Global Portfolio Network and Currency Risk Premia*

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Abstract

The position of countries in a network of external portfolio investments provides a novel macroeconomic characteristic to explain violations of uncovered interest rate parity. I derive a network centrality measure, where central countries are highly integrated with key suppliers of tradeable financial assets. Currency risk premia decrease as network centrality increases. Asset pricing tests confirm that the centrality risk factor is priced in the cross-section. Further, negative global shocks appreciate central countries' currencies and depreciate peripheral ones. In a consumption-based capital asset pricing model, central countries experience lower consumption growth in high marginal utility states, leading to currency appreciation.

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1 Introduction

The violations of uncovered interest rate parity (UIP) and the associated profitability of carry trade strategies - which borrow in low-interest-rate currencies and invest in high-interest-rate currencies - have been well documented. A large literature has derived a series of explanations using new variables and models to resolve the anomaly. One natural interpretation of the findings is that persistent interest rate differentials compensate for persistent asymmetries in countries' risk exposure (Hassan and Mano, 2019). Country-specific macroeconomic fundamentals offer an explanation for cross-sectional variation in currency risk premia, for instance, external wealth (e.g., Della Corte et al., 2016; Gourinchas and Rey, 2007, 2022; Caballero et al., 2008; Maggiori, 2017; Wiriadinata, 2021).

Over the last decades, international financial integration has increased rapidly, and gross stocks of foreign assets and liabilities have reached approximately 200% of world GDP (Lane and Milesi-Ferretti, 2017). External portfolio investments create a network of direct and indirect linkages between countries where shocks propagate through the world, but not all countries are affected alike. During times of global stress, some foreign assets are more sensitive to fluctuations in realized returns than others. Therefore, it seems rational to expect that exchange rate changes are linked to external portfolio allocations. Most prominently, risky foreign equity positions of the US tend to fall in bad times accompanied by a US dollar appreciation (Dahlquist et al., 2022).

In this paper, I connect cross-sectional variation in currency risk premia to countries' position in a network of external portfolio investments. Figure 1 depicts the underlying global portfolio network in 2020, where each line represents cross-country portfolio holdings. The circle size measures a country's share in the supply of tradeable financial assets, and the circle position corresponds to a country's network centrality. Countries are central if they have large portfolio holdings of key countries that are important for global capital allocation. Differences across network centralities offer a missing piece of the puzzle in explaining exchange rate changes. Equipped with portfolio sorting and asset pricing methods, I examine asymmetries in external portfolios as a source for varying country risk and discuss the results in a consumption-based capital asset pricing model.

My empirical findings are as follows. First, currency risk premia and interest rates decrease in network centrality. Figure 2 plots averages of currency excess returns and interest rate differentials of a US investor against countries' network centralities. The negative slope implies that investors systematically earn lower excess returns on currencies of central countries. Financial centers and central countries (Eurozone, Japan, Switzerland, United Kingdom) have lower average currency excess returns and interest rates than peripheral countries (Denmark, Hungary, New Zealand). An investment strategy that is long in the currencies of peripheral countries and short in the currencies

of central countries produces an annualized Sharpe ratio of 0.54. Second, in empirical asset pricing tests, I show that the centrality-based risk factor explains cross-sectional variation in currency portfolios and contains information different from other risk factors. Third, in times of global stress, the rate of currency depreciation decreases in network centrality. I discuss these findings in a partial equilibrium building on the implications of a consumption-based capital asset pricing model. Key countries have the most developed financial sectors and supply more tradeable financial assets. As a result, these countries bear a larger fraction of systematic risk. Capital allocations to these countries make investor countries central and increase their exposure to global shocks, resulting in an appreciation of their currencies in high marginal utility states, ceteris paribus.

Taken together, the results presented in this paper support the risk-based view of exchange rate determination conditional on differences in economic fundamentals. Currency excess returns can be viewed as compensation for taking time-varying network centrality risk: interest rate differentials are reversed by predictable exchange rate movements.

Related literature. This paper contributes to the literature on cross-sectional variation in currency risk premia conditional on persistent differences in macroeconomic fundamentals, e.g., country size (Hassan, 2013; Martin, 2013), global imbalances (Della Corte et al., 2016; Gourinchas and Rey, 2007), commodity exports (Ready et al., 2017a,b), trade network centrality (Richmond, 2019; Jiang and Richmond, 2023), fiscal conditions (Jiang, 2022), capital accumulation (Hassan et al., 2016), and distance (Lustig and Richmond, 2020). I study if external portfolio investments are relevant for the risk factor structure in exchange rates.[1] Gourinchas and Rey (2007) and Della Corte et al. (2012) find predictive power in net foreign assets for exchange rates. Della Corte et al. (2016) associate carry trade returns to external imbalances. Wiriadinata (2021) identifies the dominant role of US dollar debt for currency risk premia. Dahlquist et al. (2022) explain large movements in exchange rates with US net foreign asset positions.

Hassan and Zhang (2021) review safe haven characteristics that allow countries to have lower interest rates, e.g., countries with riskier portfolios are expected to pay on average higher returns. The prediction appears at odds for the US, which holds a risky external portfolio and has a low interest rate. Most of the recent work pays attention to the exorbitant privilege of the US (Gourinchas and Rey, 2007, 2022) and the reserve currency paradox of the US dollar (Maggiori, 2017; Farhi and Maggiori, 2018; Jiang et al., 2021; Sauzet, 2023). Caballero et al. (2008) highlight the increasing importance of US assets in global portfolios. Lilley et al. (2022) find that US residents decrease foreign bond holdings in times of high global risk aversion, followed by an

[1]There is a broad empirical and theoretical literature connecting gross external wealth to exchange rates. See, among others, Lane and Milesi-Ferretti, 2002, 2003, 2004, 2007, 2017; Lane and Shambaugh, 2010; Bénétrix et al., 2015; Hau and Rey, 2006; Habib and Stracca, 2012; Ranaldo and Soederlind, 2010; Liao and Zhang, 2020.

appreciation of the US dollar. In Dahlquist et al. (2022), time-varying risk appetite produces asymmetric portfolios, resulting in wealth transfers to the US in stress periods because a US dollar appreciation overturns falling net foreign assets. While the link between external wealth and the US has received some attention, a systematic evaluation for the rest of the world is still missing. My paper connects global portfolios to cross-sectional variation in currency risk in a multi-country framework.

This paper is related to a large literature on systematic deviations from the UIP condition, stating that exchange rate movements should offset interest rate differentials.[2] Lustig and Verdelhan (2007) provide seminal evidence of UIP failing in the cross-section of currency portfolios. A well-established asset pricing literature documents that currency excess returns compensate for exposure to common risk factors.[3] The reduced-form evidence does not reveal the ultimate source of risk. Following the idea that carry trade returns arise from variations in stochastic properties of countries, my paper contributes an economic mechanism behind the cross-section of currency risk premia.

My paper is first studying how financial network integration can explain exchange rates. Elliott et al. (2014) and Acemoglu et al. (2015) show that integrated financial institutions can be more resistant to shocks because important institutions act as shock absorbers but beyond a certain point, the system can become more fragile. Integration with key counterparties may lower the idiosyncratic risk exposure on the one side but could increase systematic risk exposure on the other side.[4]

In the construction of the measure on network centrality, I follow Richmond (2019), who connects currency risk premia to bilateral export intensities in a trade network. The motivation to explore the distinct implications of a portfolio network and a trade network for currency risk premia is twofold. On the one side, one can observe a positive correlation between bilateral goods trade and capital allocation (e.g., Bénétrix et al., 2015; Lane and Milesi-Ferretti, 2008). But on the other side, capital flows are also driven by other factors, e.g., capital market regulations, tax considerations, and investment preferences. These dimensions imply that the dynamics of both networks may differ, with centralities not necessarily correlating with each other. For instance, countries with strong trade ties may have limited portfolio investments due to capital controls or financial market barriers. Therefore, to understand the role of network centralities for exchange

[2] See Hansen and Hodrick (1980), Bilson (1981), and Fama (1984) for early findings on the carry trade anomaly.

[3] Cross-sectional and time-varying currency risk factors can be proxied, for instance, by consumption growth risk (Lustig et al., 2011), US dollar risk (Lustig et al., 2014; Verdelhan, 2018), FX volatility (Menkhoff et al., 2012; Mueller et al., 2017), downside risk (Lettau et al., 2014), crash risk (Brunnermeier et al., 2008; Burnside et al., 2011; Farhi and Gabaix, 2016), country risk (Colacito et al., 2020; Menkhoff et al., 2017; Asness et al., 2013), long-run risk (Colacito and Croce, 2011), endowment shocks (Colacito et al., 2018), term risk (Lustig et al., 2019), intermediary risk (Du et al., 2018; Cenedese et al., 2021).

[4] For more evidence on financial networks, see, for instance, Allen and Gale, 2000; Glasserman and Young, 2016; Cabrales et al., 2017; Gai and Kapadia, 2010.

rates requires a careful analysis. This paper builds on Richmond (2019)'s framework by adapting his centrality measure to capture unique dynamics in a global portfolio network, where financial flows are driven by more complex factors than trade alone.

I focus on two testable hypotheses in the empirical analysis:

1. Central countries in the global portfolio network offer lower currency risk premia and interest rates than peripheral countries.

2. When global risk aversion is high, currencies of central countries experience an appreciation while currencies of peripheral countries depreciate.

2 Data

This section describes the data used in the empirical analysis, the computation of currency excess returns and the construction of the measures on network centrality.

Data on exchange rates. The data on daily spot and one-month forward exchange rates vis-à-vis the US Dollar are obtained from Thomson Reuters via Datastream. I sample end-of-month rates from January 2001 to August 2021.[5] The sample comprises at most 26 countries: Australia (AUD), Canada (CAD), Czechia (CZK), Denmark (DKK), Eurozone (EUR), Hong Kong (HKD), Hungary (HUF), India (INR), Indonesia (IDR), Japan (JPY), Kuwait (KWD), Malaysia (MYR) Mexico (MXN), New Zealand (NZD), Norway (NOK), Philippines (PHP), Poland (PLN), Saudi Arabia (SAR), Singapore (SGD), South Africa (ZAR), South Korea (KRW), Sweden (SEK), Switzerland (CHF), Thailand (THB), Turkey (TRY), and United Kingdom (GBP). Table A.1 lists the country sample and corresponding dates of data availability. The currency sample represents more than 90% of the daily total foreign exchange (FX) turnover (Bank for International Settlements, 2022).

Currency excess returns. Let denote s_{it} and f_{it} as the log spot and forward exchange rates in units of foreign currency i per one unit of US dollar at time t. An increase in s_{it} indicates an appreciation of the US dollar. From the perspective of a US investor, the log currency excess returns rx_{it+1} on buying currency i in the forward market at time t and selling it in the spot market after one month, in $t+1$, is computed as

[5] As in Lustig et al. (2011) and other studies, observations with large deviations from covered interest rate parity (CIP) are removed.

$$rx_{it+1} = f_{it} - s_{it+1}, \tag{1}$$

which is equivalent to the log forward discount minus the change in the spot exchange rate: $rx_{it+1} = f_{it} - s_{it} - \Delta s_{it+1}$. If CIP holds, the forward discount is approximately equal to the interest rate differential: $f_{it} - s_{it} \approx i_{it} - i_t$, where i_{it} and i_t denote the foreign and US nominal risk-free interest rates, respectively.[6] In line with the literature, I compute currency excess returns using forward rates rather than interest rate differentials. First, government bonds may contain sovereign default risk, and second, commercial dealers mainly trade using forward contracts (e.g., Koijen et al., 2018). The log currency excess return is approximately equal to the interest rate differential minus the spot exchange rate return

$$rx_{it+1} \approx i_{it} - i_t - \Delta s_{it+1}. \tag{2}$$

I adjust the log currency excess returns for transaction costs using bid-ask quotes on spot and forward rates. The net log currency excess return of an investor who is long in currency i for one month is $rx^l_{it+1} = f^b_{it} - s^a_{i+1}$ where a indicates the ask price and b the bid price. The return accounts for the full round-trip transaction costs of buying the foreign currency at time t and selling at $t+1$ in the spot market.

Data on external portfolios. The end-of-year series of bilateral portfolio investments are drawn from the Coordinated Portfolio Investment Survey (CPIS) released by the International Monetary Fund (IMF). The portfolio holdings are reported on a residency level. For each reporting investor country, the survey reports the market value of investments (divided into equity and investment fund shares, long-term debt (maturity longer than one year), and short-term debt (maturity one year or less)) by residence of the issuer country.[7] The reported foreign assets are held by the following sectors: central banks, banks and other financial intermediaries, general government, non-financial corporations, and households. For the Eurozone, I construct an aggregate with all countries that adopted the Euro until the beginning of my sample by summing up their positions with other non-Euro countries into one entity (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain). The annual CPIS data is

[6] See Akram et al. (2008) for CIP holding on daily and lower frequency data prior to the financial crisis in 2008. Recent literature shows CIP violations in the aftermath (Ivashina et al., 2015; Du et al., 2018). The empirical results presented in this paper remain robust in a post-crisis sample.

[7] According to the CPIS database, equity securities comprise all instruments and records that acknowledge claims on the residual value of corporations or quasi-corporations, after the claims of all creditors have been met. Shares, stocks, participations or similar documents (such as American Depositary Receipts) usually denote ownership of equity. Debt securities are negotiable instruments serving as evidence of a debt. They give the holders the unconditional right to fixed or contractually determined variable payments (i.e., earnings of interest are not dependent on earnings of the debtors).

available from 2001 to 2020. To match monthly exchange rate observations, I keep end-of-period data constant until a new observation becomes available. Except for 2008, the value of total foreign portfolio investments increased continuously over the last two decades.

Lane and Milesi-Ferretti (2008) point out limitations using CPIS data due to incomplete country coverage (e.g., large portfolio holders such as Taiwan and the United Arab Emirates) and underreporting due to offshore centers or third-party holdings. First, I restrict my analysis to flexible exchange rates, wherefore countries mentioned above are excluded. The second limitation can be addressed with implications by Coppola et al. (2021), who highlight a "residency vs. nationality" problem using CPIS data. Global firms often finance themselves through foreign subsidiaries located in tax havens, which results in a distorted view of global portfolios when the offshore issuing affiliate, instead of the issuer's ultimate parent country, is reported.[8] I address this by restating the residency-based CPIS data on a nationality basis. Therefore, I use debt reallocation matrices based on the work in Coppola et al. (2021) obtained from www.globalcapitalallocation.com and add issuances in tax havens to the residency-based external debt liabilities of the country of the issuer's ultimate parent. As the data from Coppola et al. (2021) start in 2007, I apply stable matrices to the 2001-2007 sample period. The reallocation matrices are not available for all countries, wherefore I keep original CPIS data. The estimated country positions in a global portfolio debt network remain relatively stable.

Construction of global portfolio network centrality. I construct the network centrality measure analog to Richmond (2019) but instead of bilateral trade intensities, I measure bilateral financial ties. For each country i at month t, I build the network centrality measure according to

$$v_{it} = \sum_{j=1}^{N} \left(\frac{A_{ijt} + A_{jit}}{G_{it} + G_{jt}} \right) s_{jt}, \tag{3}$$

where A are total bilateral portfolio holdings between country i and j normalized by the pairwise total GDP G of country i and j.[9] Frankel and Rose (1998) and Lane and Milesi-Ferretti (2008) report that countries with high financial integration have more correlated business cycles, and standardizing by GDP also measures the importance of external portfolio values for countries. Finally, each of country i's relation is weighted by the share of country j for the supply of tradeable financial assets. The share s_{jt} is the relation of external held assets issued by country j to the total external assets of all countries

[8] For instance, on a residency basis, Eurozone holdings of a Cayman-Islands-based subsidiary of a Brazilian firm are reported as investments in the Cayman Islands, while on a nationality basis, the investments are classified towards Brazil.

[9] The annual GDP data is from the World Bank.

$$s_{jt} = \frac{\sum_{i=1, i\neq j}^{N} A_{ijt}}{\sum_{i=1}^{N}\sum_{j=1}^{N} A_{ijt}}. \tag{4}$$

s_{jt} measures the contribution of a country j to global portfolios. Weighting portfolio holdings by country-specific investment shares yield a measure of conditional financial integration, i.e., central countries are integrated with countries that contribute substantially to global portfolios.

Figure 3 plots time-series of network centrality rankings of 27 countries from 2001 to 2020. It is not surprising that the Eurozone, United Kingdom, and United States are the most central countries due to their dominance in global portfolios and strong integration. More interestingly, Canada and Japan are central because they have substantial portfolio holdings of these key countries. In contrast, we see that the financial hub Singapore is not as central as one might expect. Singapore has sizeable external portfolio holdings, but investments are biased towards the financial periphery. For instance, the top investment countries of Singapore are South Korea, India, and Malaysia.

3 Network centrality and currency portfolios

3.1 Explanatory power of network centrality

This section presents empirical evidence that currency risk premia decrease in network centrality. I run a simple panel regression

$$y_{it} = \alpha + \delta_t + \beta v_{it-12} + \zeta X_{it-12} + \varepsilon_{it}, \tag{5}$$

where y_{it} are currency excess returns or forward discounts of currency i at month t, respectively. v_{it-12} is standardized one-year lagged network centrality, X_{it-12} is a set of standardized lagged control variables, α is a constant term, and δ_t is a time fixed effect. β and ζ are parameters to be estimated, and ε_{it} is an error term. I use one-year lags to avoid a simultaneity problem that exchange rates affect explanatory variables. Due to intracluster correlation both across time and currencies, I adjust standard errors for clustering by month and currency.[10]

The regressions of currency excess returns and forward discounts are reported in Table 1 and Table 2, respectively. In column 1, Eq. (5) is estimated without any control variables.[11] A one-standard-deviation increase in a country's network centrality decreases currency risk premia statistically significantly by 0.93% per annum at the one-percent level and forward discounts by

[10] The baseline regression omits country fixed effects and includes only time fixed effects since network centralities exhibit relatively stable patterns over time. The main focus of the analysis is to examine how centrality influences the temporal fluctuations in currency returns within each country.

[11] Table A.2 reports correlations between explanatory variables and considered controls.

1.29% per annum at the five-percent level. The effect is economically large, given that the cross-sectional standard deviation of average currency excess returns and forward discounts are 3% and 0.4%, respectively. The R^2 of 46% and 17%, respectively, imply that investment centrality matters for currency excess returns and captures information that is relevant for interest rate differentials. This provides the first evidence for Hypothesis 1.

In column 2, I add trade network centrality according to Richmond (2019) by calculating the measure analog to Eq. (3) but with A_{ijt} being bilateral goods exports between country i and country j, and s_{jt} is the share of exports of country j relative to total trade.[12] Trade network centrality measures the output share weighted average of a country's bilateral exports intensities with all other countries relative to total bilateral GDP. Controlling for both centrality measures decreases the impact of investment centrality to 0.89% for currency excess returns and to 0.79% for forward discounts. Interestingly, the estimated effects of investment centrality remain significant at the five-percent and ten-percent level, respectively. Centrality in a global portfolio network captures different economic linkages between countries than trade network centrality but both measures complement each other in explaining currency risk premia, indicated by increasing R^2.

Next, I follow Hassan (2013) and control in column 3 for country size by using GDP shares (i.e., countries' fraction of world GDP). I find no systematic effect of country size on currency excess returns and forward discounts, and the coefficient of investment centrality is effectively unchanged. In column 4, I add additional a control for financial openness by using countries' total external portfolio holdings normalized by GDP. For example, Singapore has a sizeable investment-to-GDP ratio but is not central in the context of this paper. Consistent with my expectations, the significance of network centrality is not affected even if the estimate for investment centrality is an order of magnitude smaller now. Not unconditional external wealth but integration with key countries matters for exchange rates.

Robustness tests. In the following, various modified versions of Eq. (5) are estimated to ensure robustness of previous results. Table A.3 uses spot exchange rate changes as the dependent variable. The effect of investment centrality turns insignificant. The differences in currency returns are a result of differences in interest rates, and of currency appreciations or depreciations. Table A.4 shows estimations using real interest rate differentials. The negative relation between investment centrality and currency risk premia remains robust after adjusting for inflation differentials. Currencies of central countries are associated with lower nominal and real interest rates on average.

Even if the network centralities are relatively stable over time, countries can become more

[12] Trade data are from IMF Direction of Trade Statistics.

or less central over time, expected to decrease or increase their currency risk premia. Table A.5 and Table A.6 show regressions of currency excess returns and forward discounts on investment centrality including country fixed effects instead of time fixed effects. The coefficients on investment centrality are statistically significant at the five-percent level and negative. As predicted, if a country's centrality increases over time, currency excess returns and interest rates tend to decrease.

Further, I construct two modified measures on network centrality as in Eq. (3) by differentiating between portfolio debt securities and portfolio equity securities. Table A.7 and Table A.8 report the regression results for debt centrality and equity centrality, respectively. The negative relation between currency risk premia and both centrality measures remains mostly robust. On average, a one-standard-deviation increase in portfolio debt centrality has a larger impact on currency excess returns and forward discounts than an increase in portfolio equity centrality. This highlights the differences in riskiness across capital types. While debt flows are characterized by procyclical and volatile dynamics during global financial stress when default risk rises and GDP shrinks, equity flows remain fairly stable (e.g., Brunnermeier et al., 2012; Avdjiev et al., 2022).

Finally, I modify the sample of countries considered in the network centrality measure to address whether individual countries – i.e., especially a large country as the US – drive countries' centralities. Using this modification allows to check whether actually network centrality or just integration with the US correlate with currency excess returns. Therefore, I drop the US as an investor and issuer country and re-estimate Eq. (3). I find that the presented baseline results in Table 1 and Table 2 remain robust.

3.2 Construction of currency portfolios

Following Lustig et al. (2011) and other studies, I sort currencies into portfolios – instead of using individual currencies – to average idiosyncratic risk and focus on systematic risk in later asset pricing tests. The motivation to use portfolios of sorted assets is to reduce the impact of idiosyncratic variance of individual currencies. Sorting currencies into portfolios according to common characteristics should help to identify a source of systematic risk and improve the estimation of standard errors. At the end of each month t, currencies are allocated into four portfolios based on different signals. The log currency excess returns rx^k_{t+1} to portfolio k are computed as an equally weighted average of the log currency excess returns within portfolio k. All portfolios are rebalanced monthly. I use various currency portfolio sortings as test assets in the later asset pricing analysis.

Investment centrality portfolios. I construct investment centrality portfolios by sorting currencies according to a country's prior-year network centrality v_{it-12}, multiplied by (-1). Hence, portfolios are ranked from high to low centrality. Portfolio 1 contains currencies of central coun-

tries, and Portfolio 4 contains currencies of peripheral countries.

Table 3 summarizes the currency composition of the investment centrality portfolios and the respective frequency entering the portfolio. While the first portfolio is tilted toward developed countries, the fourth portfolio contains mostly emerging and developing countries. The turnover is relatively low, showing the persistence of network centrality over time. The currency investment strategy that is long Portfolio 4 and short Portfolio 1 is called CEN. It is noteworthy that the composition of investment centrality portfolios differs from carry trade portfolios, i.e., the information contained in the sorting process is not solely driven by interest rate differentials. For instance, the Norwegian krone is a typical investing currency in carry trades while being a funding currency in network centrality portfolios.

Carry trade portfolios. I build four carry trade portfolios sorted on currency's current forward discount $f_{it} - s_{it}$ (see Lustig et al., 2011). The portfolios are ranked from low- to high-interest-rate differentials relative to the US. Currencies with the lowest (highest) forward discounts are assigned to Portfolio 1 (Portfolio 4). The currency investment strategy that is long Portfolio 4 and short Portfolio 1 is referred to as HML_{FX} (high-minus-low).

Trade network centrality portfolios. Following Richmond (2019), I form four portfolios based on a country's prior-year trade network centrality, multiplied by (-1). The portfolios are ranked from high to low trade network centrality. Portfolio 1 contains currencies of central countries, and Portfolio 4 contains currencies of peripheral countries. The currency investment strategy that is long Portfolio 4 and short Portfolio 1 is called CEN_X.

Dollar portfolio. I build an equally weighted portfolio of all available foreign currencies, namely the Dollar portfolio DOL. The return on DOL is the average return of a US investor who buys all foreign currencies available in the forward market. This is essentially the currency market return of a US investor against a basket of foreign currencies.

Summary statistics of currency portfolios. Table 4 reports descriptive statistics of the currency portfolios. While centrality portfolios are based on unconditional economic fundamentals that are mostly rebalanced only yearly when new information becomes available, the carry trade strategy is derived from the time-series of the returns themselves. The sorting signals are observable at time t, which makes all sorts implementable trading strategies.

Panel A shows that interest rates mostly monotonically increase from central to peripheral countries, resulting in an average interest rate differential spread of 384 basis points. According

to the UIP condition, the average change in the spot exchange rates should equal the average forward discount. Currencies in the last portfolio trade at a forward discount of 341 basis points but only depreciate by 38 basis points, adding up to an average currency excess return of 303 basis points. The 384 basis point spread in the interest rate differential between the fourth and first portfolios translates into an average spread in currency excess returns of 245 basis points. This result provides more evidence for Hypothesis 1.

The findings in Panel B are in line with Lustig et al. (2011) where average currency excess returns increase monotonically from Portfolio 1 to Portfolio 4. The difference in average currency excess returns is unsurprisingly large with 508 basis points given the well-documented profitability of carry trade strategies.

Panel C replicates the results of Richmond (2019) by sorting on trade network centrality and confirms that currency excess returns decrease with trade centrality.

Summary statistics of currency risk factors. Table 5 presents descriptive statistics of the currency investment strategies. CEN has a currency excess return of 2.45% and a Sharpe ratio of 0.54. Compared with HML_{FX} and CEN_X, the performance is slightly smaller but still remarkable. Interestingly, the performance of CEN_X exceeds the findings of Richmond (2019), which could indicate the increasing relevance of trade linkages for exchange rates. In contrast to CEN, the risk factors HML_{FX}, CEN_X, and DOL strategies have a larger kurtosis paired with negative skewness, implying higher exposure to sudden crash risk (Brunnermeier et al., 2008).

4 Asset pricing tests

4.1 Methodology

This section describes the cross-sectional asset pricing approach for expected excess returns. The benchmark in empirical asset pricing relies on a stochastic discount factor (SDF) approach (e.g., Cochrane, 2009). In the absence of arbitrage opportunities, there exists a positive SDF, which is unique if financial markets are complete. The excess returns to portfolio k in period t are denoted as RX_t^k for $k = 1, \ldots, N$ and $t = 1, \ldots, T$. For any valid SDF M, risk-adjusted excess returns have a price of zero and satisfy the Euler equation

$$\mathbb{E}_t \left[M_{t+1} RX_{t+1}^k \right] = 0,$$

with M_{t+1} being a SDF that is linear in the vector of risk factors F_{t+1}, given by

$$M_{t+1} = 1 - b'(F_{t+1} - \mu), \tag{6}$$

where b is the vector of factor loadings, and μ are factor means. The beta pricing model can be defined as a linear representation

$$\mathbb{E}_t \left[RX^k_{t+1} \right] = \beta^k_t \lambda'_t, \tag{7}$$

where the expected excess return on portfolio k is equal to the risk quantities of each portfolio β^k times the factor risk prices λ. The risk exposures of the portfolio to the corresponding factor are $\beta^k_t = \text{Cov}_t(RX_{t+1}, M_{t+1})/\text{Var}_t(M_{t+1})$ and describe the sensitivity of excess returns to the risk factors, whereas the λ quantifies the price of risk per unit of risk exposure.

In the empirical analysis, I estimate traditional two-stage regressions as in the spirit of Fama and MacBeth (1973) (FMB). The first stage relates the expected excess returns to each portfolio k to the risk factors to estimate in-sample beats, i.e., β^k_t are time-series regression coefficients of excess returns RX^k_{t+1} to each portfolio k on the risk factors F_{t+1}. In the second stage, the cross-sectional pricing according to Eq. (7) is imposed by regressions of portfolio excess returns on the time-series betas to estimate the factor risk prices λ. There is no constant in the second step.

4.2 Empirical results

Since network centrality exhibits a substantial persistence over time, it is reasonable to think of it as a relevant pricing factor. The recent literature on cross-sectional asset pricing in FX markets considers a two-factor SDF. The first risk factor is the expected market excess return, measured by the average excess return on a portfolio strategy long in all foreign currencies with equal weights and short in the domestic currency, the DOL factor. This is motivated by the analysis of Lustig et al. (2011) showing that all portfolios load equally on a level factor. For the second risk factor, the literature has employed several return-based factors. For instance, return differences to carry trade portfolios (HML_{FX}) by Lustig et al. (2011), a volatility factor by Menkhoff et al. (2012), or return differences to imbalance portfolios by Della Corte et al. (2016). Following this literature, I aim to substitute the second risk factor with the network centrality factor CEN. First, I consider a two-factor SDF with DOL and CEN as risk factors to test whether currencies that are more exposed to network centrality risk offer higher risk premia. In a horse race, I also employ a three-factor SDF with DOL, CEN, and HML_{FX}. This allows to assess whether CEN has independent pricing power beyond the benchmark factor HML_{FX} in currency asset pricing. I estimate variants of Eq. (6) in the empirical analysis according to

$$M_{t+1} = 1 - b_{DOL}(DOL_{t+1} - \mu_{DOL}) - b_{CEN}(CEN_{t+1} - \mu_{CEN}) - b_{HML}(HML_{FXt+1} - \mu_{HML_{FX}}),$$

where DOL denotes excess return of the Dollar factor, HML_{FX} denotes excess return to a carry trade strategy, and CEN denotes the return to a investment network centrality strategy.

Time-series regressions. In the first step of the FMB procedure, I run time-series regressions

$$rx^k_{t+1} = \alpha^k + \beta^k_{DOL} DOL_{t+1} + \beta^k_{CEN} CEN_{t+1} + \beta^k_{HML_{FX}} HML_{FXt+1} + \varepsilon^k_{t+1}, \tag{8}$$

where rx^k is the excess return to each portfolio k. β^k are estimated risk factor loadings that capture how excess returns are exposed to the factors. ε^k is an error term. Every regression uses the same factors to determine the exposure of each portfolio's return to a set of factors.

I consider three cross-sections as test assets (i.e., four carry trade portfolios, four investment network centrality portfolios, and four trade network portfolios). The standard problem in empirical FX asset pricing models is small sample sizes in cross-sectional regressions. Therefore, I extend the investment network centrality portfolios by two more cross-sections. A larger cross-section of test assets helps to capture the relevance of network centrality risk for portfolio returns to different investment strategies.

The upper panel of Table 7 presents estimates of time-series betas with the two risk factors DOL and CEN and the lower panel adds HML_{FX}. Standard errors are based on Newey and West (1987) with optimal lag selection according to Andrews (1991). All 12 currency portfolios load strongly on the DOL factor and beta estimates are approximately one. The Dollar factor does not explain cross-sectional variation in portfolio excess returns but is necessary for the average level of excess returns. The estimates of β_{CEN} with a two-factor SDF are statistically significant at the one-percent level and monotonically increase from negative values for PF1 (low-yielding currencies) to positive values for PF4 (high-yielding currencies) in all test assets. This is in line with the view that at least part of currency risk premia can be interpreted as compensation for exposure to network centrality risk. With a three-factor SDF including HML_{FX}, the spread between β_{CEN} of high- and low-yielding portfolios shrinks but carry trade portfolios and both network centrality portfolios still load statistically significant on CEN.

Cross-sectional regressions. In the second step of the FMB procedure, I run cross-sectional regressions

$$rx^k = \lambda_{DOL}\hat{\beta}^k_{DOL} + \lambda_{CEN}\hat{\beta}^k_{CEN} + \lambda_{HML_{FX}}\hat{\beta}^k_{HML_{FX}} + \epsilon^k, \tag{9}$$

of each portfolio k's excess return on estimated betas calculated in the first step. Every regression uses constant betas to determine the exposure of the portfolio returns to factor loadings, i.e., if larger risk factor exposure implies higher excess returns. Table 6 shows the estimation results of factor risk prices λ. In the first specification, I consider a two-factor SDF including DOL and CEN as risk factors. In line with other studies, the risk price of the Dollar factor is positive but statistically insignificant (e.g., Lustig et al., 2011; Menkhoff et al., 2012). The estimate of CEN is positive and statistically significant at the one-percent level with a risk price of 0.28% (i.e., 3.36% per annum). A positive estimate of λ_{CEN} provides further evidence in favor of the view that risk premia are higher for currencies whose returns positively comove with the network centrality risk factor, whereas currencies with negative comovement offer lower risk premia. The exposure to network centrality risk can be seen as a fundamental source of risk that needs to be compensated by a premium.

In the second specification, I eventually employ a three-factor SDF including DOL, CEN and HML_{FX} as risk factors. The size of $\lambda_{HML_{FX}}$ is unsurprisingly large and similar to the results presented by Lustig et al. (2011). Even if the size of the risk price from CEN decreases to 0.19%, it remains statistically significant at the five-percent level. The price of risk associated with CEN is still almost half the magnitude of the price of HML_{FX} (i.e., 2.28% versus 5.04% per annum). The R^2 ranges satisfactory from 38% to 53%.

The bottom line is that CEN performs well in pricing the cross-section of currency portfolios, and network centrality risk is priced whether or not HML_{FX} is included as a risk factor in the model. The horse race between carry and network centrality risk suggests that both factors are related but network centrality still captures independent information that is relevant for currency excess returns.

Model fit. The cross-sectional fit of both SDF models and the magnitude of the risk factor exposures and prices support evidence that network centrality matters for systematic currency pricing. The estimated parameters can be used to calculate expected currency excess returns $\mathbb{E}(rx^k) = \hat{\lambda}_{DOL}\hat{\beta}^k_{DOL} + \hat{\lambda}_{CEN}\hat{\beta}^k_{CEN} + \hat{\lambda}_{HML_{FX}}\hat{\beta}^k_{HML_{FX}}$.

Figure 4 plots the realized mean excess returns versus the predicted excess returns for the 12 test assets. The left panel presents cross-sectional pricing errors for a two-factor SDF with DOL and CEN. The model prices not all assets perfectly, especially excess returns of the first (CT1) and fourth (CT4) forward discount-sorted portfolios are over- and underestimated but both portfolios

form an almost straight line.

The right panel shows pricing errors of a three-factor SDF with DOL, CEN, and HML_{FX}. This specification is able to capture the spread between the excess returns quite well. Even if HML_{FX} contributes significantly to price currency returns adequately, CEN offers an economic mechanism behind cross-sectional variation in currency excess returns and has risk-adjusted returns in its own right. The expected excess return implied by the model of the last network centrality-sorted portfolio IC4 is 2.83% per annum. The return share contributed by the exposure to network centrality risk is $12 \times \beta_{CEN}^{IC4} \times \lambda_{CEN} = 12 \times 0.60 \times 0.19 = 1.37\%$ per annum, meaning that nearly half of the risk premium on high-yielding peripheral currencies is associated with compensation for network centrality risk. For the first network centrality-sorted portfolio IC1 (i.e., central currencies), the DOL market risk premium of 2.18% is nearly offset by a yearly negative network centrality risk premium of -0.87% and a carry trade risk premium of -0.84%.

The main finding is that the network centrality risk factor CEN is able to reproduce the spread in mean excess returns between currency portfolios quite well and has significant explanatory power in its own right beyond the benchmark risk factor HML_{FX}.

5 Exchange rates and exposure to global shocks

5.1 Empirical tests

Now turning to Hypothesis 2, stating that when global risk aversion is high, the currency depreciation rate decreases with countries' network centrality. Following Della Corte et al. (2016), I use changes in the VIX volatility index to measure global risk aversion shocks. I estimate a panel regression of monthly log spot exchange rate changes Δs_{it} according to

$$\Delta s_{it} = \alpha_i + \delta_\tau + \beta_1 v_{it-12} + \beta_2 \Delta VIX_t + \beta_3 (\Delta VIX_t \times v_{it-12}) + \varepsilon_{it}, \tag{10}$$

where a negative Δs_{it} indicates a depreciation of currency i against the US dollar ($\Delta s_{it+1} = s_{it} - s_{it+1}$). α_i is a country fixed effect and δ_τ is a year fixed effect. v_{it-12} is standardized one-year lagged network centrality of country i at time t and ΔVIX_t the monthly change in the VIX index. β are estimated coefficients and ϵ_{it} is the error term. Standard errors are clustered by country and month. Since I add country and year fixed effects, regressions can be interpreted as how currencies behave relative to average currency movements in the sample. Alternatively, I include global risk aversion shocks with a dummy variable that takes the value of one when changes in VIX are larger than one standard deviation and zero otherwise. Hypothesis 2 requires a positive interaction coefficient β_3, implying that central countries experience a less sharp currency depreciation at

times of global stress. The results of running Eq. (10) are reported in Table 8.

The coefficients on the change in the VIX index and the interaction terms are statistically significant and of the expected sign. ΔVIX enters the regressions with a negative sign, implying that increasing global risk aversion leads to a general currency depreciation against the US dollar. The interaction terms are positive and statistically significant in both specifications at the ten-percent and one-percent levels, respectively. Countries that are more central in the global portfolio network experience a smaller currency depreciation (if any) during bad times.

Next, I estimate the marginal effects of a change in the VIX index on spot exchange rate changes conditional on network centrality. Average marginal effects are calculated by taking the derivative of spot exchange rate changes with respect to ΔVIX for different centrality levels. The results are presented in Figure 5. With increasing network centrality, the impact of a one-point increase in the VIX index on exchange rate changes decreases significantly, i.e., periods of surging global risk aversion affect currencies of peripheral countries more negatively, resulting in a stronger depreciation.

In a second test of Hypothesis 2, I estimate time-series regressions of currency excess returns and spot exchange rate changes of the investment centrality portfolios on changes in the VIX index

$$y_t^k = \alpha + \beta^k \Delta VIX_t + \varepsilon_t^k, \tag{11}$$

where y_t^k are currency excess returns or spot exchange rate changes of portfolio k at time t, respectively. ΔVIX_t is the monthly change in the VIX index. α is a constant term, β is the parameter to be estimated, and ε_t^k is an error term. Standard errors are based on Newey and West (1987) with optimal lag selection according to Andrews (1991). Remember that PF1 are the most central countries with low currency excess returns on average, while PF4 contains the most peripheral countries with high currency excess returns on average.

Table 9 shows the time-series results for both specifications. The coefficients on ΔVIX decrease almost monotonic when moving from PF1 to PF4. All coefficients are statistically significant at the one-percent level, and are the largest for PF3 and PF4, implying that currencies in the long portfolio of the investment centrality strategy depreciate the most when global risk aversion increases. Currencies of peripheral countries depreciate stronger during bad times relative to currencies of central countries.

5.2 Theoretical discussion

In the following section, I present a simple partial equilibrium to show how returns on external portfolios could affect real exchange rates in different states of the world, ceteris paribus. I use the

implications of a consumption-based capital asset pricing model.

Set-up. There are two time periods, t and $t+1$, and N countries, indexed by $i = 1, ..., N$, each populated by a representative household that can consume one domestic good. The countries are allowed to trade financial assets. t is the capital allocation period where households purchase assets. In $t+1$, the world experiences a global shock where assets differ by their sensitivity to payoff innovations. Note that country i refers to the residence of the asset holder, i.e., the investor, and country j refers to the residence of the asset issuer. For instance, the UK (country i) holds financial assets issued by the US (country j).

Assets. The definitions of the assets build on Okawa and Van Wincoop (2012). The portfolio of households in country i can contain $N-1$ foreign assets as well as a risk-free bond in their domestic currency. In time t, the prices for buying an asset from country j and the domestic risk-free bond are P_{jt} and P_{ft}, respectively. In the next period, these assets pay off, i.e., distribute cash flows to the investor. While the domestic risk-free bond pays off one unit of domestic consumption in the next period in all states of the world, the payoff of the asset issued by country j is

$$X_{jt+1} = 1 + \varepsilon_{jt+1} + \theta_j \varepsilon_{gt+1}, \tag{12}$$

where ε_j, $\varepsilon_g \sim N(0, \sigma^2)$ are country-specific and global payoff shocks, respectively. The country-specific shocks have following correlations $corr(\varepsilon_j, \varepsilon_i) = corr(\varepsilon_j, \varepsilon_g) = 0$. The constant term is 1, which is simply a normalization. Heterogeneous loadings on global shocks are introduced by $\theta_j \in (0, 1)$. This is motivated by Colacito et al. (2018) who emphasize to include cross-country variation in the exposure to global shocks.[13] In this paper, a higher θ_j is associated with higher comovement of payoffs to global shocks. A detailed definition of θ_j follows in the next step. The returns distributed via the foreign asset of country j and the risk-free bond in time $t+1$ can be written as

$$R_{jt+1} = \frac{X_{jt+1}}{P_{jt}},$$

$$R_{ft+1} = \frac{1}{P_{ft}}.$$

The overall return to the portfolio of country i, consisting of assets from $N-1$ countries and the domestic bond, can be written as

[13] Hassan and Mano (2019) provide empirical evidence for fundamental differences in country risk that are relatively persistent over time.

$$R^P_{it+1} = \sum_{j=1, i\neq j}^{N} w_{ij} R_{jt+1} + (1 - \sum_{j=1, i\neq j}^{N} w_{ij}) R_{ft+1}, \tag{13}$$

where $w_{ij} \in (0, 1)$ is the portfolio weight that country i is invested in country j. The portfolio return of country i is the weighted sum of returns to $N-1$ foreign assets and the risk-free domestic bond, respectively. Portfolio weights sum to 1.

Heterogeneous exposure to global shocks. The cross-sectional variation in the exposure to global payoff shocks is captured by $\theta_j \in (0, 1)$. In this paper, the response to global shocks depends on countries' share in the supply of tradeable financial assets. The assumption is motivated by models of Caballero et al. (2008) and Maggiori (2017), stating that differences in the development of financial markets across countries are a driver of heterogeneous exposure to shocks. Countries with the most developed financial sector, measured by a greater ability to produce tradeable financial assets, take on a larger proportion of systematic risk because their financial intermediaries are better able to deal with funding problems following negative shocks. The share in the supply of tradeable financial assets of country j is measured by the sum of bilateral claims of $N-1$ countries against country j relative to the total supply of tradeable assets

$$\theta_j = \frac{\sum_{i=1, i\neq j}^{N} A_{ij}}{\sum_{i=1}^{N} \sum_{j=1}^{N} A_{ij}} \tag{14}$$

with A_{ij} being the market value of assets that country i holds from country j. The enumerator gives the sum of assets that all $N-1$ countries hold from country j (there can be no holdings of own foreign assets). The denominator gives the set of all financial assets available. We can think of θ_j as a characteristic of a key country. For instance, the US is a key country in the global financial architecture with a greater depth of its financial markets. Key countries are important for financial intermediation and global risk sharing (Maggiori, 2017).

Network centrality. In the following, I address the question on how differences in network centralities could arise. The standard capital asset pricing model (CAPM) suggests that every country should hold the world market portfolio that represents the market-value-weighted portfolio of all assets, i.e., country i should invest in country j according to its relative market value ($w_{ij} = \theta_j$). However, countries could deviate from this prediction, e.g., due to a home bias or different risk preferences. It would be interesting to study determinants that cause previously mentioned deviations in a model but doing so is outside the scope of this paper. I focus on how given capital allocations expose countries differently to global shocks and how this affects exchange rates. For instance, two countries - the UK and Malaysia - that both hold assets issued by the US,

a key country. We can observe that the UK is overinvested in the US (holds more US assets than the US market value predicts), while Malaysia is underinvested in the US. In the context of this paper, this makes the UK more central than Malaysia, which is supported by the empirical findings presented before. Taken together Eq. (13) and Eq. (14), the measure on network centrality can interpreted as

$$v_i = \sum_{j=1, i \neq j}^{N} \widetilde{w}_{ij} \theta_j, \tag{15}$$

where network centrality increases with excess portfolio weights $\widetilde{w}_{ij}$ (actual weights minus predicted weights) invested in key countries that are important for the supply of tradeable financial assets (θ_j). In the empirical analysis, network centralities are scaled down by the total GDP of the investor and issuer country. This accounts on the one side for the relative importance of external portfolios for the country and on the other side for business cycle correlations that are typically higher between integrated countries (Frankel and Rose, 1998).

Consumption. The representative households in country i maximize their utility from consumption C_i in both periods according to

$$\max u(C_{it}, C_{it+1}) = u(C_{it}) + E[\beta u(C_{it+1})]$$

with $u(C_i) = \frac{(C_i)^{1-\gamma}}{1-\gamma}$. $\beta \in (0,1)$ and $\gamma \in (0,1)$ are the subjective time discount factor and the relative risk aversion parameter, respectively. The budget is constrained with subject to

$$C_{it} = Y_{it} - (\sum_{j=1, i \neq j}^{N} \xi_{ij} P_{jt}) - \xi_{if} P_{ft},$$

$$C_{it+1} = Y_{it+1} + R^P_{it+1}.$$

Households have an original endowment level Y. In period t, households allocate their endowment across the set of available assets, i.e., foreign and domestic assets. ξ is the amount of assets purchased at a price P. The market value of the assets is $A = \xi * P$. The consumption level in period $t+1$ increases with the realized returns on the portfolio.

Exchange rate movements. As noted by Backus et al. (2001) and Lustig and Verdelhan (2007), among others, exchange rates can be defined in terms of domestic and foreign SDFs, also known as pricing kernels M. More generally, M is a positive variable that satisfies the pricing relation for returns on all traded assets and its existence implies no arbitrage opportunities. In each

country, a representative investor has access to a domestic bond that pays off one unit of domestic consumption the next period and a foreign bond with a return that pays off one unit of foreign consumption the next period. If country i is domestic and country j is foreign, then the UIP condition implies that the expected return of a foreign investor buying a foreign bond and a domestic investor buying the same foreign bond must satisfy

$$\mathbb{E}\left[M_{jt+1}R_{jt+1}\right] = \mathbb{E}\left[M_{it+1}R_{jt+1}\frac{S_{ijt}}{S_{ijt+1}}\right], \tag{16}$$

with S_{ij} denoting the spot real exchange rate expressed in units of foreign currency j per unit of domestic currency i. In a consumption-based capital asset pricing model, assets that pay off in units of the domestic consumption goods are essentially priced by the intertemporal marginal rate of substitution $M_{t+1} = \left(\frac{u'_{t+1}}{u'_t}\right)$. In this paper, the SDF of country i can be derived as

$$M_{it+1} = \beta\left(\frac{C_{it+1}}{C_{it}}\right)^{-\gamma}. \tag{17}$$

Since the SDF is unique in complete financial markets, the change in the real exchange rate equals the ratio of the SDFs for foreign currency- and domestic-denominated assets. Using Eq. (16) and (17), the real exchange rate changes between country i and j can be defined by differences in consumption growth rates between the countries

$$\frac{S_{ijt+1}}{S_{ijt}} = \frac{M_{it+1}}{M_{jt+1}} \Rightarrow \Delta s_{ijt+1} = m_{it+1} - m_{jt+1}. \tag{18}$$

where a positive Δs_{ijt+1} means an appreciation of currency i against currency j. Real exchange rates are the relative price of two consumption bundles. As such, they should adjust to reflect differences in both current and future relative consumption across countries. The currency of country i appreciates relative to country j's when its consumption growth is lower, i.e., its marginal utility is higher. Hence, the consumption-based capital asset pricing model implies a perfect correlation between Δs_{ijt+1} and $\Delta c_{jt+1} - \Delta c_{it+1}$.

Example: negative global shock. The following illustrates exemplary real exchange rate determination in the global portfolio network. We assume that the US is the key country, and the UK is relatively more invested in the US than Malaysia ($v_i > v_j$). Then Eq. (12) implies that the realized return on the UK portfolio in Eq. (13) decreases more than the return on the Malaysian portfolio when the world gets hit by a negative global payoff shock ($\varepsilon_{gt+1} < 0$). The lower portfolio return in the UK than in Malaysia decreases consumption growth in the UK more than in Malaysia and strengthens the British pound against the Malaysian ringgit. Countries with relative low prices

receive transfer to take advantage of cheap consumption and experience a currency appreciation.

Empirical evidence. The theoretical discussion in this paper does not claim that realized returns on external portfolios are the only driver of consumption growth and due to the nature of a partial analysis, amplifying or mitigating channels can exist. The analysis has demonstrated marginal effects of portfolio returns on real exchange rates. To provide empirical evidence for the presented channel, I test whether the covariance of consumption growth increases with network centrality. Therefore, I construct consumption growth using real consumption data from the Penn World Tables 10.01. To measure country-specific and global consumption growth, I divide each country's and world real consumption of households and government, at current Purchasing Power Parity (PPP), by corresponding populations and calculate annual log growth rates. I follow Richmond (2019) and Tesar (1995) and regress each country's per capita log consumption growth on log world consumption growth

$$\Delta\tilde{c}_{it} = \alpha_{it} + \beta_{it}\Delta\tilde{c}_{Wt} + \varepsilon_{it}, \tag{19}$$

where log world per capita consumption $\tilde{c}_{Wt}$ is calculated by omitting each country i. Figure 6 plots the average consumption growth beta and network centrality for each country. The consumption growth betas measure the sensitivity of countries to changes in world consumption growth. The positive slope indicates that the exposure to world consumption growth increases on average with network centrality. If the world receives a negative consumption shock, the consumption in central countries decreases more than in peripheral countries. This connection also helps explain why interest rates of central countries are on average lower in normal/good times. During this time, central countries realize higher returns on external portfolios due to higher exposure to systematic risk and consume more relative to peripheral countries. Currencies of central countries depreciate on average in normal/good times and lower interest rates represent compensation for expectations about taking greater systematic risk than peripheral countries in bad times.

6 Conclusion

This paper establishes a robust relation between countries' external portfolios and the cross-sectional variation in currency risk premia. Central countries with large asset holdings issued by key countries, that account for a substantial share in the supply of tradeable financial assets, pay on average lower currency excess returns and interest rates. These findings are statistically and economically significant and robust to other economic fundamentals.

Empirical asset pricing tests demonstrate that the network centrality-based risk factor is priced

in the cross-section of currency portfolios. High-yielding currencies have positive loadings on the network centrality risk factor and generate low returns during global stress periods, while low-yielding currencies exhibit a negative relationship with the network centrality risk factor and appreciate, providing a hedge in bad times. The results are in line with the idea that currency excess returns compensate for time-varying risk. This paper offers an economic mechanism behind the cross-sectional variation in currency risk premia. I shed light on fundamental sources of countries' exposure to systematic risk and contribute to the understanding of exchange rate determination based on country-specific macroeconomic fundamentals.

The exposure of central countries to adverse payoff innovations in high marginal utility states can partially influence exchange rates. Central countries, being more integrated with key countries compared to peripheral countries, exhibit higher comovement with market risk as key countries bear a larger fraction of systematic risk. This highlights how network centrality can lead to asymmetric risk sharing between key countries and the rest of the world. Network centrality can be seen as currency insurance against global risk aversion shocks, which is financed by lower interest rates during normal times. This paper contributes to the risk-based view on exchange rate determination and introduces a new factor that allows a deeper examination of country risk.

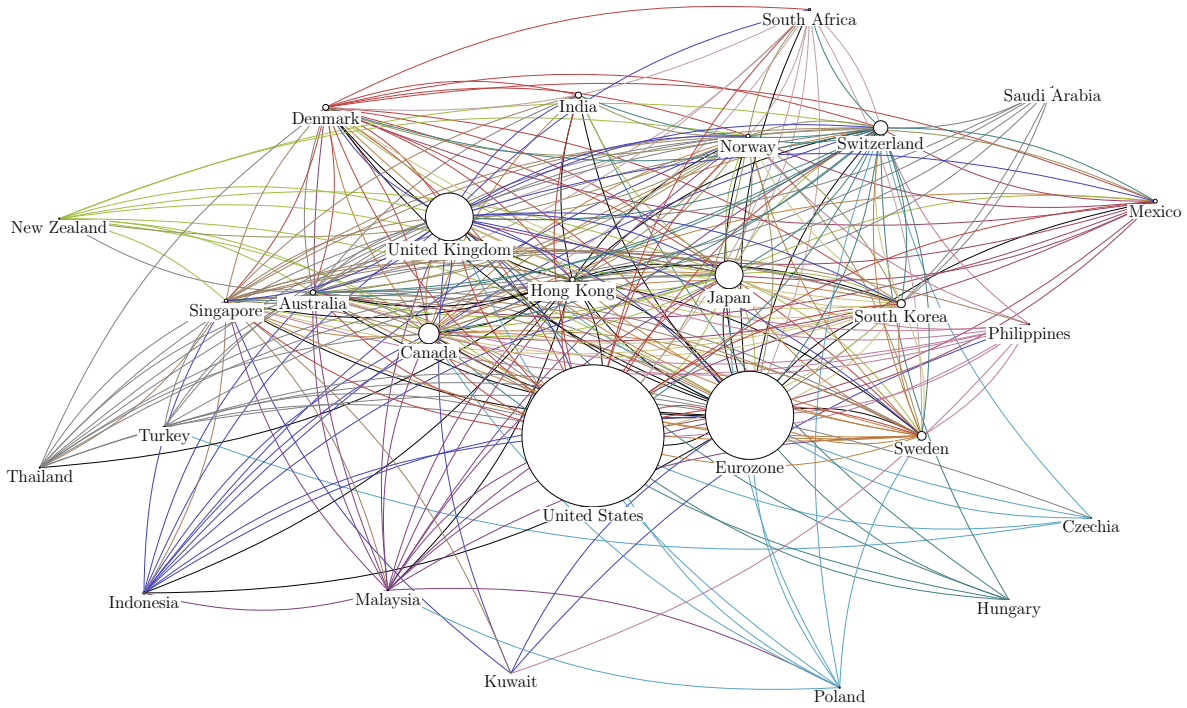


Figure 1: Global portfolio network in 2020 This figure visualizes directed country links of bilateral external equity and debt investments. The circle size represents a country's share in the total foreign asset supply and the circle position corresponds to centrality in the global portfolio network. Links are drawn if pairwise portfolio holdings standardized by pairwise GDP are greater than the cross-sectional median. Portfolio data are from IMF Coordinated Portfolio Investment Survey. The Eurozone is an aggregate with all countries that adopted the Euro until the beginning of the sample by summing up their positions with other non-Euro countries into one entity.

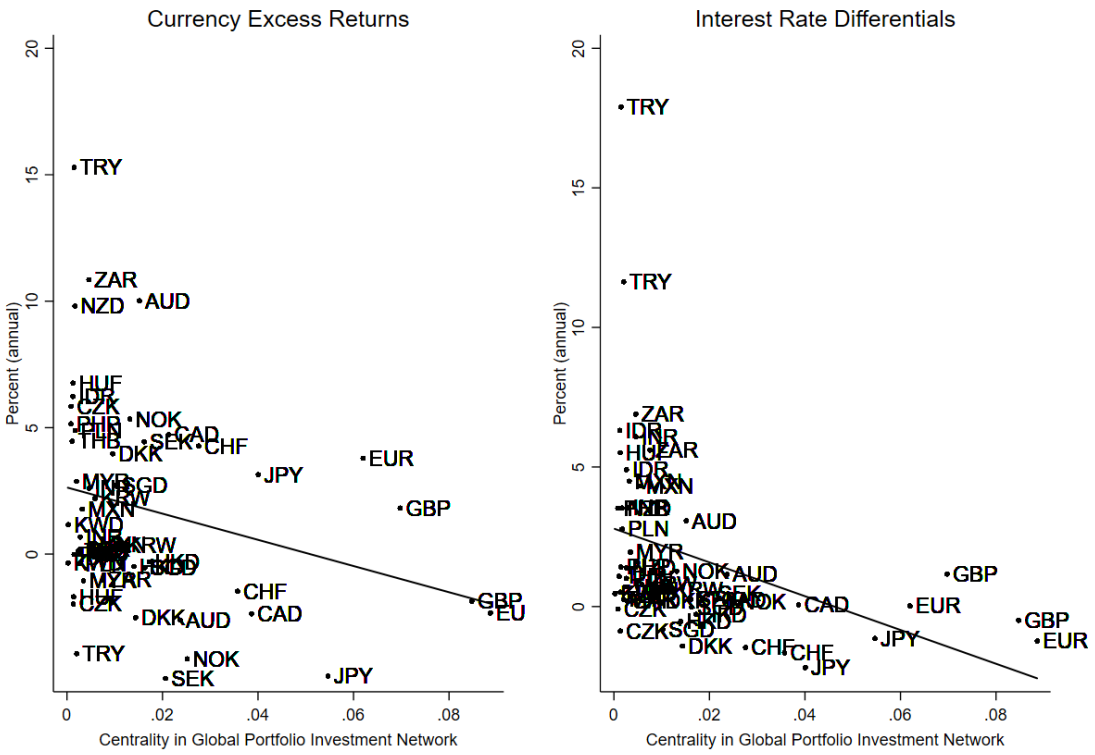


Figure 2: Currency risk premia and interest rate differentials versus centrality This figure plots ten-year-long averages of one-month annualized currency excess returns (left) and interest rate differentials (right) to US investors against one-year-lagged centrality in the global portfolio investment network for 26 countries. The log currency excess returns are computed as $f_t - s_t - s_{t+1}$, and using covered interest rate parity, the log interest rate differentials are equivalent to the forward discounts $f_t - s_t$. Exchange rates and returns are reported in US dollar. For each country, monthly observations are averaged in two time blocks (2002 to 2011, and 2012 to 2021). Centrality measures the investment share weighted average of a country's bilateral foreign portfolio positions of all other countries relative to total bilateral GDP. Portfolio data are from IMF Coordinated Portfolio Investment Survey and annual GDP data from the World Bank. The Eurozone is an aggregate with all countries that adopted the Euro until the beginning of the sample by summing up their positions with other non-Euro countries into one entity. Monthly foreign exchange data are from Reuters.

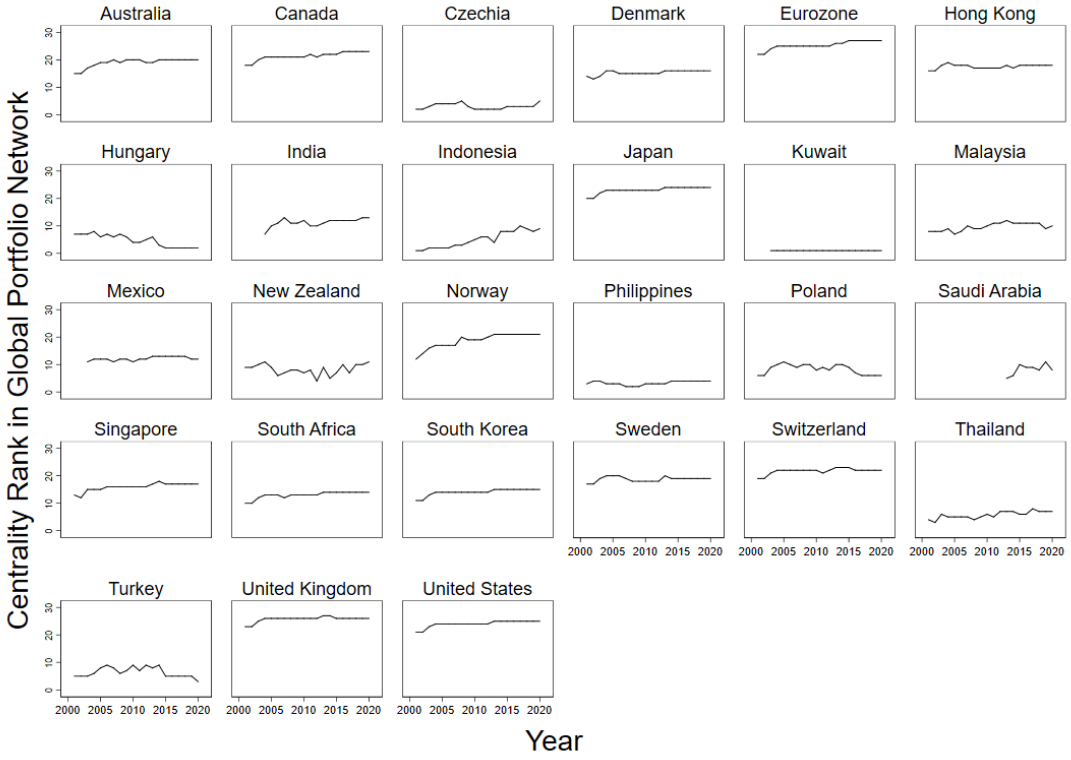


Figure 3: Time-series of network centrality ranking by country This figure shows the rankings of countries' centrality in the global portfolio network by year. Centrality measures the investment share weighted average of a country's bilateral foreign portfolio holdings of all other countries relative to total bilateral GDP. The rankings are rebalanced each year to between 1 and 27. Portfolio data are from IMF Coordinated Portfolio Investment Survey and annual GDP data from the World Bank. The Eurozone is an aggregate with all countries that adopted the Euro until the beginning of the sample by summing up their positions with other non-Euro countries into one entity. Data is annual from 2001 to 2020.

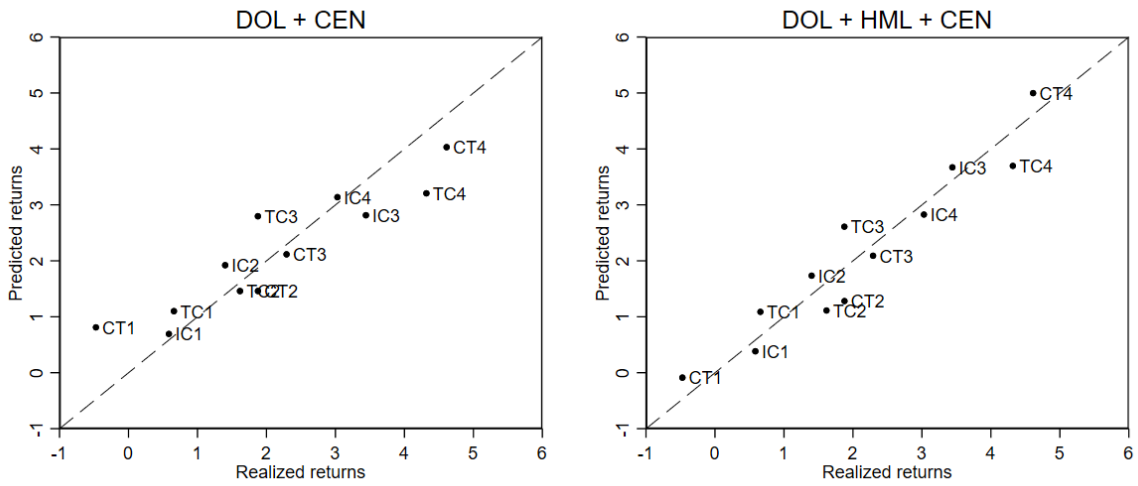


Figure 4: Pricing errors This figure shows the cross-sectional pricing errors for the two-factor SDF (left) and three-factor SDF (right). The FMB estimates are obtained using 12 currency portfolios as test assets: IC denotes investment centrality portfolios (sorted on prior-year centrality in a global portfolio network), CT denotes carry trade portfolios (sorted on current forward discounts), and TC denotes trade centrality portfolios (sorted on prior-year centrality in a trade network). The sample period covers monthly data from January 2001 to August 2021.

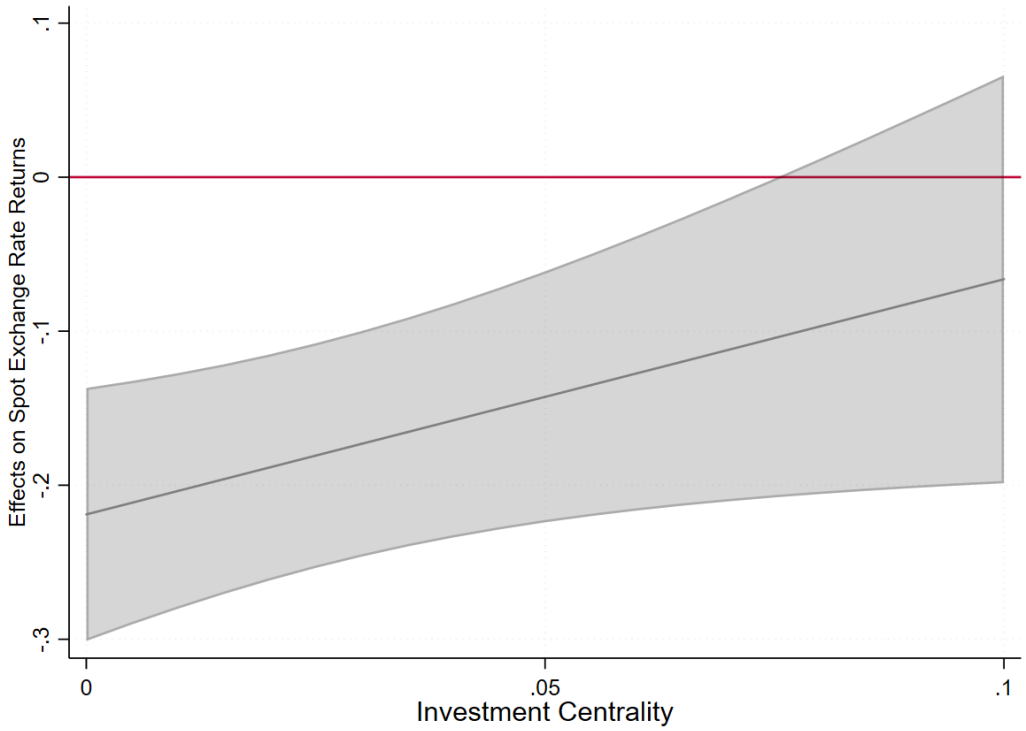


Figure 5: Marginal effects of changes in the VIX index This figure plots the average marginal effects of one point change in the VIX index for different levels of network centrality in a 95% confidence interval after running the panel regression $\Delta s_{it} = \alpha_i + \delta_\tau + \beta_1 v_{it-12} + \beta_2 \Delta VIX_t + \beta_3(\Delta VIX_t \times v_{it-12}) + \varepsilon_{it}$, where Δs_{it} are monthly log spot exchange rate returns, v_{it-12} are one-year lagged network centrality, and ΔVIX_t are monthly changes in the VIX volatility index. Year fixed effects and country fixed effects are included. Standard errors are clustered by country and month. Exchange rates and returns are reported in US dollar. The monthly changes in the VIX volatility index are from the Chicago Board Options Exchange that measure the implied volatility of S&P 500 index options. Investment centrality is the investment share weighted average of a country's bilateral foreign portfolio holdings of all other countries relative to total bilateral GDP. Portfolio data are from IMF Coordinated Portfolio Investment Survey, trade data are from IMF Direction of Trade Statistics, and annual GDP data are from the World Bank. The Eurozone is an aggregate with all countries that adopted the Euro until the beginning of the sample by summing up their positions with other non-Euro countries into one entity. Foreign exchange data are monthly from Reuters via Datastream for 26 countries from January 2001 to August 2021.

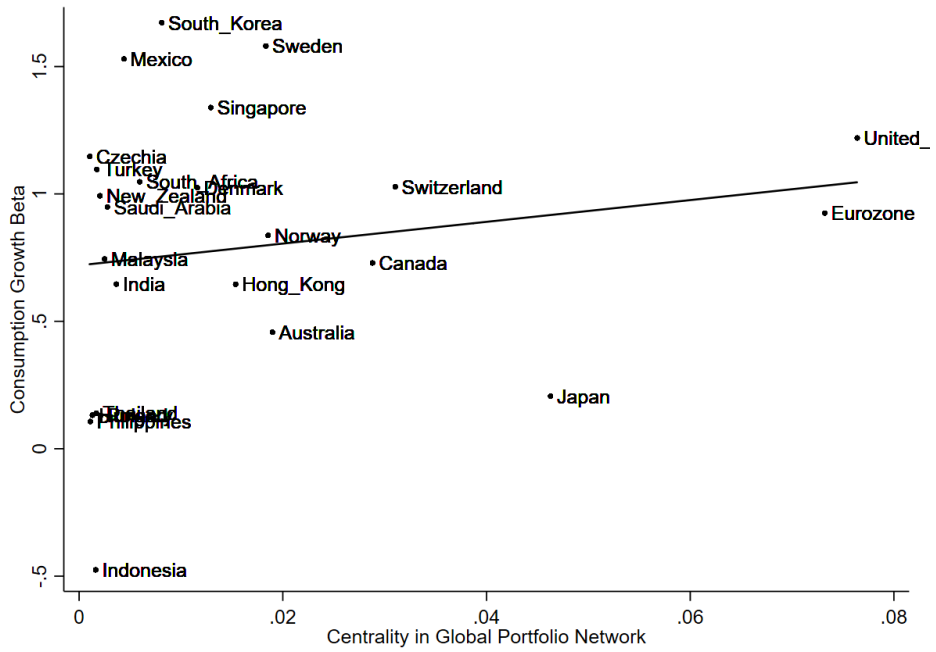


Figure 6: Consumption growth betas and network centrality This figure shows average consumption growth betas and average centrality in the global portfolio network. Consumption growth betas are from regressing country's consumption growth on world consumption growth according to $\Delta\widetilde{c}_{it} = \alpha_{it} + \beta_{it}\Delta\widetilde{c}_{Wt} + \varepsilon_{it}$. Centrality measures the investment share weighted average of a country's bilateral foreign portfolio holdings of all other countries relative to total bilateral GDP. Portfolio data are from IMF Coordinated Portfolio Investment Survey and annual GDP data from the World Bank. Data on real consumption are from the Penn World Tables. The Eurozone is an aggregate with all countries that adopted the Euro until the beginning of the sample by summing up their positions with other non-Euro countries into one entity. Data is annual from 2001 to 2020.

Table 1: Regressions of currency excess returns This table presents the results of regressions of log currency risk premia rx on standardized one-year lagged investment network centrality v_{it-12}, trade network centrality, GDP share, and investment-to-GDP ratio. All specifications include a constant and month fixed effects. The log currency excess returns are computed as $f_t - s_t - \Delta s_{t+1}$. Exchange rates and returns are reported in US dollar. The moments of returns are annualized. Investment centrality is the global portfolio share weighted average of a country's bilateral foreign portfolio holdings of all other countries relative to total bilateral GDP. Trade centrality is the output share weighted average of a country's bilateral trade intensities with all other countries relative to total bilateral GDP. GDP share is a country's fraction of the total GDP of all available countries in the sample for that year. Investment-to-GDP is a country's total foreign portfolio holdings relative to GDP. Portfolio data are from IMF Coordinated Portfolio Investment Survey, trade data are from IMF Direction of Trade Statistics, and annual GDP data are from the World Bank. The Eurozone is an aggregate with all countries that adopted the Euro until the beginning of the sample by summing up their positions with other non-Euro countries into one entity. Foreign exchange data are monthly from Reuters via Datastream for 26 countries from January 2001 to August 2021. Standard errors are clustered by country and month. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

	rx	rx	rx	rx
	(1)	(2)	(3)	(4)
Investment centrality	-0.93***	-0.58*	-0.89**	-0.73***
	(0.27)	(0.28)	(0.32)	(0.19)
Trade centrality		-0.66*		
		(0.38)		
GDP share			-0.05	
			(0.30)	
Investments/GDP				-0.55***
				(0.18)
Num. obs.	5,728	5,728	5,728	5,728
R^2	0.46	0.46	0.46	0.46

Table 2: Regressions of forward discounts This table presents the results of regressions of log forward discounts fd on standardized one-year lagged investment network centrality v_{it-12}, investment-to-GDP ratio, and trade network centrality. All specifications include a constant and month fixed effects. Using covered interest rate parity, the log interest rate differentials are equivalent to the forward discounts $f_t - s_t$. Exchange rates and returns are reported in US dollar. The moments of forward discounts are annualized. Investment centrality is the investment share weighted average of a country's bilateral foreign portfolio holdings of all other countries relative to total bilateral GDP. Trade centrality is the output share weighted average of a country's bilateral trade intensities with all other countries relative to total bilateral GDP. GDP share is a country's fraction of the total GDP of all available countries in the sample for that year. Investment-to-GDP is a country's total foreign portfolio holdings relative to GDP. Portfolio data are from IMF Coordinated Portfolio Investment Survey, trade data are from IMF Direction of Trade Statistics, and annual GDP data are from the World Bank. The Eurozone is an aggregate with all countries that adopted the Euro until the beginning of the sample by summing up their positions with other non-Euro countries into one entity. Foreign exchange data are monthly from Reuters via Datastream for 26 countries from January 2001 to August 2021. Standard errors are clustered by country and month. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

	fd	*fd*	*fd*	*fd*
	(1)	(2)	(3)	(4)
Investment centrality	-1.29**	-0.79*	-1.61*	-0.87**
	(0.48)	(0.41)	(0.80)	(0.36)
Trade centrality		-0.95*		
		(0.52)		
GDP share			0.44	
			(0.51)	
Investment/GDP				-1.14***
				(0.41)
Num. obs.	5,728	5,728	5,728	5,728
R^2	0.17	0.17	0.22	0.20

Table 3: Composition of investment centrality portfolios This table presents the currency composition of four investment network centrality portfolios. Portfolio 1 (4) contains currencies of countries with the highest (lowest) network centrality. I report the top six currencies and their frequencies entering each portfolio. Portfolios are rebalanced monthly, and foreign exchange data are from Reuters via Datastream for 26 countries from January 2001 to August 2021.

Investment Centrality Portfolios							
PF1	Frequency	PF2	Frequency	PF3	Frequency	PF4	Frequency
CHF	0.17	HKD	0.17	MXN	0.15	CZK	0.15
EUR	0.17	DKK	0.16	INR	0.14	PHP	0.15
GBP	0.17	SGD	0.16	MYR	0.13	THB	0.14
JPY	0.17	KRW	0.14	ZAR	0.12	KWD	0.13
CAD	0.17	AUD	0.14	NZD	0.11	HUF	0.13
NOK	0.10	SEK	0.10	PLN	0.10	TRY	0.10

Table 4: Currency portfolios sorted on different signals This table presents annualized summary statistics of portfolios sorted on prior-year investment centrality, current forward discounts, and prior-year trade centrality. Each month t, the currencies are ranked on one of these variables and sorted into four portfolios with equal weights. CEN, HML_{FX}, and CEN_X are long-short strategies that buy Portfolio 4 and sell Portfolio 1 (PF4-PF1). The log currency excess returns are computed as $rx_t = f_{t-1} - s_{t-1} - \Delta s_t$, and using covered interest rate parity, the log interest rate differentials are equivalent to the forward discounts $fd_t = f_{t-1} - s_{t-1}$. Exchange rates and returns are reported in US dollar. Mean and standard deviations are percentage points. Investment centrality is the investment share weighted average of a country's bilateral foreign portfolio holdings of all other countries relative to total bilateral GDP. Trade centrality is the output share weighted average of a country's bilateral trade intensities with all other countries relative to total bilateral GDP. Portfolio data are from IMF Coordinated Portfolio Investment Survey, trade data are from IMF Direction of Trade Statistics, and annual GDP data are from the World Bank. The Eurozone is an aggregate with all countries that adopted the Euro until the beginning of the sample by summing up their positions with other non-Euro countries into one entity. Foreign exchange data are monthly from Reuters via Datastream for 26 countries from January 2001 to August 2021.

	Panel A: Investment Centrality Portfolios				
	PF1	PF2	PF3	PF4	CEN
Previous centrality					
mean	4.80	1.40	0.36	0.12	-4.68
Currency excess returns					
mean	0.58	1.40	3.44	3.03	2.45
std	7.34	7.34	8.83	7.10	4.50
Forward discount					
mean	-0.43	0.47	3.86	3.41	3.84
Sharpe ratio					
mean	0.08	0.19	0.39	0.43	0.54
	Panel B: Carry Trade Portfolios				
	PF1	PF2	PF3	PF4	HML_{FX}
Previous fd					
mean	-1.19	0.11	1.52	6.41	7.60
Currency excess returns					
mean	-0.47	1.88	2.29	4.61	5.08
std	6.57	7.25	7.72	9.45	7.49
Forward discount					
mean	-1.24	0.09	1.49	6.46	7.70
Sharpe ratio					
mean	-0.07	0.26	0.30	0.49	0.68
	Panel C: Trade Centrality Portfolios				
	PF1	PF2	PF3	PF4	CEN_X
Previous centrality					
mean	0.94	0.57	0.35	0.19	-0.75
Currency excess returns					
mean	0.66	1.62	1.88	4.32	3.66
std	5.68	6.93	8.83	8.76	5.09
Forward discount					
mean	0.20	0.47	2.48	4.09	3.89
Sharpe ratio					
mean	0.12	0.23	0.21	0.49	0.72

Table 5: Summary statistics of currency strategies This table presents the annualized summary statistics of three currency risk factors from excess returns sorted into four portfolios. CEN sorts currencies on prior-year investment centrality and goes long foreign currencies of least central countries and short foreign currencies of most central countries. HML_{FX} sorts currencies on current forward discounts and goes long foreign currencies of high-interest-rate countries and short foreign currencies of low-interest-rate countries. CEN_X sorts currencies on prior-year trade centrality and goes long foreign currencies of least central countries and short foreign currencies of most central countries. DOL is the average excess return of a US investor investing in all available foreign currencies. Portfolios are rebalanced monthly. The log currency excess returns are computed as $rx_t = f_{t-1} - s_{t-1} - \Delta s_t$. Exchange rates and returns are reported in US dollar. Mean and standard deviations are percentage points. Investment centrality is the investment share weighted average of a country's bilateral foreign portfolio holdings of all other countries relative to total bilateral GDP. Trade centrality is the output share weighted average of a country's bilateral trade intensities with all other countries relative to total bilateral GDP. Portfolio data are from IMF Coordinated Portfolio Investment Survey, trade data are from IMF Direction of Trade Statistics, and annual GDP data are from the World Bank. The Eurozone is an aggregate with all countries that adopted the Euro until the beginning of the sample by summing up their positions with other non-Euro countries into one entity. Foreign exchange data are monthly from Reuters via Datastream for 26 countries from January 2001 to August 2021.

	CEN	HML_{FX}	CEN_X	DOL
Mean	2.45	5.08	3.66	2.18
SD	4.50	7.49	5.09	7.12
Sharpe ratio	0.54	0.68	0.72	0.31
Skewness	-0.18	-0.64	-0.15	-0.65
Excess kurtosis	1.44	1.81	2.02	2.01
N	236	236	236	236

Table 6: Factor risk prices This table presents cross-sectional regressions of $rx^k = \lambda_{Factors}\hat{\beta}^k_{Factors}$, where $\hat{\beta}^k_{Factors}$ denote estimated betas of time-series regressions of excess returns to currency portfolio k on the Dollar factor (DOL), investment network centrality factor (CEN), and carry trade factor (HML_{FX}). The test assets include currency excess returns to four carry trade portfolios (sorted on current forward discounts), four investment centrality portfolios (sorted on prior-year centrality in a foreign portfolio investment network), and four trade centrality portfolios (sorted on prior-year centrality in a trade network). The λ estimates are second-stage FMB regressions and standard errors are based on Newey and West (1987) with optimal lag selection according to Andrews (1991). Investment centrality is the investment share weighted average of a country's bilateral foreign portfolio holdings of all other countries relative to total bilateral GDP. Trade centrality is the output share weighted average of a country's bilateral trade intensities with all other countries relative to total bilateral GDP. Portfolio data are from IMF Coordinated Portfolio Investment Survey, trade data are from IMF Direction of Trade Statistics, and annual GDP data are from the World Bank. The Eurozone is an aggregate with all countries that adopted the Euro until the beginning of the sample by summing up their positions with other non-Euro countries into one entity. Foreign exchange data are monthly from Reuters via Datastream for 26 countries from January 2001 to August 2021. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

Factor Prices			
λ_{DOL}	λ_{CEN}	$\lambda_{HML_{FX}}$	R^2
0.18	0.28***		0.38
(0.15)	(0.10)		
0.18	0.19**	0.42***	0.53
(0.15)	(0.08)	(0.16)	

Table 7: Time-series betas This table presents time-series betas for regressions of $rx^k_{t+1} = \alpha^k + \beta^k Factors_{t+1} + \varepsilon^k_{t+1}$, where $Factors$ denotes the Dollar factor (DOL), the investment network centrality factor (CEN), and the carry trade factor (HML_{FX}). rx^k are excess returns to investment centrality portfolios (sorted on prior-year centrality in a foreign portfolio investment network in Panel A), carry trade portfolios (sorted on current forward discounts in Panel B), and trade centrality portfolios (sorted on prior-year centrality in a trade network in Panel C). The beta estimates are first-stage FMB regressions and standard errors are based on Newey and West (1987) with optimal lag selection according to Andrews (1991). Exchange rates and returns are reported in US dollar. Investment centrality is the investment share weighted average of a country's bilateral foreign portfolio holdings of all other countries relative to total bilateral GDP. Trade centrality is the output share weighted average of a country's bilateral trade intensities with all other countries relative to total bilateral GDP. Portfolio data are from IMF Coordinated Portfolio Investment Survey, trade data are from IMF Direction of Trade Statistics, and annual GDP data are from the World Bank. The Eurozone is an aggregate with all countries that adopted the Euro until the beginning of the sample by summing up their positions with other non-Euro countries into one entity. Foreign exchange data are monthly from Reuters via Datastream for 26 countries from January 2001 to August 2021. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

Factor Betas															
Panel A: Investment Centrality Portfolios						*Panel B: Carry Trade Portfolios*						*Panel C: Trade Centrality Portfolios*				
PF	α	β_{DOL}	β_{CEN}	$\beta_{HML_{FX}}$	R^2	PF	α	β_{DOL}	β_{CEN}	$\beta_{HML_{FX}}$	R^2	PF	α	β_{DOL}	β_{CEN}	$\beta_{HML_{FX}}$	R^2
1	-0.11	0.94***	-0.56***		0.96	1	-1.28**	0.79***	-0.37***		0.80	1	-0.44	0.74***	-0.21***		0.89
	(0.34)	(0.02)	(0.04)				(0.56)	(0.04)	(0.04)				(0.40)	(0.03)	(0.02)		
2	-0.52	0.99***	-0.09***		0.91	2	0.38	0.94***	-0.24***		0.88	2	0.16	0.89***	-0.19***		0.85
	(0.56)	(0.02)	(0.03)				(0.45)	(0.03)	(0.04)				(0.44)	(0.03)	(0.04)		
3	0.63	1.14***	0.13		0.85	3	0.20	1.03***	-0.06**		0.91	3	-0.92	1.19***	0.08		0.92
	(0.83)	(0.04)	(0.08)				(0.47)	(0.04)	(0.03)				(0.63)	(0.05)	(0.08)		
4	-0.11	0.94***	0.44***		0.96	4	0.58	1.20***	0.57***		0.89	4	1.11	1.16***	0.27***		0.91
	(0.34)	(0.02)	(0.04)				(0.73)	(0.03)	(0.05)				(0.87)	(0.04)	(0.07)		
1	0.20	1.01***	-0.40***	-0.17***	0.98	1	-0.39*	0.99***	0.09***	-0.48***	0.96	1	-0.43	0.74***	-0.20***	-0.01	0.89
	(0.24)	(0.02)	(0.05)	(0.02)			(0.22)	(0.03)	(0.03)	(0.02)			(0.42)	(0.03)	(0.04)	(0.03)	
2	-0.33	1.03***	0.00	-0.10**	0.87	2	0.57	0.98***	-0.15***	-0.10***	0.89	2	0.50	0.96***	-0.02	-0.19***	0.92
	(0.52)	(0.03)	(0.06)	(0.04)			(0.44)	(0.04)	(0.04)	(0.03)			(0.44)	(0.05)	(0.06)	(0.06)	
3	-0.23	0.95***	-0.30***	0.46***	0.93	3	0.23	1.04***	-0.05	-0.01	0.91	3	-0.74	1.23***	0.18***	-0.10**	0.92
	(0.52)	(0.03)	(0.06)	(0.03)			(0.47)	(0.04)	(0.04)	(0.03)			(0.58)	(0.05)	(0.07)	(0.04)	
4	0.20	1.01***	0.60***	-0.17***	0.97	4	-0.39*	0.99***	0.09***	0.52***	0.98	4	0.62	1.05***	0.03	0.26***	0.94
	(0.24)	(0.02)	(0.05)	(0.02)			(0.22)	(0.03)	(0.03)	(0.02)			(0.62)	(0.04)	(0.06)	(0.05)	

Table 8: Panel regressions of spot returns on changes in the VIX index This table presents results for panel regressions of monthly spot exchange rate returns Δs_{it} on one-year lagged investment network centrality v_{it-12}, changes in the VIX index ΔVIX_t, and an interaction term between both variables. The dummy variable equals one if ΔVIX_t is greater than one standard deviation as estimated across the entire sample, and zero otherwise. All specifications include a constant, year fixed effects, and country fixed effects. Exchange rates and returns are reported in US dollar. The monthly changes in the VIX volatility index are from the Chicago Board Options Exchange that measure the implied volatility of S&P 500 index options. Investment centrality is the investment share weighted average of a country's bilateral foreign portfolio holdings of all other countries relative to total bilateral GDP. Portfolio data are from IMF Coordinated Portfolio Investment Survey and annual GDP data are from the World Bank. The Eurozone is an aggregate with all countries that adopted the Euro until the beginning of the sample by summing up their positions with other non-Euro countries into one entity. Foreign exchange data are monthly from Reuters via Datastream for 26 countries from January 2001 to August 2021. Standard errors are clustered by country and month. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

	Δs	Δs
Investment centrality	-1.61	-5.25**
	(3.66)	(2.53)
Δ VIX	-0.22***	
	(0.04)	
Investment centrality $\times\Delta$VIX	1.48*	
	(0.75)	
ΔVIX dummy		-2.61***
		(0.67)
Investment centrality $\times\Delta$VIX dummy		16.95*
		(9.29)
Num. obs.	5,728	5,728
Adj. R^2	0.14	0.09

Table 9: Time-series regressions of portfolio currency excess returns and spot returns

This table presents results for time-series regressions of monthly currency excess returns and spot exchange rate returns to the investment centrality portfolios on a constant and changes in the VIX index. Newey and West (1987) standard errors with optimal lag selection according to Andrews (1991) are reported in parentheses. Exchange rates and returns are reported in US dollar. The monthly changes in the VIX volatility index are from the Chicago Board Options Exchange that measure the implied volatility of S&P 500 index options. Investment centrality is the investment share weighted average of a country's bilateral foreign portfolio holdings of all other countries relative to total bilateral GDP. Portfolio data are from IMF Coordinated Portfolio Investment Survey and annual GDP data are from the World Bank. The Eurozone is an aggregate with all countries that adopted the Euro until the beginning of the sample by summing up their positions with other non-Euro countries into one entity. Foreign exchange data are monthly from Reuters via Datastream for 26 countries from January 2001 to August 2021. Standard errors are clustered by country and month. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

Excess Returns				
	PF1	PF2	PF3	PF4
Δ VIX	-1.79***	-2.12***	-3.13***	-2.24***
	(0.50)	(0.46)	(0.68)	(0.55)
Constant	0.53	2.96*	3.34	1.33
	(1.68)	(1.80)	(2.29)	(1.48)
R^2	0.13	0.19	0.27	0.20
Spot Returns				
Δ VIX	-1.77***	-2.09***	-3.12***	-2.23***
	(0.50)	(0.45)	(0.67)	(0.55)
Constant	0.93	-0.44	-0.51	0.86
	(1.66)	(1.43)	(2.27)	(1.44)
R^2	0.12	0.19	0.26	0.19

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A Internet Appendix

Internet Appendix for

Global Portfolio Network and Currency Risk Premia

November 2024

Table A.1: Country sample This table shows the sample of countries that have both data on exchange rates and portfolio investments available. The portfolio data are from IMF Coordinated Portfolio Investment Survey. The annual GDP data are from the World Bank. The Eurozone is an aggregate with all countries that adopted the Euro until the beginning of the sample by summing up their positions with other non-Euro countries into one entity. Foreign exchange data are monthly from Reuters via Datastream for 26 countries.

Country	Start Date	End Date
Australia	January 2001	December 2020
Canada	January 2001	December 2020
Czechia	January 2001	December 2020
Denmark	January 2001	December 2020
Eurozone	January 2001	December 2020
Hong Kong	January 2001	December 2020
Hungary	January 2001	December 2020
India	January 2004	December 2020
Indonesia	June 2007	December 2020
Japan	January 2001	December 2020
Kuwait	January 2003	December 2020
Malaysia	July 2005	December 2020
Mexico	January 2003	December 2020
New Zealand	January 2001	December 2020
Norway	January 2001	December 2020
Philippines	January 2001	December 2020
Poland	February 2002	December 2020
Saudi Arabia	January 2013	December 2020
Singapore	January 2001	December 2020
South Africa	January 2001	December 2020
South Korea	February 2002	December 2020
Sweden	January 2001	December 2015
Switzerland	January 2001	December 2020
Thailand	January 2001	December 2020
Turkey	January 2001	December 2020
United Kingdom	January 2001	December 2020

Table A.2: Correlation of macroeconomic variables This table shows correlations of used macroeconomic variables. Investment centrality is the investment share weighted average of a country's bilateral foreign portfolio holdings of all other countries relative to total bilateral GDP. Trade centrality is the output share weighted average of a country's bilateral trade intensities with all other countries relative to total bilateral GDP. GDP share is a country's fraction of the total GDP of all available countries in the sample for that year. Investment-to-GDP is a country's total foreign portfolio holdings relative to GDP. Portfolio data are from IMF Coordinated Portfolio Investment Survey, trade data are from IMF Direction of Trade Statistics, and annual GDP data are from the World Bank. The data is annually for 26 countries from 2001 to 2021.

	Investment centrality	Trade centrality	GDP share	Investment/GDP
Investment centrality	1			
Trade centrality	0.52	1		
GDP share	0.72	0.37	1	
Investment/GDP	0.42	0.37	-0.02	1

Table A.3: Regressions of exchange rate changes This table presents the results of regressions of log exchange rate changes on standardized one-year lagged investment network centrality v_{it-12}, trade network centrality, GDP share, and investment-to-GDP ratio. All specifications include a constant and month fixed effects. The log exchange rates changes are computed as $\Delta s_{it+1} = s_{it} - s_{it+1}$. Exchange rates are reported in US dollar. The moments of exchange rate changes are annualized. Investment centrality is the investment share weighted average of a country's bilateral foreign portfolio holdings of all other countries relative to total bilateral GDP. Trade centrality is the output share weighted average of a country's bilateral trade intensities with all other countries relative to total bilateral GDP. GDP share is a country's fraction of the total GDP of all available countries in the sample for that year. Investment-to-GDP is a country's total foreign portfolio holdings relative to GDP. Portfolio data are from IMF Coordinated Portfolio Investment Survey, trade data are from IMF Direction of Trade Statistics, and annual GDP data are from the World Bank. The Eurozone is an aggregate with all countries that adopted the Euro until the beginning of the sample by summing up their positions with other non-Euro countries into one entity. Foreign exchange data are monthly from Reuters via Datastream for 26 countries from January 2001 to August 2021. Standard errors are clustered by country and month. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

	Δs	Δs	Δs	Δs
	(1)	(2)	(3)	(4)
Investment centrality	0.36	0.21	0.72	0.14
	(0.42)	(0.38)	(0.77)	(0.31)
Trade centrality		0.29		
		(0.41)		
GDP share			-0.49	
			(0.44)	
Investment/GDP				0.60
				(0.37)
Num. obs.	5,728	5,728	5,728	5,728
R^2	0.46	0.46	0.46	0.46

Table A.4: Regressions of real interest rate differentials This table presents the results of regressions of log real interest rate differentials on standardized one-year lagged investment network centrality v_{it-12}, trade network centrality, GDP share, and investment-to-GDP ratio. All specifications include a constant and month fixed effects. The log real interest rate differentials are computed as $r_{it} - r_{USt} = f_{it} - s_{it} - E[\pi_{it} - \pi_{USt}]$. Real interest rate differentials are forward spreads less expected inflation differentials. Expected inflation is the lagged year-over-year change in log CPI. Exchange rates are reported in US dollar. The moments of real interest rate differentials are annualized. Investment centrality is the investment share weighted average of a country's bilateral foreign portfolio holdings of all other countries relative to total bilateral GDP. Trade centrality is the output share weighted average of a country's bilateral trade intensities with all other countries relative to total bilateral GDP. GDP share is a country's fraction of the total GDP of all available countries in the sample for that year. Investment-to-GDP is a country's total foreign portfolio holdings relative to GDP. Portfolio data are from IMF Coordinated Portfolio Investment Survey, trade data are from IMF Direction of Trade Statistics, and annual GDP data are from the World Bank. The Eurozone is an aggregate with all countries that adopted the Euro until the beginning of the sample by summing up their positions with other non-Euro countries into one entity. Foreign exchange data are monthly from Reuters via Datastream for 26 countries from January 2001 to August 2021. Standard errors are clustered by country and month. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

	$r_i - r_{US}$	$r_i - r_{US}$	$r_i - r_{US}$	$r_i - r_{US}$
	(1)	(2)	(3)	(4)
Investment centrality	-0.99**	-0.83**	-1.26*	-0.66*
	(0.42)	(0.37)	(0.70)	(0.33)
Trade centrality		-0.30		
		(0.54)		
GDP share			0.37	
			(0.43)	
Investment/GDP				-0.88**
				(0.35)
Num. obs.	5,728	5,728	5,728	5,728
R^2	0.14	0.14	0.14	0.18

Table A.5: Regressions of currency excess returns with country fixed effects This table presents the results of regressions of log currency excess returns on standardized one-year lagged investment network centrality v_{it-12}, trade network centrality, GDP share, and investment-to-GDP ratio. All specifications include a constant and country fixed effects. The log currency excess returns are computed as $f_t - s_t - \Delta s_{t+1}$. Exchange rates are reported in US dollar. The moments of returns are annualized. Investment centrality is the investment share weighted average of a country's bilateral foreign portfolio holdings of all other countries relative to total bilateral GDP. Trade centrality is the output share weighted average of a country's bilateral trade intensities with all other countries relative to total bilateral GDP. GDP share is a country's fraction of the total GDP of all available countries in the sample for that year. Investment-to-GDP is a country's total foreign portfolio holdings relative to GDP. Portfolio data are from IMF Coordinated Portfolio Investment Survey, trade data are from IMF Direction of Trade Statistics, and annual GDP data are from the World Bank. The Eurozone is an aggregate with all countries that adopted the Euro until the beginning of the sample by summing up their positions with other non-Euro countries into one entity. Foreign exchange data are monthly from Reuters via Datastream for 26 countries from January 2001 to August 2021. Standard errors are clustered by country and month. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

	rx	*rx*	*rx*	*rx*
	(1)	(2)	(3)	(4)
Investment centrality	-10.04**	-10.48**	-14.72***	-8.54**
	(4.00)	(4.24)	(4.11)	(3.51)
Trade centrality		-6.01*		
		(2.99)		
GDP share			-20.93***	
			(5.82)	
Investments/GDP				-1.96
				(1.39)
Num. obs.	5,728	5,728	5,728	5,728
R^2	0.01	0.01	0.01	0.01

Table A.6: Regressions of forward discounts with country fixed effects This table presents the results of regressions of log forward discounts on standardized one-year lagged investment network centrality v_{it-12}, trade network centrality, GDP share, and investment-to-GDP ratio. All specifications include a constant and country fixed effects. Using covered interest rate parity, the log interest rate differentials are equivalent to the forward discounts $f_t - s_t$. Exchange rates are reported in US dollar. The moments of forward discounts are annualized. Investment centrality is the investment share weighted average of a country's bilateral foreign portfolio holdings of all other countries relative to total bilateral GDP. Trade centrality is the output share weighted average of a country's bilateral trade intensities with all other countries relative to total bilateral GDP. GDP share is a country's fraction of the total GDP of all available countries in the sample for that year. Investment-to-GDP is a country's total foreign portfolio holdings relative to GDP. Portfolio data are from IMF Coordinated Portfolio Investment Survey, trade data are from IMF Direction of Trade Statistics, and annual GDP data are from the World Bank. The Eurozone is an aggregate with all countries that adopted the Euro until the beginning of the sample by summing up their positions with other non-Euro countries into one entity. Foreign exchange data are monthly from Reuters via Datastream for 26 countries from January 2001 to August 2021. Standard errors are clustered by country and month. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

	fd	*fd*	*fd*	*fd*
	(1)	(2)	(3)	(4)
Investment centrality	-1.18***	-1.26***	-1.66**	-0.77**
	(0.31)	(0.35)	(0.62)	(0.29)
Trade centrality		-1.00		
		(0.85)		
GDP share			-2.15	
			(1.90)	
Investment/GDP				-0.54**
				(0.20)
Num. obs.	5,728	5,728	5,728	5,728
R^2	0.59	0.59	0.59	0.59

Table A.7: Regressions of currency excess returns and forward discounts - debt investment centrality This table presents the results of regressions of log currency risk premia rx and log forward discounts fd on standardized one-year lagged debt investment network centrality v_{it-12}^{Equity}, trade network centrality, GDP share, and investment-to-GDP ratio. All specifications include a constant and month fixed effects. The log currency excess returns are computed as $f_t - s_t - \Delta s_{t+1}$. Using covered interest rate parity, the log interest rate differentials are equivalent to the forward discounts $f_t - s_t$. Exchange rates and returns are reported in US dollar. The moments of returns and forward discounts are annualized. Debt investment centrality is the global portfolio debt share weighted average of a country's bilateral foreign portfolio debt holdings of all other countries relative to total bilateral GDP. Trade centrality is the output share weighted average of a country's bilateral trade intensities with all other countries relative to total bilateral GDP. GDP share is a country's fraction of the total GDP of all available countries in the sample for that year. Investment-to-GDP is a country's total foreign portfolio holdings relative to GDP. Portfolio data are from IMF Coordinated Portfolio Investment Survey, trade data are from IMF Direction of Trade Statistics, and annual GDP data are from the World Bank. The Eurozone is an aggregate with all countries that adopted the Euro until the beginning of the sample by summing up their positions with other non-Euro countries into one entity. Foreign exchange data are monthly from Reuters via Datastream for 26 countries from January 2001 to August 2021. Standard errors are clustered by country and month. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

	rx	*rx*	*rx*	*rx*	*fd*	*fd*	*fd*	*fd*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Debt investment centrality	-0.99***	-0.68**	-1.08***	-0.82***	-1.23**	-0.73*	-1.57*	-0.85**
	(0.27)	(0.27)	(0.35)	(0.20)	(0.45)	(0.39)	(0.84)	(0.36)
Trade centrality		-0.63*				-1.00*		
		(0.35)				(0.53)		
GDP share			0.12				0.45	
			(0.26)				(0.56)	
Investment/GDP				-0.56***				-1.20**
				(0.18)				(0.43)
Num. obs.	5,728	5,728	5,728	5,728	5,728	5,728	5,728	5,728
R^2	0.46	0.46	0.46	0.46	0.16	0.20	0.16	0.22

Table A.8: Regressions of currency excess returns and forward discounts - equity investment centrality This table presents the results of regressions of log currency risk premia rx and log forward discounts fd on standardized one-year lagged equity investment network centrality v_{it-12}^{Equity}, trade network centrality, GDP share, and investment-to-GDP ratio. All specifications include a constant and month fixed effects. The log currency excess returns are computed as $f_t - s_t - \Delta s_{t+1}$. Using covered interest rate parity, the log interest rate differentials are equivalent to the forward discounts $f_t - s_t$. Exchange rates and returns are reported in US dollar. The moments of returns and forward discounts are annualized. Equity investment centrality is the global portfolio equity share weighted average of a country's bilateral foreign portfolio equity holdings of all other countries relative to total bilateral GDP. Trade centrality is the output share weighted average of a country's bilateral trade intensities with all other countries relative to total bilateral GDP. GDP share is a country's fraction of the total GDP of all available countries in the sample for that year. Investment-to-GDP is a country's total foreign portfolio holdings relative to GDP. Portfolio data are from IMF Coordinated Portfolio Investment Survey, trade data are from IMF Direction of Trade Statistics, and annual GDP data are from the World Bank. The Eurozone is an aggregate with all countries that adopted the Euro until the beginning of the sample by summing up their positions with other non-Euro countries into one entity. Foreign exchange data are monthly from Reuters via Datastream for 26 countries from January 2001 to August 2021. Standard errors are clustered by country and month. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

	rx	*rx*	*rx*	*rx*	*fd*	*fd*	*fd*	*fd*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Equity investment centrality	-0.83***	-0.42	-0.65*	-0.59***	-1.32**	-0.81*	-1.48**	-0.84**
	(0.25)	(0.30)	(0.33)	(0.17)	(0.49)	(0.42)	(0.67)	(0.35)
Trade centrality		-0.74*				-0.93*		
		(0.41)				(0.51)		
GDP share			-0.27				0.24	
			(0.33)				(0.41)	
Investment/GDP				-0.57***				-1.11***
				(0.17)				(0.39)
Num. obs.	5,728	5,728	5,728	5,728	5,728	5,728	5,728	5,728
R^2	0.46	0.46	0.46	0.46	0.17	0.20	0.17	0.22