The Trade Imbalance Network and Currency Returns⋆

Ai Jun Hou, Lucio Sarno, and Xiaoxia Ye⋆⋆

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⋆⋆. **Affiliations.** Ai Jun Hou is with Stockholm University, Stockholm Business School. E-mail: Aijun.Hou@sbs.su.se. Lucio Sarno is with the University of Cambridge, Cambridge Judge Business School and Centre for Economic Policy Research. E-mail: l.sarno@jbs.cam.ac.uk. Xiaoxia Ye is with the University of Exeter, Business School. E-mail: x.ye@exeter.ac.uk.

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We extend the theory of Gabaix and Maggiori (2015a, 2015b) to study currency risk premia in a multi-country world with imperfect financial markets. Currency returns are connected to financiers' limited commitment, captured by the complexity of their balance sheets in the trade imbalance network. Guided by the theory, we construct a Centrality Based Characteristic (*CBC*), based on the centrality of the imbalance network and variance-covariance of currency returns. Sorting currencies on *CBC* generates a high Sharpe ratio, and the resulting excess returns cannot be explained by standard currency factors and intermediary asset pricing factors, suggesting a novel source of currency predictability.

Keywords: Trade imbalance network, Currency premia, Carry trade, Network centrality.

JEL Classification: F31, F37, G12, G15.

1 Introduction

International trade and trade imbalances across countries play crucial roles in determining macroeconomic and financial outcomes around the world.[1] They are also a driving force of exchange rate fluctuations and currency risk premia in a variety of theories of exchange rate determination (see, e.g., Gourinchas and Rey 2007; Gabaix and Maggiori 2015a; Colacito, Croce, et al. 2018; Maggiori 2022). Motivated by this literature, empirical research has documented a predictive link between external imbalances and currency excess returns in the cross section of countries (see, e.g., Della Corte, Sarno, and Sestieri 2012; Della Corte, Riddiough, and Sarno 2016; Della Corte and Krecetovs 2021).

However, a potential tension exists between theory and empirical research in this area. Specifically, the theory of international trade and exchange rate dynamics is typically set up in a two-country framework, whereas empirical work on currency asset pricing is conducted in the cross section of countries, under the implicit assumption that theories about bilateral relationships between countries can be readily generalized to a multi-country setting.[2] This is not necessarily the case without additional assumptions. More importantly, it seems likely that generalization of two-country theories to a multi-country setting can generate additional insights about exchange rate dynamics by capturing relationships in the trade imbalance network that are hidden in a two-country setting. Indeed, Richmond (2019) provides theory and empirical evidence that the total trade network is linked to currency risk premia in a setting that assumes complete financial markets.

In this paper, we build on this line of research by extending the theory of Gabaix and Maggiori (2015a, 2015b) to study currency risk premia in a multi-country world with imperfect financial markets.[3] In the theory, currency returns are connected to financiers' limited commitment, captured by the complexity of their balance sheets in the trade imbalance network. Then, guided by the theory, we construct a characteristic, which we term *CBC* (Centrality Based Characteristic), based on the centrality of the imbalance network and variance-covariance of currency returns. We show that sorting currencies on *CBC* generates strong predictability of currency excess returns in the cross section of countries, and a high Sharpe ratio. The source of

1. For example, Caballero and Krishnamurthy (2009) find that trade imbalances are a crucial part of the mechanism that led to the global financial crisis. Chang et al. (2022) explore the link between sovereign credit default swap (CDS) prices and the international trade network, providing evidence that this relationship is key to understanding the propagation of shocks in the global economy.

2. By "multi-country" we mean more than two countries or, equivalently, more than one exchange rate.

3. We refer to Gabaix and Maggiori (2015a) for the two-country model of exchange rate determination in their published paper, and to Gabaix and Maggiori (2015b) for the multi-country extension in their Internet Appendix.

this predictability is novel in the sense that the resulting excess returns from the cross-sectional strategy that sorts on *CBC* cannot be explained by various standard currency factors and intermediary asset pricing factors. In turn, we find that this multi-country extension provides both fresh insights into the link between trade imbalances and exchange rate dynamics, and a novel investment strategy.

In the theory of Gabaix and Maggiori (2015a), countries run trade imbalances in imperfect financial markets and financiers bear the resulting currency risk by buying the currency of the deficit country and shorting the currency of the surplus country. However, financiers' ability to take long (short) positions (i.e., risk-bearing or risk-absorbing capacity) depends on the riskiness of their balance sheets. To incentivize financiers, the currency of the deficit country has to depreciate contemporaneously and is expected to appreciate in the future to compensate for the risk financiers take. Financiers' limited risk-bearing capacity hence induces them to alter the size and compositions of their balance sheet by differentiating investment options caused by the global imbalance, which eventually alters the level and volatility of exchange rates. Two important determinants of the currency premia arise in the model: financiers' risk-bearing capacity, and the external imbalance of individual countries.[4] In their two-country setting, Gabaix and Maggiori (2015a) model the limited commitment using the variance of the exchange rate. The two-country setting in Gabaix and Maggiori (2015a) is generalized in their online appendix (Gabaix and Maggiori 2015b) to a multi-country setting, where the limited risk-bearing capacity is modeled as the variance-covariance matrix of exchange rates.

In the global trading system, bilateral imbalances and interdependence between countries constitute a global trade imbalance network that contains rich information on the financier's balance sheets and risk-bearing capacity. Yet, the effect of the imbalance network structure on financiers' limited risk-bearing commitment and currency premia has been largely overlooked in the literature. Therefore, we extend the theory of Gabaix and Maggiori (2015a, 2015b) to explicitly incorporate the information contained in the trade imbalance network into financiers' limited risk-bearing commitment. We use the Leontief inverse of the adjacency matrix of the global trade imbalance network to represent the financiers' risk-bearing capacity and theo-

4. The pricing power of the imbalance risk factor identified by Della Corte, Riddiough, and Sarno (2016) empirically supports the trade imbalance's impact on currency premia in Gabaix and Maggiori (2015a)'s theory.

retically show that the Leontief inverse-based centrality nicely captures the complexity of financiers' global balance sheet.[5]

Specifically, in the context of global trade, the trade imbalance network carries a vast amount of information on financiers' balance sheets. The complexity of financiers' balance sheet increases with the centrality of countries they intermediate by offering more investment options (Aldasoro and Alves 2018; Sasidevan and Bertschinger 2019). From the financiers' point of view, the net deficit (surplus) of a country constitutes an investment opportunity of taking a long (short) position in this country's currency on their balance sheets, which has to be balanced by a short (long) position in other currencies. Long (short) positions increase (decrease) financiers' investment options. For one particular country, its net deficit only partially measures the investment options financiers have with its currency since its net deficit induces deficit and surplus in some other countries, which further contribute to financiers' investment options with the currency depending on the closeness of this particular country with the other countries in the global trade imbalance network. This complexity can be elegantly quantified by the Leontief inverse-based centrality of the global trade imbalance network.

We posit that exploring the rich information content implicit in the global imbalance network will lead to further insights on currency premia beyond those offered in studies focusing only on the size of the imbalance of individual countries (e.g., Della Corte, Riddiough, and Sarno 2016). We take on this exploration from both theoretical and empirical perspectives. On the theoretical side, we extend the framework developed by Gabaix and Maggiori (2015a, 2015b) to a multi-country setting that allows financiers' limited risk-absorbing commitment to be a function of the adjacency matrix of the global imbalance network. An equilibrium can be obtained by solving a fixed point problem in recursive optimizations. As in Gabaix and Maggiori (2015a), the linear pricing function of currency premia is maintained in equilibrium, i.e. the expected currency return can be written as a linear function of net deficits with the coefficient capturing outside investment options. This linear pricing function provides the flexibility to incorporate both imbalance network centrality, which is a function (Leontief inverse) of the adjacency matrix, and the variance-covariance matrix of currency returns into financiers' lim-

5. The Leontief inverse of matrix $\mathbf{A}$ is given by (Simonovits 1975):

$$(\mathbf{I}-\mathbf{A})^{-1}=\sum_{k=0}^{\infty}(\mathbf{A})^{k}$$

and is closely related to the Katz-Bonacich centrality, which captures the sum of the direct and indirect influence of each node in a network.

ited risk-bearing commitment. Our model has two parameters capturing the contributions of the centrality and the variance-covariance to financiers' limited risk-bearing commitment. The two parameters can be readily calibrated to test the hypothesis that the centrality of the imbalance network and the variance-covariance of exchange rates explain the cross-section of expected currency excess returns beyond the individual countries' net deficit size.

In the empirical analysis, we employ data for up to 41 countries from 1995 to 2021. First, we provide evidence, using a training subsample of our data from 1995 to 2002, that these two parameters are significantly different from zero, controlling for net deficits. Secondly, based on the calibrated parameters and keeping them constant out of the sample, we construct a centrality-based characteristic (*CBC*) for each currency and use *CBC* to conduct portfolio sorts and formal asset pricing tests.[6] The results from portfolio sorts show that going from low *CBC* countries to high *CBC* countries, the currency portfolio returns increase monotonically. The high-minus-low portfolio (long the portfolio with the highest *CBC* and short the portfolio with the lowest *CBC*) generates an annualized Sharpe ratio of 0.65. This is higher than the Sharpe ratios obtained from sorting on the total trade network centrality of Richmond (2019, *TTNC*), the global imbalance measure of Della Corte, Riddiough, and Sarno (2016, *GImb*) and the carry trade based on our sample. Most of the existing currency factors and intermediate asset pricing factors (Adrian, Etula, and Muir 2014; He, Kelly, and Manela 2017) cannot explain the *CBC* factor, indicating that the *CBC* factor captures different information.

[*Insert Figure 1 about here*]

Figure 1 shows a clear positive relation between the *CBC* and currency premia and nicely summarizes the insight of our exploration on the global imbalance trade network. This figure shows the scatter plot of the time series averages of currency premia for a U.S. investor versus the time series average of *CBC*s. Countries with higher *CBC*, such as Mexico and New Zealand, have higher currency premia. On the contrary, countries with lower *CBC*, such as Japan and Thailand, have lower currency premia. This illustrative evidence suggests that the *CBC* is a key characteristic to understanding currency premia.

Our model allows us to decompose currency premia into three components that are related to total imbalance, individual importance, and neighborhood importance. Via a variance

6. We also carry out the exercise using a recursively updated *CBC* measure where the two calibrated parameters are updated as new information becomes available, whilst still conditioning only on available information at the time of sorting. We find that the results are qualitatively identical to the case where we do not update the calibrated parameters, because they are very stable over time.

decomposition, we empirically show that the neighborhood component explains about 68% of the total variation in cross-sectional currency premia, highlighting the importance of the network structure in understanding the dynamics of currency premia. To further demonstrate the usefulness of our framework, we also conduct counterfactual analyses to study the impacts of the 2018-2019 China-US trade war and the international sanctions against Russia in 2022 on currency premia via the trade imbalance network. We find that these two events have far-reaching effects on premia of currencies that are not directly involved in the events, emphasizing the complexity of analyzing the chain effect of international events and the usefulness of a quantitative framework like the one developed in this paper.

Related literature. Our theoretical work relates to several areas in the foreign exchange literature. This paper is distinct within this thread of the literature in that we push forward the development of multi-country settings and the trade imbalance network in the theory of currency asset pricing with *financial frictions*. First, our theoretical model enriches Gabaix and Maggiori (2015b)'s multi-country setting with imperfect financial markets by incorporating global imbalance network centrality as a measure of financiers' outside investment options. With different emphases, Jiang (2021) adopts Gabaix and Maggiori (2015a)'s two-country model and adds the government to study the implications of the US government debt issuance on the US dollar exchange rate; Della Corte and Fu (2021) also use the two-country setting of Gabaix and Maggiori (2015a) but introduce global tariff uncertainty to analyze how different tariff policies adopted by different political parties in the US affect the US dollar exchange rate. There are also theoretical studies that focus on the connection between currency risk and country-level characteristics while assuming frictionless financial markets. For example, Colacito, Croce, et al. (2018) develops a frictionless risk-sharing model with recursive preferences and shows that heterogeneous exposure to global growth shocks results in a relevant reallocation of international resources and currency adjustments.

Richmond (2019) builds a general equilibrium model with perfect financial markets and shows that the consumption growth of countries with high centrality in the total trade network is more exposed to global consumption growth shocks, resulting in lower currency premia due to high demand of these currencies for hedging global consumption growth risks. Although Richmond (2019) also studies how a trade network affects currency premia, there are three key differences between Richmond's theory and ours: a) Richmond's trade network is based on the bilateral total trade (export plus import) while our trade network is based on the bilateral trade deficit (export minus import); b) due to the difference in the network, Richmond's theory focuses on fundamental risks (global consumption growth risks), while our emphasis is on financial intermediaries' risk-bearing capacity;[7] c) Richmond circumvents financial intermediation risks by assuming perfect financial markets (i.e., unlimited risk-bearing capacity), while we allow for imperfect financial markets (i.e., limited risk-bearing capacity in financial intermediaries).

Second, our empirical work contributes to the literature on currency asset pricing and cross-sectional currency investment strategies. Lustig, Roussanov, and Verdelhan (2011) identify a "slope" factor in exchange rates by sorting currencies on their forward discounts and show that this factor accounts for much of the cross-sectional variation in currency returns. Lettau, Maggiori, and Weber (2014) find that a downside risk factor is priced in the cross-section of currency returns. Menkhoff et al. (2012, 2017) show momentum and value strategies in foreign exchange rate markets deliver high excess returns. Using individual country-level net deficit as a risk characteristic, Della Corte, Riddiough, and Sarno (2016) identify an imbalance risk factor with significantly positive premia in foreign exchange rates. Ready, Roussanov, and Ward (2017) demonstrate that countries producing commodity goods are distinct from countries producing final goods and provide evidence that sorting currencies based on the import ratio, which is the ratio of net imports of finished goods to net exports of basic commodities, generates a sizable spread in average currency excess returns. Colacito, Riddiough, and Sarno (2020) find that business cycle risk is a characteristic with significant pricing power in currency returns. Dahlquist and Hasseltoft (2020) find that a risk factor based on a trading strategy that goes long currencies with strong economic momentum and short currencies with weak economic momentum captures cross-country differences in carry. Richmond (2019) show that countries' centrality in the total trade network, in which the edges are measured using the pairwise total trade, can explain the currency risk premia and variations in interest rate differentials. Our paper adds to this strand of the literature a novel characteristic that is valuable for designing a profitable currency investment strategy.

Additionally, our paper also joins the literature on the role of financial intermediaries in the pricing of financial assets (see, e.g., He and Krishnamurthy 2013; Adrian, Etula, and Muir

7. In Richmond's theory, the key driver of the variation in cross-sectional currency returns is the countries' heterogeneous exposure to global consumption shocks. Central countries with more total-trade links to countries that are important for the production of tradable goods are more exposed to global shocks than peripheral countries. Hence, currencies' centrality in the total trade network measures the exposure to consumption risk.

2014; He, Kelly, and Manela 2017; Fleckenstein and Longstaff 2020, 2022; Du, Hebert, and Huber 2023; Maggiori 2022). Differently from this literature, our focal point is on the international trade imbalance network and currency markets. In the context of the foreign exchange literature, other than the theoretical studies of Gabaix and Maggiori (2015a, 2015b), there is empirical evidence in Cenedese, Della Corte, and Wang (2021) that regulation on the leverage ratio requirement of financial intermediaries is related to deviations from covered interest parity. Fang (2021) finds a positive relation between country-level banking sector capital ratios and currency returns. Our paper provides both theoretical developments and empirical results that the role of financial intermediaries is key to understanding the pricing of foreign exchange risk.

2 The model

Gabaix and Maggiori (2015a) present a two-country model of exchange rate determination with imperfect financial markets which shows that currencies of countries with more negative total imbalances must offer higher currency risk premia.[8] This implies a positive relationship between deficits in net foreign asset positions and currency risk premia in the cross-section of currencies. In this section, we first extend this theory to a multi-country version to show that, in that setting, total imbalances do not necessarily have a positive cross-sectional relation with currency risk premia, unless additional assumptions are made.[9] Then, based on the intuition that financiers' limited commitment is related to their outside investment options, we extend the theory to explicitly connect currency risk premia to their centrality in a trade imbalance network, which can be considered as a proxy for financiers' outside options. We conclude the section by proposing a centrality-based characteristic for currency risk premia, guided by the theory.

2.1 Multi-country setting

There are two periods: $t = 0, 1$ and n countries in the model. We define as $\{x_t\}_i$ the US dollar (USD) bilateral exchange rate of country i at period t, where $i = 1, 2, \ldots, n$. An increase in $\{x_t\}_i$ indicates an appreciation of country i's currency against the USD. The US is the primary country 1, for which we normalize $\{x_t\}_1 = 1$ in both periods. x_t is the vector of the exchange rates at period t.

8. Maggiori (2022) provides an excellent review of the recent developments in the literature on international macroeconomics and exchange rate determination under imperfect financial markets.

9. By "multi-country" we mean more than two countries or, equivalently, more than one currency pair.

We define the global trading imbalance networks in the two periods via an $n \times n$ adjacency matrix $\mathbf{A}_t$ of a directed weighted graph on n vertices, where $\{\mathbf{A}_t\}_{ii} = 0$ for $i = 1, \ldots, n$, and $\{\mathbf{A}_t\}_{ij} > 0$ for $j \neq i$ is the USD value of country j's net import from country i. In other words, if $\{\mathbf{A}_t\}_{ij} > 0$, then country j is a net debtor of country i with deficit of $\{\mathbf{A}_t\}_{ij}$. The global trading network can also be described in terms of the exports and imports matrix, e.g., the $\boldsymbol{\xi}$ matrix in Gabaix and Maggiori (2015b). We show the explicit relation between $\mathbf{A}$ and $\boldsymbol{\xi}$ below.

Gabaix and Maggiori (2015b) use the export and import matrix $\boldsymbol{\xi}_t$ in the derivations of their multi-country model (see Section A.3.B): for $i \neq j$, $\{\boldsymbol{\xi}_t\}_{ij} < 0$ and represents exports of country i to country j in country j's currency; the diagonal term $\{\boldsymbol{\xi}_t\}_{jj} > 0$ represents the total imports of country j in its currency from all other countries and is defined as: $\{\boldsymbol{\xi}_t\}_{jj} \triangleq -\sum_{i \neq j}\{\boldsymbol{\xi}_t\}_{ij}$.

Let q_i be the USD value of country i's bonds held by financiers. q is the vector of the bonds' values of all countries. Also, the fact that financiers have zero initial capital implies $\sum_{j=1}^{n} q_j = 0$. The net demand for currency i in the spot market, expressed in USD, must be zero in period 0's equilibrium:

$$-\sum_{j=1}^{n}\{\boldsymbol{\xi}_0\}_{ij}\{x_0\}_j + q_i = 0. \tag{1}$$

In matrix form, eq. (1) can be written as:

$$-\boldsymbol{\xi}_0 x_0 + q = 0. \tag{2}$$

By the definitions of $\mathbf{A}$ and $\boldsymbol{\xi}$, we have:

$$\{\mathbf{A}_t\}_{ij} = \left(\{\boldsymbol{\xi}_t\}_{ji}\{x_t\}_i - \{\boldsymbol{\xi}_t\}_{ij}\{x_t\}_j\right)^+ \tag{3}$$

where $(z)^+ = z$ if $z > 0$, and 0 otherwise. Given eq. (3), the following holds:

$$\mathbf{A}_t - \mathbf{A}_t^\intercal = (\boldsymbol{\xi}_t \mathbf{D}_t)^\intercal - \boldsymbol{\xi}_t \mathbf{D}_t, \tag{4}$$

where $\mathbf{D}_t = \operatorname{diag}(x_t)$.

In equilibrium, financiers absorb all imbalances in the trading network in period 0. Given the definition of $\mathbf{A}_t$, we have the following proposition.

Proposition 1. *In equilibrium at period 0, the USD value of the bonds' held by financiers, q, must satisfy:*

$$\left(\mathbf{A}_0 - \mathbf{A}_0^{\intercal}\right)\ell + q = 0, \tag{5}$$

where ℓ is an $n \times 1$ column vector of ones.

Proof. *By the definition of $\mathbf{A}_0$, each element in the i-th row (j-th column) of $\mathbf{A}_0$ represents the net USD value surplus (deficit) the i-th (j-th) country has with each country. This means that each element in the i-th row of $\left(\mathbf{A}_0^{\intercal} - \mathbf{A}_0\right)$ represents the net imbalance in USD the i-th country has with each country, and the i-th element of vector $\left(\mathbf{A}_0^{\intercal} - \mathbf{A}_0\right)\ell$ is the USD total net imbalance of the i-th country.*

When the market clears, these imbalances have to be absorbed by the financiers. Therefore, we have $\left(\mathbf{A}_0^{\intercal} - \mathbf{A}_0\right)\ell = q$. This completes the proof. □

It can be easily shown that eq. (5) is equivalent to eq. (1):

$$q = \left(\mathbf{A}_0^{\intercal} - \mathbf{A}_0\right)\ell = \boldsymbol{\xi}_0 \mathbf{D}_0 \ell - \left(\boldsymbol{\xi}_0 \mathbf{D}_0\right)^{\intercal}\ell = \boldsymbol{\xi}_0 x_0. \tag{6}$$

The second equality is by eq. (4), and the third equality is by the fact that $\left(\boldsymbol{\xi}_0 \mathbf{D}_0\right)^{\intercal}\ell = 0$ and $\mathbf{D}_0 \ell = x_0$.[10]

Financiers will unwind their positions in period 1. Therefore, we also have

$$\left(\mathbf{A}_1 - \mathbf{A}_1^{\intercal}\right)\ell - q = 0. \tag{7}$$

Since financiers only have limited commitment, there is a downward-sloping demand curve. Following Gabaix and Maggiori (2015b), this demand for assets, which establishes a relation between all currencies' interest-adjusted expected appreciation (currency risk premia) $\mathbb{E}\left(\bar{x}_1 - x_0\right)$ and q, is given by

$$\mathbb{E}\left(\bar{x}_1 - x_0\right) = \boldsymbol{\Gamma} q, \tag{8}$$

10. $\left(\xi_0 \mathbf{D}_0\right)^{\intercal}\ell = 0$ is immediately implied by the definition of $\{\xi_t\}_{jj}$, i.e., $\{\xi_t\}_{jj} \triangleq -\sum_{i \neq j}\{\xi_t\}_{ij}$.

where $\bar{x}_1$ is the vector of interest-adjusted exchange rates, defined as $\bar{x}_1 \triangleq \delta x_1$ with

$$\delta = \begin{bmatrix} 1 & 0 & \cdots & 0 \\ 0 & \frac{1+r_2}{1+r_1} & \cdots & 0 \\ & & \ddots & \\ 0 & \cdots & \cdots & \frac{1+r_n}{1+r_1} \end{bmatrix},$$

r_i is the risk-free interest rate of country i; and $\mathbf{\Gamma}$ is an $n \times n$ matrix and the multi-dimensional version of the Γ in Gabaix and Maggiori (2015a), capturing the limited-commitment of financiers.[11] Equation (8) is a central result of the Gabaix-Maggiori theory, capturing elegantly the relationship between the currency risk premia (left-hand-side) and the interaction of risk-bearing capacity with trade imbalances (right-hand-side).

In this setting, x_0 and x_1 are endogenous variables solved from eqs. (5), (7) and (8). Since the focus of this paper is on the relation between $\mathbb{E}(\bar{x}_1 - x_0)$ and $\mathbf{A}_0$, we concentrate on eqs. (5) and (8). Assuming the existence of a solution to a fixed point problem, we can treat both $\mathbf{A}_0$ and x_0 as given, and $\mathbf{\Gamma}$ as a function of $\mathbf{A}_0$, with eq. (8) still holding. The detailed derivations are provided in Appendices A and B. We will explore the relation between $\mathbf{\Gamma}$ and $\mathbf{A}_0$, which is the functional form of $\mathbf{\Gamma}$ in $\mathbf{A}_0$, in detail shortly. However, before that, let us analyze carefully the relationship between q and currency risk premia.

2.2 Total imbalance and currency risk premia

In the Gabaix-Maggiori theory, net debtor countries must offer a currency risk premium to compensate financiers' willingness to finance external imbalances because their currencies depreciate (perform poorly) in bad times. Therefore, the external imbalances in the trading network are a key characteristic explaining currency risk premia, as the expected currency appreciation in a country is positively related to the long position in bonds that financiers hold in this country. The value of this position is the total imbalance (deficit defined to be positive, and surplus defined to be negative) of this country in the two-country model of Gabaix and Maggiori (2015a). As shown in Proposition 1, the result that q is both the total imbalance and the position financiers hold can be generalized to a multi-country setting. However, whether the cross-sectional relation between the currency risk premia and q is positive is not straightforward given that $\mathbf{\Gamma}$ is now a matrix, while it is a scalar in a two-country setting.

11. In Gabaix and Maggiori (2015a, 2015b), $\mathbf{\Gamma} = \gamma var(x_1)^\alpha$ where the scalars $\gamma > 0$ and $\alpha \geq 0$.

To see this point in our setting, we spell out from eq. (8) the i-th element of $\mathbb{E}\left(\tilde{x}_1 - x_0\right)$, which we call rp_i (i.e., risk premia for currency i) for convenience:

$$rp_i = \mathbf{\Gamma}_{ii} q_i + \sum_{k \neq i} \mathbf{\Gamma}_{ik} q_k. \tag{9}$$

The difference between the risk premia of two currencies i and j is:

$$\begin{aligned} rp_i - rp_j &= \mathbf{\Gamma}_{ii} q_i + \sum_{k \neq i} \mathbf{\Gamma}_{ik} q_k - \mathbf{\Gamma}_{jj} q_j - \sum_{k \neq j} \mathbf{\Gamma}_{jk} q_k \\ &= \left(\mathbf{\Gamma}_{ii} - \mathbf{\Gamma}_{ji}\right) q_i - \left(\mathbf{\Gamma}_{jj} - \mathbf{\Gamma}_{ij}\right) q_j + \sum_{k \neq i \text{ or } j} \left(\mathbf{\Gamma}_{ik} - \mathbf{\Gamma}_{jk}\right) q_k \\ &= \underbrace{\left(\mathbf{\Gamma}_{ii} - \mathbf{\Gamma}_{ji}\right) \Delta q_{ij}}_{\text{total imbalance}} + \underbrace{\left[\left(\mathbf{\Gamma}_{ii} - \mathbf{\Gamma}_{ji}\right) - \left(\mathbf{\Gamma}_{jj} - \mathbf{\Gamma}_{ij}\right)\right] q_j}_{\text{individual importance}} + \underbrace{\sum_{k \neq i \text{ or } j} \left(\mathbf{\Gamma}_{ik} - \mathbf{\Gamma}_{jk}\right) q_k}_{\text{neighborhood importance}} \end{aligned} \tag{10}$$

where $\Delta q_{ij} = q_i - q_j$. Thus eq. (10) makes clear that the cross-sectional variation in rp_i has three components: total imbalance, individual importance, and neighborhood importance. This means that the total imbalance q is not the sole driver of the cross-section of currency risk premia. Indeed, $q_i > q_j$ does not necessarily imply $rp_i > rp_j$ except for most simplified cases, e.g., when $\mathbf{\Gamma}$ is a diagonal matrix with $\mathbf{\Gamma}_{ii}$ positively related to q_i. In essence, eq. (10) highlights the importance of network structure reflected in $\mathbf{\Gamma}$ in explaining the cross-section of currency risk premia.

By setting $\mathbf{\Gamma}$ to be the variance-covariance matrix of x_1, the theory does not directly predict a positive cross-sectional relation between the currency risk premia and q. In the next subsection, we explore the role of $\mathbf{\Gamma}$ as a function of $\mathbf{A}$ in explaining currency risk premia.

2.3 Trade imbalance network and risk bearing capacity of financiers

Financiers' risk bearing capacity captures the commitment to intermediating in international financial markets, $\mathbf{\Gamma}$ in the model. In turn, $\mathbf{\Gamma}$ is inversely related to the financiers' outside options and liquidity shocks, and therefore limited. Financiers' outside options increase in the *complexity* of their balance sheet. Gabaix and Maggiori (2015a, 2015b) employ the variance-covariance matrix of exchanges rate returns as a proxy for such complexity, intended to be related to the size and volatility of the balance sheet. In the multi-country setting, however, centrality is also an important dimension of the complexity of balance sheets, and hence of the outside options of financiers. Albeit in a different context, this idea is in the essence of the theoretical results of Hojman and Szeidl (2008), who show that there is a positive correlation between network centrality and agents' payoffs.

Setting $\mathbf{\Gamma}$ to be the Leontief inverse of $\mathbf{A}_0^\intercal$ elegantly captures the above intuition. Specifically,

$$\begin{aligned} \mathbf{\Gamma}\left(\mathbf{A}_0, \alpha\right) &= \left(\mathbf{I} - \alpha \mathbf{A}_0^\intercal\right)^{-1}, && (11) \\ \Rightarrow \mathbb{E}\left(\bar{x}_1 - x_0\right) &= \left(\mathbf{I} - \alpha \mathbf{A}_0^\intercal\right)^{-1} q, && (12) \end{aligned}$$

where $\mathbf{I}$ is the $n \times n$ identity matrix. The Leontief inverse is closely related to Katz/Bonacich centrality (see, e.g., Ballester, Calvó-Armengol, and Zenou 2006; Acemoglu et al. 2012; Sharkey 2017). To see the intuition more clearly, we spell out financiers' outside option in dollar values (see Gabaix and Maggiori 2015b, eq. (A.29) and Proposition A.8):

$$\theta^\intercal \left(\mathbf{I} - \alpha \mathbf{A}_0^\intercal\right)^{-1} q, \tag{13}$$

where $\theta = \mathbf{D}^{-1} q$ and $\mathbf{D} = \operatorname{diag}\left(x_0\right)$. θ can be expressed in the normal form as θ_i, which captures the holdings of country i's bonds by financiers, expressed in number of bonds,[12] and the outside option is the weighted sum of θ_is with the weight being the importance of the i-th country in the imbalance network:

$$\theta^\intercal \left(\mathbf{I} - \alpha \mathbf{A}_0^\intercal\right)^{-1} q = \sum_{i=1}^{n} \theta_i c_i, \tag{14}$$

where $c = \left(\mathbf{I} - \alpha \mathbf{A}_0^\intercal\right)^{-1} q$. Here c is a variant of Bonacich centrality (Bonacich 1987) and is defined by:[13]

$$c = q + \alpha \mathbf{A}^\intercal c. \tag{15}$$

Following Sharkey (2017), c is a measure of centrality that can be interpreted as the sum of two components: the first one is q, which can be thought of as the basic centrality that each country has; and the second one, $\alpha \mathbf{A}^\intercal$ is the additional centrality driven by how important its neighbours are in the network. The parameter α, which is non-negative and less than one, controls the contribution of the second component to c. When $\alpha = 0$, $c = q$.

12. The dollar value of those bond holdings is $q_i \equiv \theta_i x_i$.

13. The Bonacich centrality, as defined e.g. in Sharkey (2017), is: $r = \mathbf{A}^\intercal \ell + \alpha \mathbf{A}^\intercal r \Rightarrow r = \left(\mathbf{I} - \alpha \mathbf{A}^\intercal\right)^{-1} \mathbf{A}^\intercal \ell$.

More concretely, eq. (11) can be expressed in terms of the convergent power series (see, Stewart 1998, Theorem 4.20):[14]

$$\mathbf{\Gamma} = (\mathbf{I} - \alpha \mathbf{A}_0^{\intercal})^{-1} = \sum_{k=0}^{\infty} (\alpha \mathbf{A}_0^{\intercal})^k . \tag{16}$$

Therefore, $\mathbf{\Gamma}_{i,j}$ measures the importance of country i as a direct and indirect debtor (net importer) to country j in the network, where k denotes the paths of length. To see this, note that, for any i and j, eq. (16) implies

$$\mathbf{\Gamma}_{i,j} = \left(\alpha \left\{ \mathbf{A}_0^{\intercal} \right\}_{i,j} + \alpha^2 \sum_{r=1}^{n} \left\{ \mathbf{A}_0^{\intercal} \right\}_{i,r} \left\{ \mathbf{A}_0^{\intercal} \right\}_{r,j} + \alpha^3 \sum_{r=1}^{n} \left\{ (\mathbf{A}_0^{\intercal})^2 \right\}_{i,r} \left\{ \mathbf{A}_0^{\intercal} \right\}_{r,j} + \dots \right). \tag{17}$$

The first term in eq. (17) accounts for country i's role as a direct debtor to country j, the second term accounts for country i's role as a debtor to country j's debtors, and so on. In terms of the network representation of the economy, $\mathbf{\Gamma}_{i,j}$ accounts for all possible deficit chains (net import relations) that connect country i to country j across the network (Carvalho and Tahbaz-Salehi 2019).

2.4 A numerical example for intuition

To understand the intuition that financiers intermediating countries that are more central in the imbalance network have better outside options, let us consider their balance sheet composition in financing the global trade imbalance. Overall, long positions held by financiers increase their outside options, while short positions decrease their outside options due to collateral requirements for issuing bonds. Now, let us examine the outside options for financing country i. By definition, $\sum_{i=1}^{n} q_i = 0$. Therefore, to finance country i's imbalance q_i, financiers need to have q_j for $j \neq i$ on their balance sheet. q_i per se measures the direct part of the outside options for intermediating country i, that is the first term in eq. (9), $\Gamma_{i,i} q_i$. q_i also creates (reduces) indirect outside options for financiers if $q_j > 0$ ($q_j < 0$) for countries that are (direct or indirect) creditors to country i. Since $\Gamma_{i,j}$ captures all possible deficit chains connecting country i to country j, the second term in eq. (9), $\sum_{j \neq i} \Gamma_{i,j} q_j$measures the indirect part of the outside options induced by q_i. Next, we present a detailed numerical example to further illustrate the intuition.

14. See also Ballester, Calvó-Armengol, and Zenou (2006). Here we assume α is smaller than the norm of the inverse of the largest eigenvalue of $\mathbf{A}_0^{\intercal}$.

The network complexity increases exponentially with the number of nodes. To strike a balance between visibility and comprehensiveness, we present a simulated four-country network as an illustrative example in which the ranks in q and rp differ. The adjacency matrix $\mathbf{A}_0$ is given by:

$$
\begin{array}{c}
\\ C_1 \\ C_2 \\ C_3 \\ C_4
\end{array}
\begin{array}{c}
\begin{array}{cccc} C_1 & C_2 & C_3 & C_4 \end{array} \\
\begin{bmatrix}
0, & 0, & 0.23, & 0.59 \\
0.24, & 0, & 0.59, & 0 \\
0, & 0, & 0, & 0.18 \\
0, & 0.21, & 0, & 0
\end{bmatrix}
\end{array}.
$$

Therefore, q is given by:

$$
q = (\mathbf{A}_0^\intercal - \mathbf{A}_0)\,\ell = [-0.58, -0.62, 0.64, 0.56]^\intercal;
$$

and with $\alpha = 0.6$, $\mathbf{\Gamma}$ can be calculated as:

$$
\mathbf{\Gamma} = (\mathbf{I} - \alpha \mathbf{A}_0^\intercal)^{-1} =
\begin{array}{c}
\\ C_1 \\ C_2 \\ C_3 \\ C_4
\end{array}
\begin{array}{c}
\begin{array}{cccc} C_1 & C_2 & C_3 & C_4 \end{array} \\
\begin{bmatrix}
1, & 0.14, & 0.00, & 0.02 \\
0.05, & 1, & 0.01, & 0.13 \\
0.15, & 0.38, & 1, & 0.05 \\
0.37, & 0.09, & 0.11, & 1
\end{bmatrix}
\end{array};
$$

and rp:

$$
rp = \mathbf{\Gamma} q = [-0.66, -0.58, 0.34, 0.36]^\intercal.
$$

Clearly, rp and q rank differently in this example. Let us examine how the network structure affects the ranks. The network is visualized in Figure 2. Countries 3 and 4 are net deficit countries while Countries 1 and 2 are net surplus countries. Country 3 is a direct debtor to Countries 1 and 2, and Country 4 is a direct debtor to Countries 1 and 3. Since Countries 3 and 4 are in net deficit, we focus on analyzing q_3 and q_4 vs rp_3 and rp_4.

[*Insert Figure 2 about here*]

For Country 3, in addition to q_3, rp_3 aggregates q_1, q_2, and q_4 via creditor chains with these countries. Specifically, we have:

$$\begin{aligned}
rp_3 &= q_3 + \mathbf{\Gamma}_{3,1} q_1 + \mathbf{\Gamma}_{3,2} q_2 + \mathbf{\Gamma}_{3,4} q_4 \\
&= q_3 + \left(\alpha \left\{ \mathbf{A}_0^{\intercal} \right\}_{3,1} + \left\{ \left(\alpha \mathbf{A}_0^{\intercal} \right)^3 \right\}_{3,1} \right) q_1 + \left(\alpha \left\{ \mathbf{A}_0^{\intercal} \right\}_{3,2} + \left\{ \left(\alpha \mathbf{A}_0^{\intercal} \right)^2 \right\}_{3,2} \right) q_2 \\
&\quad + \left(\left\{ \left(\alpha \mathbf{A}_0^{\intercal} \right)^2 \right\}_{3,4} + \left\{ \left(\alpha \mathbf{A}_0^{\intercal} \right)^3 \right\}_{3,4} \right) q_4.
\end{aligned} \tag{18}$$

For Country 4,

$$\begin{aligned}
rp_4 &= q_4 + \mathbf{\Gamma}_{4,1} q_1 + \mathbf{\Gamma}_{4,2} q_2 + \mathbf{\Gamma}_{4,3} q_3 \\
&= q_4 + \left(\alpha \left\{ \mathbf{A}_0^{\intercal} \right\}_{4,1} + \left\{ \left(\alpha \mathbf{A}_0^{\intercal} \right)^2 \right\}_{4,1} \right) q_1 + \left(\left\{ \left(\alpha \mathbf{A}_0^{\intercal} \right)^2 \right\}_{4,2} + \left\{ \left(\alpha \mathbf{A}_0^{\intercal} \right)^3 \right\}_{4,2} \right) q_2 \\
&\quad + \alpha \left\{ \mathbf{A}_0^{\intercal} \right\}_{4,3} q_3.
\end{aligned} \tag{19}$$

[*Insert Figure 3 about here*]

The numerical values of components in eqs. (18) and (19) alongside their creditor chains are presented in Figures 3a and 3b, respectively. We can see that both Countries 3 and 4 are net debtors to the two net surplus countries (1 and 2). As shown in the first and second rows in Figures 3a and 3b, these creditor chains reduce both countries' outside options to similar extents. The key component making a difference in the rank is their creditor chains with each other: Country 4 is a direct debtor to Country 3, while Country 3 is only an indirect (two and three steps away) debtor to Country 4. Although $q_4 < q_3$, Country 4's direct debtor relation with Country 3 boosts its outside options more than that of Country 3, which has only indirect debtor relations with Country 4, i.e., $rp_4 > rp_3$.

2.5 A centrality-based characteristic for currency risk premia

With the functional form of $\mathbf{\Gamma}$ in eq. (11), the model captures the essence of financiers' limited commitment in the context of complex trade networks, i.e., financiers based in countries with higher centrality face more outside options. In other words, the model predicts that currency risk premia are closely related to imbalance network centrality. The mechanism described above implies a testable prediction, which we summarize in Hypothesis 1.

Hypothesis 1 *Cross-sectional currency risk premia are positively associated with currencies' centrality in the trade imbalance network.*

Guided by these theoretical results, we develop a measure of trade imbalance network centrality that is easy to compute empirically and allows us to test the key prediction of the theory. Gabaix and Maggiori (2015a) use the variance-covariance matrix as a proxy for the complexity of the balance sheets of financiers. This proxy captures the impact of the size of the positions and riskiness measured by the variance of the currency. Della Corte, Riddiough, and Sarno (2016) use changes in the VXY (implied-volatility) index as a proxy for conditional FX volatility and report empirical results consistent with Gabaix and Maggiori (2015a)'s choice of complexity measure.

Therefore, to incorporate both the variance-covariance and network centrality into the complexity measure, we augment $\mathbf{\Gamma}$ in eq. (11) as follows:

$$\mathbf{\Gamma}\left(\mathbf{V}, w, \mathbf{A}_0, \alpha\right) = \left[w\mathbf{I} + (1-w)\mathbf{V}\right]\left(\mathbf{I} - \alpha\mathbf{A}_0^{\intercal}\right)^{-1}, \tag{20}$$

where $0 \leq w \leq 1$, and $\mathbf{V}$ is the variance-covariance matrix of x_t. This setting nests $\mathbf{V}$ and $\left(\mathbf{I} - \alpha\mathbf{A}_0^{\intercal}\right)^{-1}$ as special cases. Indeed,

$$\mathbf{\Gamma}\left(\mathbf{V}, 0, \mathbf{A}_0, 0\right) = \mathbf{V}, \tag{21}$$

$$\mathbf{\Gamma}\left(\mathbf{V}, 1, \mathbf{A}_0, \alpha\right) = \left(\mathbf{I} - \alpha\mathbf{A}_0^{\intercal}\right)^{-1}. \tag{22}$$

Equation (21) is the $\mathbf{\Gamma}$ studied by Gabaix and Maggiori (2015a, 2015b). Under the above setting, and combined with our Proposition 1, currency risk premia can be written as:

$$\mathbb{E}\left(\bar{x}_1 - x_0\right) = \left[w\mathbf{I} + (1-w)\mathbf{V}\right]\left(\mathbf{I} - \alpha\mathbf{A}_0^{\intercal}\right)^{-1}\left(\mathbf{A}_0^{\intercal} - \mathbf{A}_0\right)\ell. \tag{23}$$

As w and α are unknown non-negative parameters, we construct a characteristic based on eq. (23) for a range of combinations of positive w and α. If such characteristic has significant predictive power on observed currency risk premia for some reasonable values of w and α, then we argue that imbalance network centrality contains valuable information about risk premia in the foreign exchange market. Hereafter, we refer to this centrality-based characteristic as

CBC, i.e.,

$$CBC = [w\mathbf{I} + (1-w)\mathbf{V}]\left(\mathbf{I} - \alpha\mathbf{A}_0^\intercal\right)^{-1}\left(\mathbf{A}_0^\intercal - \mathbf{A}_0\right)\ell. \tag{24}$$

It is apparent that calibration of w and α requires in-sample analysis. However, once we calibrate w and α over a training sample period, we rely purely on out-of-sample analysis that keeps w and α constant for the purpose of evaluating the predictive performance of *CBC* in a cross-sectional investment strategy and comparing it to other common predictive variables.

3 Data and variable construction

This section provides details on all data employed in the subsequent empirical analysis. The dataset consists of international trade data and currency returns.

3.1 Trading imbalance network

The Global Trade Deficit Network is constructed based on yearly bilateral trade data (in USD), which is collected from the UN Comtrade Database from 1995 to 2021.[15,16] For the node of Euro, from 1999, we aggregate all Euro countries into one entity by summing up all their trades with other non-Euro countries. These data allow us to construct the export/import matrix $\boldsymbol{\xi}$ described in Section 2.1, from which we can further construct $\mathbf{A}_{ij}$ using eq. (3). To avoid $\mathbf{A}_{ij}$ being dominated by country size, we also normalize $\mathbf{A}_{ij}$ to be the ratio of the net imbalance to its corresponding value of total trade. More technical details are presented in Appendix C.

3.2 Currency excess returns

Spot and forward exchange rates. The currency data are collected from Thomson Reuters Datastream for the period from 1995 to 2021. We use daily spot and forward exchange rates

15. Each country reports import and export values relative to each of its trading partners. However, there is a well-known inconsistency in their reported values. One reason for this is that imports are normally reported at Cost, Insurance, and Freight (CIF) value, while exports are normally reported at Freight On Board (FOB) value. Therefore, we choose to only use the reported export value and set the country's import value as its partner's reported export to this country. If we cannot find the corresponding bilateral export data, we use the import data reported by the partner country.

16. The bilateral trade data we collect here include both intermediate goods and final goods. Ready, Roussanov, and Ward (2017) elucidate the rationale behind countries producing intermediate goods typically offering higher average interest rates, whereas countries exporting final goods tend to maintain lower interest rates. Consequently, they contend that the trade composition within various countries influences exchange rates through the currency carry trade. In a global economy where financiers exhibit limited commitment, such as in our model, comprehending currency returns hinges on grasping the dynamics of currency demand and supply in global trade. The aggregation of both intermediate and final goods provides a more holistic depiction of the currency demand and supply landscape spanning various countries.

against USD. Following Lustig, Roussanov, and Verdelhan (2011) and Richmond (2019), we build end-of-month series based on daily data. Our main data set contains at most 41 countries: Australia, Austria, Belgium, Canada, China, Czech Republic, Denmark, Europe, Finland, France, Germany, Greece, Hong Kong, Holland, Hungary, India, Indonesia, Ireland, Italy, Japan, Kuwait, Malaysia, Mexico, New Zealand, Norway, Philippine, Poland, Portugal, Russia, Saudi Arabia, Singapore, South Korea, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, U.K., United Arab Emirates, United States of America. Data for some currencies do not cover the whole period. For the Euro area, we subsume all countries included in the Euro zone after 1999. The sample size varies for different currencies, most importantly because some currencies cease to exist due to the adoption of the euro. Hence, our panel of individual currencies is unbalanced. The detailed data availability is presented in Table A1.

Currency excess returns. We use $s_{it} = log(S_{it})$ to denote the log spot exchange rate in units of foreign currency per US dollar, and $f_t = log(F_t)$ for the log forward exchange rate, also in units of foreign currency per US dollar. Hence, an increase in s means an appreciation of the home currency (USD). For any variables that pertain to the home country (the US), we drop the subscript. The log excess return rx_{it} from buying foreign currency i in the forward market and then selling in the spot market after one month is:

$$rx_{i,t+1} = f_{i,t} - s_{i,t+1}. \tag{25}$$

This excess return can also be stated as the log forward discount minus the change in the spot rate:

$$rx_{i,t+1} \approx r_{i,t} - r_t - \Delta s_{i,t+1}. \tag{26}$$

Indeed, under covered interest parity (CIP), the interest rate differential is equal to the forward discount, i.e. $r_{i,t} - r_t \approx f_{i,t} - s_{i,t}$, where $r_{i,t}$ and r_t denote country i's and US nominal risk-free rates over the maturity of the forward contract, respectively. Following common practice in the literature, we compute currency excess returns using forward rates rather than interest rate differentials for two main reasons. First, marginal investors (such as, e.g., hedge funds and large banks) that are responsible for the determination of exchange rates trade mostly using forward contracts (e.g., Koijen et al. 2018). Second, for many countries, forward rates are available for longer time periods than short-term interest rates.

3.3 Empirical construction of *CBC*

This subsection details the empirical construction of *CBC*. Given the adjacency matrix $\mathbf{A}$ of the annual imbalance networks and currency risk premia, we calibrate w and α to compute the *CBC*s using eq. (24). We allow w and α to vary every year and calibrate conditioning only on information available. Specifically, at each year t, we match $\mathbf{A}$ and $\mathbf{V}$ from previous years (up to $t-1$) to their next year's realized currency risk premia (up to t) and conduct a 300×300 grid search from 0 to 1 for both w and α to find all combinations of w and α that result in significantly positive (with p-value < 0.005) Spearman correlations between *CBC*s and the realized currency risk premia (all data up to t).[17] The estimates of w and α at year t are the weighted average of the points identified on the grid with the weights being the Spearman correlation coefficients. The calibrated w and α at year t are then the averages of all estimates up to year t. The calibrated w and α, alongside year-t $\mathbf{A}$ and $\mathbf{V}$, are then used to compute *CBC* at time t via eq. (24) for predicting currency excess returns at time $t+1$. This setup ensures that the constructed *CBC* is only based on the information available up to the point of construction, for each exchange rate. We use the sample from 1995 to 2002 for initial calibration and start the out-of-sample *CBC* construction from 2003 to the end of the sample in 2021.

[*Insert Figure 4 about here*]

We plot the calibrated w and α and the resulting Spearman correlations in Figure 4. Both w and α appear remarkably stable over time. For example, w stabilizes around 0.52 early in the sample, confirming the information from the variance-covariance matrix is useful in predicting currency risk premia. More importantly for the purpose of our paper, we find that α is in the range between 0.68 and 0.74 and converges to around 0.68, clearly very far from zero. This suggests that the imbalance network centrality has significant predictive power for the cross-sectional variation of currency excess returns, controlling for the variance-covariance matrix of returns. The Spearman correlations between *CBC*, calibrated using these values of w and α,

17. To make Spearman correlations meaningful, we apply a rank-preserving transformation to the original *CBC*s at $t-1$ so that their max and min values match those of the currency risk premia at $t-1$. Again no future information is used in the calibration at each time t. Also, we require a p-value < 0.005 to establish statistical significance rather than a conventional significance level of, e.g., 0.05, because we are considering a large number of combinations of w and α. Hence we face a potential multiple hypothesis testing bias, which calls for more conservative p-values (see, e.g., Harvey, Liu, and Zhu 2016).

and currency excess returns (risk premia) are large, in the range from 0.12 to 0.3 (Figure 4b). In Figure 4b, we also plot the Spearman correlations for cases assuming $\mathbf{\Gamma} = \mathbf{V}$ ($w = 0, \alpha = 0$) and $\mathbf{\Gamma} = \mathbf{I}$ ($w = 1, \alpha = 0$). When $\mathbf{\Gamma} = \mathbf{V}$, the Spearman correlation is negative, albeit small in magnitude, indicating that $\mathbf{V}$ per se is not a particularly strong candidate for $\mathbf{\Gamma}$ empirically. The case of $\mathbf{\Gamma} = \mathbf{I}$ essentially only uses the total imbalance to explain the currency risk premia. We find the Spearman correlation is consistently lower than that in the case of *CBC* with calibrated w and α. In essence, combining $\mathbf{V}$ and the imbalance network information significantly improves the model's ability to explain currency risk premia.

[*Insert Figure 5 about here*]

To show how the relative positions of the *CBC*s change, we plot the positions of the top, middle and bottom three currencies in the percentage ranks over time in Figure 5. Net importing countries (e.g., Kuwait, Mexico, South Africa) are clearly in the top panel, whereas net exporters (e.g., China, Hong Kong, Thailand) are in the bottom panel. We also observe that currencies in the middle display higher turnover in the relative ranks than those in the top and bottom, indicating pronounced time-variation of the premia in the majority of currencies.

In short, the calibration exercise provides a first indication of the usefulness of the information implicit in the imbalance network and variance-covariance matrix that goes beyond the total imbalance. We then test whether the constructed *CBC*s have stronger performance in explaining the global currency risk premia than existing factors that are based solely on total imbalances in an out-of-sample setting. Indeed, in the out-of-sample analysis we use *CBC* in two different variants: one where w and α are updated when constructing *CBC* in the way described above, conditioning on new information becoming available a time t; and another where we simply set w and α equal to the calibrated values obtained during the 1995-2002 period and never change them over the out-of-sample period. In the latter case, for given values of w and α, variation in *CBC* across currencies and time is driven only by international trade data and the variance-covariance matrix of returns.

4 Empirical analysis

In this section, we first show the performance results of the portfolios sorted on *CBC* and a comparison with several benchmarks. We then present a variance decomposition highlighting the importance of the network effect in explaining the cross-sectional variation of currency premia, and a counterfactual analysis showing the usefulness of this framework in assessing the impact of significant international events on currency premia.

4.1 Performance comparison

To assess the predictive power of *CBC* for the cross-section of currency excess returns, in this section we compare portfolios sorted on *CBC* to six benchmarks: portfolios sorted on the Total trade network centrality (*TTNC*) proposed by Richmond (2019); the trade imbalance (*TImb*) defined as total net import (this is equivalent to setting $\mathbf{\Gamma}$ equal to $\mathbf{I}$); the forward discount (*FD*), the carry trade characteristic common in a vast literature, e.g. Lustig, Roussanov, and Verdelhan (2011); global imbalances (*GImb*), studied by Della Corte, Riddiough, and Sarno (2016); the variance-covariance weighted trade imbalance ($\mathbf{V}$-weighted *TImb*) denoted as $\mathbf{V}q$ (this is equivalent to setting $\mathbf{\Gamma}$ equal to $\mathbf{V}$); The dollar factor as in Lustig, Roussanov, and Verdelhan (2011), i.e. the currency excess return on a portfolio strategy long all foreign currencies with equal weights and short the domestic currency, denoted as *DOL*.

Monthly currency excess returns are used in this exercise, consistent with the vast majority of papers in the currency asset pricing literature. However, portfolio sorts are based on characteristics constructed based on information from the year prior to the realized currency returns, since CBC can only be constructed at yearly frequency. Hence, the sorted portfolios are rebalanced yearly. To have a level playing field across characteristics, we construct all benchmark characteristics using yearly data even though some of them (e.g., *FD* and *DOL*) are available at higher frequency. The portfolio sorts are carried out such that the safest currencies are in the low (short) portfolio and the most risky in the high (long) portfolio. Specifically, currencies are sorted in ascending order of *CBC*, *TImb*, *FD*, and $\mathbf{V}$-weighted *TImb*, and in descending order of *TTNC* into four groups (G1 to G4). For *GImb*, the portfolios are formed from a 2×2 conditional double sort by nfa and ldc, following Della Corte, Riddiough, and Sarno (2016), where nfa is the net foreign asset position (the difference between foreign assets and foreign liabilities) relative to the size of the economy (GDP) and ldc is the proportion of external liabilities denominated in domestic currency.[18]

[*Insert Table 1 about here*]

18. The end-of-year series on foreign assets and liabilities and gross domestic product (GDP) are from Lane and Milesi-Ferretti (2001, 2007), kindly updated by Gian Maria Milesi-Ferretti. The end-of-year series on the proportion of external liabilities denominated in domestic currency are from Bénétrix, Lane, and Shambaugh (2015), who update the data from Lane and Shambaugh (2010), kindly provided by Philip Lane and Agustín Bénétrix.

The results from the portfolio sorts for *CBC* and the six benchmarks are shown in Table 1. Columns G1 to G4 present the equal-weighted average excess returns of the different portfolios. Recall that we use *CBC* in two different ways in this out-of sample analysis. Starting from the case where w and α are updated over time conditioning on new information becoming available (*CBC* updated), we find that the average returns increase monotonically from the first portfolio G1 to the last portfolio G4. When using *CBC* constructed on the basis of the calibrated values of w and α obtained over the 1995-2002 period (*CBC* static), the results are qualitatively identical. This is not suprising given the stability displayed by w and α over time illustrated earlier, and it is reassuring in that it should allay any concern about potential look-ahead bias. The monotonic increase in portfolios G1 to G4 also occurs for *FD*, i.e. carry. Comparing the excess returns of the long-short portfolio (long G4 and short G1) shows that *CBC* clearly delivers the highest return (statistically significant at 5% significance), and the highest annualized Sharpe ratio, i.e., 0.54 and 0.65 for *CBC* updated and static, respectively.

[*Insert Figure 6 about here*]

To see how the various characteristics perform over time, we also plot the long-short portfolios' cumulative returns from 2003 to 2021 in Figure 6. All characteristics have similar performance before 2008, but after 2008 *CBC* clearly dominates relative to other sorting variables.

Using the excess returns of the long-short strategies, we define a tradable factor for each characteristic mentioned above, except for *DOL* which is a well-defined factor per se. For example, the *CBC* factor is defined as the excess returns of the long-short strategies (G4 minus G1), where G1 and G4 are the first and fourth quartile portfolios sorted by *CBC*, respectively. By design, this *CBC* factor captures financiers' limited commitment embedded in the global imbalance network. Therefore, it is also interesting to check if the *CBC* factor is correlated with intermediary asset pricing factors. To this end, we consider two well-known intermediary asset pricing factors due to Adrian, Etula, and Muir (2014, AEM) and He, Kelly, and Manela (2017, HKM). The details for constructing the tradable AEM and HKM factors are presented in Appendix D. Next, we ask how the time-series variation of the *CBC* factor is related to that of various factors (the six factors considered above plus AEM and HKM).

[*Insert Table 2 about here*]

According to Barillas and Shanken (2017), when all factors are tradable, OLS regressions are all that is needed to establish whether one factor prices another, and the focus can be directly on the alpha of the regression. Therefore, we regress the *CBC* factor on each of the above existing factors and examine the size and statistical significance of the alpha in the regression to test whether any of the factors subsumes the information in *CBC*. In essence, the alpha coefficients alongside their statistical significance allow us to assess whether the *CBC* factor is subsumed by these factors. The results are reported in Table 2a. These results show that the alpha coefficients are statistically significant for all regressions, and they are large. This is clear evidence that the *CBC* factor captures information that cannot be spanned by these currency pricing factors or the intermediate asset pricing factors considered.

We then ask the question whether and how well the *CBC* factor explains other factors by regressing each of these factors on the *CBC* factor.[19] The results are reported in Table 2b. We find that all of the alphas except one are statistically insignificantly different from zero, indicating that the *CBC* factor explains well the majority of the factors. The only exception is that the alpha coefficient of the *GImb* factor of Della Corte, Riddiough, and Sarno (2016) is statistically significant. This suggests that although the *GImb* factor delivers a lower return than the *CBC* factor in the performance comparison shown in Table 1, it carries some information that cannot be explained by the *CBC* factor, amounting to an alpha of just over 2% per annum.[20]

In summary, the performance comparison in this subsection confirms the predictive power of *CBC* and further suggests that its information content cannot be subsumed by any of the alternative factors considered.

4.2 Variance decomposition

We show in eq. (10) that the variation in cross-sectional currency premia can be decomposed into three components: total imbalance, individual importance, and neighborhood importance. In this subsection, we study the relative importance of these three components in driving the cross-section of currency premia via a variance decomposition, in the spirit of Nozawa (2017). Specifically, we use themodel to decompose all unique pair-wise currency premia differences, $\Delta rp_{i,j} = rp_i - rp_j$ defined in eq. (10), into the three components over all sample years. We adjust each year's model implied premia to have the same min and max values of their empirical

19. See Hou and Robinson (2006) for a similar practice of placing a key factor on either side of regressions separately.

20. This is presumably because *GImb* is constructed using not only information on external imbalances but also data on the proportion of external liabilities denominated in domestic currency, which does not enter the construction of *CBC*.

counterparts in that year via an affine rank-preserving transformation. Pooling all these data together allows us to compute the variance ratios of the three components relative to $\Delta rp_{i,j}$.

[*Insert Table 3 about here*]

The results are presented in Table 3. The sample means of the three components are close to zero, so is the sample mean of $\Delta rp_{i,j}$, as shown in Table 3a. The variance ratio (VR) results in Table 3a provide interesting insights: the total imbalance component only explains about 11% of the cross-sectional variation in currency premia; the individual importance component explains even less of the variation, with a VR of 5%; the majority, around 68%, of the variation is explained by the neighborhood importance component. This result highlights the importance of considering all three components rather than just total imbalances, as predicted by the theory.

It is worth noting that the VRs do not add up to one as the three components are not orthogonal by construction. Their correlation coefficients are shown in Table 3b. Again, among the three components, the neighborhood importance has a nearly perfect correlation with $\Delta rp_{i,j}$ (0.96 with standard error of 0.03). The total imbalance component is also significantly positively correlated with $\Delta rp_{i,j}$ (0.57 with standard error of 0.16). The individual importance component is not significantly correlated with $\Delta rp_{i,j}$ or either of the other two components. The total imbalance and the neighborhood importance components are positively correlated, which is intuitively consistent with the notion that countries with a larger imbalance tend to have larger centrality and stronger connections with other countries.

To show the extent to which α and w affect the distribution of the VRs, we vary α and w from zero to one and recompute these VRs for various combinations of α and w from the variance decomposition. The results are shown in Figure 7. Overall, the results confirm that the neighborhood component is crucial in explaining the cross-sectional variation in currency premia when α is not zero and w is not one. The total imbalance dominates the other two components only when α approaches zero and w approaches one, i.e., when $\mathbf{\Gamma}$ approaches the identity matrix, $\mathbf{I}$.[21]

[*Insert Figure 7 about here*]

21. It is interesting to note that the effect of α on the neighborhood importance is nonlinear: as α moves away from zero towards one, the impact increases and peaks around $\alpha = 0.3$, and then decreases slightly and stabilizes. This observation could be a feature embedded in the global trade imbalance network.

As specified in eq. (20), our empirical setup has much flexibility that accommodates the total imbalance component-only scenario as a special case ($w = 1$ and $\alpha = 0$). The fact that the calibrated model is far away from the total imbalance component-only scenario speaks directly to the importance of the trade imbalance network in explaining the variation of currency premia. The results in Table 3 and Figure 7 quantify the relative importance among the three components. The dominance of the neighborhood importance component highlights the essential role of trade imbalance network centrality emphasized in our theory.

4.3 Counterfactual analysis

In this subsection, we apply our framework to assess the impact of two recent international events on global currency premia via counterfactual analyses. We look at the US-China trade war starting in 2018, and the collective trade sanctions against Russia in the wake of its 2022 invasion of Ukraine.

In 2018, the US launched a trade war with China. Both countries escalated tariffs that ultimately covered about $450 billion in trade flows. By late 2019, the US had imposed tariffs on roughly $350 billion of Chinese imports, and China had retaliated on $100 billion US exports, with many of the escalated tariffs persisting beyond 2021 (Fajgelbaum and Khandelwal 2022; Fajgelbaum, Goldberg, et al. 2023). In response to the 2022 Russian invasion of Ukraine, a broad swathe of countries have imposed a bevy of sanctions against Russia. More than 35 countries (including many large industrialized economies) have participated in efforts to limit Russia's access to the global economy (Allen 2022). Existing studies on the US-China trade war and the sanctions against Russia focus on real economic impact (Fajgelbaum and Khandelwal 2022; Allen 2022) and costs for equity markets (Huang and Lu 2022). Using counterfactual analyses, our framework allows us to pin down the effects of these events on the trade imbalance network and the implications on global currency risk premia.

US-China Trade War. In our data, we find the relative deficit (defined as the ratio of net import to total trade) the US had with China went up to 0.60 in 2019 from 0.54 in 2017. This indicates that the trade war had a larger reduction in China's imports from the US than the other way around. This is consistent with existing evidence that US consumers of imported goods have borne the brunt of the tariffs through higher prices (Fajgelbaum and Khandelwal 2022). The effect of the US-China trade war clearly goes beyond impacting these two countries, as bystander countries increased their trades with the US and China (Fajgelbaum, Goldberg, et al. 2023). In our counterfactual analysis, we take the adjacency matrix of the global trade imbalance network in 2017 as the base and replace its rows and columns corresponding to the US and China with those from the adjacency matrix in 2019. By doing so, we essentially isolate changes in the adjacency matrix due to the trade war. We attribute any resulting changes in the *CBC* ranks to the impact of the US-China trade war. We present the results in Figure 8. Interestingly, we find that the rank of CNY has not changed and the seven currencies noticeably affected are THB (3% raise in the percentage ranks), RUB (3% drop), GBP (3% raise), IDR (3% drop), PHP (3% raise), SEK (3% drop), ZAR (3% raise), SAR (3% raise), and MXN (6% drop). The fact that these currencies are not directly involved in the US-China trade war shows that within a complex trade imbalance network one international event could have far-reaching effects on seemingly unrelated currencies.

[*Insert Figure 8 about here*]

Russia-Ukraine Conflict. Next, we turn to study the impact of the collective trade sanctions against Russia in response to its 2022 invasion of Ukraine. With reference to Funakoshi, Lawson, and Deka (2022), we identify a group of currencies, USD, EUR, GBP, AUD, JPY, CAD, CHF, NOK, PLN, KRW, and NZD, corresponding to the countries/economies that have imposed severe trade sanctions against Russia. For illustration purposes, we simply assume the sanctions make Russia's trade activities with these currencies shrink by 90% of the figures in 2020.[22] Specifically, we implement the reduction of trade activities by multiplying 0.1 to the values of elements related to RUB and the group of currencies in the adjacency matrix of the trade imbalance network in 2020. Then, we compare the ranks of *CBC* before and after this reduction. The results, shown in Figure 9, suggest a significant impact on global currency premia in this case. There are seven currencies whose *CBC* ranks change noticeably. Among the seven currencies, RUB has the largest drop, 6%, in the percentage ranks. It is worth noting that DKK (3% drop), THB (3% drop), and ZAR (3% raise) are not in the group of countries that imposed severe sanctions on Russia but disaply noticeable changes, while GBP, AUD, JPY, CAD, CHF, and PLN, which are in the group, do not display much of a change. This analysis again shows that the global trade imbalance network brings complexity in assessing the effect of significant

22. We choose 2020 instead of 2021 as the reference year to avoid the unusual impact of Russia's abnormal trading activities in 2021 on the network. There was a dramatic increase in Russia's exports in 2021 relative to the average level from previous years. According to Russian official sources, its goods exports totaled $492 billion in 2021, up 46% from 2020 (CRS 2023).

international events on currency premia. Our framework provides a useful tool for conducting such analyses.

[*Insert Figure 9 about here*]

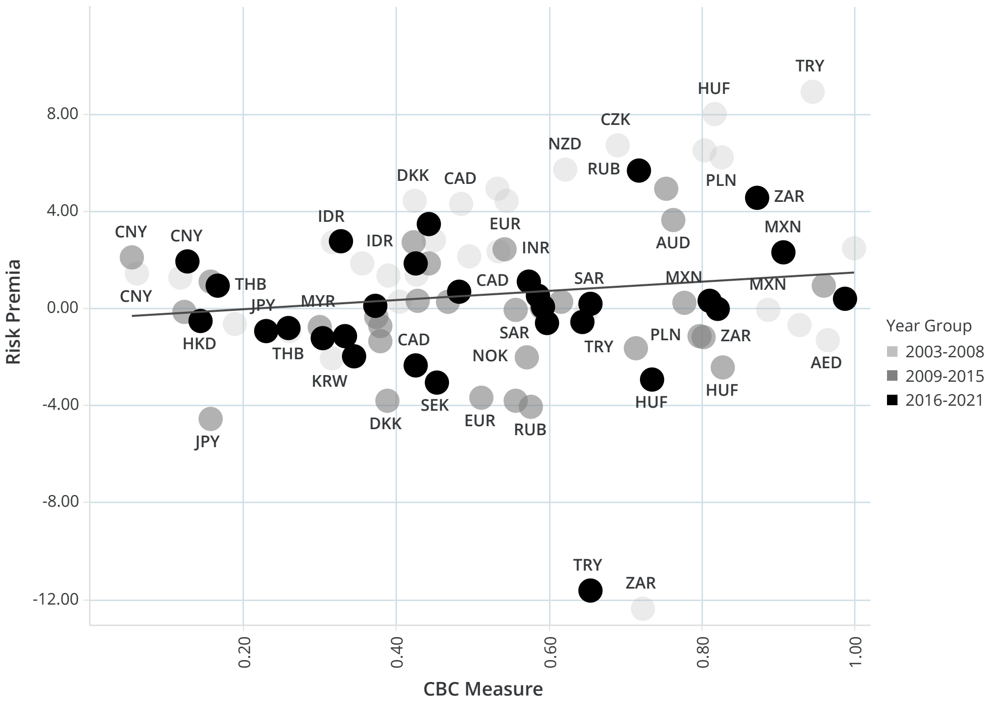
5 Conclusions

Imbalances in trade and capital flows have been considered to shed important light on our understanding of the foreign exchange rate fluctuations and currency risk premia. In this paper, we develop a model of currency risk premia determination with imperfect financial markets and global trade imbalances. In the theory, the expected returns of currencies are connected to their centrality in the global trade imbalance network through financiers' limited commitment, captured using the Leontief inverse-based centrality of the global trade imbalance network.

Guided by the model, we construct a currency-level risk characteristic (*CBC*) based on a score from the calibrated model that combines the centrality and variance-covariance of currency returns. Empirically, in currency portfolio sorting, we show that the *CBC* carries strong pricing power and significantly positive risk premia, relative to various existing currency pricing factors proposed by, e.g., Lustig, Roussanov, and Verdelhan (2011), Della Corte, Riddiough, and Sarno (2016), and Richmond (2019). The time series variation in the *CBC* factor cannot be explained by these currency pricing factors or by well as well-known intermediate asset pricing factors, indicating novel, systematic sources of currency risk embedded in the *CBC* factor.

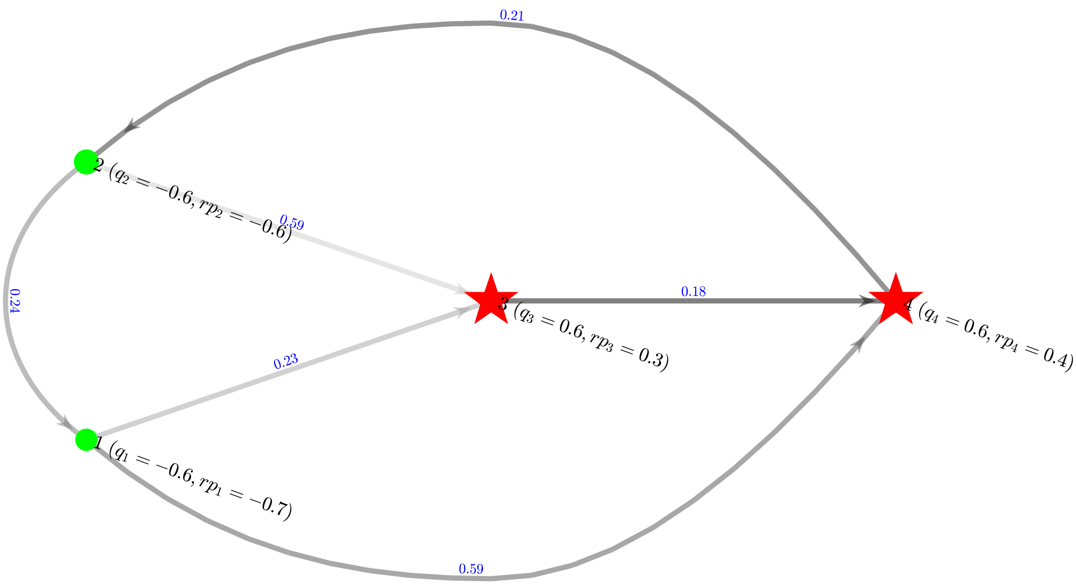
Overall, our study provides theoretical and empirical support for the existence of a connection between currency returns and the global trade imbalance network, which is a robust relation largely overlooked in previous research.

Fig. 1: *CBC* versus currency risk premia



Notes: This figure plots the global trade *CBC* measure of 40 countries versus the average of annualized risk premia rx. The plots contain averages over three seven-year periods, i.e., 2003-2008, 2009-2015, 2016-2021. The *CBC* deficit network centrality is weighted by the pair-wise bilateral trades. The trade data are collected from the UN Comtrade Database. The foreign exchange (spot and forward currency rates) are collected from Thomson Reuters Datastream. The centrality measure is log-scaled. For the *Euro* area, we construct an aggregate with all countries that adopted the euro.

Fig. 2: Example four-country network graph



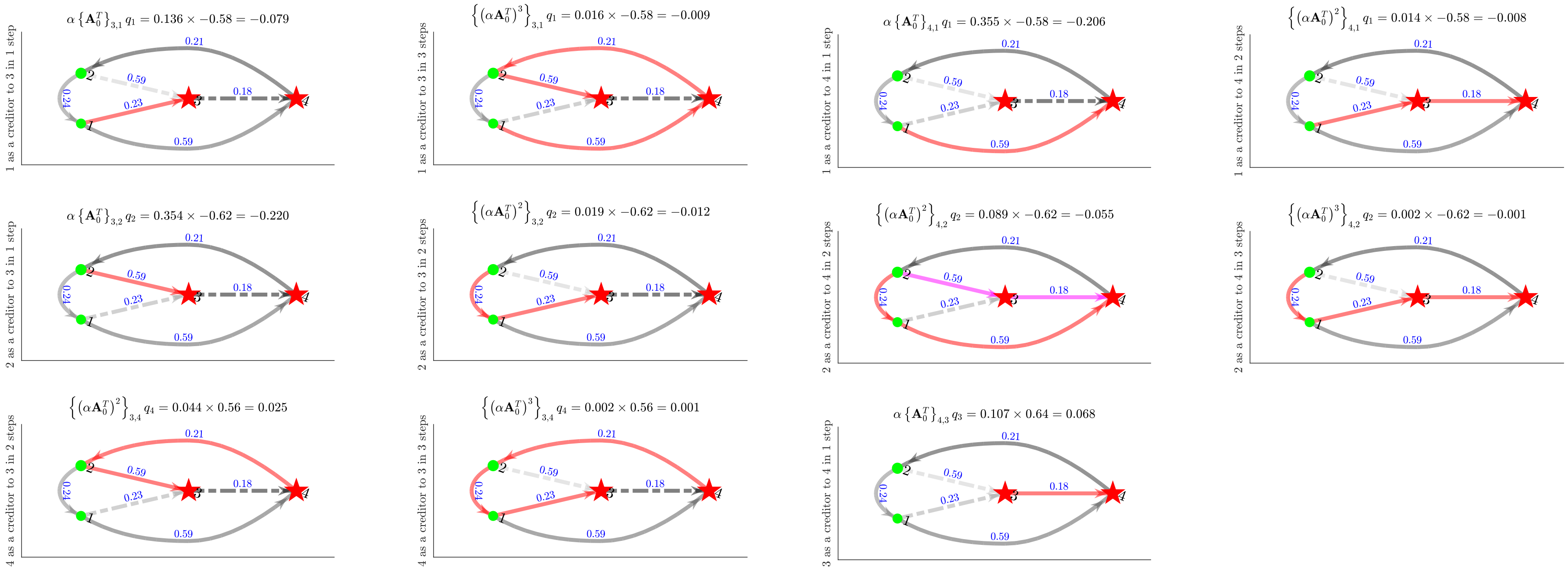
Note: This figure plots the network structure of the four-country example. The numerical values for $\mathbf{A}_0$ are given by:

$$\begin{array}{c c} & \begin{array}{cccc} C_1 & C_2 & C_3 & C_4 \end{array} \\ \begin{array}{c} C_1 \\ C_2 \\ C_3 \\ C_4 \end{array} & \begin{bmatrix} 0, & 0, & 0.23, & 0.59 \\ 0.24, & 0, & 0.59, & 0 \\ 0, & 0, & 0, & 0.18 \\ 0, & 0.21, & 0, & 0 \end{bmatrix} \end{array}$$

This is a directed network with arrows pointing to deficit countries. $\alpha = 0.6$ for the $\mathbf{\Gamma}$ function. The values of q and rp are $q = [-0.58, -0.62, 0.64, 0.56]^\intercal$; $rp = [-0.66, -0.58, 0.34, 0.36]^\intercal$. They are shown in parentheses alongside the nodes. The darkness of the edge color is proportional to the edge size (the net deficit between the connected pair), which is shown on each edge. The nodes for net deficit countries are in the star shape in red, and those for net surplus countries are in the circle shape in green. The node size is proportional to its ranking in rp.

Fig. 3: Creditor chains in the four-country network

(a) Creditor chains of country 3 **(b)** Creditor chains of country 4



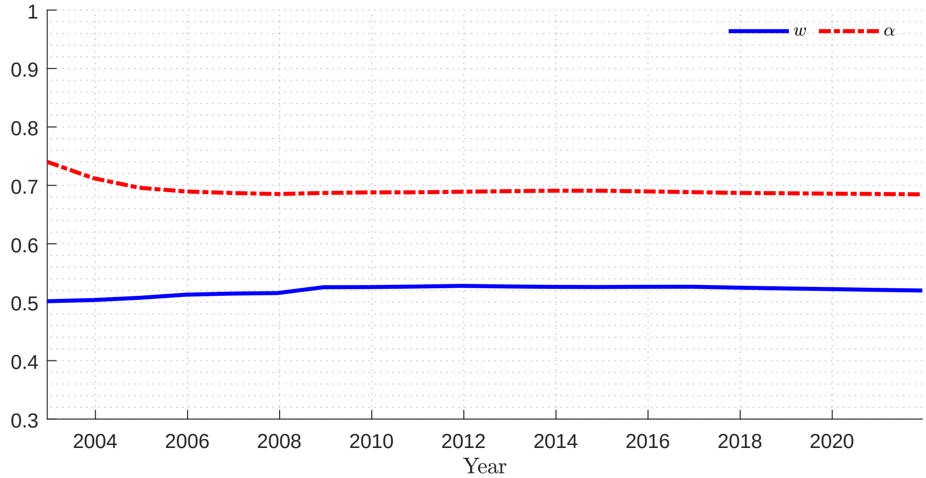
Note: This figure plots the creditor chains on the network for countries 3 (Panel a) and 4 (Panel b) in the four-country example presented in Figure 2. The numerical values for $\mathbf{A}_0$ and $\mathbf{\Gamma}$ are given by:

$$\mathbf{A}_0 = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \\ C_4 \end{array}\!\!\begin{array}{c} \begin{array}{cccc} C_1 & C_2 & C_3 & C_4 \end{array} \\ \begin{bmatrix} 0, & 0, & 0.23, & 0.59 \\ 0.24, & 0, & 0.59, & 0 \\ 0, & 0, & 0, & 0.18 \\ 0, & 0.21, & 0, & 0 \end{bmatrix} \end{array}, \quad \mathbf{\Gamma} = \left(\mathbf{I} - \alpha \mathbf{A}_0^{\intercal}\right)^{-1} = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \\ C_4 \end{array}\!\!\begin{array}{c} \begin{array}{cccc} C_1 & C_2 & C_3 & C_4 \end{array} \\ \begin{bmatrix} 1, & 0.14, & 0.00, & 0.02 \\ 0.05, & 1, & 0.01, & 0.13 \\ 0.15, & 0.38, & 1, & 0.05 \\ 0.37, & 0.09, & 0.11, & 1 \end{bmatrix} \end{array}.$$

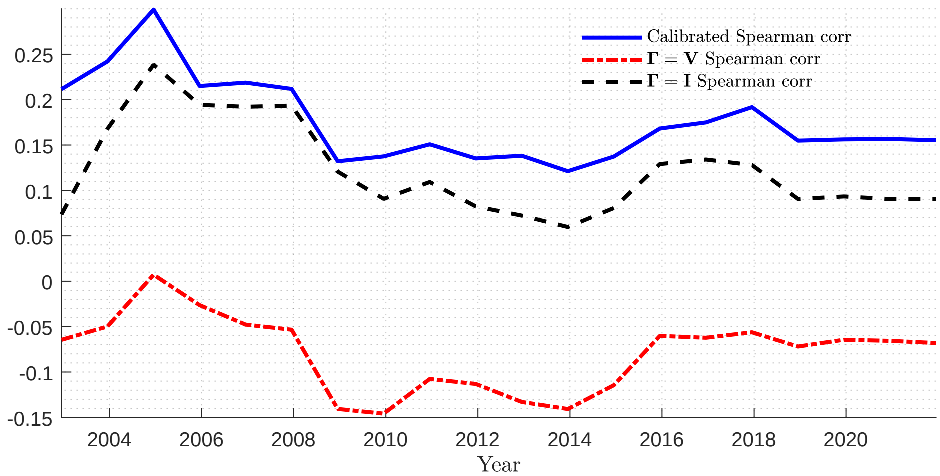
This is a directed network with arrows pointing to deficit countries. $\alpha = 0.6$ for the $\mathbf{\Gamma}$ function. The values of q and rp are $q = [-0.58, -0.62, 0.64, 0.56]^{\intercal}$; $rp = [-0.66, -0.58, 0.34, 0.36]^{\intercal}$. The nodes for net deficit countries are in the star shape in red, and those for net surplus countries are in the circle shape in green. The node size is proportional to its ranking in rp. The creditor chains are highlighted in red on the corresponding edges. If there are two chains within the same steps, the second one is highlighted in pink. The numerical value of the chain's contribution to rp is shown in the subtitle of each subplot.

Fig. 4: Calibrated w and α over time

(a) w and α

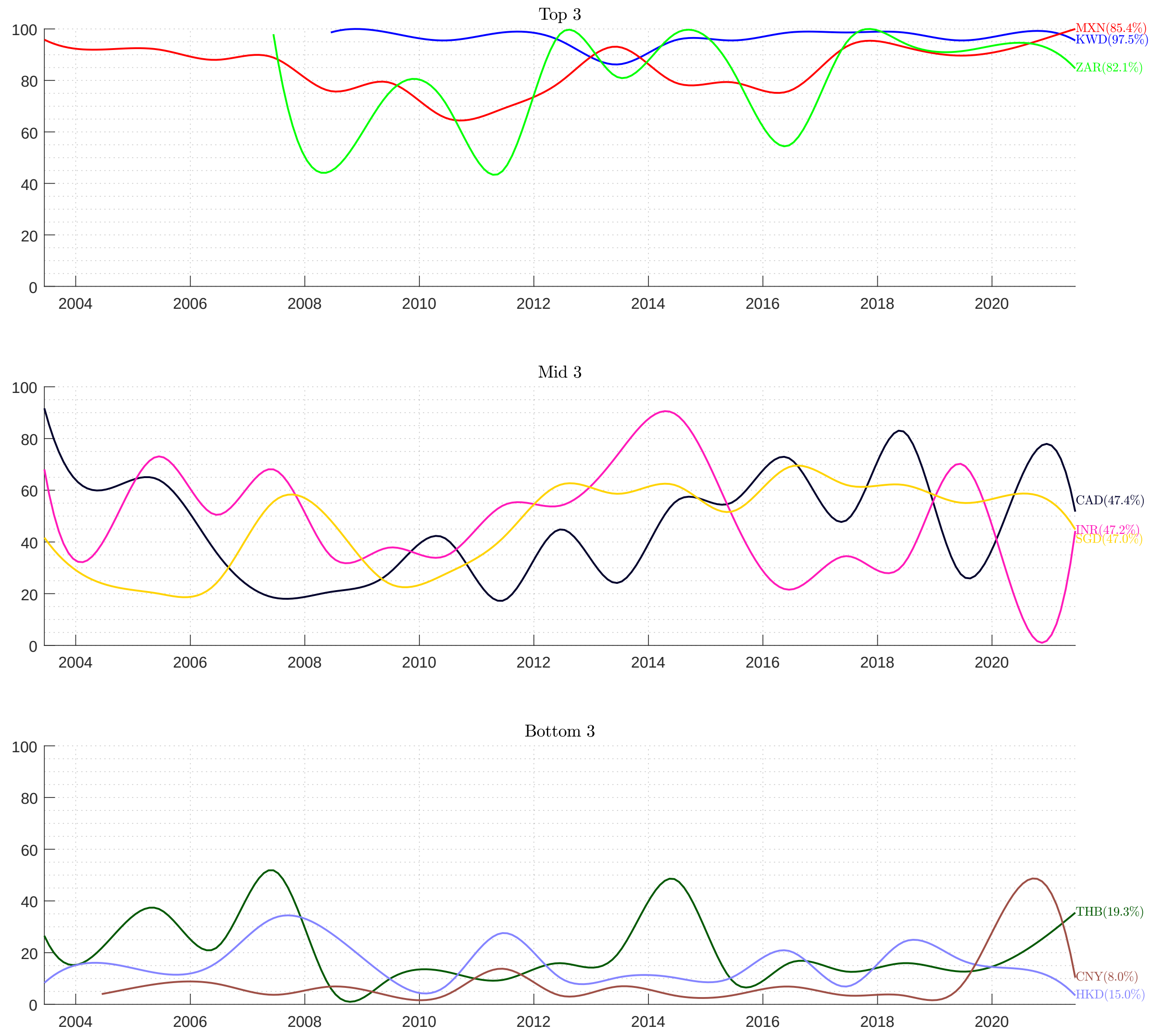


(b) Spearman correlation in the expanding window



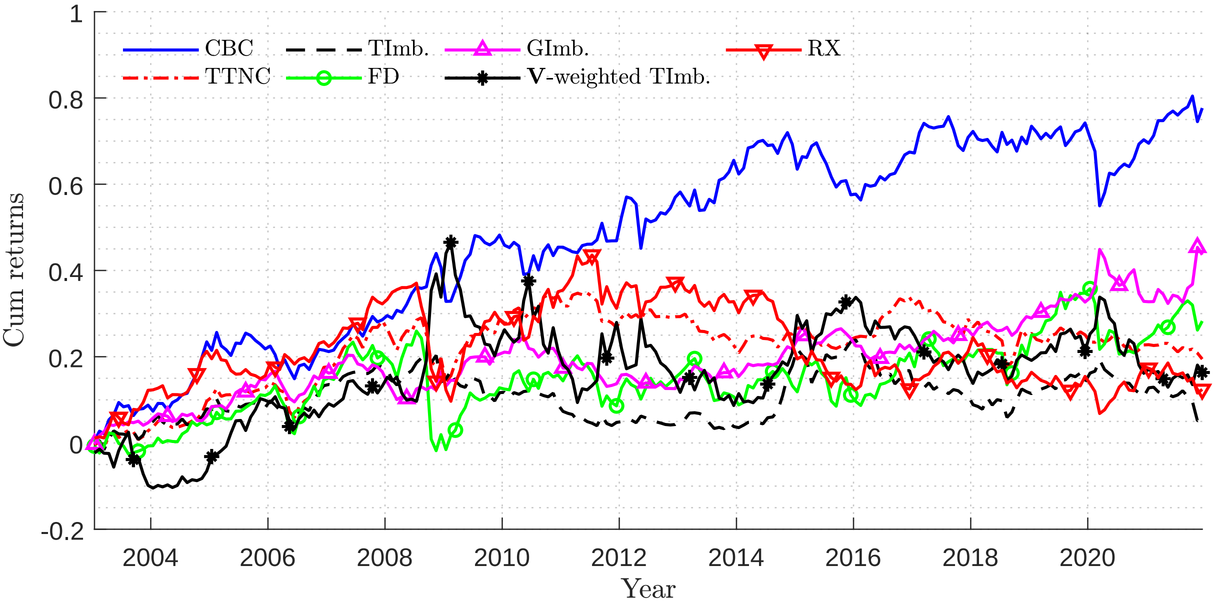
Note: In this figure, Panel (a) plots the calibrated w and α over time; Panel (b) plots Spearman correlations coefficient between all *CBCs* and currency risk premia over time. The sample period is from 2003 to 2021 (and the initial values of w and α are calibrated using data from 1995 to 2002). The data frequency is yearly and the calibration is done in yearly expanding windows. In Panel (b), the solid line is the Spearman correlation of the currency risk premia and the model expected currency return based on calibrated w and α shown in Panel (a), and the dashed line (dash-dotted line) is the Spearman correlation of the currency risk premia and the model expected currency return assuming $w = 0$ and $\alpha = 0$ ($w = 1$ and $\alpha = 0$), i.e., $\mathbf{\Gamma} = \mathbf{V}$ ($\mathbf{\Gamma} = \mathbf{I}$).

Fig. 5: *CBC* relative percentage ranks over time



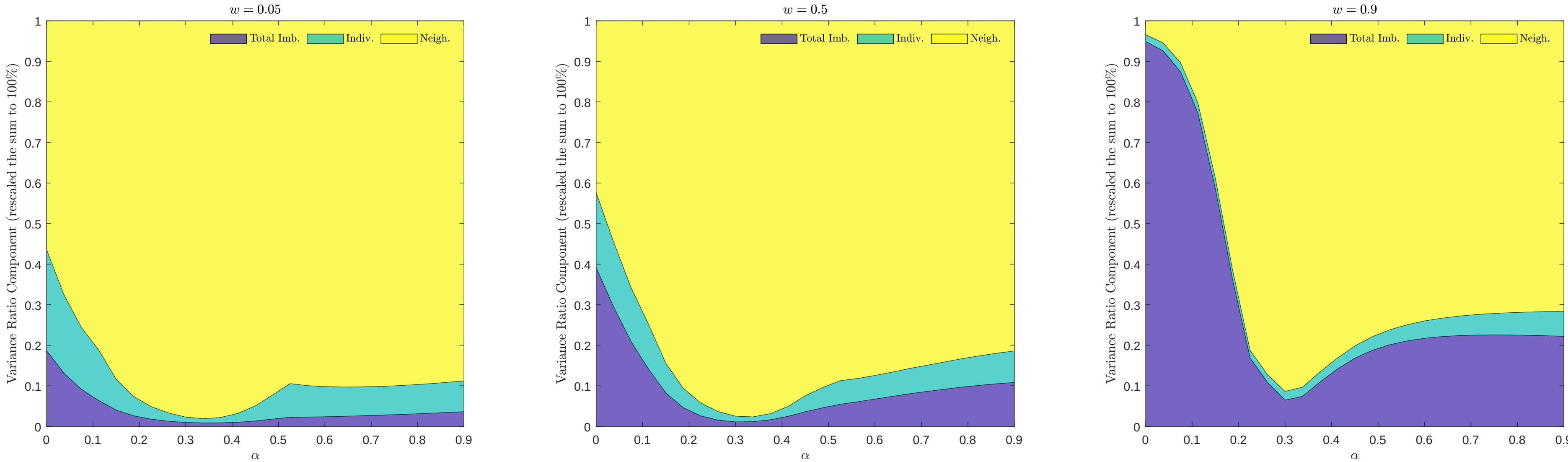
Note: The top, middle, and bottom panels in this figure show the over-time dynamics of the positions of the top, middle, and bottom three currencies, respectively, in the percentage ranks. The currencies in different panels are identified through their full sample average percentage ranks, which are shown in the parentheses right next to their legends in the plot. For example, the top three currencies are the top three currencies with the highest full sample average *CBC* ranks in descending order.

Fig. 6: Cumulative returns over time in portfolio sorting comparison



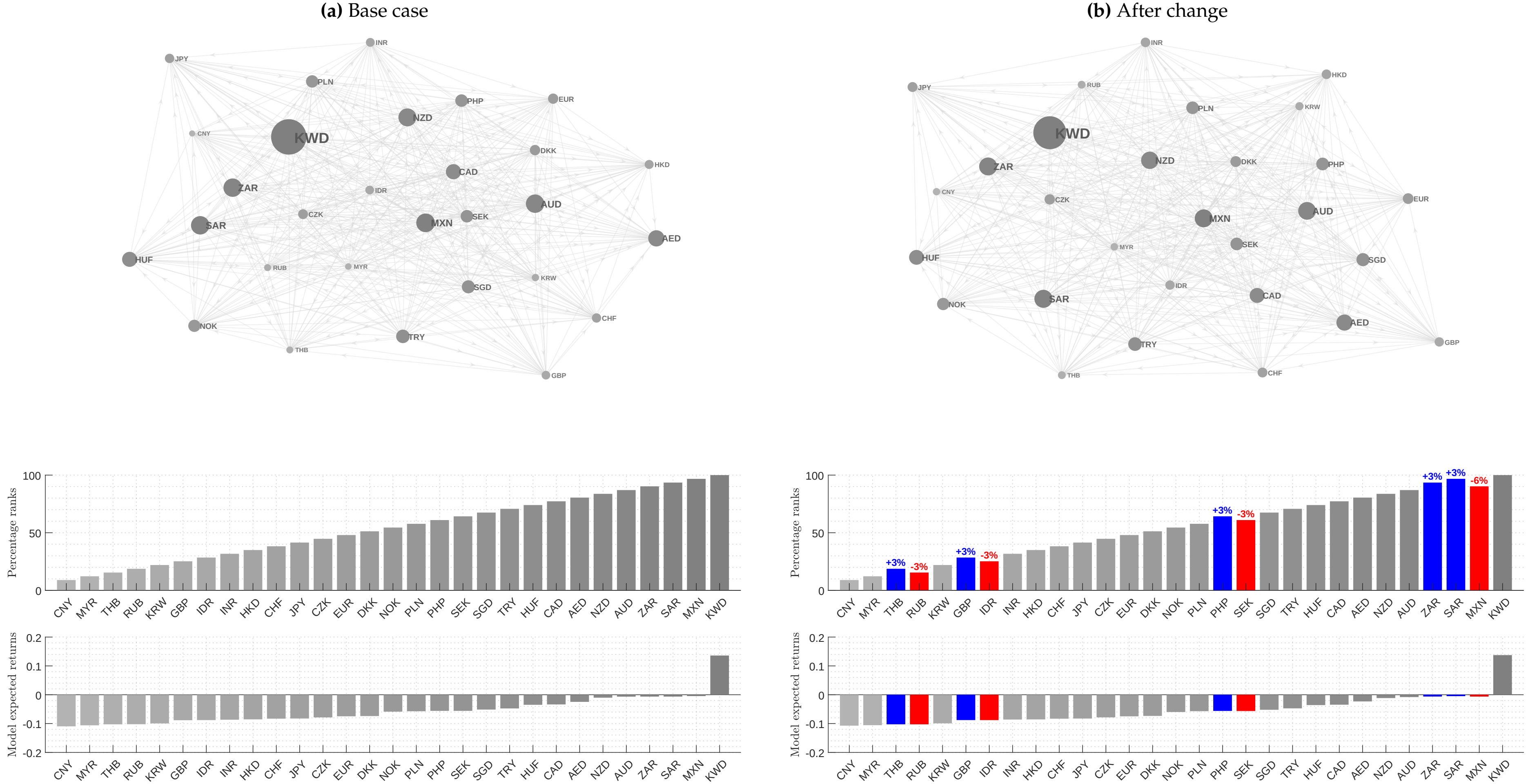
Note: This figure plots the cumulative returns of buying G4 and selling G1 in the portfolio sorting using as characteristics: *CBC*, total trade network centrality (*TTNC*), trade imbalance (*TImb*), forward discount (*FD*), global imbalance (*GImb*), and variance-covariance weighted trade imbalance (**V**-weighted *TImb*), as well as the average currency excess return (*DOL*). *TTNC* is proposed by Richmond (2019), *TImb* is inspired by Gabaix and Maggiori (2015a), *FD* is the carry trade characteristic from Lustig, Roussanov, and Verdelhan (2011), *GImb* is used by Della Corte, Riddiough, and Sarno (2016), and **V**-weighted *TImb* is inspired by Gabaix and Maggiori (2015b). *DOL* is the currency "market" return in dollars available to a U.S. investor (Lustig, Roussanov, and Verdelhan 2011). The sample period is 2003-2021, which is the out-of-sample period in our out-of-sample analysis. All returns are in percentage. All characteristics are constructed based on information one year prior to the realized currency returns. Currencies are sorted in the ascending order of *CBC*, *TImb*, *FD*, and **V**-weighted *TImb*, and in the descending order of *TTNC* into quartiles (G1 to G4). For *GImb* the G1 to G4 are formed from a 2×2 conditional double sorting by nfa and ldc following Della Corte, Riddiough, and Sarno (2016). The sorted portfolios are rebalanced yearly.

Fig. 7: Variance decomposition with varying α and w



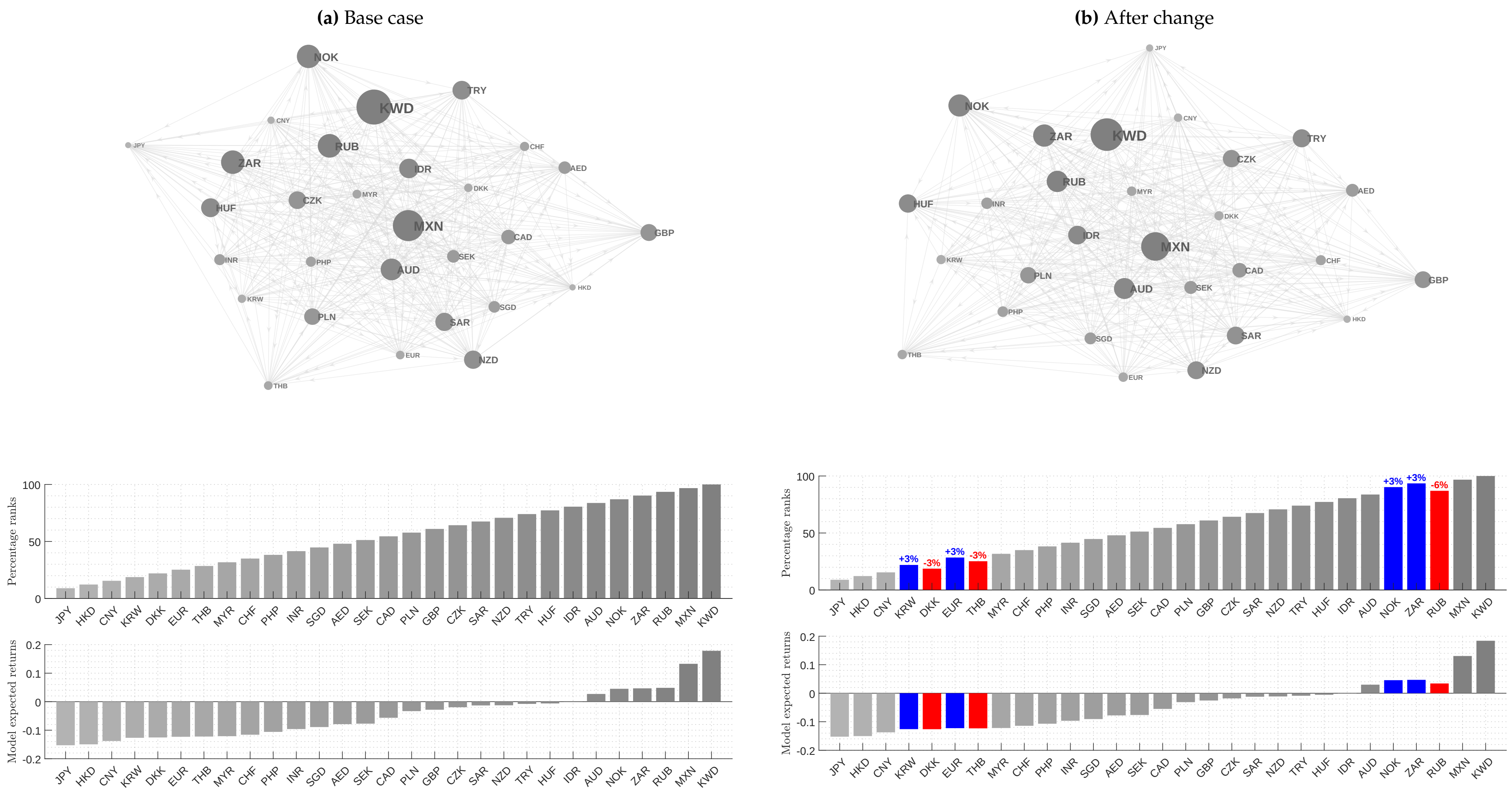
Note: The panels in this figure plot the (re-scaled) variance ratios of total imbalance (Total Imb.), individual importance (Indiv.), and neighborhood importance (Neigh.) given different values of α and w. α goes from 0 to 0.9 in all three panels. The left panel shows the variance ratios components for $w = 0.05$, the center panel for $w = 0.5$, and the right panel for $w = 0.9$. The results are generated based on the data in the out-of-sample period, from 2003 to 2021. For ease of presentation, the variance ratios are re-scaled to sum of one, with their relative importance preserved for each combination of α and w.

Fig. 8: Counterfactual analysis: the effect of US-China trade war on currency premia



Note: In this figure, Panel (a) plots the global trade imbalance network based on 2017 pairwise bilateral imports and exports, Panel (b) plots the same network with pairs related to CNY and USD replaced by the data in 2019. The upper parts of the panels are network graphs in which the arrows in edges point toward the debtors (deficit parties), the length of edges is inversely proportional to the size of the relative deficit, and the size of nodes is proportional to their *CBC*. The middle and lower parts in Panel (a) show respectively the percentage ranks of all currencies' *CBC*s in ascending order and rank-preserved transformed *CBC*s matching the cross-sectional mean and standard deviation of currency risk premia in 2017 for the base case; while the middle part in Panel (b) shows the same order with currencies, whose ranks have changed, highlighted: currencies becoming lower (higher) in the ranks are highlighted in red (blue) bars and the size of changes is indicated on the top of the bars; the lower part in Panel (b) shows the rank-preserved transformed *CBC*s after the change.

Fig. 9: Counterfactual analysis: the effect of collective sanctions on Russia on currency premia



Note: In this figure, Panel (a) plots the global trade imbalance network based on 2021 pairwise bilateral imports and exports, Panel (b) plots the same network with the values of elements in the adjacency matrix related to RUB and a group of currencies shrink by 90%. The group of currencies are USD, EUR, GBP, AUD, JPY, CAD, CHF, NOK, PLN, KRW, and NZD, with reference to Funakoshi, Lawson, and Deka (2022). The upper parts of the panels are network graphs in which the arrows in edges point toward the debtors (deficit parties), the length of edges is inversely proportional to the size of the relative deficit, and the size of nodes is proportional to their *CBC*. The middle and lower parts in Panel (a) show respectively the percentage ranks of all currencies' *CBC*s in ascending order and rank-preserved transformed *CBC*s matching the cross-sectional mean and standard deviation of currency risk premia in 2021 for the base case; while the middle part in Panel (b) shows the same order with currencies, whose ranks have changed, highlighted: currencies becoming lower (higher) in the ranks are highlighted in red (blue) bars and the size of changes is indicated on the top of the bars; the lower part in Panel (b) shows the rank-preserved transformed *CBC*s after the change.

Table 1: Portfolio sorting performance comparison

Sorting Var.	G1	G2	G3	G4	G4-G1	
					return	Sharpe
CBC (updated)	−0.06	0.13	0.20	3.14	3.21**	0.54
CBC (static)	−0.33	−0.05	0.50	3.25	3.58***	0.65
TTNC	0.74	−0.54	1.30	1.78	1.04	0.23
TImb	0.37	0.37	1.71	0.76	0.40	0.08
FD	−0.12	0.49	1.41	1.49	1.61	0.21
GImb	−1.00	0.96	1.72	1.01	2.01*	0.45
V-weighted *TImb*	0.21	−0.17	1.69	1.44	1.23	0.13
DOL	-	-	-	-	0.83	0.13

Note: This table shows the performance comparison among portfolios sorted by: *CBC*, total trade network centrality (*TTNC*), trade imbalance (*TImb*), forward discount (*FD*), and global imbalance (*GImb*), variance-covariance weighted trade imbalance (**V**-weighted *TImb*), as well as the average currency excess return (*DOL*). *TTNC* is proposed by Richmond (2019), *TImb* is inspired by Gabaix and Maggiori (2015a), *FD* is the carry trade characteristic from Lustig, Roussanov, and Verdelhan (2011), *GImb* is used by Della Corte, Riddiough, and Sarno (2016), and **V**-weighted *TImb* is inspired by Gabaix and Maggiori (2015b). The *DOL* is the currency "market" return in dollars available to a U.S. investor (Lustig, Roussanov, and Verdelhan 2011). The sample period is 2003 to 2021, which is the out-of-sample period for α and w calibration. Two sets of results, "updated" and "static", are reported for *CBC* where *CBC* (updated) is calculated based on annually updated α and w while *CBC* (static) is based on static α and w calibrated from the initial sample before 2023. All returns and Sharpe ratios are annualized and the sorted portfolios are rebalanced yearly. All returns are in percentage. All characteristics are constructed based on information from the previous calendar year-end. Currencies are sorted in the ascending order of *CBC*, *TImb*, *FD*, and **V**-weighted *TImb*, and in the descending order of *TTNC* into quartiles (G1 to G4). For *GImb* the G1 to G4 are formed from a 2×2 conditional double sorting by nfa and ldc following Della Corte, Riddiough, and Sarno (2016). The last two columns, respectively, report the average return and Sharpe ratio of the returns from longing G4 and shorting G1. ***, **, and * indicate the statistical significance level of 1%, 5%, and 10%, respectively. The significance level for the average return is calculated from t-test.

Table 2: Time-series variation of *CBC* factor in relation to various factors

(a) How well various factors explain the *CBC* factor

CBC is on LHS	Alpha (%)	T-Alpha	Beta	T-Beta	R^2
TTNC	2.78**	2.43	0.41***	3.51	10.00%
TImb	3.18***	2.73	0.06	0.50	0.24%
FD	2.75**	2.24	0.29**	2.23	13.44%
GImb	3.35***	3.00	−0.07	−0.40	0.29%
V-weighted *TImb*	3.48***	3.07	−0.22**	−2.38	12.02%
DOL	2.84**	2.42	0.44***	3.33	23.98%
AEM	3.91***	2.82	0.23	1.45	4.14%
HKM	3.04**	2.56	0.11	0.91	0.54%

(b) How well the *CBC* factor explains various factors

CBC is on RHS	Alpha (%)	T-Alpha	Beta	T-Beta	R^2
TTNC	0.26	0.26	0.25***	3.80	10.00%
TImb	0.27	0.25	0.04	0.49	0.24%
FD	0.10	0.07	0.47***	3.65	13.44%
GImb	2.13**	1.97	−0.04	−0.39	0.29%
V-weighted *TImb*	2.97	1.56	−0.55***	−3.05	12.02%
DOL	−0.90	−0.68	0.54***	5.63	23.98%
AEM	−1.52	−1.02	0.18	1.53	4.14%
HKM	1.39	1.43	0.05	0.98	0.54%

Notes: Panel (a) in this table presents the Alpha and Beta coefficients from regressing the *CBC* factor (defined as the G4 - G1 portfolio returns) on various factors. Panel (b) presents the Alpha and Beta coefficients from regressing various factors on the *CBC* factor. The column labeled 'T-Alpha' ('T-Beta') reports the t-statistics of Alpha (Beta) estimates based on Newey-West standard errors. Alpha estimates are in annualized percentage. ***, **, and * indicate 1%, 5%, and 10% significance levels, respectively. The sample peiod is 2003-2021.

Table 3: Variance decomposition of cross-sectional currency premia

(a) Mean and variance ratio

	$\Delta rp_{i,j}$	Total Imb.	Indiv.	Neigh.
Mean	-0.014	-0.007	0.005	-0.013
	(0.116)	(0.039)	(0.026)	(0.096)
VR	-	0.114	0.049	0.684
		(0.055)	(0.037)	(0.131)

(b) Correlation matrix

	$\Delta rp_{i,j}$	Total Imb.	Indiv.
Total Imb.	0.568		
	(0.159)		
Indiv.	0.073	-0.424	
	(0.261)	(0.305)	
Neigh.	0.958	0.392	-0.007
	(0.032)	(0.159)	(0.244)

Note: Panel (a) presents the sample mean (Mean) of $\Delta rp_{i,j}$, total imbalance (Total Imb.), individual importance (Indiv.) and neighborhood importance (Neighb.), and the variance ratio (VR) of Total Imb., Indiv. and Neighb. VR is defined as ratio of sample variance of one of the three components to that of $\Delta rp_{i,j}$. Panel (b) presents the correlation coefficient matrix of $\Delta rp_{i,j}$, Total Imb., Indiv. and Neighb. Standard errors are shown in parentheses. The standard error of Mean is the sample standard deviation. Other standard errors are the time-series standard deviation of yearly estimates. The sample peiod is 2003-2021.

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Appendices

A Recursive equilibrium

In this appendix, we relate eq. (8) to the optimization problem financiers need to solve. We first show that eq. (8) is the solution to the problem in the case of x_0 and $\mathbf{\Gamma}_0$ being exogenous to q, then use a recursive optimization to show that eq. (8) holds even if x_0 and $\mathbf{\Gamma}_0$ are endogenously linked to q. In the latter case, we assume the recursive optimization converges, which amounts to the existence of solution to a fixed point problem. Since we only consider eqs. (5) and (8), we set $\boldsymbol{\xi}_t$ and $\mathbb{E}(\bar{x}_1)$ as exogenous.

A.1 Exogenous x_0 and $\mathbf{\Gamma}_0$

The financiers optimally set q to maximize their expected return while subject to a quadratic outside option constraint:

$$\max_q \mathbb{E}\left(\bar{x}_1 - x_0\right)^\intercal \mathbf{D}_0^{-1} q, \;\; s.t. \;\; \mathbb{E}\left(\bar{x}_1 - x_0\right)^\intercal \mathbf{D}_0^{-1} q \geq q^\intercal \mathbf{D}_0^{-1} \mathbf{\Gamma}_0 q. \tag{A1}$$

Following Gabaix and Maggiori (2015b, footnote 64), we solve eq. (A1) by assuming that $\mathbb{E}\left(\bar{x}_1\right)$, x_0, and $\mathbf{\Gamma}_0$ are exogenous to q. To solve eq. (A1), we set up the Lagrangian:

$$\mathcal{L} = \mathbb{E}\left(\bar{x}_1 - x_0\right)^\intercal \mathbf{D}_0^{-1} q + \lambda \left[\mathbb{E}\left(\bar{x}_1 - x_0\right)^\intercal \mathbf{D}_0^{-1} q - q^\intercal \mathbf{D}_0^{-1} \mathbf{\Gamma}_0 q\right] \tag{A2}$$

The FOC w.r.t q implies:

$$\mathbb{E}\left(\bar{x}_1 - x_0\right) = \frac{2\lambda}{1+\lambda} \mathbf{\Gamma}_0 q \Leftrightarrow q^\intercal \mathbf{D}_0^{-1} \mathbb{E}\left(\bar{x}_1 - x_0\right) = \frac{2\lambda}{1+\lambda} q^\intercal \mathbf{D}_0^{-1} \mathbf{\Gamma}_0 q. \tag{A3}$$

Since the right-hand side of the constraint in eq. (A1) is convex in q, the constraint always binds. From eq. (A3), this means $\lambda = 1$. Therefore, we have $\mathbb{E}\left(\bar{x}_1 - x_0\right) = \mathbf{\Gamma}_0 q$ which is eq. (8).

A.2 Endogenous x_0 and $\mathbf{\Gamma}_0$ and recursive optimization

Now, we relax the assumption that x_0 and $\mathbf{\Gamma}_0$ are exogenous to q and allow them to be endogenously linked to q. Indeed, from the market clearing condition eq. (2), we know x_0 is related to q and $\boldsymbol{\xi}_0$ (assuming $\boldsymbol{\xi}_0$ is exogenous). Also, $\mathbf{\Gamma}_0$ changes with x_0 via $\mathbf{A}_0$, as we assume $\mathbf{\Gamma}$ is a function of $\mathbf{A}$.

Starting with some initial $\tilde{x}_0$ and $\tilde{\mathbf{\Gamma}}_0$, the financiers follow the steps in Appendix A.1 and obtain an optimal $\tilde{q}_1$ satisfying

$$\mathbb{E}\left(\bar{x}_1 - \tilde{x}_0\right) = \tilde{\mathbf{\Gamma}}_0 \tilde{q}_1. \tag{A4}$$

While the financiers are adjusting to $\tilde{q}_1$, the market clearing condition eq. (2) results in new $\tilde{x}(\tilde{q}_1)$ and $\tilde{\mathbf{\Gamma}}(\tilde{q}_1)$, which will induce the financiers to obtain a new optimal $\tilde{q}_2$. Continuing this process imposes a recursive formula for $\tilde{q}_k$ with $k \geq 1$:

$$\tilde{q}_{k+1} \tilde{\mathbf{\Gamma}}(\tilde{q}_k) = \left[\mathbb{E}(\bar{x}_1) - \tilde{x}(\tilde{q}_k)\right]. \tag{A5}$$

We assume that $\tilde{q}_k$ converges to q as k increases, i.e., $\lim_{k\to\infty} \tilde{q}_k = q$. This assumption is equivalent to assuming there exists a solution of q to the following fixed point problem:

$$q \tilde{\mathbf{\Gamma}}(q) = \left[\mathbb{E}(\bar{x}_1) - \tilde{x}(q)\right]. \tag{A6}$$

With this assumption, when the above recursive process converges, period 0's equilibrium is reached, in which we have $x_0 = \tilde{x}(q)$, $\mathbf{\Gamma}_0 = \tilde{\mathbf{\Gamma}}(q)$, and

$$\mathbb{E}\left(\bar{x}_1 - x_0\right) = \mathbf{\Gamma}_0 q.$$

A detailed algorithm solving this recursive equilibrium alongside a three-country numerical example is presented in Appendix B.

B Numerical example of recursive equilibrium

We partition q, $\mathbf{\Gamma}$, x_t, and $\boldsymbol{\xi}_t$ as

$$q = \begin{bmatrix} \underbrace{q_1}_{1\times 1}, & \underbrace{q_p^\intercal}_{1\times(n-1)} \end{bmatrix}^\intercal; \; \mathbf{\Gamma} = \begin{bmatrix} \underbrace{\gamma}_{1\times 1} & \underbrace{\Gamma_{\text{row1}}}_{1\times(n-1)} \\ \underbrace{\Gamma_{\text{col1}}}_{(n-1)\times 1} & \underbrace{\mathbf{\Gamma}_p}_{(n-1)\times(n-1)} \end{bmatrix};$$

$$x_t = \begin{bmatrix} 1, & \underbrace{x_{t,p}^\intercal}_{1\times(n-1)} \end{bmatrix}^\intercal; \; \boldsymbol{\xi}_t = \begin{bmatrix} \underbrace{\xi_{t,1}}_{1\times 1} & \underbrace{\xi_{t,\text{row1}}}_{1\times(n-1)} \\ \underbrace{\xi_{t,\text{col1}}}_{(n-1)\times 1} & \underbrace{\boldsymbol{\xi}_{t,p}}_{(n-1)\times(n-1)} \end{bmatrix}.$$

Since $\ell^\intercal q = 0$, we have $q_1 = -\ell^\intercal q_p$. By construction, country 1 is the US and $\{\tilde{x}_1\}_1 = \{x_0\}_1 = 1$. Therefore, we set $\gamma = 0$ and $\Gamma_{\text{row1}} = 0$.

Given $\tilde{x}_0$ and $\tilde{\mathbf{\Gamma}}$, the optimal $\tilde{q}_p$ is given by:

$$\tilde{q}_p(\tilde{x}_{0,p}, \tilde{\mathbf{\Gamma}}) = \left(\tilde{\mathbf{\Gamma}}_p - \tilde{\Gamma}_{\text{col1}}\ell^\intercal\right)^{-1}\left[\mathbb{E}\left(x_{1,p}\right) - \tilde{x}_{0,p}\right]. \tag{A7}$$

Given a $\tilde{q}$, by eq. (2) we have:

$$\tilde{x}_p(\tilde{q}_p, \boldsymbol{\xi}_0) = \left(\ell\xi_{0,\text{row1}} + \boldsymbol{\xi}_{0,p}\right)^{-1}\left[(\mathbf{I} - \ell\ell^\intercal)\tilde{q}_p - (\ell\xi_{0,1} + \xi_{0,\text{col1}})\right]. \tag{A8}$$

The recursive equilibrium can be solved using Algorithm 1.

Setting $\mathbf{\Gamma} = (\mathbf{I} - \alpha\mathbf{A}_0^\intercal)^{-1}$ and obtaining $\mathbf{A}_0$ from x_0 and $\boldsymbol{\xi}_0$ via eq. (3), we show a three-country numerical example in Figure A1. In this example, the convergence happens quickly (within six iterations) and is robust to different initial values. This numerical example shows that the existence of solution to the fixed point problem of eq. (A6) is a mild assumption.

[*Insert Figure A1 about here*]

Algorithm 1 An algorithm for solving the recursive equilibrium

$x_0 \leftarrow \tilde{x}_0$
$\mathbf{\Gamma} \leftarrow \tilde{\mathbf{\Gamma}}_0$
$q_p \leftarrow \tilde{q}_p(x_{0,p}, \mathbf{\Gamma})$
while $\left| q_p - q_p^* \right| > \varepsilon$ **do**
    $q_p^* \leftarrow q_p$
    $x_{0,p} \leftarrow \tilde{x}_p(q_p^*, \boldsymbol{\xi}_0)$
    $\mathbf{\Gamma} \leftarrow \tilde{\mathbf{\Gamma}}(x_0, \boldsymbol{\xi}_0)$
    $q_p \leftarrow \tilde{q}_p(x_{0,p}, \mathbf{\Gamma})$
end while

C Details of constructing the trade imbalance networks

In this subsection, we give one example of how we construct the imbalance networks based on currencies used in five countries/areas: Euro area, the US, New Zealand, Japan, and Mexico. In the original data, each country reports its import and export (in USD) from all trade partners. As mentioned in the paper, in order to keep the reported export and import consistency, we choose to use the exports reported by each country. A small sample of the trade data in 2018 are shown in Table A2. RISO and PISO are the ISO of the reporting and trading partner countries, respectively. We first use the import of each country by the reported export of its trade partners, and then calculate the trade balance as the difference between the export and import values, i.e., export minus import (see Table A3). After this, we use the "Balance" column in Table A3 to create an edge for each paired trading partners, which reveals a binary relation, either deficit or surplus. The absolute value of the balance is the edge/link size (see Table A4) of the deficit or surplus trade network. However, countries that have the same amount of deficit may be exposed to different levels of risks if these countries have very different amount of total trade. For example, if country A has a deficit of $20000, and its total trade is $2 million, then the relative deficit to its total trade is just 1% compared with another country B with the same amount of deficit but a total trade of $200000, whose relative deficit would be 10%. It is obvious that country B is riskier than country A. Therefore, we construct the trade network by normalizing the imbalance by the total trade of paired countries.

[*Insert Tables A2 to A4 about here*]

In the trade deficit network, the direction always points to the deficit country (the target node). The deficit network constructed with the above-mentioned five countries is visualized in Figure A2. The left panel plots the network edged/linked with the pairwise value of the deficit. The right panel plots the network edged/linked with *RTL*, i.e., the pairwise deficit normalized by the total trades. From Figure A2, we can see that the risk of the same amount of deficit is very different for the countries with different total trade: in the right panel of Figure A2, currency risk would be smaller for the US, which has a deficit from the Euro area after normalizing the deficit by the total trades of these two currencies, than as shown in the left panel of Figure A2 where the US has a deficit from the Euro area without normalizing by their total trade.

[*Insert Figure A2 about here*]

D Construction of the tradable AEM and HKM factors

AEM use shocks to the leverage of securities broker-dealers to construct an intermediary discount factor, they find that this factor can price size, book-to-market, momentum, and bond portfolios. Congruently, HKM use shocks to the equity capital ratio of financial intermediaries to construct a systematic risk factor and find that exposures to this factor have significant explanatory power for cross-sectional variation in expected returns in many assets.

We follow Fama and French (1993) and form portfolios using the individual currency returns based on factor betas, where betas are computed using expanding window regressions. We form four portfolios based on ex-ante betas of the AEM and HKM factors.[23] We use the high-minus-low portfolio (portfolio 4 minus portfolio 1) as tradable proxies of AEM and HKM factors.

E Supplementary results

This appendix contains supplementary results omitted in the main text. We further verify the predictability of the *CBC* on currency returns by regressing either the future FD (top panel) or currency excess returns (bottom panel) on *CBC*. In the regressions, we control for various economic variables used in the existing currency asset pricing literature. Following Richmond (2019, Table I), all regression specifications include year-fixed effects. The results are reported in Table A5. We can see from the table that one standard deviation in *CBC* increases FD by about 1.2% and currency excess returns by about 1.5%. The coefficients are all statistically significant

23. AEM factor data are available at https://sites.google.com/site/tylersmuir/home/data-and-code and HKM factor data are available at https://voices.uchicago.edu/zhiguohe/data-and-empirical-patterns/intermediary-capital-ratio-and-risk-factor/.

at least at the 5% significance level. We consider five control variables that are commonly used in the existing currency asset pricing literature.

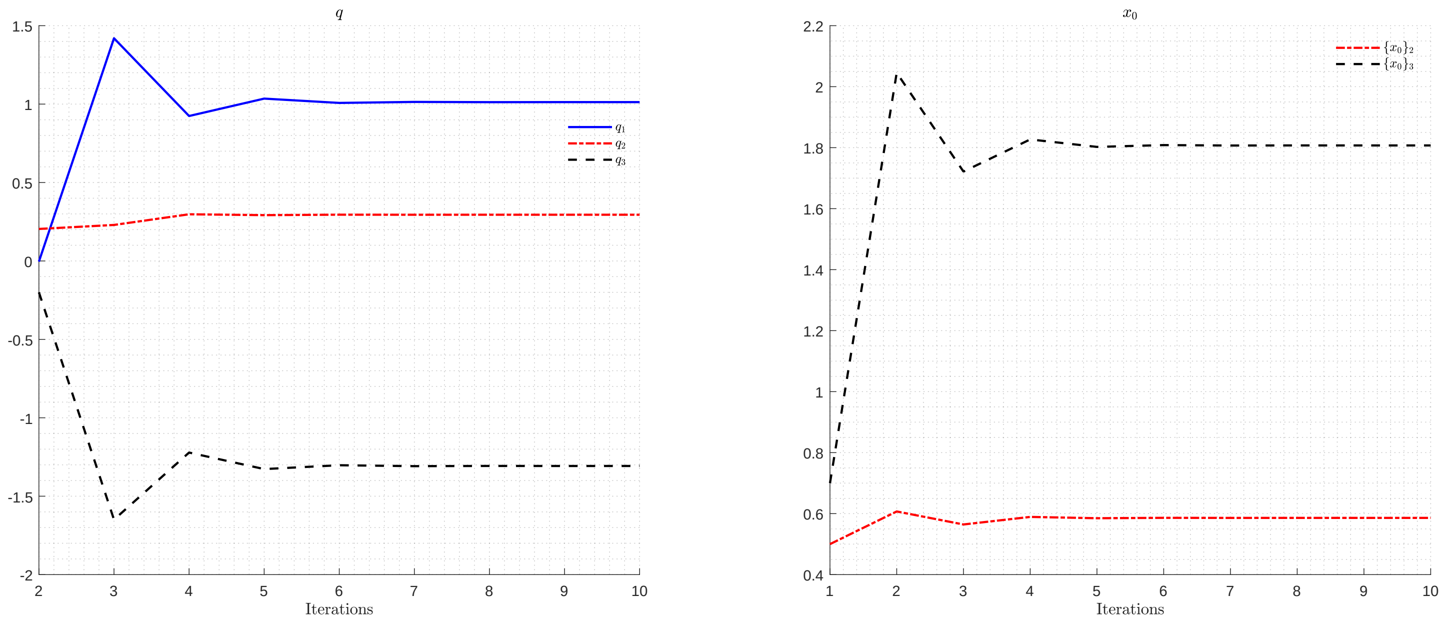
Economy size (GDP) Central countries may be large on average, and the size of a country affects its trade and deficit. Therefore, we first control for the size using GDP following Hassan (2013). We find that the centrality coefficient is effectively unchanged and the magnitude of the centrality effect remains unchanged.

Trading size (trade to GDP) To make sure our results are not driven by trade size, we control for a country's total trade-to-GDP ratio, a measure of trade size. As shown in the table, *CBC* still matters for *FD* and currency premia after controlling for the trade to GDP.

Deficit size (deficit to trade and deficit to GDP) We also control for the size of the total deficit by including the deficit to trade and deficit to GDP, which effectively controls for Della Corte, Riddiough, and Sarno (2016)'s total imbalance effect to a large extent. We find no significant change in the coefficient of *CBC* after controlling for either deficit to trade or deficit to GDP.

Global production risk (total trade network centrality) Finally, we also control for the total trading network centrality of Richmond (2019), and the results remain unchanged, indicating our results are not driven by the risk channel argued by Richmond (2019).

Fig. A1: Convergence in the recursive equilibrium

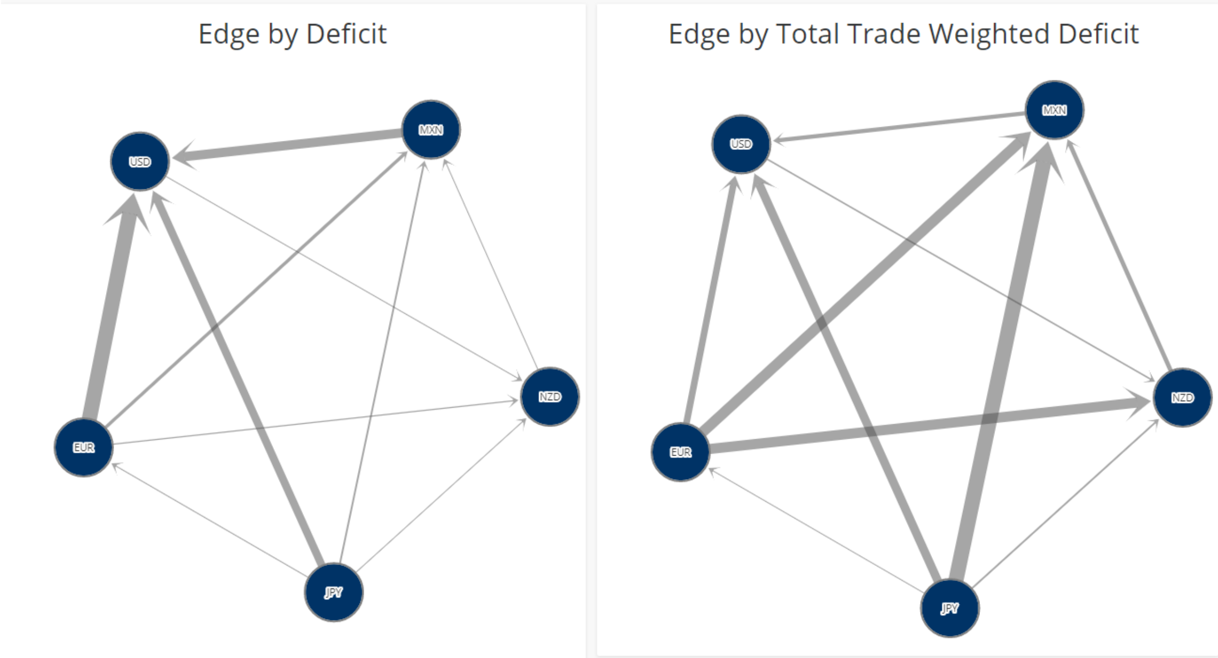


Note: This figure plots how q and x_0 converge to equilibrium values within 10 interactions in the recursive equilibrium described in Appendices A and B based on a three-country numerical example. The left (right) panel shows the convergence paths of q (x_0). The numerical values for ξ are given by

$$\xi_0 = \begin{bmatrix} 10, & -3, & -4 \\ -2, & 7, & -1 \\ -8, & -4, & 5 \end{bmatrix}.$$

$\alpha = 0.4$ for the $\mathbf{\Gamma}$ function. The initial values of $\tilde{x}_0$ are $[1, 0.5, 0.7]^\intercal$. The equilibrium values of x_0 and q are $x_0 = [1, 0.59, 1.81]^\intercal$; $q = [1.01, 0.29, -1.30]^\intercal$.

Fig. A2: Global trade imbalance network Construction



Metrics			Deficit		
Currency	EUR	JPY	MXN	NZD	USD
EUR			2E+10	2E+09	1E+11
JPY	6E+08		8E+09	2E+08	7E+10
MXN					8E+10
NZD			6E+07		
USD				2E+08	

Metrics			Weighted Deficit		
Currency	EUR	JPY	MXN	NZD	USD
EUR			0.3842	0.3658	0.2271
JPY	0.0050		0.5602	0.0376	0.3031
MXN					0.1298
NZD			0.1387		
USD				0.0287	

Notes: This figure shows an example of how we construct the directional trade imbalance network with five economies: the Euro area, the US, New Zealand, Japan, and Mexico. The left panel plots the network edged with the pair-wise value of the deficit. The right panel plots the network edged with the pair-wise deficit normalized by the total trades of the paired economies. All empty cells in the tables in both panels are zero.

Table A1: Sample of countries with currency and trade data

Currency	Country	Start Date	End Date
AED	United Arab Emirates	2007	2021
ATS	Austria	1997	2021
AUD	Australia	1990	2021
BEP	Belgium	1997	2020
CAD	Canada	1990	2021
CHF	Switzerland	1990	2021
CNY	China	2003	2021
CZK	Czech Republic	1997	2021
DEM	Germany	1997	2020
DKK	Denmark	1990	2021
ESP	Spain	1997	2020
EUR	Europe	1999	2021
FIM	Finland	1997	2020
FRF	France	1997	2020
GBP	U.K and Northern Ireland	1995	2021
GRD	Greece	1997	2020
HKD	Hong Kong	1994	2021
HUF	Hungary	1996	2021
IDR	Indonesia	1995	2021
IEP	Ireland	1997	2020
INR	India	1996	2021
ITL	Italy	1997	2020
JPY	Japan	1990	2021
KRW	Korea	2018	2021
KWD	Kuwait	2007	2021
MXN	Mexico	1999	2021
MYR	Malaysia	1990	2021
NLG	Holland	1997	2020
NOK	Norway	1997	2021
NZD	New Zealand	1990	2021
PHP	Philippines	1996	2021
PLN	Poland	1996	2021
PTE	Portugal	1997	2020
RUB	Russia	1996	2021
SAR	Saudi Arabia	2006	2021
SEK	Sweden	1990	2021
SGD	Singapore	1990	2021
THB	Thailand	1995	2021
TRY	Turkey	1995	2021
USD	United States of America	1998	2021
ZAR	South Africa	2006	2021

Notes: This table reports the sample of countries that have both foreign currency data and trade date available. Trade data are collected from the UN Comtrade Database. Foreign currency data are in the monthly frequency collected from the Thomas Reuter's Datastream. The sample covers 41 countries from 1995 to 2021.

Table A2: Sample of reported exports

No.	Year	RISO	PISO	Export value
1	2018	NZL	USA	3,825043,650
2	2018	NZL	EUR	2,138,581,224
3	2018	NZL	JPN	2,423,871,663
4	2018	NZL	MEX	232,374,184
5	2018	USA	NZL	4,051,216,879
6	2018	USA	EUR	229,777,221,710
7	2018	USA	JPN	75,226,085,623
8	2018	USA	MEX	265,434,782,525
9	2018	EUR	NZL	4,605,947,750
10	2018	EUR	USA	364,821,303,175
11	2018	EUR	JPN	59,152,997,645
12	2018	EUR	MEX	39,571,499,573
13	2018	JPN	NZL	2,613,481,256
14	2018	JPN	USA	140,663,642,062
15	2018	JPN	EUR	59,747,235,497
16	2018	JPN	MEX	11,624,698,902
17	2018	MEX	NZL	175,751,837
18	2018	MEX	USA	344,602,283,959
19	2018	MEX	EUR	17,604,199,785
20	2018	MEX	JPN	3,277,293,629

Notes: This table shows the sample data, the exports from five countries/areas in 2018: the US (USA), New Zealand (NZL), Euro (EUR), Japan (JPN), Mexico (MEX). RISO is the ISO code for the reporting country, PISO is the ISO code for the partner country. Trade data are collected from the UN Comtrade Database.

Table A3: Paired trading partners

Year	RISO	PISO	Export	Import	Balance
2018	NZL	USA	3,825043,650	4,051,216,879	-226,173,229
2018	NZL	EUR	2,138,581,224	4,605,947,750	-2,467,366,526
2018	NZL	JPN	2,423,871,663	2,613,481,256	-189,609,593
2018	NZL	MEX	232,374,184	175,751,837	56,622,347
2018	USA	EUR	229,777,221,710	364,821,303,175	-135,044,081,465
2018	USA	JPN	75,226,085,623	140,663,642,062	-65,437,556,439
2018	USA	MEX	265,434,782,525	344,602,283,959	-79 167 501 434
2018	EUR	JPN	59,152,997,645	59,747,235,497	-594 237 852
2018	EUR	MEX	39,571,499,573	17,604,199,785	21 967 299 788
2018	JPN	MEX	11,624,698,902	3,277,293,629	8,347,405,273

Notes: This table shows the sample exports and imports based on five reporting countries trade in 2018. The five countries/areas are the US, New Zealand, the Euro area, Japan, and Mexico. Trade data are collected from the UN Comtrade Database.

Table A4: Deficit or surplus edges

Year	Deficit	Surplus	Balance
2018	NZL	USA	226,173,229
2018	NZL	EUR	2,467,366,526
2018	NZL	JPN	189,609,593
2018	MEX	NZL	56,622,347
2018	USA	EUR	135,044,081,465
2018	USA	JPN	65,437,556,439
2018	USA	MEX	79,167,501,434
2018	EUR	JPN	594,237,852
2018	MEX	EUR	21,967,299,788
2018	MEX	JPN	8,347,405,273

Notes: This table shows the edges (deficit or surplus) used to construct the trade imbalance network using sample export reported from five countries/areas in 2018: the US, New Zealand, the Euro area, Japan, and Mexico. Trade data are collected from the UN Comtrade Database.

Table A5: Regression results for forward discount and currency excess return: with year fixed effect

Forward discount: $f - s$						
CBC	1.227** 0.431	1.187** 0.434	1.113** 0.443	1.110** 0.445	1.210** 0.421	0.954** 0.477
GDP		-0.145** 0.310				
Trade to GDP			-0.543 0.268			
Deficit to trade				-0.240** 0.470		
Deficit to GDP					-0.156 0.326	
Centrality of Rm						-0.531** 0.308
Adjusted R2	0.113	0.112	0.133	0.114	0.113	0.178
Currency premia: rx						
CBC	1.484*** 0.415	1.519*** 0.388	1.531*** 0.433	1.708 *** 0.476	1.492 *** 0.420	1.669*** 0.481
GDP share		-0.129* 0.445				
Trade to GDP			0.224 0.204			
Deficit to trade				0.457 0.295		
Deficit to GDP					0.069 0.157	
Centrality of Rm						-0.023 0.217
Adjusted R2	0.417	0.416	0.416	0.418	0.416	0.460

Notes: This table reports regression results of log forward discount ($f_t - s_t$) and log currency excess return (rx) on *CBC* and various control variables at $t - 1$. The log forward discount and log currency excess return are the yearly averages of annualized observations. The control variables are: GDP share (to the global total GDP), trade to GDP, deficit to total trade ratio, deficit to GDP ratio, and the total trade network centrality of Richmond (2019). The foreign currency and trade data are collected from Datastream and UN Comtrade for 41 countries covering 1/2002-11/2021. *, **, *** denote the significance level at the 10%, 5%, and 1%, respectively.