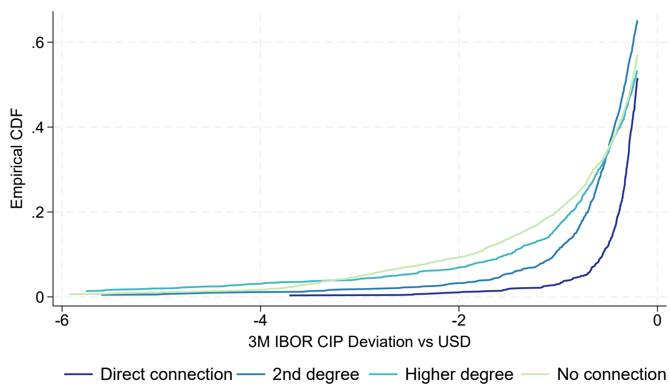
Column (1) has the estimates of a pooled quantile (10th percentile) regression of $X_{i,t}^{\$}$ on the three dummy variables. The prediction is that the coefficients would be negative, and increasingly so as the degree of the connection increases. This holds in the estimates.

Figure 11: CIP ceilings and connection degree in the world network of liquidity lines

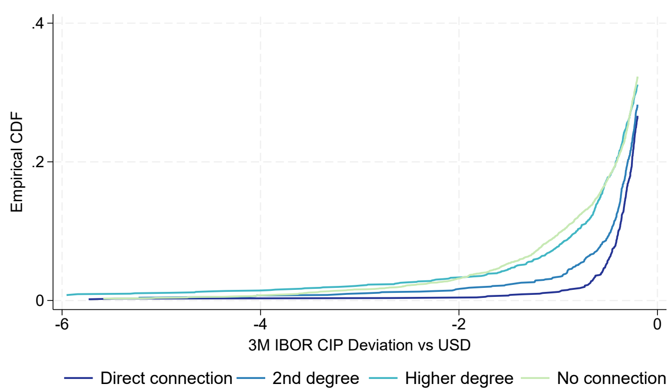
(a) Average ceiling versus connection degree



(b) Tail of empirical cumulative density function for USD CIP deviations



(c) Tail of empirical CDF residualised by time and country fixed effects



Note: Panel (a) shows the average implicit ceiling by degree of connection to the Fed, ECB, and PBoC. We measure the degree by the shortest path from the network of bilateral lines, and ceilings by using the minimum cost shortest path. Panel (b) shows the left tail of the empirical cumulative density function of monthly USD CIP deviations pooled across currencies by degree of connection to the Fed. We winsorize the left hand tail of the distribution at the 0.1% level to aid with visualisation. Panel (c) repeats the exercise in panel (b) after residualising the CIP deviations with respect to time and country fixed effects.

Table 1: The degree of the liquidity line connection and CIP deviations

	Pooled Quantile Regression	Time Fixed Effects	15th Quantile	5th Quantile	For Euro (ECB)	For Renminbi (PBoC)	Country Fixed Effects	Linear Probability Models	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
2nd degree	-0.481*	-0.416	-0.384^{+}	-0.348	-0.413	0.507^{+}	0.267	0.099**	0.029*
vs direct	(0.26)	(0.39)	(0.26)	(0.84)	(0.46)	(0.40)	(0.39)	(0.05)	(0.02)
Higher degree	-0.956^{+}	-0.736^{+}	-0.633	-1.471	-0.623	-0.209	-0.590	0.169***	0.070**
vs direct	(0.61)	(0.70)	(0.46)	(1.30)	(0.53)	(0.69)	(0.52)	(0.07)	(0.04)
No connection	-1.320	-1.116^{+}	-0.746**	-1.364*	-1.189*	-0.708*	-0.210	0.175***	0.082
vs direct	(0.46)	(0.48)	(0.36)	(0.82)	(0.45)	(0.45)	(0.44)	(0.05)	(0.04)
Higher degree	-0.474	-0.321	-0.249	-1.123	-0.210	-0.716	-0.857**	0.071	0.040
vs 2nd degree	(0.60)	(0.61)	(0.43)	(1.12)	(0.63)	(0.70)	(0.39)	(0.07)	(0.04)
no connection	-0.839*	-0.700*	-0.362	-1.016^{+}	-0.776	-1.215***	-0.476^{+}	0.077	0.053
vs 2nd degree	(0.45)	(0.42)	(0.36)	(0.62)	(0.59)	(0.47)	(0.32)	(0.06)	(0.04)
N	7786	7786	7786	7786	7786	7786	7786	7786	7786
Time F.E.	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country F.E.	No	No	No	No	No	No	Yes	No	No
Counterparty	Fed	Fed	Fed	Fed	ECB	PBoC	Fed	Fed	Fed
Quantile	0.10	0.10	0.15	0.05	0.10	0.10	0.10		
Ceiling								-100	-200

Note: Estimates of the impact of the degree of liquidity line connectivity between a country and a source central bank (the counterparty) on the average CIP deviation between their respective currencies for the month. The explanatory variables are three dummy variables that take a value of one if the country has respectively a second degree connection, higher degree connection, or no connection with the source central bank (all relative to no connection). Sample period is an unbalanced monthly panel covering 42 countries from January 2007 and August 2023. Standard errors and p-values were calculated using 1000 replications of a blocked bootstrap, where the sample size is kept constant by resampling an equal number of blocks as in the original data from each group of blocks with the same size. + $p < 0.15$, * $p < 0.1$ * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Column (1) has a pooled quantile regression at the 10th percentile using the US as a counterparty. Column (2) adds a time fixed effect using the Canay (2011) quantile fixed effects estimator. Columns (3)-(4) are as column (2) but considering the 5th and 15th percentiles. Columns (5)-(6) are as column (2) but use the ECB and PBoC as counterparties. Column (7) is as column (2) but includes a country fixed effect. Columns (8) and (9) use a linear probability model with the explanatory variable taking a value of one if the negative of the average CIP deviation exceeds a value of a ceiling: column (8) uses a ceiling of 100bp, (9) a ceiling of 200bp.

The primary identification concern is that the agreements are entered into at times of crises, when CIP deviations are volatile. Perhaps the expansion in the network is simply calming overall market conditions, which reflects itself in CIP deviations not through the ceiling channel. Or, perhaps the expansion in the liquidity lines is a lagged response to the crisis, which then coincides with financial conditions easing (including CIP deviations) as shocks revert to the mean. To deal with this problem, we introduce time fixed effects using the fixed location shift panel quantile model of Canay (2011). Column (2) shows this has little impact on the estimates.

The next five columns show robustness to other choices. Columns (3) and (4) show that the coefficients continue to be negative, and more so as the degree rises, at other quantiles. Columns (5) and (6) show that the result is not USD specific, as it applies to the EUR and RMB as well. Connections with the ECB or the PBoC also lower CIP deviations, although the effects are not as precisely estimates. Column (7) controls for country fixed effects. The effect of connection degree relative to a direct connection are now all statistically insignificant, but there is a general pattern of weaker connections shifting the tail of the distribution outward.

Columns (8) and (9) consider an alternative specification to the quantile regression. They show the estimates of a linear probability model, that regresses $Pr(X_{i,t} < c)$ on time fixed effects and the degree of the connection. The prediction of the theory is that the coefficients should be positive: the higher is the degree of the connection, the more likely there would be violations of the soft ceiling. We choose the ceiling in the regression c motivated by the numbers in panel (a) of figure 11. Throughout, the coefficients are always positive, statistically significant, and increasing in the degree of connection.

5 Are the lines complements or substitutes for FX reserves?

Many central banks hold large reserves of foreign currency and assets. One of their uses is to lend to domestic banks in a financial crisis. Another is to buy the domestic currency and prop up its exchange rates, either to pursue a peg, or to slow down a balance of payment crisis. If countries accumulate reserves as a precaution against capital outflows, then the lines provide an alternative insurance against these shocks. In these uses, FX reserves are substitutes to liquidity lines by providing another form of access to foreign currency. Obstfeld, Shambaugh and Taylor (2009) noted this substitutability in the context of the great financial crisis.

At the same time, as a country and its currency become more financially integrated with the world, FX reserves and liquidity lines can become complements. Both can support a financial centre and reduce counterparty risk for their financial institutions. Moreover, signing a line may reduces the need for reserves to backstop trade credit and the settlement of international transactions signalling strength against speculative attacks. Repurchase lines like the Fed's FIMA make the complementarity explicit, as they are tools to convert bond reserves into currency quickly and cheaply

Finally, if accumulating reserves is a response to trade surpluses to prevent an appreciation of the exchange rate, then the lines may be independent of reserves altogether.

5.1 Drawdown of reserves before signing a liquidity line

Sharp falls in FX reserves often come right before a financial crisis. Countries face stigma and political backlash if they ask for IMF support. An attractive alternative is to improve the position in the network of liquidity lines to access foreign funds through this route. This section asks: does a fall in reserves of a foreign currency predict the central bank signing a liquidity line that lowers its degree of connection in that currency's network?

Let $Y_{i,t}$ be a dummy variable for whether a country i improves its position in a currency's network in month t. This, of course, throws out all the observations where the country was directly connected to start with. Let the predictor, $V_{i,t} - V_{i,t-18}$, be the log change in reserves over 18 months prior.[5] Our unbalanced panel comprises 42 countries from January 2007 to August 2023 for which we observed FX reserves and who were part of the liquidity line network at some point.

We estimate the following regression:

$$Y_{i,t} = \alpha_i + \delta_t + \beta(V_{i,t} - V_{i,t-18}) + \text{error}_{i,t} \tag{5}$$

where β is the coefficient of interest. The α_i are country fixed effects, to control for the potential confounder that some countries both have more volatile reserves and are more active participants in and out of the network of liquidity lines. The δ_t are month fixed effects, to deal with the possibility that during global financial crises, both FX reserves and the network of liquidity lines are volatile.

Table 2 shows the results of these predictive regressions, where the measurement of $Y_{i,t}$ varies across columns.

Column (1) shows the estimated effect of shortening the connection degree to the USD as a result of the country signing a new liquidity line agreement. The coefficient shows that there is a statistically significant correlation between a decline in reserves in the months before, and an action by the central bank to improve its access to USD via the global network of liquidity lines.

[5] An 18-month window gave the more precise results, but the pattern of falling reserves is present for other horizons. After all, reserves tend to be on a downward trend prior to an agreement being signed, as illustrated graphically in 12.

Table 2: Predicting a shortening of access to the liquidity lines

	Improved Connection (own action)	Direct Connection	Improve Higher Order Connection (own action)	Direct Connection (ECB)	Direct Connection (PBoC)	Improve Higher Order Connection (no action)
	(1)	(2)	(3)	(4)	(5)	(6)
Δlog(Reserves)	-0.014**	-0.007*	-0.007*	0.001	-0.011*	0.007*
	(0.007)	(0.004)	(0.004)	(0.001)	(0.006)	(0.003)
N	6535	6535	6535	6226	4849	6535
Time F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Country F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Network	USD	USD	USD	EUR	RMB	USD
No. of connections	65	24	41	15	55	40

Note: Estimates of equation (5). Sample has 42 countries at a monthly frequency from January 2007 to August 2023. Observations where the country is already directly connected to the counterparty are dropped. Standard errors and p-values are two-way clustered by time and country: + $p < 0.15$, * $p < 0.1$ * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Column (1) considers any liquidity line that results in an improved degree of connectivity with the Fed. Column (2) considers only direct connections, and column (3) only has indirect connections. Columns (4) and (5) consider direct connections to the ECB and the PBoC. Column (6) is a placebo where we consider improvements in connectivity where the country itself did not sign an agreement.

Columns (2) and (3) split the new agreements into two cases: either it was with the Fed (in which case the degree would fall to 1) in column (2), or with another central bank that had a lower-degree connection to the Fed. Splitting the sample reduces statistical accuracy. Nonetheless, it appears that a decline in reserves is equally predictive of signing an agreement directly with the Fed or just improving an indirect connection.

Column (4) looks at direct connections to the EUR. There is no discernible pattern, although it is worth noting we observe fewer cases of these. Column (5) focuses on RMB lines. These are more interesting since, unlike the USD lines, they cover more developing countries and grew during 2010–15. The effect of a drawdown on reserves on them being signed is similar to the USD lines.

Finally, column (6) shows a placebo, by looking at case where there is an improvement in position in the network for the country that comes about from another country's actions. An example is when a country is connected to another country, which was only indirectly connected to the Fed, and now signs an agreement that gives it direct access to the USD. The degree of the first country in the USD networks falls, even though it did nothing to make this happen. This is not predicted by a fall in the country's own reserves. If anything reserves are on an upward trend, although this is barely statistically significant. This provides some support to the other columns revealing a purposeful action by the central banks.

To conclude, the evidence suggests that liquidity lines are signed to partly substitute for FX reserves after these had declined significantly.

5.2 Reserves after a fall in the degree of the connection in the network

We now ask what are the effects of signing a liquidity line on reserves.

As in the previous section, consider the same event of becoming more integrated in the network. Label it e for country i at date t_e. Towards a stacked event study design, we form a sample of treated countries that have an event. We then measure the evolution of log reserves in windows of 12 months before and 12 months after the event: $\{V_{e,i,s}\} = \{V_{i,t_e-12}, V_{i,t_e-11}, \ldots, V_{i,t_e+12}\}$, where s indexes the event time. Then, for each event e with $\{i, t_e\}$, we select two control countries, that: (i) have the same connectivity of country i at date $t_e - 12$, (ii) do not change their position in the network during the event window and (iii) are the closest to country i in terms of reserves to import ratio at time $t_e - 12$.

With these stacked events, we estimate the regression over the j countries (both treated and control):

$$V_{e,j,s} = \alpha_{j,e} + \delta_{s,e} + \beta_s \times \mathbf{1}\left[j = \text{event country}\right] + \text{controls}_{e,j,s} + \text{error}_{e,j,s}. \qquad (6)$$

Normalising $\beta_{-1} = 0$ as the base effect, then the estimates of β_s give the average evolution of FX reserves before and after an improvement in a country's position in the liquidity line network. We control for the logarithm of the country's imports to reflect changes in its external position through trade flows.

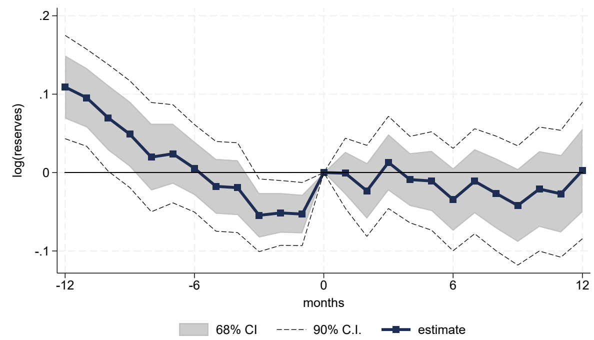
Figure 12 shows the estimates of $\{\beta_s\}$ across the three currencies. The results of the predictive regressions in table 2 are confirmed by the plots on the left-hand side for the periods before the line is signed: especially for the USD, bleeding foreign reserves is associated to the country trying to establish a direct connection to the central bank with the source currency.

After the line is signed, there is a slight increase in reserves. However, given the fall before, these estimates potentially suffer from an endogeneity bias. The estimated increase may be due to a reversion back to the average level of reserves, and not be caused by the line itself.

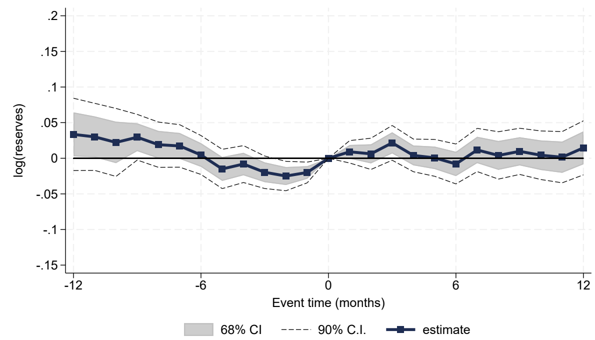
The figures on the right-hand side help with this regard. When we include the higher-degree connections, there is no longer an effect of reserves prior to signing a line. This is consistent with the estimates in column (6) of table 2. Looking at the path of reserves after

Figure 12: Foreign reserves around improvements in the connection to the network

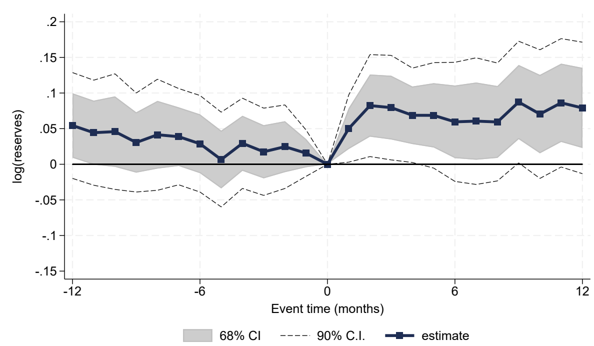
(a) USD: direct connections



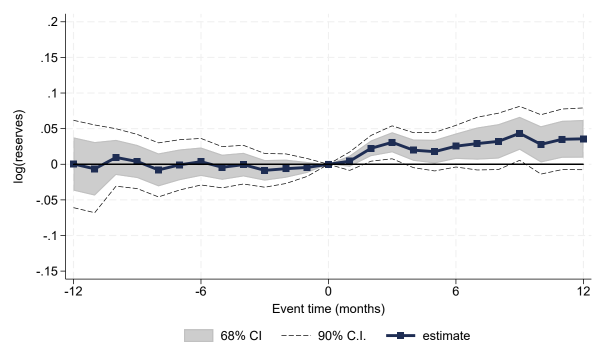
(b) USD: all connections



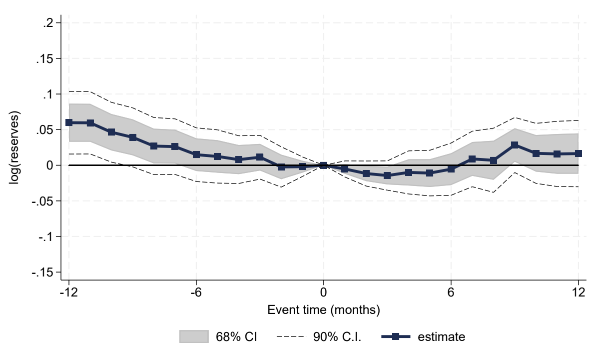
(c) EUR: direct connections



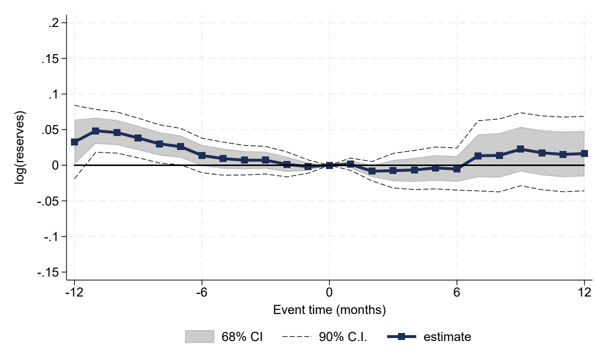
(d) EUR: all connections



(e) RMB: direct connections



(f) RMB: all connections



Note: Estimates of $\{\beta_s\}$ in equation (6) measuring the impact on FX reserves of signing a bilateral liquidity line that moves the signing country to a lower degree in the network that gives access to USD, EUR, RMB respectively at date zero. Confidence intervals are constructed from standard errors clustered at the event country level. Left panel: improving to direct connection (moving to degree 1 from any higher degree); Right panel: improving to any lower level. Number of events unique considered per panel: (a) 26, (b) 116, (c) 16, (d) 111, (e) 59, (f) 98. Disconnected countries treated as distance 5 to source for the purpose of differencing connections.

the improvement in position, there is an increase in reserves, albeit barely statistically significant.

Figure 13 moves further in the direction of dealing with endogeneity, by including only the events where there is an improvement in higher-degree access to the network of a country that happens as a result of an action taken by other countries. If country A improves its access to USD because country B signed a liquidity line, this event was plausibly outside of country A's control and therefore not subject to the same problem of endogeneity. This is the set of estimates that both best filter out the bias from signing a line because of a fall in reserves, and at the same time are also less exposed to the confounding influence of other shocks that may be hitting the country at the same time.

Panel (a) has the results for the USD. They clearly show that, outside of a crisis, FX reserves and liquidity lines are complements. The effect for the PBoC is even larger, in panel (b), while it is weaker but still significant for the ECB in panel (c).

6 Conclusion

Empirical studies of the international financial system face many challenges. A major one is that some of its main institutions, like the IMF, some of its main discretionary policies, like official loans within regions, and some of its main tools, like official FX reserves, change only infrequently and almost always in response to the variables that they want to affect. With little variation, and much of it endogenous, it is hard to assess their effects.

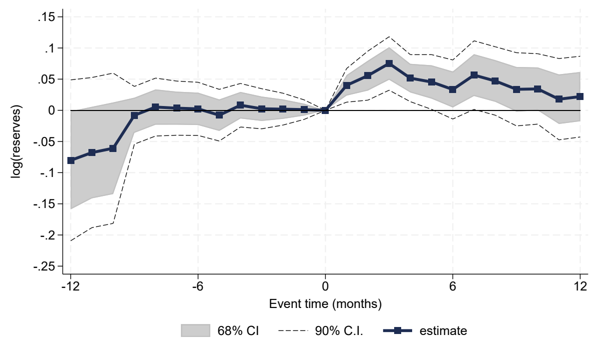
The liquidity lines signed between central banks offer a new path for progress. They are large, work through important economic channels, and have evolved quickly in the XXIst century so far, with plenty of differences across time and countries. This variability gives the hope for identification.

This paper provided one step towards realising this hope by compiling a comprehensive dataset of cross-border central bank liquidity lines between 2000 and 2023. There were several interesting patterns in the data. We collect them in this section for ease of reference:

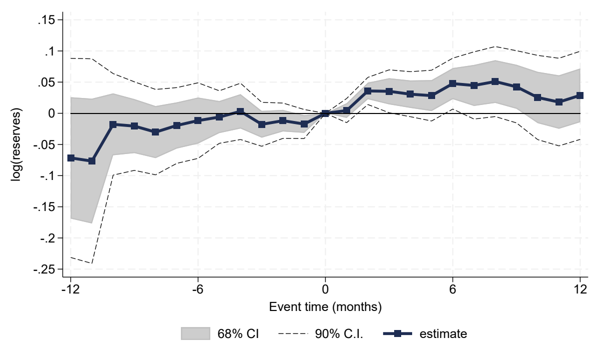
First, there was as much growth in the network in 2010–15 as there was during the great financial crisis. Bilateral lines signed during this period mostly by the ECB and the PBoC overtook the big-5 multilateral network set up by the Fed during the crisis that most research has focused on.

Figure 13: Foreign reserves after an improvement in network access due to another country's action

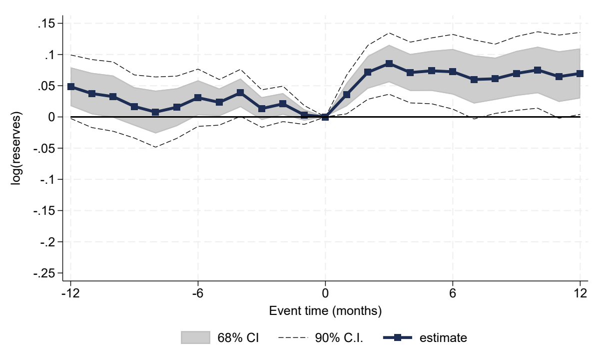
(a) USD



(b) EUR



(c) RMB



Note: Estimates of $\{\beta_s\}$ in equation (6) with the impact on FX reserves of another country signing a liquidity line that leads to a country lowering its degree of connection in the network at date 0, for access to the USD in panel (a), EUR in panel (b), and RMB in panel (c). Note there is an overlap in the events across these three specifications.

Second, the network globalised during the 2007–09 great financial crisis, and reached a peak during the 2020 pandemic. The sub-networks for the USD and the RMB are partly segmented from each other, with the ECB (and the BoJ to a smaller extent) providing a bridge in between them.

Third, we established a new result concerning the liquidity lines: because they form a network, it is possible for banks to indirectly have access to a currency that its central bank does not have direct access to. As a result, banks in countries accounting for approximately 80% of the world GDP have access to USD, in spite of the small number of liquidity lines involving the Fed. Moreover, and perhaps surprising, the coverage of the USD is similar to that of the EUR and the RMB, but they differ in the degree of their connections, with the USD having more indirect connections.

Fourth, with indirect connections, other central banks intermediate access to a currency that is not their own. We found that the PBoC plays a relevant role in the USD network. If geopolitical tensions or other events excluded the PBoC from the network, the reach of the USD network would fall by 25% of world GDP, and the average degree of its connections would rise by 0.5. Across currencies, the PBoC is the more central in their networks, but recently the ECB is equally important in providing a shortest path to currencies in the network.

Fifth, we proved that these indirect connections create (soft) ceilings on the size of CIP deviations. As the degree of a connection increases, the ceiling tends to rise with it. Collecting new data for CIP deviations in 42 countries, we found a strong correlation between the degree of the connection between two currencies in the network and the size of CIP deviations.

Sixth, we found that signing a liquidity line is often preceded by a strong decline in USD reserves. In this sense, a run on reserves temporarily causes signing a liquidity line and, arguably, the line is seen as a substitute for exhausted reserves.

Seventh, the indirect connections in the network create variation in the access to the resources of the liquidity line that is plausibly exogenous with respect to what was happening to a country's FX reserves. This provided an identification strategy that we used to find that an increase in the degree of integration in the network of liquidity lines is followed over the next 12 months by an increase in the FX reserves of the country. In this sense, lines and reserves are complements.

Many questions are left unanswered. Who chooses to join the network, and what country features or global variables drive those choices? Would indirect connections resist a large global shock, and if not, how fragile is the global network? When a country has multiple connections to a currency in the network, does this provide robustness, and is one route systematically used? How has the global network affected and been affected by the networks of international tarde, capital flows, and cross-border bank loans? How do geopolitical developments interact with changes in the network, and how have they affected the shift from multilateral to bilateral? We hope the data in this paper will help future research to explore some of these.

References

Albrizio, Silvia, Iván Kataryniuk, and Luis Molina. 2023. "ECB Euro Liquidity Lines." *IMF Working Paper 2023/96*.

Bacchetta, Philippe, J. Scott Davis, and Eric van Wincoop. 2023. "Dollar Shortages, CIP Deviations, and the Safe Haven Role of the Dollar." *NBER Working Paper 31937*.

Bahaj, Saleem, and Ricardo Reis. 2020. "Jumpstarting an International Currency." *CEPR discussion paper 14793*.

Bahaj, Saleem, and Ricardo Reis. 2022*a*. "Central Bank Swap Lines: Evidence on the Lender of Last Resort." *Review of Economic Studies*, 89(4): 1654–1693.

Bahaj, Saleem, and Ricardo Reis. 2022*b*. "The Economics of Liquidity Lines Between Central Banks." *Annual Review of Financial Economics*, 14(1): 57–74.

Bahaj, Saleem, and Ricardo Reis. 2023. "The Workings of Liquidity Lines Between Central Banks." In *The Research Handbook of Financial Markets*. , ed. Refet Gurkaynak and Jonathan Wright. Edward-Elgar.

Bohórquez, Diego. 2023. "The United States as the International Lender of Last Resort." Universitat Pompeu Fabra manuscript.

Bordo, Michael D, Owen F Humpage, and Anna J Schwartz. 2015. "The Evolution of the Federal Reserve Swap Lines since 1962." *IMF Economic Review*, 63(2): 353–372.

Canay, Ivan A. 2011. "A Simple Approach to Quantile Regression for Panel Data." *The Econometrics Journal*, 14(3): 368–386.

Cerutti, Eugenio M, and Haonan Zhou. 2024. "Uncovering CIP Deviations in Emerging Markets: Distinctions, Determinants and Disconnect." *IMF Economic Review*, forthcoming.

Cesa-Bianchi, Ambrogio, Fernando Erugen-Martin, and Andrea Ferrero. 2022. "Dollar Shortages and Central Bank Swap Lines." Oxford University manuscript.

Du, Wenxin, and Jesse Schreger. 2016. "Local Currency Sovereign Risk." *The Journal of Finance*, 71(3): 1027–1070.

Ferrara, Gerardo, Philippe Mueller, Ganesh Viswanath-Natraj, and Junxuan Wang. 2022. "Central Bank Swap Lines: Micro-level Evidence." *Bank of England Working Paper 977*.

Goldberg, Linda S., and Fabiola Ravazzolo. 2022. "The Fed's International Dollar Liquidity Faciltiies: New Evidence on Effects." *NBER Working Paper 29982*.

Horn, Sebastian, Brad Parks, Carmen M. Reinhart, and Christoph Trebesch. 2023. "China as an International Lender of Last Resort." *NBER working paper 31105*.

Kekre, Rohan, and Moritz Lenel. 2023. "The High Frequency Effects of Dollar Swap Lines." *NBER working paper 31901*.

Kelly, Steven. 2023. “United States: FIMA Repo Facility, 2020.” *Journal of Financial Crises*, 5: 1558–1579.

McCauley, Robert N., and Catherine R. Schenk. 2020. “Central Bank Swaps Then and Now: Swaps and Dollar Liquidity in the 1960s.” *BIS Working Paper 851*.

Obstfeld, Maurice, Jay C. Shambaugh, and Alan M. Taylor. 2009. “Financial Instability, Reserves, and Central Bank Swap Lines in the Panic of 2008.” *American Economic Review Papers and Proceedings*, 99(2): 480–86.

Perks, Michael, Yudong Rao, Jongsoon Shin, and Kiichi Tokuoka. 2021. “Evolution of Bilateral Swap Lines.” *IMF Working Paper 2021/210*.

Róldan, Francisco, and César Sosa-Padilla. 2023. “Central Bank Swap Lines as Bilateral Sovereign Debt.” University of Notre Dame manuscript.

Data Appendix

A More details on the data

Liquidity lines. We used the January 2024 vintage of the data available from https://r2rsquaredlse.github.io/web-lines/. The data is at the agreement level, and has the day when the agreement went into effect and the day when it expired. We convert it into a monthly panel by looking at whether there is an active agreement between any given country pair at the start of the month. The network is directed: unidirectional liquidity lines are recorded as a one way connection and reciprocal lines are recorded as a two way connections. When we focus on bilateral connections only, we exclude connections that are formed via multilateral agreements like the Chiang-Mai initiative.

FX reserves and GDP data. Data on FX reserves comes from the IMF International Financial Statistics database (last accessed on November 29th of 2023). We use data item "Official Reserve Assets and Other Foreign Currency Assets in US Dollars" (RAF_USD) at a monthly frequency from January 2000. GDP data is also from the IMF International Financial Statistics database.

CIP deviations. We use daily financial market data from Datastream and Bloomberg, with a preference for the former when both sources are available. The exact tickers we use are available in the supplementary materials. The CIP deviation for currency g vis-a-vis the USD is:

$$X^{g,\$} = (1 + i^{\$}) - (S^{g,\$}/F^{g,\$})(1 + i^{g})$$

We measure i^g as currency g's interbank offered rate (IBOR) at a 3-month tenor. $(S^{g,\$}/F^{g,\$})$ is the 3-month forward premium on currency g vis-a-vis the USD computed using mid prices. We use outright forward rates when available, if not, we calculate the implicit forward rate from the swap rate as an alternative. We always take forward (or swap) and spot rates from the same source (Datastream or Bloomberg). If 3-month tenors are not available, we switch to a 1-month tenor. If neither are available, we code the observation as missing. The USD interest rate at 3 and 1 month tenors is, of course, always available.

When computing CIP deviations vis-a-vis the RMB or Euro we impose that triangular arbitrage holds in FX markets. So for RMB deviations for example, we have:

$$X^{g,€} \approx X^{g,\$} + X^{€,\$}$$

This approximation relieves us from having to find FX derivatives for multiple different crosses.

Our raw sample covers all available trading days from January 2007 to August 2023 for 42 countries. The daily data is exposed to occasional outliers which cause CIP deviations to spike for one trading day. This could be due to a stale price or a data entry mistake, so we impose a filter that trims such values.

B Constructing CIP Ceilings

To construct the CIP ceilings used in figure 11a, we make the following assumptions:

1. The Fed priced its swap lines at 100bp over OIS from their start until 1st December 2011, after which it switched to 50bp. This was further cut to 25bp on 15 March 2020. The Fed does not appear to distinguish by counterparty. This gives a time series of $i^{l,\$} - i^{\$}$ for all central banks with a direct connection to the Fed.

2. We assume the remaining five central banks in the swap line network with the Fed (that is the ECB, Bank of Japan, Bank of England, Bank of Canada and Swiss National Bank), follow the same pricing strategy on their swap lines with each other and with the Fed. These central banks reciprocate and coordinate on terms amongst themselves. Since most of the lines are inactive most of the time this assumption cannot be verified. However, consistent with the assumption, the BoE and ECB have activated their reciprocal liquidity line using the same spread as the Fed's lines with the ECB and BoE and also implemented the same rate cut on 15 March 2020.

3. We assume that the ECB prices its swap lines with other EU countries in line with its line with the Bank of England. This does not extend to its repo lines.

4. The PBoC's swap lines with developed economies (Singapore, Korea, Japan, UK, Australia, New Zealand and the Euroarea) are priced according to prevailing interbank rates and do not have a spread attached to them. The spread on the PBoC's lines with the HKMA and Macau was 50bp until 22nd July 2022 when it was cut

to 25bp, reflecting the spread charged on the HKMA's RMB liquidity facility. For the remaining PBoC lines to developing economies, without any information, we impose a 250bp spread consistent with the work of Horn et al. (2023).

5. The above covers 66% of liquidity lines in existence. For the remainder it is hard to get precise figures. We assume a 100bp spread reflecting anecdotal information.

The implicit ceiling behaves slightly differently for CIP deviations vis-a-vis the RMB, as the PBoC appears to operate a two-tiered pricing strategy: for lines with developed economies is charges prevailing market rates to access the liquidity line. For developing economies it charges approximately a 250bp spread (Horn et al. (2023)). This spread is higher than that typically charged by the Fed or the ECB. Countries that have a second degree connection with the PBoC are typically going via the ECB and paying the lower spread, and in turn, the ECB would pay the market rate to access the PBoC. As a result, and counterintuitively, the ceiling for the second degree connections with the PBoC ends up being lower than for the typical direct connection.