The Global Network of Financial Intermediation and Exchange Rates[*]

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Abstract

In a world with imperfect financial markets, the ability financiers to intermediate bilateral financial flows matters for exchange rate determination. This bilateral financial connection has been the focus of the literature. In this paper, we show both theoretically and empirically, that higher-order connections, and thus the entire network structure of cross-border financial intermediation, matters for exchange rates. Empirically, we find that, conditional on external financing needs (i.e., trade imbalances), higher-order financial connections predict future exchange rate returns, with different effects depending on both the source of the trade shock and the size of the country. We rationalize these findings by extending Gabaix and Maggiori (2015) model to a multi-country set-up with a rich financial network structure and heterogeneous country sizes that unveils the importance of network effects for exchange rate determination.

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1 Introduction

Fluctuations in the balance sheet of financial intermediaries can affect exchange rates both theoretically (e.g., Gabaix and Maggiori, 2015) and empirically (e.g., Du, Hebert and Wang, 2021; Fang, 2021). Financial intermediaries, however, operate through a complex network of cross-border interactions and it is unclear whether the structure of this network can amplify or mitigate the impact of balance sheet variations on the dynamics of exchange rates. We attempt to fill this gap, both in theory and in the data, by studying whether the structure of the global network of financial intermediation matters for the determination of future exchange rates. We show that differentiating between direct and indirect connections within a global network of financial intermediation is key to decoding how exchange rates respond to different sources of trade shocks.

We propose a theoretical framework that builds on the theory of exchange rate determination of Gabaix and Maggiori (2015). We extend their model to multiple countries facing different degrees of financial intermediation and show that exchange rates depend on both the first-order and higher-order financial connections of a country relative to its counterparties. First-order connections capture the direct intermediation of a country with its counterparties, whereas higher-order connections reflect the indirect intermediation that a country establishes with the partners of its counterparties. Specifically, first-order financial intermediation always mitigates the response of future exchange rates to current trade shocks. However, higher-order financial intermediation plays a more subtle role since it can amplify or mitigate the response of future exchange rates depending on the source of the trade shock. While the former is a standard prediction of Gabaix and Maggiori (2015), the latter is a novel prediction that emerges from our model.

We then empirically test the predictions of our model by constructing a network of financial intermediations based on the bilateral cross-border banking activity arising from the *restricted* version of the Locational Banking Statistics by residence (LBSR) compiled by the BIS. We observe that an increase in a country's higher-order financial connections dampens the impact of large foreign import demand shocks but heightens the impact of large domestic import demand shocks on its future exchange rate return. Finally, future exchange rate returns are sensitive to a network of cross-border positions denominated in the currencies of the counterparty countries as opposed to positions denominated in a vehicle currency like the US dollar.

To better understand the mechanism proposed by our model, consider a world with three countries: the US, the Eurozone, and Japan. All countries trade with each other and have balanced external accounts, but there is no direct financial intermediation between the Eurozone and Japan. We can then consider two different scenarios. In the first one, the US economy experiences a negative import demand shock that causes a domestic trade surplus coupled with foreign trade deficits. According to Gabaix and Maggiori (2015), countries requiring capital inflows will experience a currency depreciation today and an expected currency appreciation tomorrow so that financiers are willing to bridge their negative external imbalances. This mechanism, which is also nested in our model, suggests that the euro and yen should both fall in value against the dollar today to generate a positive exchange rate return tomorrow. We add to this result by adding the role of higher-order financial connections. To this end, suppose that Japan has stronger first-order financial connections with the US resulting from financiers having more balance sheet capacity to intermediate dollar-denominated and yen-denominated bonds. With the US facing a negative import demand shock, Japan will be able to run a larger trade deficit than the Eurozone due to greater capital flows between the US and Japan and lower capital flows between the US and the Eurozone. In this scenario, the yen will decline less than the euro because first-order financial links are stronger between Japan and the US and weaker between the Eurozone and the US. However, the Eurozone will now have a smaller trade deficit, and the euro will depreciate less versus the dollar in response to a positive US trade shock. From the perspective of the Eurozone, higher-order financial connections mitigate the effect of a large import demand shock abroad on the euro. Put differently, while a trade shock determines the sign of the exchange rate return, higher-order financial connections affect the magnitude of the exchange rate return. This is a novel prediction of our model that complements the standard prediction of Gabaix and Maggiori (2015).

Consider then the second scenario, where the Eurozone experiences a positive import demand shock that leads to a local trade deficit along with trade surpluses in the US and Japan. In this situation, the euro is projected to weaken today and appreciate tomorrow against the dollar, while the opposite is expected to happen for the yen. Because of the lack of direct financial intermediation between Japan and the Eurozone, Japan would divert more capital flows to the US, which would then be redirected to the Eurozone. If Japan improves its first-order financial linkages with the United States, it will be able to increase its external surplus, allowing more money to flow to the Eurozone via the US. As a result, the euro will experience a greater decline in value today coupled with a greater increase in value tomorrow. From the perspective of the Eurozone, higher-order financial connections amplify the exchange rate response to a negative import demand shock at home. Additionally, this prediction requires that the Eurozone is a large economy so that its import demand shock causes significant trade surpluses in other countries. If not, the amount of capital flows between Japan and the US would not be significant enough to impact exchange rate fluctuations. This is another novel prediction of our model that complements the standard prediction of Gabaix and Maggiori (2015).

Armed with these insights, we proceed to use data on bilateral cross-border banking activity and derive an empirical measure that captures network effects through a simple yet powerful mathematical formulation of *eigenvector centrality*. For this exercise, we use the *restricted* Locational Banking Statistics by residence (LBSR) compiled by the BIS and construct a network of cross-border banking activity for a large cross-section of reporting countries against more than 70 counterparty countries. This dataset is released on a restricted basis to the central banks of reporting countries. Importantly, the restricted version provides a currency breakdown of the cross-border positions for major vehicle currencies as well as for the local currency of the reporting country, which enables us to pin down the specific *currency* network that has a stronger association with exchange rate returns and thus conduct a more robust test of the theoretical model.

To compute our measure of financial intermediation centrality, we construct an adjacency matrix that contains the sum of claims and liabilities of counterparty countries against banks in reporting countries. This matrix encompasses a network of gross cross-border banking intermediation, whose eigenvector associated with the largest eigenvalue derives the measure of centrality. We then decompose eigenvector centrality into first-order and higher-order financial connections so that we can verify the predictions suggested by our model. In particular, the first prediction states that and increase in a country's higher-order financial connections mitigates the impact of large import demand shocks abroad on its future exchange rate return. The second prediction, moreover, adds that an increase in a country's higher-order financial connections amplifies the impact of large import demand shocks at home on its future exchange rate return, and this effect vanishes as the country becomes small. Finally, the last prediction, suggests that the relevant network of financial intermediation is the one denominated in the currencies of the counterparty countries and not the one denominated in a vehicle currency such as the US dollar.

In our empirical analysis, we first validate the use of cross-border banking intermediation as a proxy for balance sheet capacity by showing that countries that exhibit higher levels of foreign banking intermediation experience lower future exchange rate returns, conditional on a worsening position in the trade balance. According to the baseline model of Gabaix and Maggiori (2015), an increase in balance sheet capacity should be associated with lower future exchange rate returns whenever a country has external financing needs. Thus, we find empirical support for our novel theoretical predictions using a battery of panel regressions that employ first-order and higher-order financial connections as key explanatory variables. We find that, conditional on a positive shock to the US trade balance used to quantify a large import demand shock abroad, higher-order financial connections attenuate future exchange rate fluctuations. Intuitively, the US is the largest consumer of tradable goods in the world, and thus shocks to their trade balance are transmitted worldwide on a large scale, causing large marginal changes in the supply of external capital in the rest of the world. Whenever the financial counterparties of a given country have a higher capacity to intermediate their external capital with the US, its residual supply of available capital is diminished, and thus the exchange rate response is attenuated. In contrast, we find that countries with higher-order network effects exhibit an *amplification* of their exchange rate fluctuations in response to idiosyncratic shocks to their trade balance. But this effect is proportional to the size of the country and is thus only present in very large countries (in terms of their share of total trade). At the core of these findings is the fact that large trade shocks (that is, originating in large trading countries) have non-negligible implications for the total supply of external capital to be intermediated by financiers. Hence, heterogeneous changes in the capacity of financiers to intermediate this capital lead to heterogeneous effects on exchange rate fluctuations. These findings are aligned with our predictions, lending support to higher-order network effects in exchange rate determination and providing further evidence of gross financial intermediation as the economic quantities affected by the balance sheet capacity of financiers.

Literature Review. This paper contributes to several strands of the literature. On the theoretical front, by extending Gabaix and Maggiori (2015) to a multi-country setting with an embedded network structure, we contribute to the growing literature on the financial intermediation of global imbalances under imperfect markets; along with many other important contributions (Obstfeld and Rogoff, 1995; Bruno and Shin, 2015; Maggiori, 2017; He et al., 2019). On the empirical front, an important contribution of this paper is to the literature on exchange rate determination. In terms of network effects, Richmond (2019) documents the importance of trade centrality in explaining cross-sectional differences in risk premia. Unlike the measure of banking network centrality that we propose in this paper, trade centrality correlates with currency risk premia through interest rate differentials, whereas we find banking centrality to be primarily associated with exchange rate returns. In addition, extensive work has contributed on understanding the factors behind cross-sectional variation in excess currency returns (e.g., Lustig et al., 2011, 2014; Della Corte et al., 2016). Finally, another stream of related literature studies the intersection of capital flows and macroeconomic variables such as exchange rates. Camanho et al. (2022) study how capital flows from international equity investors rebalancing their portfolios affect exchange rates when international markets are segmented. Correa et al. (2021), also use the restricted Locational Banking Statistics dataset from the BIS to analyze the impact of monetary policy on cross-border bank flows.

The remainder of this paper is organized as follows. Section 2 extends the model of Gabaix and Maggiori (2015) to a multi-country setting. Section 3 presents a detailed description of our confidential dataset on cross-border banking activity and discuss the construction of network centrality. Section 4 verifies the prediction of the theoretical model of the importance of banking network centrality for future exchange rate returns before we conclude in Section 5. A separate Internet Appendix provides proofs and other supporting analyses.

2 MODEL

This model builds on the basic Gamma model in Gabaix and Maggiori (2015) of exchange rate determination with imperfect financial markets. We extend their model to allow for an arbitrary number of countries N, as well as bilateral-specific constraints on financial intermediation representing a financial network. This simple extension is sufficient to generate a rich set of predictions for how higher-order financial network connections matter for exchange rates.

2.1 ENVIRONMENT

Time is discrete and there are two periods: $t = 0, 1$. There is no uncertainty, period 1 variables are known as of period 0. There is a set N of countries; for exposition, Country 1 serves as the base and we refer to it as the US and its currency as the dollar. Each country is populated by a mass of households of different sizes who trade internationally in the goods market. Financial markets are segmented. Households trade solely in a risk-free bond denominated in local currency and cross-border trade in bonds occurs only via financiers connected to the country (we are precise on what we mean by connected below). Financiers are subject to limited commitment problem. As in the basic Gamma model, this friction will induce a downward-sloping demand curve for bonds in each currency.

HOUSEHOLDS. Each country j is populated by a mass of households of size h_j. We normalise the global population to one, $\sum_j h_j = 1$. Households have a per capita endowment of a Country-specific non-tradeable good, $Y_{NT,j,t}$, and tradeable good, $Y_{T,j,t}$. They derive period utility of the form: $\theta_{j,t} \ln \left(C_{j,t}\right)$, where $C_{j,t}$ is the per capita consumption basket

$$C_{j,t} = \left((C_{NT,j,t})^{\chi_{j,t}} (C^{j}_{T,j,t})^{\alpha_{j,t}} \prod_{i \neq j}^{N} (C^{i}_{T,j,t})^{h_i \iota_{j,t}} \right)^{\frac{1}{\theta_{j,t}}}. \tag{1}$$

$C_{NT,j,t}$ is per capita consumption of j's the nontradeable good and $C^{i}_{T,j,t}$ is per capita consumption of Country i's tradeable good. The preference parameters $\{\chi_{j,t}, a_{j,t}, \iota_{j,t}\}$ are defined such that $\chi_{j,t} + a_{j,t} + \sum_{i \neq j}^{N} H_i \iota_{j,t} = \theta_{j,t}$.

The nontradeable good in each economy is the numeriare, i.e., $p_{NT,j,t} = 1$. The exchange rate, $e_{j,t}$, is the relative price of nontradeables between Country j and the US. An increase is a dollar depreciation. As in the standard Gamma model, the non-tradeable can be interpreted as a money like good. This gives the exchange rate the classic and empirically relevant interpretation as the relative price of two moneys (Mussa, 1977).

Let $p^{i}_{T,j,t}$ denote the price of tradeable good i in terms of currency j. There are no frictions to trade in goods hence the law of one price holds: $e_{j,t} p^{i}_{T,j,t} = p^{i}_{T,1,t}$. Last, households can also trade in a risk-free bond denominated in their domestic currency either locally or with financiers with a connection to the country.

As in Gabaix and Maggiori (2015), we make the assumption that the endowment for non-tradable goods follows the process: $Y_{NT,j,t} = \chi_{j,t}$. We lay out the solution to the household problem in full in the Internet Appendix A. However, as the problem is standard, it suffices to explain the consequences of this assumption: it ensures that the marginal value of an additional unit of expenditure in any period t is always unity.

This has two implications for household behaviour. First, the equilibrium interest rate on domestic currency bonds is pinned down by the inverse of the household discount factor. For simplicity, we assume no-discounting. Hence, the equilibrium gross interest rate will be one in each economy. Second, household expenditures in a domestic currency on an imported tradeable good i is simply given by: $p^i_{T,j,t}C^i_{T,j,t} = h_i \iota_{j,t}$, and so parameter $\iota_{j,t}$ pins down per capita import demand.

FINANCIERS. Financiers are randomly selected from the population, act as price takers and intermediate bond flows across pairs of countries. Specifically, each group of financiers is randomly assigned to conduct one of the $\frac{N(N-1)}{2}$ possible combinations of long-short trading strategies: i.e., a financier raises revenues using Country $i's$ bonds to invest in the bonds of Country j or vice versa, and engages in no other trade. Let Q_{ji} denote the net long position (in dollar currency terms) of bonds of currency j financed by bonds issues by currency i by financiers operating between i and j. The profits of the financier in dollars are given by

$$V_{ji} = \left(\frac{e_{j,1}}{e_{j,0}} - \frac{e_{i,1}}{e_{i,0}} \right) Q_{ji}.$$

We assume that financiers value their business in currency of Country s_{ji}. They can choose to divert a fraction $(1 - \Gamma_{ji} | \frac{Q_{ji}}{e_{s_{ji},0}} |)$ of their short position and default on their borrowing. This limited commitment problem leads to the following incentive compatibility constraint

$$|Q_{ji}| \leq \frac{e_{s_{ji},0}}{\Gamma_{ji}} \left| \frac{e_{j,1}}{e_{j,0}} - \frac{e_{i,1}}{e_{i,0}} \right|. \tag{2}$$

The parameter Γ_{ji} effectively pins down the slope of the demand curve for bilateral financial flows between countries j and i in terms of the relative change in exchange rates. A higher value of Γ_{ji} indicates that financiers have less capacity for intermediation so greater relative shifts in exchange rates are needed to generate equivalent movements in capital. Note also that if financiers were unconstrained they would compete away all profits and we would have $\frac{e_{j,1}}{e_{j,0}} = \frac{e_{i,1}}{e_{i,0}}$. Hence, constraint in Equation (2) holds with equality in equilibrium. Last, financiers are defined by their country-pair and values are defined symmetrically. So we have that $Q_{ji} = -Q_{ij}$ and $\Gamma_{ji} = \Gamma_{ij}$, and, hence, $V_{ij} = V_{ji}$. Financiers profits in period-1 are distributed such that the dollar value of a country's net borrowing in period 0 is equal to the dollar value of its net repayments in period 1.[1]

Balance of payments identities and equilibrium. Recall that per capita household expenditure, in local currency, on import i is given by $h_i \iota_{j,t}$. Aggregating across markets and across households and accounting for financiers' profits, we end up with the following two dollar denominated balance of payments identities for country j:

$$t = 0: \quad \underbrace{h_j \sum_{i \neq j} H_i e_{i,0} \iota_{i,0}}_{\text{export revenues}} - \underbrace{h_j(1-h_j) e_{j,0} \iota_{j,0}}_{\text{import costs}} + \underbrace{\sum_{i \neq j} \frac{e_{s_{ij},0}}{\Gamma_{ji}} \mathbb{E}\left(\frac{e_{j,1}}{e_{j,0}} - \frac{e_{i,1}}{e_{i,0}}\right)}_{\text{net borrowing}} = 0 \quad , \tag{3}$$

$$t = 1: \quad \underbrace{h_j \sum_{i \neq j} h_i e_{i,1} \iota_{i,1}}_{\text{export revenues}} - \underbrace{h_j(1-h_j) e_{j,1} \iota_{j,1}}_{\text{import costs}} - \underbrace{\sum_{i \neq j} \frac{e_{s_{ij},0}}{\Gamma_{ji}} \left(\frac{e_{j,1}}{e_{j,0}} - \frac{e_{i,1}}{e_{i,0}}\right)}_{\text{net repayments}} = 0 \quad . \tag{4}$$

As in Gabaix and Maggiori (2015), in equilibrium, exchange rates adjust to ensure that balance of payments identities in Equation (3) and Equation (4) are satisfied for all countries.

[1]Precisely, let $\Pi_{j,t}$ denote the profits transfered from financiers to the households of country j. We have that $\Pi_{j,0} = 0$ and we assume that the transfer rule is such that $\Pi_{i,1} = \left(\frac{1}{e_0} - 1\right) \sum_{i \neq j} Q_{ji}$. This ensures that, in dollar terms, the revenue country j receives from financiers just offsets the capital loss from the higher value of it's liabilities when its exchange rate appreciates. This assumption follows the multicountry set up in the Appendix of Gabaix and Maggiori (2015).

2.2 ANALYSIS

To start, consider the generic N country case and now, for convenience, we make the assumption that $e_{s_{ji},0} = 1 \; \forall i, j$. Let $\underline{\iota}_t = (\iota_{1,t}, \iota_{2,t}, \ldots, \iota_{N,t})'$ and $\underline{e}_t = (1, e_{2,t}, \ldots, e_{N,t})'$, and denote $\circ$ as a Hadamard product and $^{\circ(-1)}$ as a Hadamard inverse. Stacking the balance of payments conditions across countries, we end up with the following result.

Lemma 1. *In the case where $e_{s_{ji},0} = 1, \forall i, j$, the balance of payments conditions can be stacked across countries to yield the following $2N \times 1$ system of equations:*

$$\Omega_0 \underline{e}_0 + \Gamma^- \left(\underline{e}_1 \circ \underline{e}_0^{\circ(-1)} \right) = 0,$$

$$\Omega_1 \underline{e}_1 - \Gamma^- \left(\underline{e}_1 \circ \underline{e}_0^{\circ(-1)} \right) = 0,$$

where $\Omega_t = H \left(\mathbf{1}_{N\times 1} \otimes \underline{\iota}_t{}' H \right) - diag\{H \underline{\iota}_t\}$, with $H = diag(h_1, h_2, \ldots, h_N)$, and $\Gamma^- = diag\{\tilde{\Gamma}^- \mathbf{1}_{N\times 1}\} - \tilde{\Gamma}^-$, with $\tilde{\Gamma}^-$ a matrix where each off-diagonal element j, i is equal to Γ_{ji}^{-1} and diagonals equal to nil. An equilibrium is two vectors $\underline{e}_0$ and $\underline{e}_1$ such that the balance of payments conditions are satisfied.

Proof. All proofs in Internet Appendix A. □

Two points standout from the conditions described in Lemma 1. First, the matrix Γ^- captures the capacity of the network of financiers to intermediate capital flows between countries. The jth diagonal element of Γ^- is given by $\sum_i \frac{1}{\Gamma_{ji}}$. This represents the combined capacity of financiers with a first order connection to j and captures the slope of the immediate demand curve for j's bonds.

However, the off diagonal elements in Γ^- also matter for the equilibrium level of exchange rates. Note that $\tilde{\Gamma}^-$, which determines the off-diagonal elements, can be interpreted as weighted adjacency matrix tracking the capacity of financiers to intermediate between any countries. It follows that the complete network structure plays a role. What matters for exchange rates is not just total capacity of financiers connected to Country j to intermediate capital flows but whose those financiers are connected to and, in turn, higher order connections beyond that.

Second, consider the matrix Ω_t. This captures the role played by networks in trade. As we have written the model, trade weights are just proportional to country size. However, differing trade weights among countries would manifest as richer heterogeneity in Ω_t and, in turn, alter how demand shocks transmit to the exchange rate through trade flows. This links to existing work on trade networks and exchange rate returns (Richmond, 2019). And to extent that trade and financial networks are likely correlated, this illustrates that it is important to control for the former when exploring whether the latter plays a role in the data.

THREE COUNTRY EXAMPLE. To build intuition for how higher order network of connections affect exchange rate determination, we now switch to an example where $N = 3$, that permits closed form solutions. With the US as the central country, will assume that $h_1 \geq h_2, h_3$ but has a weight less than a half. We assume that $\Gamma_{23}(= \Gamma_{32}) = 0$ such that flows of capital between Country 3 and Country 2 must be intermediated via Country 1. We also revert back to the specification of the standard Gamma model and assume that $s_{12} = 2$ and $s_{13} = 3$. Hence, the net capital flows from Country 1 to Countries 2 and 3 are given by:

$$Q_{21} = \Gamma_{12}^{-1} \left(e_{2,1} - e_{2,0}\right), \; Q_{31} = \Gamma_{13}^{-1} \left(e_{3,1} - e_{3,0}\right). \tag{5}$$

Our focus will be on comparative statistics over $e_{2,0}$ with respect to a change in import demand in Country 2, $\iota_{2,0}$, and in the US as the central country, $\iota_{1,0}$. How these comparative statics vary with Γ_{13} provides a way to guage the role of higher order financial connections in exchange rate determination. As above, we set $\underline{\iota}_1 = \mathbf{1}_{3\times 1}$.

To start, combine the two conditions in Lemma 1 to obtain $\Omega_0 \underline{e}_0 = -\Omega_1 \underline{e}_1$.[2] Substituting $\underline{\iota}_t$ into the definition of Ω_t, one can express $\underline{e}_1$ as a function of $\underline{e}_0$ and shocks to import demand

$$e_{2,1} = 1 + \iota_{1,0} - \iota_{2,0} e_{2,0}, \; e_{3,1} = 1 + \iota_{1,0} - e_{3,0}.$$

And, hence,

$$Q_{21} = \Gamma_{12}^{-1} \left[(1+\iota_{1,0}) - (1+\iota_{2,0})\, e_{2,0} \right], \; Q_{31} = \Gamma_{13}^{-1} \left[(1+\iota_{1,0}) - 2e_{3,0} \right]. \tag{6}$$

Substituting Equation (6) the date-0 balance of payments conditions for countries 2 and 3, we obtain the following results:

Proposition 1. *The equilibrium value of $e_{2,0}$ is given by*

$$e_{2,0} = \frac{\left(\frac{(1+\iota_{1,0})}{\Gamma_{12}} + h_1 h_2 \iota_{1,0}\right)\left(\frac{1}{\Gamma_{13}}(\iota_{3,0}+1) + h_3(1-h_3)\iota_{3,0}\right) + h_2 h_3 \iota_{3,0}\left(\frac{(1+\iota_{1,0})}{\Gamma_{13}} + h_1 h_3 \iota_{1,0}\right)}{\left(\frac{1}{\Gamma_{13}}(\iota_{3,0}+1) + h_3(1-h_3)\iota_{3,0}\right)\left(\frac{1}{\Gamma_{12}}(\iota_{2,0}+1) + h_2(1-h_2)\iota_{2,0}\right) - (h_2 h_3)^2 \iota_{2,0}\iota_{3,0}},$$

Hence, an import demand shock abroad causes an appreciation of country 2's current exchange rate, $\frac{de_{2,0}}{d\iota_{1,0}} > 0$ and an import at home causes a current depreciation, $\frac{de_{2,0}}{d\iota_{2,0}} < 0$. Furthermore, at the point $\underline{\iota}_0 = \mathbf{1}_{3\times 1}$, an increase in county 2's first order financial connection with country 1, Γ_{12}^{-1}, moderates the effect of both demand shocks on the exchange rate such that $\frac{de_{2,0}}{d\iota_{1,0}}$ is decreasing in Γ_{12}^{-1} and $\frac{de_{2,0}}{d\iota_{2,0}}$ is increasing.

The intuition for Proposition 1 is identical to the standard two-country Γ model. An

[2] Note that the change of the definition of s_{ij} in our $N = 3$ example changes the expressions for net borrowing and net repayments that appear in the Lemma, but this does not alter the fact that borrowing must equal repayments when the interest rate is one.

import demand shock at Home generates a trade deficit that needs financing. Financiers will only intermediate the required funds if offered a sufficient return, this is achieved by a current depreciation in country 2's exchange rate which generates a future return on the currency. The required return is decreasing in Γ_{12}^{-1}, hence an increase in this parameter moderates the exchange rate depreciation. Similar reasoning, albeit inverted, applies to an import demand shock in country 1 (or country 3).

What is less obvious is how the parameter Γ_{13}^{-1} alters results are the terms related to the cross derivatives.

Proposition 2. *Given the expression for the equilibrium exchange rate, we obtain the following:*

(i) An increase in country 2's higher order connection, Γ_{13}^{-1}, moderates *the impact of an import demand shock in the central country, that is:*

$$\left.\frac{d^2 e_{2,0}}{d\iota_{1,0} d\left(\Gamma_{13}^{-1}\right)}\right|_{\iota_0=\mathbf{1}_{3\times 1}} < 0$$

(ii) An increase in country 2's higher order connection, Γ_{13}^{-1}, amplifies *the impact of an import demand shock in the country 2, that is:*

$$\left.\frac{d^2 e_{2,0}}{d\iota_{2,0} d\left(\Gamma_{13}^{-1}\right)}\right|_{\iota_0=\mathbf{1}_{3\times 1}} < 0.$$

(iii) The amplification of the country 2 import demand shock only occurs if country 2 is large, that is:

$$\lim_{h_2\to 0} \left.\frac{d^2 e_{2,0}}{d\iota_{2,0} d\left(\Gamma_{13}^{-1}\right)}\right|_{\iota_0=\mathbf{1}_{3\times 1}} = 0.$$

The first cross derivative in the proposition states that increasing the capacity of the financiers intermediating between Countries 1 and 3 moderates the response to import shocks from the central country, that is $e_{2,0}$ appreciates by less for a given increase in $\iota_{1,0}$ as Γ_{13} becomes smaller. The second cross derivative has the opposite interpretation, stronger high order connections amplify the exchange rate movement in responses to a domestic import demand shock: that is $e_{2,0}$ depreciates by more for a given increase in $\iota_{2,0}$ as Γ_{13} becomes smaller.

To understand the intuition for these result, first note that we can rewrite Country 2's balance of payments condition as the following expression:

$$\underbrace{\Gamma_{12}^{-1}\left[(1+\iota_{1,0})-(1+\iota_{2,0})\,e_{2,0}\right]}_{Q_{21}} = \underbrace{\Gamma_{13}^{-1}\left[2e_{3,0}-(1+\iota_{1,0})\right]}_{-Q_{31}} + \underbrace{h_1\frac{h_2e_{2,0}\iota_{2,0}+h_3e_{3,0}\iota_{3,0}}{2}-h_1(1-h_1)\iota_{1,0}}_{\text{Country 1 trade balance}}. \tag{7}$$

The left side represents a demand curve for international lending to Country 2 by financiers. The right side can be interpreted as supply curve. It is the total surplus capital in Country 1 available to be lent to the financiers. This is simply the sum of Country 1's trade surplus plus the net lending from Country 3 to Country 1. Hence, a change in Γ_{13}^{-1} can be thought of as acting like a supply shifter.

Let us go back to the result on the cross derivative with $\iota_{1,0}$. Consider a scenario where there is a positive shock to $\iota_{1,0}$. This leads to a trade surplus in countries 2 and 3, and a deficit in country 1. The larger $\Gamma_{1,3}^{-1}$ is, the greater the amount of capital flowing from country 3 to country 1. This increases the right side of equation (7) and so moves the equilibrium down the demand curve for country 2 borrowing. So the net effect of larger $\Gamma_{1,3}^{-1}$ is to moderate the appreciation of $e_{2,0}$. An alternative way of thinking about this result is a simple composition effect: as $\Gamma_{1,3}^{-1}$ increases more of country 1's deficit is financed from country 3 as that financial friction is looser. Hence, country 2 ends up lending less to country 1, so financiers linking countries 1 and 2 demand a lower return which amounts to a smaller FX depreciation.

Now consider the cross derivative with $\iota_{2,0}$. An increase in $\iota_{2,0}$ generates trade surpluses in Countries 1 and 3, and a deficit in Country 2. Country 3's surplus always flows to Country 1 but the size of the flow depends on Γ_{13}^{-1}. The greater Γ_{13}^{-1}, the greater surplus the financiers linking 1 and 3 are able to intermediate and so greater the supply of capital in Country 1. From the perspective of Country 2, which is running a deficit and needs to borrow, this acts a financial supply shock which moves the equilibrium down the financiers' demand curve, i.e., the left hand side of Equation (7). This means there is a greater depreciation of $e_{2,0}$. In essence, financiers linking countries 1 and 2 are required to absorb a larger supply of capital. However, given their limited risk-taking capacity, this requires their expected profits to be larger, leading to a corresponding increase in the exchange rate return.

What we learn from this is that the source of shock matters. Higher order connections amplify the response to domestic import demand shocks but moderate the response to demand shocks abroad. The intuition here comes from whether the third country trade balance moves in the same or different direction to the domestic trade balance. If the two balances move in the same direction, as in the case of a shock in the central country, better third country connections take pressure off the domestic exchange rate as the other country can absorb surplus/finance deficits elsewhere more easily. When the balances move in opposite directions, as in the case of a domestic import demand shock, better connections elsewhere mean more foreign surpluses are recycled back to the domestic economy (and foreign deficits drain more finance away from it). The need for financiers to absorb this adds additional pressure on the exchange rate.

This intuition based on the trade balance in the third country also helps explain the final result, (iii), in the proposition. As country 2 becomes small, an increase in Γ_{13}^{-1} no longer ampifies the response to $\iota_{2,0}$. If country 2 is small its trade shocks cannot meaningfully affect the capital flow between 1 and 3 which was key in generated the interaction Γ_{13}^{-1} and $i_{2,0}$. This can be seen inspecting the right side of equation (7): as $h_2 \to 0$ the right side does not change with $\iota_{2,0}$ (given that $e_{3,0}$ does not respond). This curtails the effect through the shift in supply discussed above. And, hence, there is no amplification.

2.3 Empirical Predictions

We now bring togther the analysis above to form empirical predictions. This paper's goal is to proxy the financial connections between countries, i.e. Γ_{ji}, using gross banking flows. So we frame our empirical predictions in those terms. We also articulate predictions in terms of FX returns, which will match the empirical specification. In our theoretical framework, an exchange depreciation today generates a positive FX return tomorrow.

Prediction 0. *The stronger the first-order financial connections of a country, the smaller the increase in future FX returns following a positive shock to its trade balance.*

This prediction is a standard implication of the Gamma model of Gabaix and Maggiori (2015) and follows from Proposition 1. An increase in the capacity of financiers with a first order connection to a country acts to moderate the impact of the import demand change on the exchange rate. So we would expect to see a country with stronger first-order connections having less volatile FX returns.

Prediction 1. *An increase in a country's higher-order financial connections mitigates the impact of large import demand shocks abroad on its future exchange rate return.*

This prediction arises from the first cross derivative presented in Proposition 2. As the higher-order financial connections of country i strengthen, its currency would experience a lower future depreciation (appreciation) in response to an improvement (deterioration) of its current trade balance caused by positive (negative) import demand shocks affecting large trading partners.

Prediction 2. *An increase in a country's higher-order financial connections amplifies the impact of large import demand shocks at home on its future exchange rate return. This effect goes to zero as the country becomes small.*

This prediction follows directly from the second cross derivative presented in Proposition 2. Conditional on the strength of its first-order financial connections, as the higher-order financial connections of country i strengthen, its currency would experience a higher future appreciation (depreciation) in response to a deterioration (improvement) of its current trade balance caused by positive (negative) import demand shocks affecting the local economy. This effect goes to zero as the local economy becomes small.

Prediction 3. *The relevant network of financial intermediation is the one denominated in the currencies of the counterparty countries and not the one denominated in a vehicle currency such as the US dollar.*

This prediction is a more subtle outcome of the model. The link between financial connections and the exchange rates arises from financiers adopting long/short strategies in the currencies of the countries they are intermediating between. Exchange rates adjust to allow financiers to make sufficient arbitrage profits to intermediate the necessary capital flow. If financial flows were in a vehicle currency; for example, if the financiers were raising dollars in one country to lend dollars in another, the mechanism breaks down. The exchange rate plays no part in determining financiers profitability.

To test these predictions, we will construct a measure of financial intermediation centrality that makes use of bilateral cross-border banking activity. We describe these data in the next section.

2.4 From the Model to the Data

The empirical predictions of the previous section are about the response of exchange rate returns to import demand shocks, conditional on the level of intermediation capacity. To take the model to the data, we need to proxy for intermediation capacity and import demand shocks. For the former, we will use bilateral cross-border banking data, and for the later we will use the residuals on a factor model of trade balances. We describe each in the next section.

However, further discussion on the use of cross-border banking data to proxy for intermediation capacity is warranted: As we will elaborate in the next section, we make use of cross-border *gross banking positions* to construct an empirical proxy for the Γ matrix from the model that determines the intermediation capacity of financiers at the bilateral level. The underlying assumption is that intermediation capacity, which is a latent unobservable variable possibly driven by regulatory constraints or unobserved risk-taking parameters, is positively correlated with the size of bilateral gross banking positions. Under this assumption, we will exploit this correlation in reduced form to proxy for intermediation capacity. It is important to emphasize that we do not make use of cross-border banking data to measure the net positions that intermediate financial imbalances, but rather the gross positions that capture bilateral intermediation capacity. To the extent that the intermediation capacity between two countries improves, one would expect an increase in both borrowing and lending (and therefore gross positions) between these two countries.

Once we have constructed this empirical proxy for Γ, we need to estimate the higher-order connections. Compared to the 3-country example, this exercise is particularly challenging as there are many more higher-order connections for each country in the data. Hence, the empirical strategy will be to collapse all the higher-order connections of each country into a single point estimate, for each time period. To this end, we will use tools of network analysis. In particular, we will compute a particular measure of *network centrality* for each country in this network (i.e., matrix) of financial connections, from which we will disentangle between first and higher-order connections. Equipped with this measure, we will exploit cross-sectional variation in this higher-order centrality to test our predictions.

3 Data Description and Network Centrality

In this section, we start with a description of our database on bilateral cross-border banking claims and liabilities. Next, we provide a review of other datasets used in our empirical research, including exchange rates and bilateral trade data. Finally, we measure banking network centrality at the country-level to proxy for intermediaries' risk-taking capacity before turning to preliminary summary statistics.

3.1 Data Description

Cross-Border Banking Data. We source data on cross-border banking activity from the restricted *Locational Banking Statistics by residence* (LBSR) database, compiled by the Bank for International Settlement (BIS) and released on a restricted basis to the central banks of reporting countries. This dataset provides quarterly data on cross-border financial claims and liabilities of internationally active banks and institutions located in 45 reporting countries against the counterparties in more than 200 countries. Both claims and liabilities are reported at the country level, adjusted for exchange rate fluctuations across quarters, and revised for breaks-in-series due, for example, to changes in reporting practices and methodologies (BIS, 2019).

TABLE 1 ABOUT HERE

The LBSR database is useful to examine the interconnections at the country level since it records aggregate international financial assets and liabilities of banks and institutions on the basis of their residence rather than their nationality. Specifically, banks and institutions report their positions on an unconsolidated basis for each individual entity within their group, including intra-group positions with foreign subsidiaries and foreign branches. The LBSR database will then aggregate these position at the country level using principles that are consistent with balance of payments and international investment position statistics. For example, a loan that originates from an HSBC branch in Germany will be identified as a German claim (as per the location of the bank), rather than a British claim (as per the nationality of the bank). Ultimately, the database embodies the outstanding amount of cross-border financial claims and liabilities between all reporting banks and institutions in the source country and the counterparty sectors in the destination country. The *restricted* version of LBSR database also provides a breakdown by currency (i.e., local currency of the reporting country, British pound, euro, Japanese yen, Swiss franc, US dollar, and other foreign currencies), instrument (i.e., debt securities, loans and deposits, and other instruments), and counterparty sector (i.e., banks, non-bank financial institutions, non-financial corporations, general government, and households).

TABLE 2 ABOUT HERE

We merge the LBSR database with other datasets described below, which in our main specification limits our sample to 71 countries between December 1983 to December 2019 that are counterparties to each of the set of reporting countries in the dataset and also have observations on the other datasets. As we will discuss later in Section 3.2, when computing banking network centrality, we do so from the perspective of a country as a counterparty in the dataset. As a result, the sample of countries that have a measure of centrality corresponds to the set of counterparty countries at each point in time. Table 2 lists the counterparty countries in the dataset and thus the sample of countries with a measure of centrality, whereas Table 1 lists the reporting countries, which by construction will be the only countries that determine the centrality of other countries in the network. Following the introduction of the euro in January 1999, we aggregate claims and liabilities for all available members of the Euro Area, and only consider bilateral positions with non-Eurozone countries. Armed with quarterly observations on cross-border assets and liabilities, we first construct a measure of network centrality described later in this section, and then retrieve monthly observations by forward filling, i.e., by keeping end-of-period data constant until a new observation becomes available.

EXCHANGE RATE DATA. We source daily spot and one-month forward exchange rates from Barclays Bank and WM Refinitiv via Datastream for a large cross-section of 71 countries. All exchange rates are defined as units of US dollars per unit of foreign currency so that an increase in the exchange rate indicates an appreciation of the foreign currency (or, equivalently, a US dollar depreciation). The analysis uses monthly data obtained by sampling exchange rates on the last business day of each month between December 1983 and January 2020.

OTHER DATA. Our empirical analysis uses supplementary data, in addition to exchange rates and cross-border financial data. First, we collect quarterly observations on bilateral merchandise exports and imports from the IMF's Direction of Trade Statistics, and annual observations on country-level gross domestic product from the World Bank database between 1983 and 2019. Second, we obtain annual observations on the financial openness index of Chinn and Ito (2006), a *de jure* measure of capital account openness, from Ito's website between 1983 and 2019. Finally, we gather data on FX interventions recorded by Adler, Chang, Mano and Shao (2021) from the IMF's website. We focus on FX interventions in the spot market available for a large number of countries at the monthly frequency between January 2000 and December 2019.

3.2 Measuring Our Key Variables

FX Returns. The FX return from purchasing a unit of foreign currency at time t while reversing the position at time $t+1$ in the spot market is then calculated as follows

$$\Delta s_{i,t+1} = \ln(e_{i,t+1}/e_{i,t}),$$

where $e_{i,t}$ is the spot exchange rate of currency i relative to the US dollar at time t and Δ denotes the first-difference operator. While the model assumes for tractability that interest rates are zero, our empirical analysis also controls for the possibility that interest rates could endogenously clear the market in response to trade imbalances. To this end, we quantify the interest rate differential between the US dollar and the foreign currency i using the forward premium as

$$fp_t = \ln(f_{i,t}/e_{i,t}),$$

where $f_{i,t}$ is the forward exchange rate at time t with delivery date $t+1$.

Financial Intermediation Centrality. A network can be viewed as a collection of nodes and edges. In our context, countries represent the nodes and their connections denote the edges. The importance of a node in a network is then quantified by network centrality, which depends on the connections that a node holds with its neighbors. While there exists different methods to identify the key players of a network, we rely on a measure of network centrality – *eigenvector centrality* – that accounts for the centrality of a node while giving consideration to the importance of its neighbors (e.g., Bonacich, 1972). This means that not all countries are equally important and being connected to countries with high centrality scores is more important than being connected to countries with low centrality scores. Since first-order and higher-order connections play a different role in our model, eigenvector centrality is particularly useful for evaluating our empirical predictions.

For each country i, we compute eigenvector centrality at time t as follows

$$\mathcal{C}_{i,t} = \lambda_t^{-1} \sum_{j=1}^{N} \mathcal{A}_{ij,t} \mathcal{C}_{j,t}, \tag{8}$$

where $\mathcal{C}_{i,t}$ and $\mathcal{C}_{j,t}$ are the network centralities of country i and j at time t, $\mathcal{A}_{ij,t}$ denotes the sum of claims and liabilities held by country i against banks in country j at time t, λ_t is a scaling parameter determined at time t, and N refers to the number of countries. Country i can then achieve high centrality by engaging in cross-border activity with other countries that are themselves important. This definition, however, makes eigenvector centrality self-referential measure and, to get the solution, we need to solve a system of equations. It is thus worth rewriting Equation (8) in matrix form as

$$\lambda_t \mathcal{C}_t = \mathcal{A}_t \mathcal{C}_t, \tag{9}$$

where $\mathcal{C}_t$ is the $N \times 1$ vector of eigenvector centralities and $\mathcal{A}_t$ is the $N \times N$ adjacency matrix that groups together the network of claims and liabilities and has zeros along the main diagonal. This representation shows that $\mathcal{C}_t$ can be seen as an eigenvector of $\mathcal{A}_t$ with eigenvalue λ_t, and the solution is obtained by selecting the eigenvector corresponding to the largest eigenvalue. This eigenvector is known as the *leading eigenvector* and is the only one with non-negative entries (e.g., Newman, 2018). Finally, since the leading eigenvector may be affected by the size of the network, we follow the standard practice and normalize $\mathcal{C}_t$ to have unit Euclidean norm (e.g., Ruhnau, 2000).

FINANCIAL CONNECTIONS. Our model differentiates between *first-order* and *higher-order* connections and suggests that the latter plays a critical role for exchange rate determination. Specifically, the ability of a country to intermediate capital flows is determined not only by its direct connections but also by the connections of its partners, thus highlighting the role of higher-order network effects. Since the eigenvector centrality of a country consists of direct and indirect weighted paths leading to other countries, we can disentangle higher-order connection form first-order connection by simply separating the weighted pathways that travel directly and indirectly from country i to any other country j in the network.

Following Bonacich (1987) and Bonacich (2007), we can rewrite the vector of eigenvector centralities as the infinite sum of weighted paths activated directly and indirectly by each node in a network as

$$\mathcal{C}_t = \sum_{\ell=0}^{\infty} \lambda_t^{-\ell} \mathcal{A}_{ij,t}^{\ell+1} 1_N, \tag{10}$$

where ℓ denotes the number of paths, λ_t is the largest eigenvalue of the adjacency matrix, and 1_N is a $N \times 1$ vector of ones.[3] The vector of first-order (or direct) connections is then the first element of the infinite sum as

$$\mathcal{F}_t = \mathcal{A}_{ij,t} 1_N, \tag{11}$$

[3] The power centrality of Bonacich (1987) converges to the eigenvector centrality when the scaling factor of this formulation approaches the reciprocal of the largest eigenvalue of the adjacency matrix.

whereas the vector of higher-order (or indirect) connections is the residual part of the infinite sum, which we truncate up to a reasonable large number $\overline{\ell}$ as

$$\mathcal{H}_t = \lambda_t^{-1}\mathcal{A}_{ij,t}^2 1_N + \lambda_t^{-2}\mathcal{A}_{ij,t}^3 1_N + \ldots + \lambda_t^{\overline{\ell}}\mathcal{A}_{ij,t}^{\overline{\ell}} 1_N. \tag{12}$$

Our empirical analysis sets $\overline{\ell} = 100$, but results remain numerically identical for larger values. It is worth to notice that eigenvalues may also be affected by the size of the network and we normalize $\mathcal{H}_t$ to have unit Euclidean norm.

CURRENCY DENOMINATION OF NETWORKS. In our model, financiers go long the currency of the debtor country and short the currency of the creditor country, and exchange rates have to fluctuate to compensate them for intermediating the necessary capital flows. If capital flows were instead intermediated in a vehicle currency, for example the dollar or the euro, the exchange rate adjustment would play no role in determining the profitability of financiers. According to this process, the network of financial intermediation that matters for exchange rate determination is the one denominated in the currencies of the countries involved. In contrast, a network of financial intermediation handled in a vehicle currency would have no relationship with exchange rates. Since we observe the currency breakdown of cross-border claims and liabilities, we construct a measure of network centrality that is closely aligned with the mechanism unveiled in our model. Specifically, we compute $\mathcal{C}_{i,t}$, $\mathcal{F}_{i,t}$, and $\mathcal{H}_{i,t}$ using only claims and liabilities of country i against banks in country j expressed in the currency of country j (reporting country), thus excluding cross-border positions denominated in other currencies. As a robustness exercise, we also build measures of network centrality based on positions denominated in a vehicle currency, like the US dollar. We will refer to them as $\mathcal{C}_{i,t}^{usd}$, $\mathcal{F}_{i,t}^{usd}$, and $\mathcal{H}_{i,t}^{usd}$, respectively.

Trade Shocks. Our model postulates that exchange rates respond to an increase in higher-order network centrality conditional on import demand shocks, which are not directly observable from the data. To estimate these import demand shocks, we rely on the following latent factor model

$$D_{i,t} = \alpha_i + \beta_i' P_t + I_{i,t}, \tag{13}$$

where $D_{i,t}$ is the year-on-year trade deficit as percentage of GDP of country i at time t, P_t is the set of principal components at time t estimated from the cross-section of trade deficits (including the US trade deficits), and $I_{i,t}$ is the residual component unexplained by common trade factors. An increase in $I_{i,t}$ can be associated to a deterioration in the trade balance of country i and thus viewed as a positive import demand shock experienced at home. In our analysis, we select eleven principal components. i.e., we pick a principal component as along as it explains at least one percent of the trade deficit variation.

Differently from other countries, we run the following latent factor model for the US

$$S_{us,t} = \alpha_{us} + \beta_{us}' P_t + I_{us,t}, \tag{14}$$

where $S_{i,t}$ is the year-on-year US trade surplus as percentage of GDP at time t, P_t is the set of principal components described above, and $I_{us,t}$ is the residual component unexplained by common trade factors. An increase in $I_{us,t}$ can be associated to an improvement in the US trade balance (or a deterioration in the trade balance of country i) and thus interpreted as a large negative import demand shock abroad (or a large positive import demand at home).

Trade Centrality. A recent study shows that trade network centrality is an important determinant of interest rate differentials and currency risk premia (Richmond, 2019). Following this paper, we also calculate trade network centrality using bilateral trade intensity coupled with the global share of exports each country i in our sample and use it as a control variable in our empirical analysis.

Accounting for Country Heterogeneity. There exists a certain degree of heterogeneity across countries that may arise, for example, from differences in size, development, openness, and regulations. These persistent differences can affect network centrality and make a cross-country comparison challenging. Akin to Richmond (2019), we thus standardize the centrality of each country, including first-order and higher-order connections, relative to its sample mean and standard deviation, and work with these measures thorough the rest of this paper. In doing so, we address the question of *which country is becoming more central in the network*, rather than dealing with the question of *who is the most central country in the network*. We also standardize every other variable except interest rate differentials and exchange rate returns, hence the same interpretation follows for these economic quantities.

3.3 Preliminary Analysis

Before turning to our empirical analysis, it is worth to visualize the sample properties of our key variables, i.e., first-order and higher-order connections based on cross-border positions denominated in the local currency of the reporting country. In Panel A of Figure 1, we plot the cross-country average of first-order connections $\mathcal{F}_{i,t}$. We also include the interquartile range and as well as shaded areas denoting US recessions based on NBER dates.[4] In Panel B of Figure 1, we move to the high-order connections $\mathcal{H}_{i,t}$ and plot their cross-country averages. They are likely to capture different sources of information since the average of first-order connection is higher in times of economic expansion and lower during periods of economic contraction, whereas the average higher-order connection tends to be more volatile during the same periods.

FIGURE 1 ABOUT HERE

Finally, one may wonder whether our measures of centrality are somehow correlated with trade centrality.[5] We address this concern in Figure 1. Here, for each time period, we plot the cross-sectional correlation between trade centrality and first-order connection in Panel A, and between trade centrality and higher-order connection in Panel B. Both first-order and higher-order connections are based on cross-border positions denominated in the local currency of the reporting country. Panel A shows that correlation between first-order connection and trade centrality varies substantially over time, and it generally positive with average value close to 16%. Interestingly, the relationship between first-order connection and trade centrality is not always positive since it is negative in a few occasions like the late 1990s and the late 2010s. Panel B, moreover, displays the correlation between higher-order connection and trade centrality, and reveals no clear pattern. The average correlation is about -2%, indicating that the latter is fairly distinct from the former. For example, correlation is primarily negative in the 1980s, reverses sign a few times in the 1990s, slightly positive in the 2000s, and then often negative in the last decade of our sample. In absolute terms, moreover, correlation has been substantially decreasing over time,

[4]The first-order connection of country i is the sum all of cross-border claims and liabilities against banks in other countries. Not surprisingly, this quantity displays an upward trend that may be associated to a period of greater globalization. To better visualize the average dynamics of first-order connection, we detrend the first-order connection of each country i using a linear trend.

[5]We plot the cross-country average of trade centrality in the Internet Appendix Figure A.1. Similarly to the first-order connection, we detrend the trade centrality of each country i using a linear trend to better visualize its dynamics.

a phenomenon that may be attribute to financial liberalization. For example, correlation reached its lowest value of about -80% in the late 1980s, peaked in the 1990s at about 80% but dropped to roughly -40% in the last decade of our sample. Last but not least, according to NBER data, correlation does not have a clear pattern around US recessions.

FIGURE 2 ABOUT HERE

In addition to cross-sectional correlations, we also compute time-series correlations country by country. The average of these correlations between trade centrality and first-order connection is close to 41%, whereas between trade centrality and higher-order connection is about -11%. Taken together, these figures suggests that financial intermediation centrality and trade centrality are likely to capture different determinants of currency returns.

We now move to the next section, where we use panel regressions run at a monthly frequency as a device to test the predictions of our model. For those variables available at a quarterly or annual frequency, we retrieve monthly observations by forward filling, i.e., by keeping end-of-period data constant until a new observation becomes available. Finally, we winsorize exchange rate returns at the 1% level on both tails to remove outliers.

4 EMPIRICAL RESULTS

This section empirically tests the predictions of our model. As discussed in Section 2.3, the transmission of trade shocks to exchange rates depends on the ability of financiers to intermediate capital between affected countries, both directly or indirectly. First, we evaluate the efficacy of gross intermediation flows as a reliable proxy for balance sheet capacity. This step is crucial for establishing the foundational validity of our subsequent analyses. Second, we investigate the role of higher-order connections for future exchange rate returns, aiming to confirm whether these effects align with our model's predictions. We then delve into the type of currency network that is most pertinent for capturing the mechanism under study. Specifically, we compare the relevance of the US dollar as a vehicle currency against cross-border intermediation conducted in non-vehicle currencies. Lastly, as an auxiliary test of the validity of gross intermediation flows as a proxy for balance sheet capacity, we explore the effectiveness of FX interventions in countries that have become more peripheral in the global network of cross-border banking intermediation. This will provide additional insights into whether changes in a country's network position is related to changes in its balance sheet capacity.

4.1 GROSS FINANCIAL INTERMEDIATION AND EXCHANGE RATES

Our model highlights the role higher-order financial connections for exchange rate returns. Before testing our novel predictions, one may wonder whether future exchange rate returns are also sensitive to first-order financial connections as indicated by the model of Gabaix and Maggiori (2015). While testing this prediction, we also verify whether information embedded in the higher-order financial connections is not completely subsumed by information included in the first-order financial connections. To address these questions, we start our empirical investigation by running panel regressions summarized by the following specification

$$\Delta s_{i,t+1} = \beta \mathcal{F}_{i,t} D_{i,t} + \gamma \mathcal{H}_{i,t} D_{i,t} + Controls_{i,t} + fe + \varepsilon_{t+1} \tag{15}$$

where $\Delta s_{i,t+1}$ is the exchange rate return of country i relative to the US dollar between months t and $t+1$ in percentage per annum, $\mathcal{F}_{i,t}$ is the first-order financial connection of country i relative to banks located in all reporting countries at time t, $\mathcal{H}_{i,t}$ is the corresponding higher-order financial connection, $D_{i,t}$ is the trade deficit of country i, and

$Controls_{i,t}$ refers to country-specific control variables that capture time-variant observed characteristics and comprises the capital account openness of Chinn and Ito (2006), forward premium, share of world GDP, and the trade network centrality of Richmond (2019). Both measures of financial strength $\mathcal{F}_{i,t}$ and $\mathcal{H}_{i,t}$ are based on cross-border positions denominated in the local currency of the reporting country. Also, we use a trade deficit instead of a trade shock since the model of Gabaix and Maggiori (2015) links exchange rate returns to trade imbalances, which can arise from shocks to the external account of country i or the external accounts of the counterparty countries. Finally, all specifications include the single regressors $\mathcal{F}_{i,t}$, $\mathcal{H}_{i,t}$, and $D_{i,t}$ (not displayed to save space and notation) and time fixed-effects fe that absorb unobserved time-variant factors that are common to all countries.

TABLE 3 ABOUT HERE

Table 3 reports the estimates of β and γ with standard errors clustered at the country level in parentheses. Specification (1) focuses on the interaction between first-order connections and trade deficits, which is equivalent to assessing the effect of gross financial intermediation on exchange rates conditional on trade imbalances. We uncover a negative and highly statistically significant estimate on β of -0.835 with a standard error of 0.316, which corroborates the baseline model of Gabaix and Maggiori (2015). In their model, countries whose funding needs are intermediated by financiers with larger balance sheet capacity should experience a lower exchange rate returns in the future, provided that their trade balance deteriorates. Specification (2) adds country-specific control variables but yields qualitatively similar results: the estimate on β is about -0.787 with a standard error of 0.295. Taken together, these specifications suggests that, in economic terms, a one standard deviation increase in first-order connection and trade deficit decreases the future exchange rate return approximately by one percent per annum, with and without control variables.

Specifications (3) focuses on the interaction between higher-order connections and trade deficits. We report a negative and highly statistically significant estimate on γ of -0.666 with a standard error of 0.260, in line with the predictions of our model. In particular, countries connected to financial counterparties that have higher balance sheet capacity experience lower exchange rate returns, conditional on a worsening of their trade balance. Specifications (4) controls for country-specific variables but unveils qualitatively similar results. In economic terms, a one standard deviation increase in financial centrality and one standard deviation increase in higher-order connection and trade deficit decreases the future exchange rate return approximately by 0.9 percent per annum, with and without controls. Specification (5), finally, stacks together both first-order and higher-order financial connections. The coefficients on the interaction terms are both negative and statistically significant, which would be consistent with our model in Section 2 where both first and higher-order connections matter for exchange rates. Although these results suggest that higher-order network effects are likely to play a role for exchange rate returns, we would need to test the specific predictions of our model to get a better sense of their effects.

Overall, the findings presented in Table 3 indicate that gross financial intermediation (or first-order connection) is associated to future exchange rate returns, and can be interpreted as a proxy for the balance sheet capacity og global intermediaries. Furthermore, our results also demonstrate that higher-order connections may be a valuable source of information for future exchange rate returns.

4.2 Higher-Order Connections and Exchange Rates

We now move to testing the theoretical predictions described in Section 2.3 by running panel regressions based on the following specification

$$\Delta s_{i,t+1} = \beta\, \mathcal{H}_{i,t}\, I_{us,t} + \gamma\, \mathcal{H}_{i,t}\, I_{i,t} + \theta\, \mathcal{H}_{i,t}\, I_{i,t}\, L_{\alpha,t} + Controls_{i,t} + fe + \varepsilon_{t+1}, \tag{16}$$

where $\Delta s_{i,t+1}$ is the exchange rate return of country i relative to the US dollar between months t and $t+1$ in percentage per annum, $\mathcal{H}_{i,t}$ is the higher-order financial connection of country i relative to banks located in all reporting countries at time t, $I_{us,t}$ indicates a positive trade surplus shock experienced by the US at time t (a proxy for a negative import demand shock in a large foreign country), and $I_{i,t}$ denotes a positive trade deficit shock affecting country i at time t (a proxy for a positive import demand shock at home). By using a different sign on import demand shocks, we seek to facilitate the interpretation of our estimates since higher $I_{i,t}$ and $I_{us,t}$ both refer to a deterioration in trade balance of country i at time t, everything else being equal. In addition, $L_{\alpha,t}$ denotes a dummy variable that equals one, and zero otherwise, if country i is large enough at time t (in the top α percent of the countries by share of global trade), and $Controls_{i,t}$ refers to country-specific control variables that capture time-variant observed characteristics and comprises the capital account openness of Chinn and Ito (2006), first-order financial connections, forward premium, share of world GDP, and the trade network centrality of Richmond (2019). All specifications include the single regressors $\mathcal{H}_{i,t}$, $I_{i,t}$, and $I_{us,t}$ as well as the interaction terms $\mathcal{H}_{i,t}L_{\alpha,t}$ and $I_{i,t}L_{\alpha,t}$ (not displayed to save space and notation). Finally, specifications are saturated with country and time fixed-effects fe.

The first interaction $\mathcal{H}_{i,t}I_{us,t}$ is motivated by Prediction 1, where $I_{us,t}$ should be interpreted as an import demand shock affecting a large trading partner. According to this prediction, as $\mathcal{H}_{i,t}$ increases, we should expect a lower future exchange rate return for country i

in response to an improvement of its current trade balance caused by a positive yet large import demand shock abroad. As a result, we should expect a negative estimate of β. Prediction 2, moreover, supports the second interaction $\mathcal{H}_{i,t} I_{i,t}$ and the triple interaction $\mathcal{H}_{i,t} I_{i,t} L_{\alpha,t}$, where $I_{i,t}$ should be viewed as an import demand shock at home. According to this prediction, as $\mathcal{H}_{i,t}$ increases, we should anticipate a higher future appreciation of currency i in response to a deterioration in its current trade balance caused by a positive import demand shock affecting the local economy. This predictive relationship, however, disappears as the local economy becomes small. To discriminate between large and small economies, we introduce the dummy variable $L_{\alpha,t}$ that selects countries that are sufficiently large in terms of their share of global trade. For our primary exercise, we set α at 5%, which corresponds to the largest eight economies. Later on, however, we offer a robustness experiment in which we employ several levels of α. As a result, we should expect an insignificant estimate of γ but a positive estimate of θ.

TABLE 4 ABOUT HERE

Table 4 reports the estimates of β, γ, and θ, with standard errors clustered at the country level in parentheses. We uncover a negative and highly statistically significant estimate on β, a positive and highly statistically significant estimate on θ but an insignificant estimate of γ as predicted by our model. These findings suggests that a large foreign demand import shocks (in our case a large increase in the US trade balance unexplained by common trade factors) is associated with lower exchange rate returns for those countries whose counterparties become more central in the global financial network. In economic terms, one standard deviation increase in US net exports and one standard deviation increase in higher-order centrality is associated with an average of 0.7 percent lower exchange rate returns per annum. To recover the intuition of the model, following a large external trade shock that causes a negative shock to the trade balance of each country in the network, those country whose financial counterparties increase their capacity to intermediate their external financing needs, will see their residual supply of external capital shrink as it will be absorbed by these financial counterparties that have become more financially connected. Hence, their deficit, all else equal, will be lowered thus requiring a lower exchange rate return, i.e., a moderation of the exchange rate response.

FIGURE 3 ABOUT HERE

An interesting feature of the model is that it predicts the magnitude of network effects on exchange rate returns to be conditional on the size of the country experiencing the trade shock. The impact that a country's trade shock has on the global supply of external capital is proportional and monotonically increasing with the country's share of global trade. To test this, we run the fully saturated regression model described in Equation (16) that includes all set of controls with both country and time fixed effects for different thresholds of country size, and report the estimates of θ. Figure 3 displays the estimated coefficient for each threshold of country share of global trade, along with the 90% confidence interval. The estimated coefficients become larger with the size threshold, which is suggestive that the effect of network effects on exchange rate returns, conditional on country-specific trade shocks, is monotonically increasing with the size of the country experiencing the trade shock.

4.3 Currency Denomination of Networks

Our measures of financial connections are based on cross-border positions denominated in the local currency of the reporting country. However, given the specialness of the US dollar as vehicle currency, it is natural to ask whether cross-border claims and liabilities denominated in US dollars are equally important. Put differently, does it matter whether financiers intermediate trade imbalances in US dollars or in the currencies of the counterparty countries? Prediction 3 claims that the relevant network of financial intermediation is the one denominated in the currencies of the counterparty countries.

To validate our theoretical prediction, we perform a *horse-race* based on the following panel specification:

$$\Delta s_{i,t+1} = \beta\, \mathcal{H}_{i,t}\, I_{us,t} + \gamma\, \mathcal{H}_{i,t}\, I_{i,t} + \theta\, \mathcal{H}_{i,t}\, I_{i,t}\, L_{\alpha,t}$$
$$+ \beta'\, \mathcal{H}^{us}_{i,t}\, I_{us,t} + \gamma'\, \mathcal{H}^{us}_{i,t}\, I_{i,t} + \theta'\, \mathcal{H}^{us}_{i,t}\, I_{i,t}\, L_{\alpha,t} + Controls_{i,t} + fe + \varepsilon_{t+1}$$

where $\Delta s_{i,t+1}$ is the exchange rate return of country i relative to the US dollar between months t and $t+1$ in percentage per annum, $\mathcal{H}_{i,t}$ is the higher-order financial connection of country i relative to banks located in all reporting countries based on cross-border positions denominated in the local currency of the reporting country at time t, $\mathcal{H}^{us}_{i,t}$ is the corresponding higher-order financial connection based on cross-border positions denominated in US dollars, $I_{us,t}$ indicates a positive trade surplus shock experienced by the US at time t, $I_{i,t}$ denotes a positive trade deficit shock affecting country i at time t, $L_{\alpha,t}$ denotes a dummy variable that equals one, and zero otherwise, if country i is large enough at time t (in the top α percent of the countries by share of global trade), and $Controls_{i,t}$ refers to country-specific control variables that capture time-variant observed characteristics and comprises the capital account openness of Chinn and Ito (2006), first-order financial connections, forward premium, share of world GDP, and the trade network centrality of Richmond (2019). All specifications include the single regressors $\mathcal{H}_i$, $\mathcal{H}^{us}_i$, I_i, and I_{us} as well as the interaction terms $\mathcal{H}_{i,t}L_\alpha$, $\mathcal{H}^{us}_{i,t}L_\alpha$, and $I_{i,t}L_\alpha$ (not displayed to save space and notation). Finally, specifications are saturated with country and time fixed-effects fe.

TABLE 5 ABOUT HERE

Table 5 reports the estimates of β, θ, β', and θ' with standard errors clustered at the country level in parentheses. Our results indicate, in line with our model's predictions, that financial connections based on dollar-denominated cross-border positions play no major role for future exchange rate returns. This is consistent with a world in which the key determinant for a country's capacity to intermediate trade imbalances in the presence of imperfect financial markets, is the ability of financiers to trade claims in the currency of the counterparty. Hence, to the extent that network centrality is an empirical proxy for balance sheet capacity, the relevant network is the one denominated in the currency of the counterparty.

4.4 Other Measures of Financial Connections

In our core analysis, we use cross-border claims and liabilities as a proxy for the balance sheet capacity of global intermediaries. To ensure the robustness of our findings, we replicate Table 4 using measures of financial connections based either on cross-border claims or cross-border liabilities.

Table 6 about here

Specifically, in Table 6, we only use cross-border claims to form the adjacency in Equation (8) but find qualitatively similar results, meaning that estimates of β are negative and statistically significant as indicated by Prediction 1, whereas estimates of θ are positive and statistically significant as suggested by Prediction 2.

Table 7 about here

In Table 7, moreover, we only use cross-border liabilities to assemble the adjacency in Equation (8). We confirm our main findings since estimates of β remain negative and statistically significant as suggested Prediction 1, whereas estimates of θ continue to positive and statistically significant as implied from Prediction 2.

4.5 The Role of Pegged Currencies

Our analysis is based on a broad sample of countries, some of which may be subject to restrictions on cross-border capital flows and/or have pegged exchange rate regimes at various points in time.

Table 8 about here

To guard against illiquid and hard-to-trade currencies, we first construct a dummy variable $Peg_{i,t}$ that assigns in each month a value of one if country i operates under a pegged exchange rate regime using the exchange rate classification index of Ilzetzki, Reinhart and Rogoff (2019), and zero otherwise.[6] Hence, we augment the panel regressions described by Equation (16) by interacting the key explanatory variables with the dummy variable $Peg_{i,t}$ as

$$\begin{aligned}\Delta s_{i,t+1} = {} & \beta\,\mathcal{H}_{i,t}\,I_{us,t} + \gamma\,\mathcal{H}_{i,t}\,I_{i,t} + \theta\,\mathcal{H}_{i,t}\,I_{i,t}\,L_{\alpha,t} \\ & + \beta'\mathcal{H}_{i,t}I_{us,t}Peg_{i,t} + \gamma'\mathcal{H}_{i,t}I_{i,t}Peg_{i,t} + \theta'\mathcal{H}_{i,t}I_{i,t}L_{\alpha,t}Peg_{i,t} + Controls_{i,t} + fe + \varepsilon_{t+1},\end{aligned}$$

We report our estimates in Table 8 but document no major changes in our estimates of β, γ, and θ. We thus conclude that illiquid and hard-to-trade currencies do not drive the main outcome of our empirical investigation.

[6] Using the fine exchange rate classification, the dummy variable is equal to zero if a currency belongs to a pre-announced crawling band that is wider than or equal to ±2%, a *de facto* crawling band that is narrower than or equal to ±5%, a moving band that is narrower than or equal to ±2%, a managed float, a free float, or a free-falling regime. These scenarios have a code between 9 and 14.

5 Conclusions

Understanding the complex interplay underlying global financial intermediation is vital to devise effective policy responses aiming at financial stability in the wake of global shocks. This paper illustrates, both theoretically and empirically, the role of financial connections for future exchange rate returns. Using the *restricted* Locational Banking Statistics by residence database compiled by the BIS, we construct a network of international bank lending and show that a country-level measure of banking centrality is associated with lower future currency returns conditional on higher external financing needs (proxied by trade deficit). This mechanism, moreover, can be attributed to banking positions denominated in the local currency of the lender rather than banking positions denominated in a vehicle currency like the US dollar or the euro.

Overall, we provide empirical support for the existence of a meaningful link between exchange rate returns and countries' financial connections, a fundamental and theoretically motivated driving force with an amplifying effect stemming from countries' external financing needs. We thus contribute to the recent literature on the role of financiers' risk-bearing capacity and global imbalances in determining future exchange rates (e.g., Gabaix and Maggiori, 2015).

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Figure 1. First-order and Higher-order Connections

This figure displays, for each time period, the cross-sectional average of the first-order connection (Panel A) and higher-order connection (Panel B) based on cross-border claims and liabilities denominated in the local currency of the reporting country. The figure also reports the interquartile range and vertical shaded areas denoting US recessions based on NBER dates. The sample runs at the quarterly frequency between December 1983 and December 2019. Data are collected from the restricted version of the Locational Banking Statistics by Residence (LBSR) compiled by the *Bank for International Settlements*.

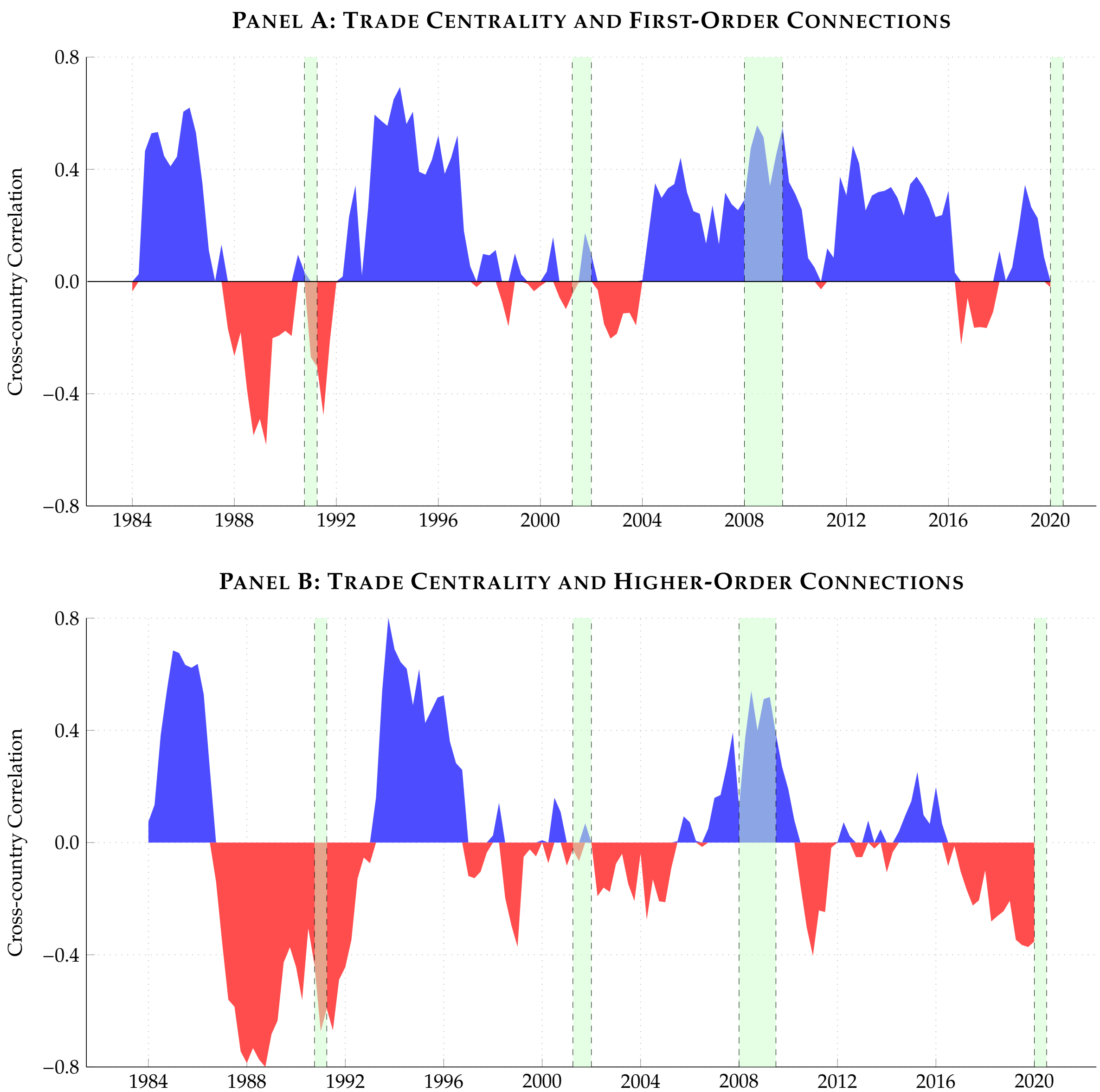

Figure 2. Correlation with Trade Centrality

This figure displays, for each time period, the cross-sectional correlation between trade centrality and first-order connection (Panel A) and trade centrality and higher-order connection (Panel B). Trade centrality is constructed as in Richmond (2019) using bilateral trade intensity and global share of exports. First-order and high-order connections are based on cross-border claims and liabilities denominated in the local currency of the reporting country. The figure also reports the interquartile range and vertical shaded areas denoting US recessions based on NBER dates. The sample runs at the quarterly frequency between December 1983 and December 2019. Data are collected from the restricted version of the Locational Banking Statistics by Residence (LBSR) compiled by the *Bank for International Settlements*, Datastream, IMF's Direction of Trade Statistics, and World Bank.

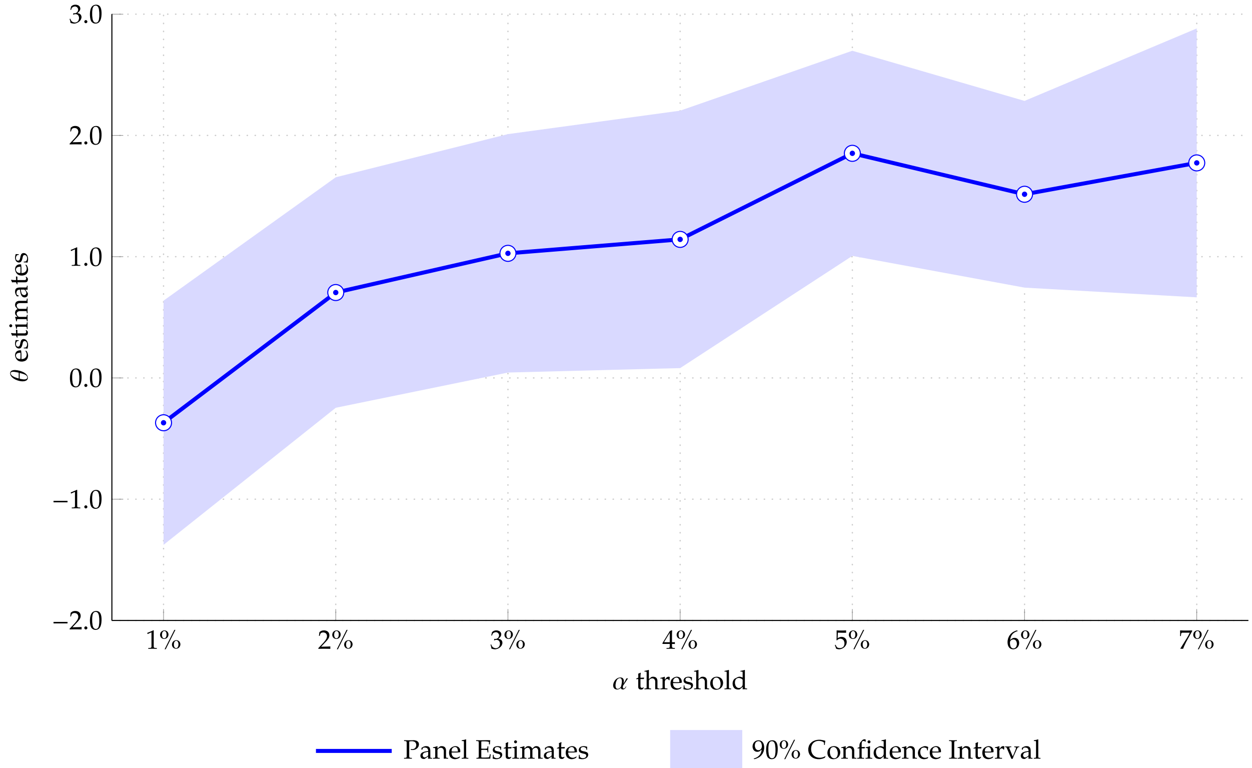

FIGURE 3. COUNTRY SIZE AND CONDITIONAL EXCHANGE RATE RETURNS

This table presents the panel estimates of θ based on the following specification

$$\Delta s_{i,t+1} = \beta \mathcal{H}_{i,t} I_{us,t} + \gamma \mathcal{H}_{i,t} I_{i,t} + \theta \mathcal{H}_{i,t} I_{i,t} L_{\alpha,t} + Controls_{i,t} + fe + \varepsilon_{t+1},$$

where Δs_i is the future exchange rate return of country i relative to the US dollar, $\mathcal{H}_i$ is the higher-order connection of country i relative to banks located in reporting countries, I_{us} is a positive trade surplus shock experienced by the US, I_i is a positive trade deficit shock affecting country i, and L_α is a binary variable that selects countries that are sufficiently large (top α percent) in terms of share of global trade. $Controls_i$ refers to country-specific control variables that capture time-variant observed characteristics and comprises the capital account openness of Chinn and Ito (2006), first-order financial connections, forward premium, share of world GDP, and the trade network centrality of Richmond (2019). Exchange rate returns are expressed in percentage per annum, the measures of financial strengths are based on cross-border positions denominated in the local currency of the reporting country, and α is set at 5% corresponding to the largest 8 economies. The above specification is further complemented with country and time fixed-effects fe. All specifications include the single regressors $\mathcal{H}_i$, I_i, and I_{us} as well as the interaction terms $\mathcal{H}_i L_\alpha$ and $I_i L_\alpha$ (not displayed to save space and notation). The sample runs at a monthly frequency between September 1983 and December 2019. Cross-border claims and liabilities are from the restricted Location Banking Statistics by residence database compiled by the BIS. Other data are from Datastream, IMF Direction of Trade Statistics, World Bank, and IMF's website.

TABLE 1. CROSS-BORDER BANKING ACTIVITY: LIST OF REPORTING COUNTRIES

This table lists the source countries of bilateral cross-border banking claims and liabilities in our sample. The sample runs at the quarterly frequency between December 1983 and December 2019. Data are collected from the restricted version of the Locational Banking Statistics by Residence (LBSR) compiled by the *Bank for International Settlements*.

Year	Reporting Countries
1983	Austria, Bahamas, Belgium, Canada, Cayman Islands, Denmark, Finland, France, Germany, Hong Kong, Ireland, Italy, Japan, Luxembourg, Netherlands, Netherlands Antilles, Spain, Sweden, Switzerland, United Kingdom, United States
1997	Australia, Portugal
2000	Taiwan, Turkey
2001	Guernsey, India, Isle of Man, Jersey
2002	Bermuda, Brazil, Chile, Panama
2003	Greece, Macau, Mexico
2005	South Korea
2007	Malaysia
2008	Cyprus
2009	South Africa
2010	Curacao, Indonesia
2014	Norway
2015	China
2016	Philippines
2017	Saudi Arabia

TABLE 2. CROSS-BORDER BANKING ACTIVITY: LIST OF COUNTERPARTY COUNTRIES

This table lists the destination countries of bilateral cross-border banking claims and liabilities in our sample. The sample runs at the quarterly frequency between December 1983 and December 2019. Data are collected from the restricted version of the Locational Banking Statistics by Residence (LBSR) compiled by the *Bank for International Settlements*.

Year	Counterparty Countries
1984	Austria, Australia, Belgium, Canada, Denmark, Germany, Hong Kong, Ireland, Italy, Japan, Liechtenstein, Netherlands, Norway, Nauru, New Zealand, Portugal, Singapore, Spain, South Africa, Sweden, Switzerland, United Kingdom, United States
1990	Kuwait, Saudi Arabia, Tuvalu
1992	Kiribati
1995	United Arab Emirates
1996	Czech Republic, France, Greece, Indonesia, Malaysia, Mexico, Poland, Taiwan
1997	Hungary, India
1998	Andorra, Finland, Greenland, Thailand, Vatican City
1999	Euro Area, San Marino
2000	Bahrain, Philippines, Turkey
2001	Guernsey, Isle of Man, Jersey
2002	South Korea, Slovakia
2004	Argentina, Bulgaria, Brazil, Chile, Colombia, Croatia, Egypt, Iceland, Israel, Jordan, Kazakhstan, Kenya, Lithuania, Latvia, Malta, Morocco, Oman, Peru, Pakistan, Palestinian Authority, Qatar, Russia, Slovenia, Tunisia
2005	China, Romania
2006	Montenegro
2010	Ukraine
2011	Botswana, Serbia, Sri Lanka, Uganda, Vietnam, Zambia

Table 3. Gross Financial Intermediation and Exchange rates

This table presents panel regression estimates based on the following specification:

$$\Delta s_{i,t+1} = \beta \mathcal{F}_{i,t} D_{i,t} + \gamma \mathcal{H}_{i,t} D_{i,t} + Controls_{i,t} + fe + \varepsilon_{t+1},$$

where Δs_i is the future exchange rate return of country i relative to the US dollar in percentage per annum, $\mathcal{F}_i$ is the first-order connection of country i relative to banks located in reporting countries, $\mathcal{H}_i$ is the corresponding higher-order connection, D_i is the trade deficit of country i, and $Controls_i$ includes country-specific variables as the capital account openness of Chinn and Ito (2006), forward premium, share of world GDP, and the trade network centrality of Richmond (2019). he measures of financial strengths are based on cross-border positions denominated in the local currency of the reporting country. fe denotes time fixed-effects. All specifications include the regressors $\mathcal{F}_i$ and $\mathcal{H}_i$ (not displayed to save space). Standard errors (in parentheses) are clustered by country. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively. The sample runs at a monthly frequency between September 1983 and December 2019. Cross-border claims and liabilities are from the restricted Location Banking Statistics by residence database compiled by the BIS. Other data are from Datastream, IMF Direction of Trade Statistics, World Bank, and IMF's website.

	(1)	(2)	(3)	(4)	(5)
$\mathcal{F}_i$	−0.391	−0.440			0.562
	(0.280)	(0.289)			(0.352)
$\mathcal{F}_i \times D_i$	−0.835***	−0.787***			−0.581**
	(0.316)	(0.295)			(0.278)
$\mathcal{H}_i$			−1.009***	−1.056***	−1.278***
			(0.260)	(0.273)	(0.334)
$\mathcal{H}_i \times D_i$			−0.666**	−0.734***	−0.510*
			(0.296)	(0.258)	(0.262)
# Observations	14,981	14,981	14,981	14,981	14,981
Time fe	✓	✓	✓	✓	✓
Controls		✓		✓	✓

TABLE 4. FINANCIAL CONNECTIONS AND EXCHANGE RATES

This table presents panel regression estimates based on the following specification

$$\Delta s_{i,t+1} = \beta\,\mathcal{H}_{i,t}\,I_{us,t} + \gamma\,\mathcal{H}_{i,t}\,I_{i,t} + \theta\,\mathcal{H}_{i,t}\,I_{i,t}\,L_{\alpha,t} + Controls_{i,t} + fe + \varepsilon_{t+1},$$

where Δs_i is the future exchange rate return of country i relative to the US dollar in percentage per annum, $\mathcal{H}_i$ is the higher-order connection of country i relative to banks located in reporting countries, I_{us} is a positive trade surplus shock experienced by the US, I_i is a positive trade deficit shock affecting country i, L_α is a binary variable that selects countries that are sufficiently large (top α percent) in terms of share of global trade, and $Controls_i$ includes country-specific variables as the capital account openness of Chinn and Ito (2006), first-order financial connections, forward premium, share of world GDP, and the trade network centrality of Richmond (2019). The measures of financial strengths are based on cross-border positions denominated in the local currency of the reporting country, and α is set at 5% corresponding to the largest 8 economies. fe denotes country and time fixed-effects fe. All specifications include the single regressors $\mathcal{H}_i$, I_i, and I_{us} as well as the interaction terms $\mathcal{H}_i L_\alpha$ and $I_i L_\alpha$ (not displayed to save space and notation). Standard errors (in parentheses) are clustered by country. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively. The sample runs at a monthly frequency between September 1983 and December 2019. Cross-border claims and liabilities are from the restricted Location Banking Statistics by residence database compiled by the BIS. Other data are from Datastream, IMF Direction of Trade Statistics, World Bank, and IMF's website.

	(1)	(2)	(3)	(4)	(5)
$\mathcal{H}_i$	−1.000***	−1.058***	−1.023***	−1.278***	−0.858**
	(0.275)	(0.299)	(0.298)	(0.352)	(0.361)
$\mathcal{H}_i \times I_{us}$	−0.631***	−0.643***	−0.651***	−0.648***	−0.650***
	(0.216)	(0.221)	(0.217)	(0.219)	(0.219)
$\mathcal{H}_i \times I_i$	−0.281	−0.419	−0.449	−0.445	−0.353
	(0.277)	(0.289)	(0.299)	(0.297)	(0.283)
$\mathcal{H}_i \times I_i \times L_\alpha$		1.886***	1.843***	2.246***	2.051***
		(0.551)	(0.579)	(0.433)	(0.432)
# Observations	14,981	14,981	14,981	14,981	14,981
Time fe	✓	✓	✓	✓	✓
Country fe			✓		✓
Controls				✓	✓

TABLE 5. FINANCIAL CONNECTIONS AND CURRENCY DENOMINATION

This table presents panel regression estimates based on the following specification

$$\Delta s_{i,t+1} = \beta \mathcal{H}_{i,t} I_{us,t} + \gamma \mathcal{H}_{i,t} I_{i,t} + \theta \mathcal{H}_{i,t} I_{i,t} L_{\alpha,t} + \beta' \mathcal{H}^{us}_{i,t} I_{us,t} + \gamma' \mathcal{H}^{us}_{i,t} I_{i,t} + \theta' \mathcal{H}^{us}_{i,t} I_{i,t} L_{\alpha,t} + Controls_{i,t} + fe + \varepsilon_{t+1},$$

where Δs_i is the future exchange rate return of country i relative to the US dollar in percentage per annum, $\mathcal{H}_i$ is the higher-order connection of country i relative to banks located in reporting countries based on cross-border positions denominated in the local currency of the reporting country, $\mathcal{H}^{us}_i$ is the higher-order connection of country i relative to banks located in reporting countries based on cross-border positions denominated in US dollars, I_{us} is a positive trade surplus shock experienced by the US, I_i is a positive trade deficit shock affecting country i, L_α is a binary variable that selects countries that are sufficiently large (top α percent) in terms of share of global trade, and $Controls_i$ includes country-specific variables as the capital account openness of Chinn and Ito (2006), first-order financial connections, forward premium, share of world GDP, and the trade network centrality of Richmond (2019). The measures of financial strengths are based on cross-border positions denominated in the local currency of the reporting country, and α is set at 5% corresponding to the largest 8 economies. fe denotes country and time fixed-effects. All specifications include the single regressors $\mathcal{H}_i$, $\mathcal{H}^{us}_i$, I_i, and I_{us} as well as the interaction terms $\mathcal{H}_i L_\alpha$, $\mathcal{H}^{us}_i L_\alpha$, and $I_i L_\alpha$ (not displayed to save space and notation). Standard errors (in parentheses) are clustered by country. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively. The sample runs at a monthly frequency between September 1983 and December 2019. Cross-border claims and liabilities are from the restricted Location Banking Statistics by residence database compiled by the BIS. Other data are from Datastream, IMF Direction of Trade Statistics, World Bank, and IMF's website.

	(1)	(2)	(3)	(4)
$\mathcal{H}^{us}_i \times I_{us}$	−0.409	−0.354	−0.397	−0.340
	(0.272)	(0.277)	(0.282)	(0.286)
$\mathcal{H}_i \times I_{us}$	−0.474**	−0.465**	−0.486**	−0.426**
	(0.211)	(0.217)	(0.206)	(0.211)
$\mathcal{H}^{us}_i \times I_i \times L_\alpha$	2.206*	2.132*	2.421**	2.152*
	(1.129)	(1.153)	(1.191)	(1.196)
$\mathcal{H}_i \times I_{i,t} \times L_\alpha$	1.945***	1.953***	2.040***	1.946***
	(0.601)	(0.610)	(0.645)	(0.638)
# Observations	14,957	14,957	14,957	14,957
Time fe	✓	✓	✓	✓
Country fe		✓		✓
Controls			✓	✓

Table 6. Cross-Border Claims and Exchange Rates

This table presents panel regression estimates based on the following specification

$$\Delta s_{i,t+1} = \beta\, \mathcal{H}_{i,t}\, I_{us,t} + \gamma\, \mathcal{H}_{i,t}\, I_{i,t} + \theta\, \mathcal{H}_{i,t}\, I_{i,t}\, L_{\alpha,t} + Controls_{i,t} + fe + \varepsilon_{t+1},$$

where Δs_i is the future exchange rate return of country i relative to the US dollar in percentage per annum, $\mathcal{H}_i$ is the higher-order connection of country i relative to banks located in reporting countries, I_{us} is a positive trade surplus shock experienced by the US, I_i is a positive trade deficit shock affecting country i, L_α is a binary variable that selects countries that are sufficiently large (top α percent) in terms of share of global trade, and $Controls_i$ includes country-specific variables as the capital account openness of Chinn and Ito (2006), first-order financial connections, forward premium, share of world GDP, and the trade network centrality of Richmond (2019). The measures of financial strengths are based on cross-border claims denominated in the local currency of the reporting country, and α is set at 5% corresponding to the largest 8 economies. fe denotes country and time fixed-effects. All specifications include the single regressors $\mathcal{H}_i$, I_i, and I_{us} as well as the interaction terms $\mathcal{H}_i L_\alpha$ and $I_i L_\alpha$ (not displayed to save space and notation). Standard errors (in parentheses) are clustered by country. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively. The sample runs at a monthly frequency between September 1983 and December 2019. Cross-border claims and liabilities are from the restricted Location Banking Statistics by residence database compiled by the BIS. Other data are from Datastream, IMF Direction of Trade Statistics, World Bank, and IMF's website.

	(1)	(2)	(3)	(4)	(5)
$\mathcal{H}_i$	−0.769***	−0.761***	−0.729***	−0.721***	−0.387
	(0.233)	(0.244)	(0.243)	(0.263)	(0.270)
$\mathcal{H}_i \times I_{us}$	−0.677***	−0.721***	−0.677***	−0.664***	−0.622**
	(0.232)	(0.237)	(0.239)	(0.242)	(0.242)
$\mathcal{H}_i \times I_i$	−0.112	−0.241	−0.296	−0.190	−0.145
	(0.270)	(0.283)	(0.297)	(0.272)	(0.271)
$\mathcal{H}_i \times I_i \times L_\alpha$		1.767***	1.800***	2.178***	2.107***
		(0.624)	(0.639)	(0.431)	(0.430)
# Observations	14,981	14,981	14,981	14,981	14,981
Time fe	✓	✓	✓	✓	✓
Country fe			✓		✓
Controls				✓	✓

TABLE 7. CROSS-BORDER LIABILITIES AND EXCHANGE RATES

This table presents panel regression estimates based on the following specification

$$\Delta s_{i,t+1} = \beta \, \mathcal{H}_{i,t} \, I_{us,t} + \gamma \, \mathcal{H}_{i,t} \, I_{i,t} + \theta \, \mathcal{H}_{i,t} \, I_{i,t} \, L_{\alpha,t} + Controls_{i,t} + fe + \varepsilon_{t+1},$$

where Δs_i is the future exchange rate return of country i relative to the US dollar in percentage per annum, $\mathcal{H}_i$ is the higher-order connection of country i relative to banks located in reporting countries, I_{us} is a positive trade surplus shock experienced by the US, I_i is a positive trade deficit shock affecting country i, L_α is a binary variable that selects countries that are sufficiently large (top α percent) in terms of share of global trade, and $Controls_i$ includes country-specific variables as the capital account openness of Chinn and Ito (2006), first-order financial connections, forward premium, share of world GDP, and the trade network centrality of Richmond (2019). The measures of financial strengths are based on cross-border liabilities denominated in the local currency of the reporting country, and α is set at 5% corresponding to the largest 8 economies. fe denotes country and time fixed-effects. All specifications include the single regressors $\mathcal{H}_i$, I_i, and I_{us} as well as the interaction terms $\mathcal{H}_i L_\alpha$ and $I_i L_\alpha$ (not displayed to save space and notation). Standard errors (in parentheses) are clustered by country. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively. The sample runs at a monthly frequency between September 1983 and December 2019. Cross-border claims and liabilities are from the restricted Location Banking Statistics by residence database compiled by the BIS. Other data are from Datastream, IMF Direction of Trade Statistics, World Bank, and IMF's website.

	(1)	(2)	(3)	(4)	(5)
$\mathcal{H}_i$	−0.756***	−0.809***	−0.839***	−0.816***	−0.527*
	(0.279)	(0.307)	(0.303)	(0.313)	(0.300)
$\mathcal{H}_i \times I_{us}$	−0.655***	−0.679***	−0.669***	−0.674***	−0.661***
	(0.241)	(0.251)	(0.235)	(0.239)	(0.225)
$\mathcal{H}_i \times I_i$	−0.287	−0.381	−0.354	−0.382*	−0.258
	(0.247)	(0.254)	(0.253)	(0.225)	(0.214)
$\mathcal{H}_i \times I_i \times L_\alpha$		1.578***	1.453***	1.851***	1.614***
		(0.477)	(0.502)	(0.371)	(0.376)
# Observations	14,981	14,981	14,981	14,981	14,981
Time fe	✓	✓	✓	✓	✓
Country fe			✓		✓
Controls				✓	✓

Table 8. Financial Connections and Pegged Currencies

This table presents panel regression estimates based on the following specification:

$$\Delta s_{i,t+1} = \beta\,\mathcal{H}_{i,t}\,I_{us,t} + \gamma\,\mathcal{H}_{i,t}\,I_{i,t} + \theta\,\mathcal{H}_{i,t}\,I_{i,t}\,L_{\alpha,t} + \beta'\mathcal{H}_{i,t}I_{us,t}Peg_{i,t} + \gamma'\mathcal{H}_{i,t}I_{i,t}Peg_{i,t} + \theta'\mathcal{H}_{i,t}I_{i,t}L_{\alpha,t}Peg_{i,t} + Controls_{i,t} + fe + \varepsilon_{t+1},$$

where Δs_i is the future exchange rate return of country i relative to the US dollar in percentage per annum, $\mathcal{H}_i$ is the higher-order connection of country i relative to banks located in reporting countries, I_{us} is a positive trade surplus shock experienced by the US, I_i is a positive trade deficit shock affecting country i, L_α is a binary variable that selects countries that are sufficiently large (top α percent) in terms of share of global trade, Peg_i is a dummy variable that selects pegged currencies using the classification of Ilzetzki et al. (2019), and $Controls_i$ includes country-specific variables as the capital account openness of Chinn and Ito (2006), first-order financial connections, forward premium, share of world GDP, and the trade network centrality of Richmond (2019). The measures of financial strengths are based on cross-border liabilities denominated in the local currency of the reporting country, and α is set at 5% corresponding to the largest 8 economies. The above specification is further complemented with country and time fixed-effects fe. All specifications include the single regressors $\mathcal{H}_i$, I_i, I_{us}, and Peg_i as well as all other interaction terms (not displayed to save space and notation). Standard errors (in parentheses) are clustered by country. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively. The sample runs at a monthly frequency between September 1983 and December 2019. Cross-border claims and liabilities are from the restricted Location Banking Statistics by residence database compiled by the BIS. The exchange rate classification is from Ilzetzki's website. Other data are from Datastream, IMF Direction of Trade Statistics, World Bank, and IMF's website.

	(1)	(2)	(3)	(4)	(5)
$\mathcal{H}_i$	−1.000***	−1.058***	−1.023***	−2.446***	−2.078***
	(0.275)	(0.299)	(0.298)	(0.649)	(0.644)
$\mathcal{H}_i \times I_i$	−0.281	−0.419	−0.449	−0.780	−0.641
	(0.277)	(0.289)	(0.299)	(0.551)	(0.511)
$\mathcal{H}_i \times I_{us}$	−0.631***	−0.643***	−0.651***	−1.182***	−1.208***
	(0.216)	(0.221)	(0.217)	(0.452)	(0.449)
$\mathcal{H}_{i,t} \times I_{i,t} \times L_\alpha$		1.886***	1.843***	2.627***	2.494***
		(0.551)	(0.579)	(0.715)	(0.726)
# Observations	14,981	14,981	14,981	14,981	14,981
Time fe	✓	✓	✓	✓	✓
Country fe			✓		✓
Controls				✓	✓

Internet Appendix to

The Global Network of Financial Intermediation and Exchange Rates

(not for publication)

Abstract

This appendix presents additional derivations and results not included in the main body of the paper.

A Model's derivation

A.1 The household's problem in full

The household's maximization problem is

$$\max_{(C_{H,j,t}, C_{NT,j,t}, (C^i_{F,j,t})_{i\neq j})} \quad \theta_{j,0} \ln C_{j,0} + \beta \mathbb{E}[\theta_{j,1} \ln C_{j,1}], \tag{A.1}$$

subject to (1) and

$$\sum_{t=0}^{1} R_j^{-t} \left(Y_{NT,j,t} + p_{H,j,t} Y_{H,j,t} + (1/h_j)\Pi_{j,t}\right) = \sum_{t=0}^{1} R_j^{-t} \left(C_{NT,j,t} + p_{H,j,t} C_{T,j,t} + \sum_{i\neq j}^{N} p^i_{F,j,t} C^i_{F,j,t}\right). \tag{A.2}$$

where R_j^{-t} is the interest rate in currency j and $\Pi_{i,t}$ is the total profit transfered from financiers to households in country j. Here we have introduced β as a discount factor.

This optimization problem can be divided into two separate problems. The first is a static problem, whereby households choose their optimal consumption allocation across the different goods given their total consumption expenditure for a given period, and the second is a dynamic intertemporal optimization problem whereby households decide how much to save and consume in each period. The static utility maximization problem is:

$$\begin{aligned} \max_{(C_{H,j,t}, (C^i_{T,j,t})_i)} \quad & \chi_{j,t} \ln C_{NT,j,t} + a_{j,t} \ln C^j_{T,j,t} + \iota_{j,t} \sum_{i\neq j}^{N} h_i \ln C^i_{T,j,t} \\ & + \lambda_{j,t} \left(CE_{j,t} - C_{NT,j,t} - p^j_{T,j,t} C^j_{T,j,t} - \sum_{i\neq j}^{N} p^i_{T,j,t} C^i_{T,j,t} \right) \end{aligned} \tag{A.3}$$

where $CE_{j,t}$ is the household's total consumption expenditure in period t which is taken as exogenous in this static problem, $\lambda_{j,t}$ is the Lagrange multiplier on the budget constraint.

The first order conditions for this problem are:

$$\frac{\chi_{j,t}}{C_{NT,j,t}} = \lambda_{j,t}$$
$$\frac{a_{j,t}}{C^j_{T,j,t}} = \lambda_{j,t} p^j_{T,j,t}$$
$$\frac{h_i \iota_{j,t}}{C^i_{T,j,t}} = \lambda_{j,t} p^i_{T,j,t} \quad \forall i \neq j$$

Imposing that nontradeable goods are produced by an endowment process $Y_{NT,j,t} = \chi_{j,t}$, we obtain $\lambda_{j,t} = 1$ and hence $p^i_{T,j,t} C^i_{T,j,t} = h_i \iota_{j,t}$.

Next, we turn to the intertemporal optimization problem. Given that we assume that the risk-free bond pays one unit of nontradable good in all states of the world, the household's intertemporal budget constraint is:

$$1 = \mathbb{E}\left[\beta R_j \frac{U'_{j,1,C_{NT}}}{U'_{j,0,C_{NT}}}\right] = \mathbb{E}\left[\beta R_j \frac{\left(\frac{\chi_{j,1}}{C_{NT,j,1}}\right)}{\left(\frac{\chi_{j,0}}{C_{NT,j,0}}\right)}\right] = \beta R_j$$

where $U'_{j,1,C_{NT}}$ is the marginal utility of consumption of nontradeables at time t. The last equality follows from the assuming that $C_{NT,j,t} = \chi_{j,t}$. Note that $R_j = \beta^{-1} = R_i$ since we have assumed that all households have the same rate of time preference. As a result, there will be no interest differential between countries and if there is no discounting, as we assumed in the main text, the gross interest is one throughout the economy.

A.2 PROOF OF LEMMA 1

To start, define $\tilde{\Gamma}^{-1}_j$ as the jth row of $\tilde{\Gamma}^{-}$ (as defined in the Lemma) and $\underline{h} = (h_1, h_2, \ldots, h_N)$ with $H = diag\{\underline{h}\}$. Country $j's$ period-0 balance of payments condition can be written as

$$h_j \sum_i h_i e_{i,0} \iota_{i,0} - \sum_{i \neq j} \frac{1}{\Gamma_{ij}} \frac{e_{i,1}}{e_{i,0}} = h_j e_{j,0} \iota_{j,0} - \sum_{i \neq j} \frac{1}{\Gamma_{ij}} \frac{e_{j,1}}{e_{j,0}}.$$

In vector notation, this amounts to

$$h_j \underline{\iota}_0{}' H \underline{e}_0 - \tilde{\Gamma}_j^- \left(\underline{e}_1 \circ \underline{e}_0^{\circ(-1)} \right) = h_j e_{j,0} \iota_{j,0} + \tilde{\Gamma}_j^- \left(\frac{e_{j,1}}{e_{j,0}} \otimes \mathbf{1}_{N \times 1} \right).$$

Stacking across j we obtain, for $t = 0$:

$$H \left(\mathbf{1}_{N \times 1} \otimes \underline{\iota}_0{}' H \right) \underline{e}_0 - \tilde{\Gamma}^- \left(\underline{e}_1 \circ \underline{e}_0^{\circ(-1)} \right) = H \left(\underline{\iota}_0 \circ \underline{e}_0 \right) - \left(\tilde{\Gamma}^- \mathbf{1}_{N \times 1} \right) \circ \left(\underline{e}_1 \circ \underline{e}_0^{\circ(-1)} \right).$$

Defining $\Gamma^- = \text{diag}\{\tilde{\Gamma}^- \mathbf{1}_{N \times 1}\} - \tilde{\Gamma}^-$, we have:

$$H \left(\mathbf{1}_{N \times 1} \otimes \underline{\iota}_0{}' H \right) \underline{e}_0 + \Gamma^- \left(\underline{e}_1 \circ \underline{e}_0^{\circ(-1)} \right) = H \left(\underline{\iota}_0 \circ \underline{e}_0 \right).$$

Define $\Omega_t = H \left(\mathbf{1}_{N \times 1} \otimes \underline{\iota}_t{}' H \right) - \text{diag}\{H \underline{\iota}_t\}$. Then we have

$$\Omega_0 \underline{e}_0 + \Gamma^- \left(\underline{e}_1 \circ \underline{e}_0^{\circ(-1)} \right) = 0.$$

The parallel condition for $t = 1$ is

$$\Omega_1 \underline{e}_1 - \Gamma^- \left(\underline{e}_1 \circ \underline{e}_0^{\circ(-1)} \right) = 0.$$

A.3 Proof of Proposition 1

We start by solving for $e_{2,0}$. To proceed, write out the period 0 balance constraint as

$$\begin{pmatrix} -h_1(1-h_1)\iota_{1,0} & h_1h_2\iota_{2,0} & h_1h_3\iota_{3,0} \\ h_1h_2\iota_{1,0} & -h_2(1-h_2)\iota_{2,0} & h_2h_3\iota_{3,0} \\ h_1h_3\iota_{1,0} & h_2h_3\iota_{2,0} & -h_3(1-h_3)\iota_{3,0} \end{pmatrix} \begin{pmatrix} 1 \\ e_{2,0} \\ e_{3,0} \end{pmatrix} + \begin{pmatrix} -Q_{21}-Q_{31} \\ Q_{21} \\ Q_{31} \end{pmatrix} = 0.$$

Dropping the top row (which is redundant) and substituting in expressions for Q_{21} and Q_{31} from equation (6)

$$\begin{pmatrix} h_1h_2\iota_{1,0} \\ h_1h_3\iota_{1,0} \end{pmatrix} + \begin{pmatrix} -h_2(1-h_2)\iota_{2,0} & h_2h_3\iota_{3,0} \\ h_2h_3\iota_{2,0} & -h_3(1-h_3)\iota_{3,0} \end{pmatrix} \begin{pmatrix} e_{2,0} \\ e_{3,0} \end{pmatrix} = -\begin{pmatrix} \Gamma_{12}^{-1}\left[(1+\iota_{1,0})-(1+\iota_{2,0})\,e_{2,0}\right] \\ \Gamma_{13}^{-1}\left[(1+\iota_{1,0})-(1+\iota_{3,0})\,e_{3,0}\right] \end{pmatrix}$$

Rearranging this yields

$$\begin{pmatrix} e_{2,0} \\ e_{3,0} \end{pmatrix} = \frac{1}{\left(\frac{1}{\Gamma_{13}}(\iota_{3,0}+1)+h_3(1-h_3)\iota_{3,0}\right)\left(\frac{1}{\Gamma_{12}}(\iota_{2,0}+1)+h_2(1-h_2)\iota_{2,0}\right)-(h_2h_3)^2\,\iota_{2,0}\iota_{3,0}}$$

$$\times \begin{pmatrix} \frac{1}{\Gamma_{13}}(\iota_{3,0}+1)+h_3(1-h_3)\iota_{3,0} & h_2h_3\iota_{3,0} \\ h_2h_3\iota_{2,0} & \frac{1}{\Gamma_{12}}(\iota_{2,0}+1)+h_2(1-h_2)\iota_{2,0} \end{pmatrix} \begin{pmatrix} \frac{(1+\iota_{1,0})}{\Gamma_{12}}+h_1h_2\iota_{1,0} \\ \frac{(1+\iota_{1,0})}{\Gamma_{13}}+h_1h_3\iota_{1,0} \end{pmatrix},$$

and hence

$$e_{2,0} = \frac{\left(\frac{(1+\iota_{1,0})}{\Gamma_{12}} + h_1 h_2 \iota_{1,0}\right)\left(\frac{1}{\Gamma_{13}}(\iota_{3,0}+1) + h_3(1-h_3)\iota_{3,0}\right) + h_2 h_3 \iota_{3,0}\left(\frac{(1+\iota_{1,0})}{\Gamma_{13}} + h_1 h_3 \iota_{1,0}\right)}{\left(\frac{1}{\Gamma_{13}}(\iota_{3,0}+1) + h_3(1-h_3)\iota_{3,0}\right)\left(\frac{1}{\Gamma_{12}}(\iota_{2,0}+1) + h_2(1-h_2)\iota_{2,0}\right) - (h_2 h_3)^2 \iota_{2,0}\iota_{3,0}}.$$

To complete the second part of the proof, we first focus on the derivative $\frac{de_{2,0}}{d\iota_{1,0}}$. This is given by

$$\frac{de_{2,0}}{d\iota_{1,0}} = \frac{\left(\Gamma_{12}^{-1} + h_1 h_2\right)\left(\Gamma_{13}^{-1}(\iota_{3,0}+1) + h_3(1-h_3)\iota_{3,0}\right) + h_2 h_3 \iota_{3,0}\left(\Gamma_{13}^{-1} + h_1 h_3\right)}{\left(\Gamma_{13}^{-1}(\iota_{3,0}+1) + h_3(1-h_3)\iota_{3,0}\right)\left(\Gamma_{12}^{-1}(\iota_{2,0}+1) + h_2(1-h_2)\iota_{2,0}\right) - (h_2 h_3)^2 \iota_{2,0}\iota_{3,0}}.$$

This is positive as $h_3(1-h_3)h_2(1-h_2)\iota_{2,0}\iota_{3,0} > (h_2 h_3)^2 \iota_{2,0}\iota_{3,0}$ and all other terms are positive.

Next we wish to show that an increase in Γ_{12}^{-1} moderates the impact of the country 1 demand shock. That is $\frac{de_{2,0}}{d\iota_{1,0} d\Gamma_{12}^{-1}} < 0$ at the point $\underline{\iota}_0 = \mathbf{1}_{3\times 1}$. Imposing $\underline{\iota}_0 = \mathbf{1}_{3\times 1}$, we obtain

$$\frac{de_{2,0}}{d\iota_{1,0}} = \frac{\left(\Gamma_{12}^{-1} + h_1 h_2\right)\left(2\Gamma_{13}^{-1} + h_3(1-h_3)\right) + h_2 h_3\left(\Gamma_{13}^{-1} + h_1 h_3\right)}{\left(2\Gamma_{13}^{-1} + h_3(1-h_3)\right)\left(2\Gamma_{12}^{-1} + h_2(1-h_2)\right) - (h_2 h_3)^2}. \tag{A.4}$$

The derivative of the numerator in equation (A.4) with respect to $\Gamma_{12}^{-1}$is given by

$$\left(2\Gamma_{13}^{-1} + h_3(1-h_3)\right)$$

and the derivative of the denominator is

$$2\left(2\Gamma_{13}^{-1} + h_3(1-h_3)\right).$$

At the point $\iota_0 = \mathbf{1}_{3\times 1}$, the necessary condition for $\frac{de_{2,0}}{d\iota_{1,0} d\Gamma_{12}^{-1}} \leq 0$ is

$$\left(2\Gamma_{13}^{-1} + h_3(1-h_3)\right)\left[\left(2\Gamma_{13}^{-1} + h_3(1-h_3)\right)\left(2\Gamma_{12}^{-1} + h_2(1-h_2)\right) - (h_2h_3)^2\right] <$$
$$2\left(2\Gamma_{13}^{-1} + h_3(1-h_3)\right)\left[\left(\Gamma_{12}^{-1} + h_1h_2\right)\left(2\Gamma_{13}^{-1} + h_3(1-h_3)\right) + h_2h_3\left(\Gamma_{13}^{-1} + h_1h_3\right)\right].$$

After some algebra, this condition reduces to

$$0 < 2h_2\Gamma_{13}^{-1} + h_2h_3$$

which is always true.

We now turn to the derivative $\frac{de_{2,0}}{d\iota_{2,0}}$. This is given by

$$\frac{de_{2,0}}{d\iota_{2,0}} = -\frac{\left(\Gamma_{13}^{-1}(\iota_{3,0}+1) + h_3(1-h_3)\iota_{3,0}\right)\left(\Gamma_{12}^{-1} + h_2(1-h_2)\right) - (h_2h_3)^2\,\iota_{3,0}}{\left(\Gamma_{13}^{-1}(\iota_{3,0}+1) + h_3(1-h_3)\iota_{3,0}\right)\left(\Gamma_{12}^{-1}(\iota_{2,0}+1) + h_2(1-h_2)\iota_{2,0}\right) - (h_2h_3)^2\,\iota_{2,0}\iota_{3,0}} e_{2,0}.$$

This is negative as $h_3(1-h_3)h_2(1-h_2)\iota_{2,0}\iota_{3,0} > (h_2h_3)^2\,\iota_{2,0}\iota_{3,0}$ and all other terms entering the quotient are positive, as is $e_{2,0}$.

Next we wish to show that an increase in Γ_{12}^{-1} moderates the impact of the country 2 demand shock. That is $\frac{de_{2,0}}{d\iota_{1,0} d\Gamma_{12}^{-1}} > 0$ at the point $\iota_0 = \mathbf{1}_{3\times 1}$. Imposing $\iota_0 = \mathbf{1}_{3\times 1}$ and noting $e_{2,0} = 1$ at this point, we obtain

$$\frac{de_{2,0}}{d\iota_{2,0}} = -\frac{\left(2\Gamma_{13}^{-1} + h_3(1-h_3)\right)\left(\Gamma_{12}^{-1} + h_2(1-h_2)\right) - (h_2h_3)^2}{\left(2\Gamma_{13}^{-1} + h_3(1-h_3)\right)\left(2\Gamma_{12}^{-1} + h_2(1-h_2)\right) - (h_2h_3)^2}. \tag{A.5}$$

The necessary condition for $\frac{de_{2,0}}{d\iota_{2,0}d\Gamma_{12}^{-1}} > 0$ is

$$\left(2\Gamma_{13}^{-1} + h_3(1-h_3)\right)\left[\left(2\Gamma_{13}^{-1} + h_3(1-h_3)\right)\left(2\Gamma_{12}^{-1} + h_2(1-h_2)\right) - (h_2h_3)^2\right] <$$
$$2\left(2\Gamma_{13}^{-1} + h_3(1-h_3)\right)\left[\left(2\Gamma_{13}^{-1} + h_3(1-h_3)\right)\left(\Gamma_{12}^{-1} + h_2(1-h_2)\right) - (h_2h_3)^2\right].$$

After some algebra, this reduces to

$$0 < \left[\left(2\Gamma_{13}^{-1} + h_3(1-h_3)\right)h_2(1-h_2) - (h_2h_3)^2\right],$$

which is true. This completes the proof.

A.4 Proof of Proposition 2

Start with the first part of the proposition, (i). From equation (A.4), the derivative $\frac{de_{2,0}}{d\iota_{1,0}}$ evaluated at the point $\underline{\iota}_0 = \mathbf{1}_{3\times 1}$ is given by.

$$\frac{de_{2,0}}{d\iota_{1,0}} = \frac{\left(\Gamma_{12}^{-1} + h_1h_2\right)\left(2\Gamma_{13}^{-1} + h_3(1-h_3)\right) + h_2h_3\left(\Gamma_{13}^{-1} + h_1h_3\right)}{\left(2\Gamma_{13}^{-1} + h_3(1-h_3)\right)\left(2\Gamma_{12}^{-1} + h_2(1-h_2)\right) - (h_2h_3)^2}.$$

We now turn to the effect of Γ_{13}^{-1} on $\frac{de_{2,0}}{d\iota_{1,0}}$. The derivative of the numerator in equation (A.4) with respect to $\Gamma_{13}^{-1}$is given by

$$2\left(\Gamma_{12}^{-1} + h_1h_2\right) + h_2h_3,$$

and the denominator by

$$2\left(2\Gamma_{12}^{-1} + h_2(1-h_2)\right).$$

So the condition for $\frac{de_{2,0}}{d\iota_{1,0}d\Gamma_{13}^{-1}} < 0$ is

$$\left[2\left(\Gamma_{12}^{-1}+h_1h_2\right)+h_2h_3\right]\left[\left(2\Gamma_{13}^{-1}+h_3(1-h_3)\right)\left(2\Gamma_{12}^{-1}+h_2(1-h_2)\right)-(h_2h_3)^2\right] <$$
$$2\left(2\Gamma_{12}^{-1}+h_2(1-h_2)\right)\left[\left(\Gamma_{12}^{-1}+h_1h_2\right)\left(2\Gamma_{13}^{-1}+h_3(1-h_3)\right)+h_2h_3\left(\Gamma_{13}^{-1}+h_1h_3\right)\right].$$

Let $A=\left(2\Gamma_{12}^{-1}+h_2(1-h_2)\right)$, then this condition can be rewritten as

$$\left[\left(2\Gamma_{13}^{-1}+h_3(1-h_3)\right)A-(h_2h_3)^2\right]-\left[2\left(\Gamma_{12}^{-1}+h_1h_2\right)+h_2h_3\right](h_2h_3) < 2\left(\Gamma_{13}^{-1}+h_1h_3\right)A,$$

which reduces to

$$h_3(1-h_3)A < 2h_1h_3A+\left[2\left(\Gamma_{12}^{-1}+h_1h_2\right)\right](h_2h_3),$$

since $(1-h_3)=h_1+h_2$, this equivalent to

$$0 < (h_1-h_2)\,h_3A+\left[2\left(\Gamma_{12}^{-1}+h_1h_2\right)\right](h_2h_3).$$

which is always true with $h_1 \geq h_2$ as assumed. This completes the proof of (i).

Now consider the second part of the proposition, (ii). From equation (A.5), the derivative $\frac{de_{2,0}}{d\iota_{2,0}}$ evaluated at the point $\iota_0 = \mathbf{1}_{3\times 1}$ is given by

$$\frac{de_{2,0}}{d\iota_{2,0}} = -\frac{\left(2\Gamma_{13}^{-1}+h_3(1-h_3)\right)\left(\Gamma_{12}^{-1}+h_2(1-h_2)\right)-(h_2h_3)^2}{\left(2\Gamma_{13}^{-1}+h_3(1-h_3)\right)\left(2\Gamma_{12}^{-1}+h_2(1-h_2)\right)-(h_2h_3)^2}.$$

We now consider the effect of Γ_{13}^{-1} on $\frac{de_{2,0}}{d\iota_{2,0}}$. The derivative of the numerator in equation

(A.4) with respect to $\Gamma_{13}^{-1}$is given by

$$2\left(\Gamma_{12}^{-1}+h_2(1-h_2)\right),$$

and the denominator by

$$2\left(2\Gamma_{12}^{-1}+h_2(1-h_2)\right).$$

So the condition for $\frac{de_{2,0}}{d\iota_{2,0}d\Gamma_{13}^{-1}}<0$ is

$$\begin{aligned}&2\left(2\Gamma_{12}^{-1}+h_2(1-h_2)\right)\left(\left(2\Gamma_{13}^{-1}+h_3(1-h_3)\right)\left(\Gamma_{12}^{-1}+h_2(1-h_2)\right)-(h_2h_3)^2\right)<\\&2\left(\Gamma_{12}^{-1}+h_2(1-h_2)\right)\left(\left(2\Gamma_{13}^{-1}+h_3(1-h_3)\right)\left(2\Gamma_{12}^{-1}+h_2(1-h_2)\right)-(h_2h_3)^2\right)\end{aligned}\tag{A.6}$$

This reduces to

$$-\left(2\Gamma_{12}^{-1}+h_2(1-h_2)\right)(h_2h_3)^2\le-\left(\Gamma_{12}^{-1}+h_2(1-h_2)\right)(h_2h_3)^2,$$

which is always true.

To prove (iii), it is sufficient to show condition (A.6) holds with equality as $h_2\to0$. This is obvious from inspecting the inequality immediately above.

This completes the proof of (ii), (iii) and, hence, the Proposition.

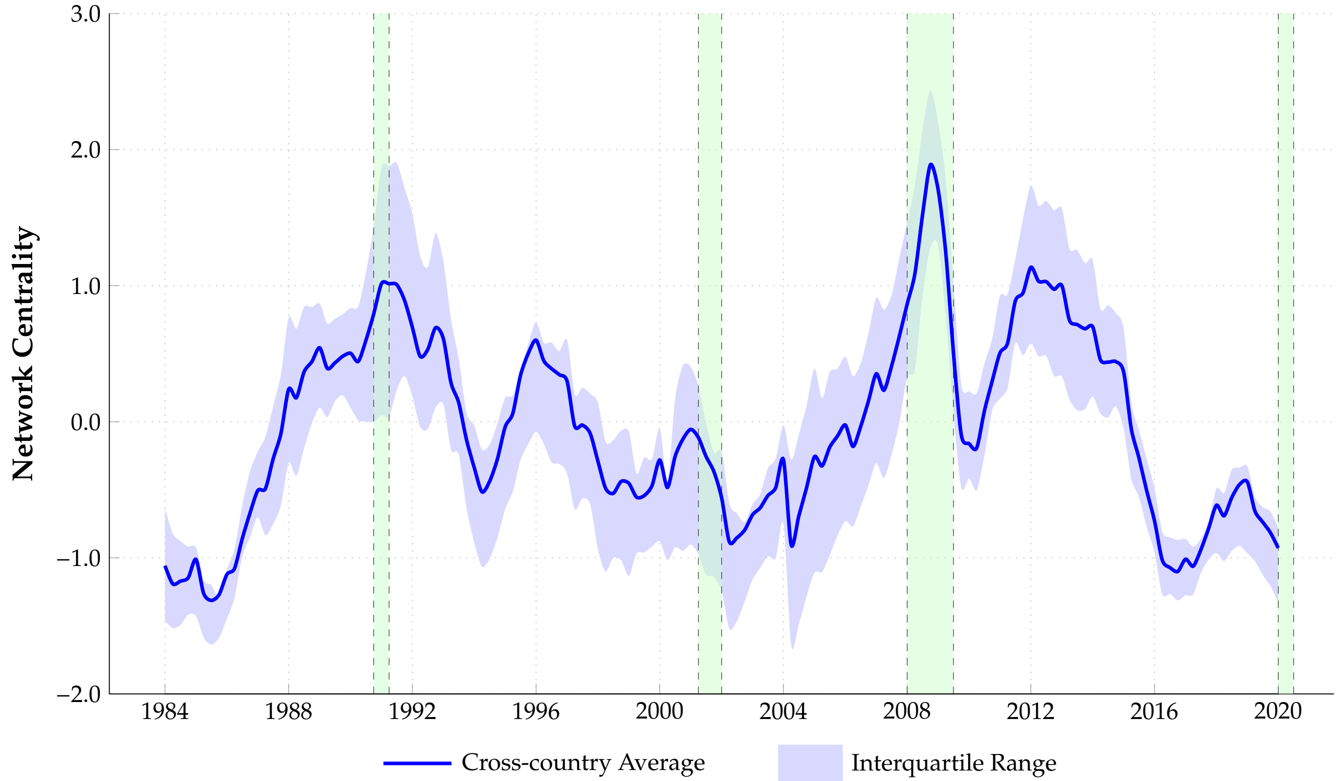

FIGURE A.1. TRADE CENTRALITY

This figure displays the cross-country correlation between two standardized measures of banking centrality, i.e., one based on cross-border claims an liabilities denominated in US dollars and another one based on cross-border claims an liabilities denominated in the local currency of the lender (non-vehicle currencies). Cross-border claims and liabilities are from the Locational Banking Statistics by residence. The vertical shaded areas denote US recessions based on NBER dates. The sample runs at the quarterly frequency between March 1984 and September 2022.

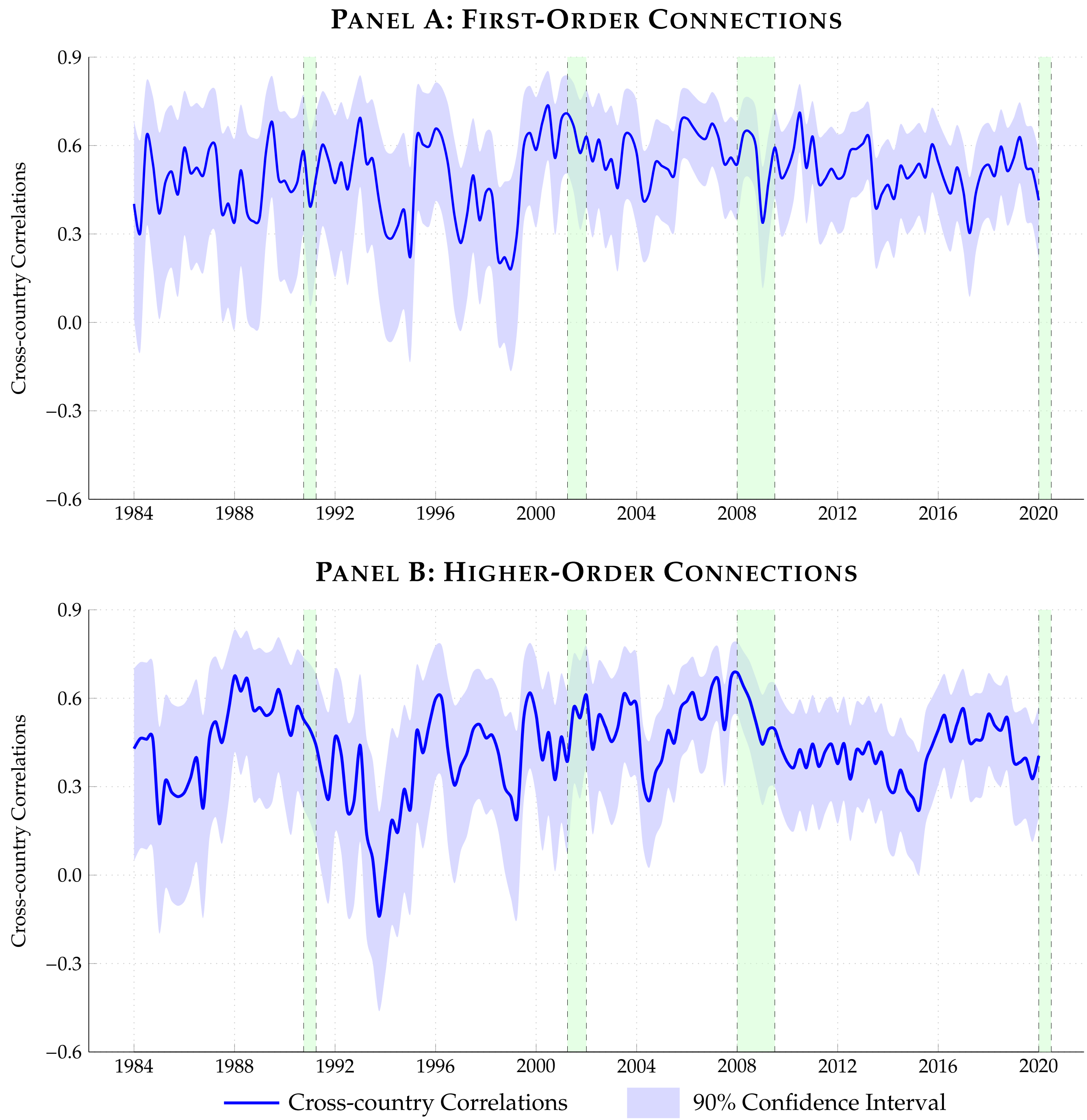

FIGURE A.2. BANKING CENTRALITY: US DOLLARS VS LOCAL CURRENCIES

This figure displays the cross-country correlation between two standardized measures of banking centrality, i.e., one based on cross-border claims an liabilities denominated in US dollars and another one based on cross-border claims an liabilities denominated in the local currency of the lender (non-vehicle currencies). Cross-border claims and liabilities are from the Locational Banking Statistics by residence. The vertical shaded areas denote US recessions based on NBER dates. The sample runs at the quarterly frequency between March 1984 and September 2022.