Trade Network Centrality and Currency Risk Premia

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Abstract

I uncover an economic source of exposure to global risk that drives international asset prices. Countries which are more central in the global trade network have lower interest rates and currency risk premia. To explain these findings, I present a general equilibrium model where central countries' consumption growth is more exposed to global consumption growth shocks. This causes the currencies of central countries to appreciate in bad times, resulting in lower interest rates and currency risk premia. Empirically, central countries' consumption growth covaries more with world consumption growth and their equity Sharpe ratios are higher, further validating the proposed mechanism.

JEL classification: F31, F41, G12, G15, E44

Keywords: Exchange Rates, Currency Risk Premia, Carry Trade, UIP, Trade, Networks

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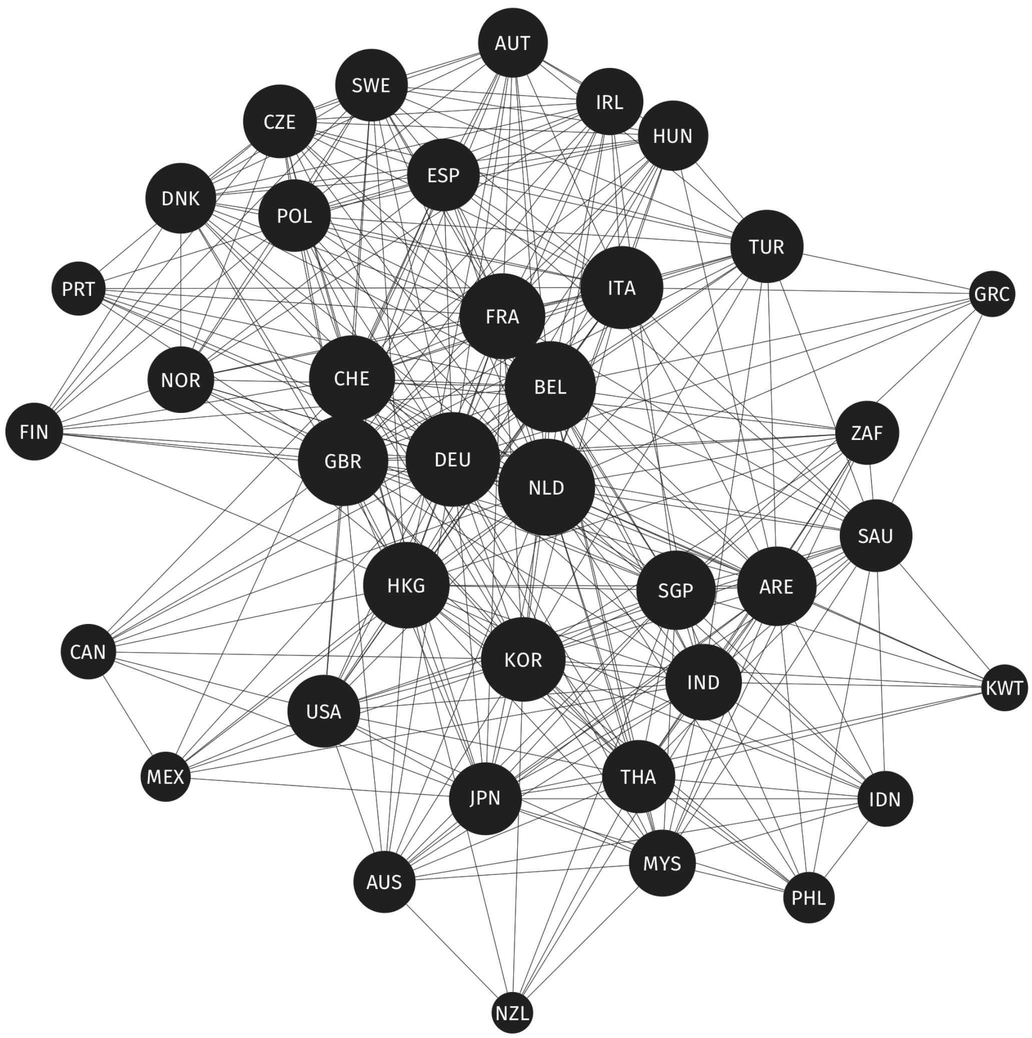
Carry trade investors who went long in currencies with high average interest rates, by borrowing in currencies with low average interest rates, obtained an annualized Sharpe ratio of 0.43 between 1995 and 2013. This Sharpe ratio is similar to those found in U.S. equity markets and is surprising given the strategy's simple, unconditional nature. Although the returns to carry trade strategies are well studied, less is known about their economic origins. In this paper, I show that differences in interest rates that drive currency returns are explained by countries' trade network centrality — a measure of their position in the global trade network. By connecting returns to economic quantities, I shed light on the fundamental origins of exposure to risk that drives international asset prices.

To make the connection between returns and quantities, I begin with the simple observation that countries share and are exposed to risk through trade links. These trade links form a global trade network, which is depicted for 2013 in Figure (1). Each circle represents a country and each line represents a trade link. Trade links are measured using pair-wise total trade normalized by pair-wise total GDP and only the top half are displayed. The position and size of each circle corresponds to the country's *overall* position in the trade network — its trade network centrality. Countries are more central if they have many strong links to countries that are themselves central. For example, global trade hubs, such as Singapore and Hong Kong, are central. In contrast, countries which only trade a small amount with a few partners, such as New Zealand, are peripheral. These cross-sectional differences in trade network centrality turn out to be a significant determinant of countries' unconditional interest rates and currency risk premia.

Figure (2) illustrates the relation between centrality, interest rates, and currency risk premia. To focus on unconditional variation, I plot 10-year averages of interest rate differentials and risk premia for a U.S. investor versus 10-year averages of trade network centrality. Central countries, such as Singapore, have low average interest rates and currency risk premia. On the contrary, peripheral countries, such as New Zealand, have high average interest rates and currency risk premia. In general, interest rates and currency risk premia are decreasing in trade network centrality. These patterns hold for both nominal and real risk premia and interest rate differentials[1]. A U.S. investor who went long in a portfolio of peripheral countries' currencies and short in a portfolio of central countries' currencies from 1984 through 2013 received an annualized Sharpe ratio of 0.56 — similar to that of the unconditional carry trade.

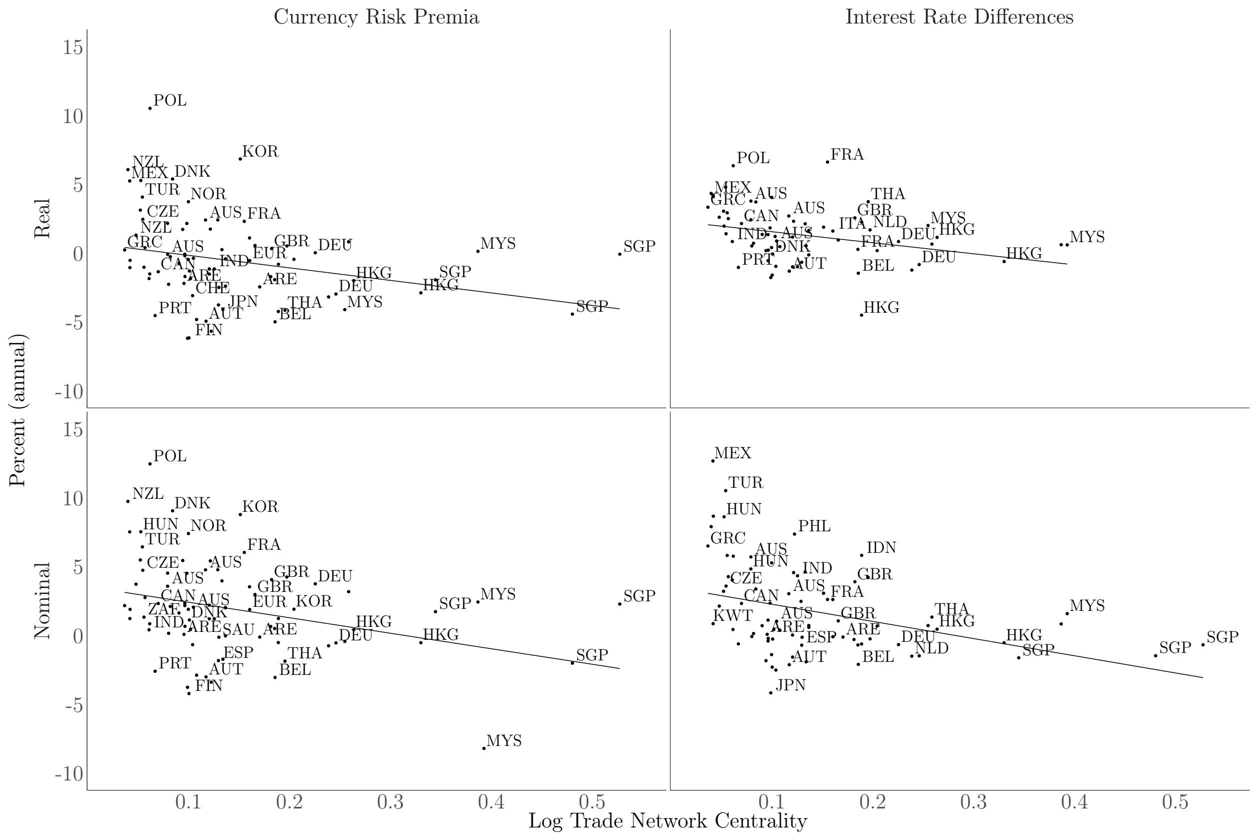
[1]For real values, inflation expectations are lagged year-over-year inflation as in Atkeson and Ohanian (2001). The patterns are very similar using ex-post realized inflation.

Figure 1: World Trade Network in 2013



Country links are measured by bilateral trade intensity — pair-wise total trade normalized by pair-wise total GDP. Links are drawn if bilateral trade intensity is greater than the cross sectional median. Circle size and position corresponds to alpha centrality calculated on the adjacency matrix of bilateral trade intensities. Trade data are reported exports from the IMF Direction of Trade Statistics GDP data from the World Bank, both in dollars.

Figure 2: Risk Premia and Interest Rate Differentals versus Centrality



Decade long averages of annualized risk premia rx and annualized 1-month interest rate differences (measured using covered interest rate parity with forward spreads $f - s$) versus trade network centrality for 39 countries. For real values, inflation expectations are lagged year-over-year inflation as in Atkeson and Ohanian (2001). For each country, monthly observations are averaged into 3 blocks (1984-1992, 1993-2002, 2003-2013). Centrality is Katz (1953) centrality centrality of an adjacency matrix of bilateral trade intensities — pair-wise total trade divided by pair-wise total GDP. Trade data are annual reported exports from the IMF Direction of Trade Statistics and annual GDP data are from the World Bank, both in dollars. For the euro area, I construct an aggregate with all countries that adopted the euro, beginning in 1999. Foreign exchange data are monthly from Barclay's and Reuter's.

Why do central countries have lower interest rates and currency risk premia? To answer this question, I present a tractable, multi-country model which shows that the currencies of central countries are a good hedge against global consumption risk. Households in each country consume a non-tradable good and a bundle of tradable goods produced in a global production network. The production network gives rise to global risk that drives differences in interest rates and currency risk premia. Central countries are more important in the production network than peripheral countries because more of global output relies on their goods as intermediates. Therefore, production shocks in the center of the network affect global output more than production shocks in the periphery. Importantly, bad shocks to tradables output coincide with bad shocks to non-tradables output. This causes central countries' consumption bundles to be more exposed to bad shocks to global output.

Countries' differential exposure to global shocks imputes variation in their real exchange rates. This is because real exchange rates are simply the relative price of countries' consumption bundles. When a country receives a bad shock, the price of its non-tradables increases relative to tradables, which increases the overall price of its bundle. In particular, when central countries receive a bad shock, global marginal utility is high. In these high marginal utility states, the relative price of central countries' consumption bundle increases, causing their currency to appreciate. As a result, central countries' currencies appreciate in high marginal utility states and are a good hedge against global consumption risk. This results in central countries having low interest rates and currency risk premia.

To test the model, I construct an empirical counterpart of the model's centrality measure using observed trade data. As predicted, a 1 standard deviation increase in a country's centrality lowers its annualized currency risk premia by 0.8% and its interest rate differential by 1.4%, relative to the U.S. This is a large effect given that the cross-sectional standard deviation of average risk premia and interest rate differentials are 3.5% and 5.3% respectively. I control for two alternative explanations. First, countries may have low risk premia and interest rates because they are large (Hassan, 2013). Although countries' GDP share does have a significant impact on their interest rates, controlling for GDP share does not change the economic or statistical significance of trade network centrality. Second, countries may rely heavily on trade causing them to be highly exposed to global shocks. This mechanism could also result in lower interest rates and currency risk premia. Interestingly, countries' trade-to-GDP ratio does not impact interest rates or currency risk premia when controlling for centrality. This suggests that a country's importance for global trade, rather than the importance of trade for the country, is a key determinant of interest rates and currency risk premia.

As an additional test, I sort currencies into portfolios. Sorting into portfolios reduces idiosyncratic currency risks (Fama and MacBeth, 1973; Lustig and Verdelhan, 2007) and focuses on variation associated with countries' trade network centrality. When sorted on trade network centrality, interest rates and currency risk premia are increasing from the portfolio of central countries to the portfolio of peripheral countries. Furthermore, countries' consumption growth covariances with world consumption growth, as well as their equity market Sharpe ratios, are decreasing from the central to peripheral portfolios. Both findings are consistent with the model's implications.

Using the portfolio sorts, I compare the returns of a centrality based risk factor, PMC, to an unconditional carry trade risk factor, $UHML^{FX}$. PMC is long peripheral countries' currencies and short central countries' currencies, while $UHML^{FX}$ is long high average interest currencies and short low average interest rate currencies. In a regression of $UHML^{FX}$ on PMC there is no unexplained excess return and $UHML^{FX}$ moves almost one-for-one with PMC. This finding provides an economic explanation of the assymetric exposure to global risk that is necessary for the carry trade (Lustig et al., 2011).

More broadly, my results link fundamental quantities to international asset prices by contributing to three active areas of research: networks, exchange rate determination, and international risk sharing. I make these contributions theoretically by embedding the non-tradables friction of Backus and Smith (1993) within a multi-country version of the network model of Acemoglu et al. (2012)[2]. The latter work shows how production networks can give rise to aggregate economic fluctuations. The model illustrates in an international context how the global production network generates heterogenous exposure to global shocks at the country level. Additionally, the model provides a tractable framework to jointly understand exchange rate behavior, international quantities, and other asset prices such as interest rates and equity market Sharpe ratios.

Importantly in the context of this paper, the endogenous differences in exposure to aggregate fluctuations generated by the model leads to variation in real exchange rates. The variation in real exchange rates implied by the model is consistent with Burstein et al. (2006) and Betts and Kehoe (2008). Both papers show that variation in the relative price of non-tradables to tradables is important for movement in real exchange rates. Additional variation

[2] As an implication of Acemoglu et al. (2012), Ahern (2012) shows that firms which are in central industries earn higher equity returns because they are more exposed to market risk. Barrot and Sauvagnat (2016) show that input specificifity in production networks generates propagation of idiosyncratic shocks between suppliers and customers.

in real exchange rates arises due to relative prices of tradable goods across countries, as noted in Engel (1999). A survey of the connection between prices and exchange rates can be found in Burstein and Gopinath (2014).

Research on the relation between exchange rates and interest rates began with tests of the uncovered interest parity (UIP) condition by Bilson (1978) and Fama (1984). Hassan and Mano (2013) decomposes the returns to various currency strategies and shows how they are related. Lustig and Verdelhan (2007) were the first to sort currencies into portfolios on interest rates and to show that U.S. consumption growth risk exposure explains this cross-section of currency returns. Work by Bekaert (1996), Bansal (1997), Backus et al. (2001), and Lustig et al. (2011) provides restrictions on models that are necessary to explain deviations from UIP. My work helps to understand the economic source of these deviations, both theoretically and empirically.

Additionally, my paper is related to work on global risk, market integration, and international asset pricing models. Solnik (1974) presents an international CAPM model. Following this work, Harvey (1991) and Dumas and Solnik (1993) examine the global price of risk and stock and FX markets, respectively. Bekaert and Harvey (1995) examine the time variation in global market capital market integration and show how this varition impacts expected returns across countries. Ferson and Harvey (1993) show how predictability in equity markets is related to global economic risks. Barrot et al. (2016) show that firms in low shipping cost industries carry a risk premium associated with displacement risk.

My results on consumption covariances relate to work on international risk sharing such as Stockman and Tesar (1990), Obstfeld (1994), Lewis (1995), and Tesar (1995). In particular, the last paper presents the cross-section of consumption growth covariances that I show is related to trade network centrality. Colacito and Croce (2011) show that correlation in long-run consumption risk can resolve disconnects between economic fundamentals and asset prices.

Most closely related to my paper are papers that also study unconditional currency returns using country asymmetries. Hassan (2013) shows that currencies of larger countries hedge investors against a greater proportion of consumption risk and therefore have lower currency risk premia and interest rates. Ready et al. (2013) solve and empirically test a model where countries that produce commodity goods are distinct from countries that produce final goods. In their model, currencies of commodity producing countries depreciate in bad times, increasing their currency risk premia.

Theoretical explanations of conditional currency returns include Alvarez et al. (2009), Verdelhan (2010), Bansal and Shaliastovich (2012), and Gabaix and Maggiori (2014). Della Corte et al. (2013) empirically test the last paper and show that external imbalances explain a large proportion of the cross-section of currency returns. Lettau et al. (2014) show that the cross-section of currency returns can be priced by a model of downside risk. Maggiori (2011) presents a model which explains why financially developed countries' currencies become reserve currencies.

This paper is organized as follows. In Section (1), I develop a theoretical model that motivates the link between centrality, interest rates, and currency risk premia. In Section (2), I construct an empirical measure of centrality and test the model's predictions. I conclude in Section (3). Appendix A contains derivations and proofs for the model. Appendix B contains details on the empirical results and robustness checks.

1 Model with Network-Based Production

In this section, I present a tractable multi-country model with network-based production. The model embeds the production of structure Long and Plosser (1983) and Acemoglu et al. (2012) into an international setting with differing goods varieties as in Backus and Smith (1993) and Tesar (1993). This generalization to differing goods varieties generates rich behavior of exchange rates, international asset prices, and consumption correlations. In particular, the model shows that countries that are central in the global trade network have lower interest rates and currency risk premia due to higher exposure to common consumption growth risk. In addition, the model predicts that equity market Sharpe ratios should be higher in central countries than in peripheral countries.

I use tractable functional forms in order to obtain analytic results for the relation between relevant quantities and trade network centrality. In recent work, Baqaee and Farhi (2017) generalize the standard single-country model from Cobb-Douglas to CES and show how network effects relate to the underlying functional forms. That said, obtaining analytic results in an international setting with differing goods varieties remains limited to functional forms similar to those presented here.

1.1 Model Environment

The economy consists of N countries indexed $i = 1, \ldots, N$. Each country has a representative household, a production sector for a unique tradable good, and a production sector for non-tradable goods. Tradable goods are used as intermediates for production of other tradable goods and for consumption. There are three time periods, $t = 0, 1, 2$. Time 0 is a planning period. At $t = 1, 2$ each country realizes a pair of shocks denoted Z_{it} and Y_{it}. At $t = 1, 2$ each representative household is endowed with one unit of labor which it supplies to the domestic production sectors. The shocks are summarized by $\xi_t = \{(Z_{it}, Y_{it})\}_{i=1}^{N}$. At time $t = 1$, there is no risk and shocks are normalized to 1. At time $t = 2$, shocks have i.i.d. distributions across countries. The distributions of the shocks are

$$z_{i1} = \log(Z_{i1}) = 0, \tag{1}$$

$$y_{i1} = \log(Y_{i1}) = 0, \tag{2}$$

$$z_{i2} = \log(Z_{i2}) \overset{i.i.d}{\sim} G_z, \tag{3}$$

$$y_{i2} = \log(Y_{i2}) \overset{i.i.d}{\sim} G_y \text{ for all } i. \tag{4}$$

The representative household in country i ranks consumption according to

$$\log\left(\overline{C}_{i1}(\xi_1)\right) + \beta E\left[\log\left(\overline{C}_{i2}(\xi_2)\right)\right], \tag{5}$$

where $\beta \in (0, 1)$ is the subjective discount factor and $\overline{C}_{it}(\xi_t)$ is the time t consumption aggregator over tradable and non-tradable goods given by

$$\overline{C}_{it}(\xi_t) = (N_{it}(\xi_t))^{\theta} \left(\prod_{j=1}^{N} (C_{ijt}(\xi_t))^{\frac{1}{N}}\right)^{1-\theta}. \tag{6}$$

For each country i at time t, $C_{ijt}(\xi_t)$ is its consumption of country j's unique tradable good and $N_{it}(\xi_t)$ is its non-tradable endowment. The parameter $\theta \in (0, 1)$ measures the preference weighting between non-tradable and tradable goods. To emphasize trade network position as the only source of country hetereogeneity, all countries have symmetric preferences and each tradable goods has equal weight $\frac{1-\theta}{N}$.

All goods are non-storable. The domestic production sectors distribute any profits to their country's representative household. Output at times $t = 1, 2$ in country i's non-tradable sector is

$$N_{it}(\xi_t) = (Z_{it})^{\rho} \left(L_{it}^{N}(\xi_t)\right)^{\rho} (Y_{it})^{1-\rho}, \tag{7}$$

where $L_{it}^{N}(\xi_t)$ is the labor supplied to non-tradables production and $\rho \in (0, 1]$ is a weighting parameter between the shocks. When $\rho < 1$ non-tradables endowments depend on both shocks, Z_{it} and Y_{it}. When $\rho = 1$, non-tradables endowments are only a function of the shocks Z_{it}. The shocks Z_{it} are the same shocks that impact domestic tradables output specified next. Therefore, low realizations of non-tradables coincide with negative productivity shocks in the domestic tradeables sector. In a standard calibration, Stockman and Tesar (1995) find a correlation of 0.46 between shocks to traded and non-traded sectors within countries.

Each country produces its unique tradable good in a domestic production sector using other countries' tradable goods as intermediates. The structure of this production network is determined by production weights w_{ij}. These production weights are the key source of assymetries across countries that determines their trade network centrality and the resulting variation in international asset prices. Specifically, output at $t = 1, 2$ of country i's tradable good is

$$\overline{X}_{it}(\xi_t) = (Z_{it})^{\alpha} \left(L_{it}^{T}(\xi_t)\right)^{\alpha} \prod_{j=1}^{N} (X_{ijt}(\xi_t))^{(1-\alpha)w_{ij}}\,, \tag{8}$$

where $X_{ijt}(\xi_t)$ is the amount of country j tradables used as an intermediate in country i's tradables production, Z_{it} is the idiosyncratic shock in country i, and $L_{it}^{T}(\xi_t)$ is labor supplied to the tradables sector in country i. The parameter $\alpha \in (0, 1)$ measures the elasticity of output with respect to labor. The intermediate production weights, $w_{ij} \geq 0$, measure the importance of other countries' tradable goods for country i's output. A larger w_{ij} implies that more of country j's tradable good is needed to produce a unit of country i's tradable goods. I assume $\sum_{j=1}^{N} w_{ij} = 1$ for all i so that tradables output has constant returns to scale.

Output of country i tradables must equal the total amount used as intermediates in the production of other tradables plus the total amount consumed. Additionally, total labor supplied to the non-tradables and tradables sector in each country must equal each representative household's endowment. Therefore, the market clearing conditions are

$$\overline{X}_{it}(\xi_t) = \sum_{j=1}^{N} X_{jit}(\xi_t) + \sum_{j=1}^{N} C_{jit}(\xi_t) \quad \forall\ i, \tag{9}$$

$$1 = L_{it}^{N}(\xi_t) + L_{it}^{T}(\xi_t) \qquad \forall\ i. \tag{10}$$

Financial markets are complete — at time 0, the representative households and firms trade a complete set of Arrow-Debreu claims for non-tradable goods at price $P_{it}^{N}(\xi_t)$, tradable goods at price $P_{it}^{T}(\xi_t)$, and to provide labor at wage $\Omega_{it}(\xi_t)$. This implies that the time 0 budget constraint for country i's representative household is given by

$$
\begin{aligned}
& P_{i1}^{N}(\xi_1)N_{i1}(\xi_1) + \sum_{j=1}^{N} P_{j1}(\xi_1)C_{ij1}(\xi_1) + \\
& \int_{\xi_2}\left(P_{i2}^{N}(\xi_2)N_{i2}(\xi_2) + \sum_{j=1}^{N} P_{j2}(\xi_2)C_{ij2}(\xi_2)\right)d\xi_2 \\
\leq\ & \Omega_{i1}(\xi_1) + \Pi_{i1}^{N}(\xi_1) + \Pi_{i1}^{T}(\xi_1) + \int_{\xi_2}\left(\Omega_{i2}(\xi_2) + \Pi_{i2}^{N}(\xi_2) + \Pi_{i2}^{T}(\xi_2)\right)d\xi_2,
\end{aligned}
\tag{11}
$$

where $\Pi_{it}^{N}(\xi_t)$ and $\Pi_{it}^{T}(\xi_t)$ are the time 0 state-contingent value of profits from the domestic non-tradables and tradables production sectors, respectively. Profits in the non-tradables and tradables sectors are

$$
\Pi_{it}^{N}(\xi_t) = P_{it}^{N}(\xi_t)N_{it}(\xi_t) - \Omega_{it}(\xi_t)L_{it}^{N}(\xi_t)\ , \tag{12}
$$

$$
\Pi_{it}^{T}(\xi_t) = P_{it}^{T}(\xi_t)\overline{X}_{it}(\xi_t) - \Omega_{it}(\xi_t)L_{it}^{T}(\xi_t) - \sum_{j=1}^{N} P_{jt}^{T}(\xi_t)X_{ijt}(\xi_t). \tag{13}
$$

The equilibrium definition is as follows.

Definition 1. *An Arrow-Debreu competitive equilibrium consists of non-tradable goods prices* $\{P_{it}^{N}(\xi_t)\}_{i=1\ldots N}$*, tradable goods prices* $\{P_{it}^{T}(\xi_t)\}_{i=1\ldots N}$*, wages* $\{\Omega_{it}(\xi_t)\}_{i=1\ldots N}$*, non-tradable labor input* $\{L_{it}^{N}(\xi_t)\}_{i=1\ldots N}$*, tradable labor input* $\{L_{it}^{T}(\xi_t)\}_{i=1\ldots N}$*, tradable goods inputs* $\{X_{ijt}(\xi_t)\}_{i,j=1\ldots N}$*, and tradable goods consumptions* $\{C_{ijt}(\xi_t)\}_{i,j=1\ldots N}$ *for each* ξ_t*, such that households maximize Equation (5) subject to Equation (11), non-tradables firms maximize Equation (12), tradables firms maximize Equation (13), tradable goods markets clear, Equation (9), and labor markets clear, Equation (10), for all* i*.*

1.2 Social Planner Solution

Instead of solving directly for the competitive equilibrium, I exploit the second welfare theorem and solve a social planner's problem. Specifically, the competitive equilibrium can be supported as the solution to a social planner's problem with some Pareto weights for each representative household (Negishi, 1960). This is possible because financial markets are complete — agents trade a complete set of state contingent claims. I assume that lump sum transfers occur before trading such that all Pareto weights are equal to 1. Details of the solution in this section can be found in Appendix A.

Because preferences are time-separable and goods are non-storable, the solution to the planner problem can be found by solving a simple static problem for each shock realization. For notational simplicity, I omit dependence on ξ_t going forward. The social planner's objective is

$$\underset{\substack{\{C_{ijt},\, X_{ijt}\}_{i,j=1\dots N} \\ \{L_{it}^N,\, L_{it}^T\}_{i=1\dots N}}}{\text{maximize}} \quad \sum_{i=1}^{N}\Big(\log\left(\overline{C}_{i1}\right)+\beta E\big[\log\left(\overline{C}_{i2}\right)\big]\Big) \tag{14}$$

$$\text{subject to} \quad \overline{C}_{it} = \left((Z_{it})^{\rho}\left(L_{it}^N\right)^{\rho}(Y_{it})^{1-\rho}\right)^{\theta}\left(\prod_{j=1}^{N}(C_{ijt})^{\frac{1}{N}}\right)^{1-\theta} \tag{15}$$

$$(Z_{it})^{\alpha}\left(L_{it}^T\right)^{\alpha}\prod_{j=1}^{N}(X_{ijt})^{(1-\alpha)w_{ij}} = \sum_{j=1}^{N}X_{jit}+\sum_{j=1}^{N}C_{jit} \tag{16}$$

$$1 = L_{it}^N + L_{it}^T \qquad \forall\, i,t. \tag{17}$$

Equation (15) is household i's consumption basket with its non-tradables endowment substituted in — non-tradable goods must be consumed domestically. Equation (16) is the market clearing condition with output replaced by the tradables production function. Equation (17) is the market clearing condition for labor in each country. In each period t and for each possible realization of shocks, the planner chooses intermediate usages of tradables $\{X_{ijt}\}_{i,j=1,\dots,N}$, tradables final consumptions $\{C_{ijt}\}_{i,j=1,\dots,N}$, and labor supplies $\left\{L_{it}^N,\ L_{it}^T\right\}_{i=1\dots N}$. These quantities imply total tradable goods outputs $\left\{\overline{X}_{it}\right\}_{i=1,\dots,N}$ and consumption baskets $\left\{\overline{C}_{it}\right\}_{i=1,\dots,N}$.

To solve the model, I assign Lagrange multipliers Ψ_{it} to each resource constraint in Equation (16) and G_{it} to each labor market constraint in Equation (17). The Lagrange multipliers Ψ_{it} measure the shadow price of each country's tradable good. First order conditions with respect to C_{jit} and X_{jit} give

$$C_{jit} = \frac{(1-\theta)}{N\Psi_{it}}, \tag{18}$$

$$X_{jit} = \frac{\Psi_{jt}\overline{X}_{jt}(1-\alpha)w_{ji}}{\Psi_{it}}. \tag{19}$$

Rearranging Equation (19) shows how the production weights, w_{ji}, are related to expenditure shares:

$$X_{jit} = \frac{\Psi_{jt}\overline{X}_{jt}(1-\alpha)w_{ji}}{\Psi_{it}} \implies \frac{\Psi_{it}X_{jit}}{\Psi_{jt}\overline{X}_{jt}} = (1-\alpha)w_{ji}. \tag{20}$$

Country j's production expenditure on country i's tradable goods, normalized by the value of j's output, is proportional to the production weights w_{ji}. Combining the first order conditions with the resource constraint, Equation (16), implies

$$\begin{aligned}\overline{x}_t &= (\boldsymbol{I} - (1-\alpha)W)^{-1}(\alpha z_t + a) \\ &= \left(\boldsymbol{I} + (1-\alpha)W + (1-\alpha)^2W^2 + (1-\alpha)^3W^3 + \ldots\right)(\alpha z_t + a)\,,\end{aligned} \tag{21}$$

where $\overline{x}_t = \left[\log(\overline{X}_{1t}), \ldots, \log(\overline{X}_{Nt})\right]'$ is the vector of log tradable outputs, $z_t = [\log(Z_{1t}), \ldots, \log(Z_{Nt})]'$ is the vector of log shocks, $W = [w_{ij}]$ is the matrix of production weights, and the constant vector a is defined in Appendix A. Throughout the paper, I define $\mathbf{1}$ as the vector of ones of and $\boldsymbol{I}$ as the identity matrix — both are assumed to be of the appropriate dimension. The second equality follows from expanding the inverse as a series.

Equation (21) shows that tradables output is the result of propagation of shocks due to the interdependent nature of production. The way that shocks propagate through the production network is determined by the matrix of production weights W. Equilibrium output is the result of direct and indirect effects of the network's structure. A shock to the output of one country impacts production of all countries that rely on its goods as intermediates and, in turn, the countries that rely on those. The decay of this propagation is governed by the value of $1-\alpha$, where higher values imply that shocks propagate further due to more reliance on intermediates in production. With Cobb-Douglas production technology, propagation only occurs downstream because price changes exactly offset the output impact of production shocks (Shea, 2002). With more general production technology, shocks could propagate via importing relationships. Therefore, in the empirical tests I examine whether shocks propagate upstream, downstream, or in both directions.

Given tradables output of each country in Equation (21), log consumption baskets are

$$\overline{c}_t = \theta\left(\rho z_t + (1-\rho)y_t\right) + \frac{(1-\theta)\alpha}{N}\left(z_t'(\boldsymbol{I} - (1-\alpha)W')^{-1}\mathbf{1}\right) + d, \tag{22}$$

where $y_t = [\log(Y_{1t}), \ldots, \log(Y_{Nt})]'$ is the vector of log shocks, $\overline{c}_t = \left[\log(\overline{C}_{1t}), \ldots, \log(\overline{C}_{Nt})\right]'$ is the vector of log consumptions, and d is a vector of constants defined in Appendix A.

The term $(\boldsymbol{I} - (1-\alpha)W')^{-1}\mathbf{1}$ in Equation (22) is known as Katz centrality in the network literature (Katz, 1953; Bonacich and Lloyd, 2001). For a symmetric adjacency matrix, $W = W'$, Katz centrality is equivalent to Eigenvector centrality (Bonacich and Lloyd, 2001). Throughout the remainder of the paper, I refer to this measure as trade network centrality or simply centrality. Centrality measures a country's importance in the production network and is the key quantity in the model.

Country i's centrality, v_i, is just the i'th element of the centrality vector, which I define as v:

$$v_i = \left[(\boldsymbol{I} - (1-\alpha)W')^{-1} \mathbf{1} \right]_i . \tag{23}$$

With this definition, log consumption at time t for country i is

$$\begin{aligned} \overline{c}_{it} &= \theta \left(\rho z_{it} + (1-\rho) y_{it} \right) + \frac{(1-\theta)\alpha}{N} \left(\sum_{j=1}^{N} v_j z_{jt} \right) + d_i \\ &= \theta \left(\rho z_{it} + (1-\rho) y_{it} \right) + F_t + d_i, \end{aligned} \tag{24}$$

where the second equality is just a definition of F_t. Each country's consumption depends on two components. The first component in Equation (24), $\theta \left(\rho z_{it} + (1-\rho) y_{it} \right)$, is country i's non-tradable endowment. The second component is a centrality weighted sum of all production shocks in the economy given by

$$F_t = \frac{(1-\theta)\alpha}{N} \left(\sum_{j=1}^{N} v_j z_{jt} \right). \tag{25}$$

Importantly, this second component is symmetric across countries. It can be interpreted as the common risk factor in global consumption growth (Lustig et al., 2011). Shocks to central countries impact the common component more than shocks to peripheral countries. This can be seen simply because central countries have larger values of v_i in the sum. Economically, a shock in the center of the network will have large effects on aggregate consumption because global output relies more on central country goods as intermediates. Because shocks to non-tradables endowments are positively correlated with shocks to tradables production, central countries' consumption growth is more exposed to common consumption growth shocks. This is the key mechanism in the model.

To formally show that the consumption of central countries' is more exposed to common consumption shocks, I calculate average global consumption growth

$$\begin{aligned} \widehat{\Delta \overline{c}_2} &= \frac{1}{N} \sum_{j=1}^{N} \Delta \overline{c}_{j2} \\ &= \left(\frac{1}{N} \sum_{j=1}^{N} \left(\theta\rho + v_j \alpha (1-\theta) \right) z_{j2} \right) + \left(\frac{\theta(1-\rho)}{N} \sum_{j=1}^{N} y_{j2} \right), \end{aligned} \tag{26}$$

where changes in log consumption between period 1 and 2 are given by $\Delta \overline{c}_{i2}$ for $i = 1, \ldots, N$. There are no time 1 shocks in consumption growth terms because $z_{i1} = y_{i1} = 0$ for all i. I define σ_z^2 as the variance of z_{i2} for all i. In the following proposition, I show that central country consumption growth covaries more with global average consumption growth.

Proposition 1. *For two countries i and j*

$$\mathrm{Cov}(\Delta\bar{c}_{i2}, \widehat{\Delta\bar{c}_2}) - \mathrm{Cov}(\Delta\bar{c}_{j2}, \widehat{\Delta\bar{c}_2}) = \frac{\sigma_z^2}{N}\theta\rho\alpha(1-\theta)(v_i - v_j). \tag{27}$$

Therefore, $v_i > v_j$ implies $\mathrm{Cov}(\Delta\bar{c}_{it}, \widehat{\Delta\bar{c}_2}) > \mathrm{Cov}(\Delta\bar{c}_{jt}, \widehat{\Delta\bar{c}_2})$.

The mechanism that drives Proposition (1) also impacts asset prices and exchange rates. For each country, assets that pay off in units of the local consumption baskets are priced by the intertemporal marginal rate of substitution (IMRS) of the country's representative household. I use M_{i2} to denote the IMRS of country i's representative household between time 1 and time 2. Country i's log IMRS is given by

$$\begin{aligned} m_{i2} &= \delta + \bar{c}_{i1} - \bar{c}_{i2} \\ &= \delta - \theta\left(\rho z_{i2} + (1-\rho)y_{i2}\right) - \frac{(1-\theta)\alpha}{N}\left(\sum_{j=1}^{N} v_j z_{j2}\right), \end{aligned} \tag{28}$$

where I have used $\delta = \log(\beta)$ and $z_{i1} = y_{i1} = 0$.

Exchange rates are simply the relative price of countries' consumption baskets. Therefore, given complete financial markets, exchange rate changes are the ratio of the countries' IMRS:

$$M_{i2}\frac{Q_{ij1}}{Q_{ij2}} = M_{j2} \implies \Delta q_{ij2} = m_{i2} - m_{j2}, \tag{29}$$

where Q_{ijt} denotes the time t exchange rate in units of currency j per unit of currency i and lowercase letters denote logs. This expression shows that country i's currency appreciates relative to country j's when it has higher marginal utility growth. Equivalently, country i's currency appreciates when the relative price of its consumption basket increases. For example, if the U.S. receives a negative consumption shock that increases the price of its consumption basket relative to Mexico's, the Dollar will appreciate relative to the Peso.

The time 1 log interest rate in country i is $rf_{i1} = -\log E\left[M_{i2}\right]$, which implies that the log interest rate differential between country j and country i at time 1 is

$$rf_{j1} - rf_{i1} = \log E\left[M_{i2}\right] - \log E\left[M_{j2}\right]. \tag{30}$$

Foreign currency investors receive the interest differential over their home country and lose any appreciation of the home currency. Combining Equation (29) and Equation (30) gives the log risk premium to going long in currency j for a country i investor:

$$\begin{aligned} E\left[rx_{ij2}\right] &= rf_{j1} - rf_{i1} - E\left[\Delta q_{ij2}\right] \\ &= \left(\log E\left[M_{i2}\right] - \log E\left[M_{j2}\right]\right) - \left(E\left[m_{i2}\right] - E\left[m_{j2}\right]\right). \end{aligned} \tag{31}$$

For intuition, consider the case where the production shocks are log-normally distributed: $z_{i2} \overset{i.i.d}{\sim} \mathcal{N}(\mu_z, \sigma_z^2)$. In this case, risk premia and interest rate differentials have a particularly simple form:

$$\mathrm{E}\left[rx_{ij2}\right] = rf_{j1} - rf_{i1} = \sigma_z^2 \frac{\theta(1-\theta)\alpha\rho}{N}\left(v_i - v_j\right). \tag{32}$$

This equation shows that central countries have lower currency risk premia and interest rates. When country i is more central than country j, i.e. $v_i > v_j$, the currency risk premium for a country i investor going long in the currency of country j is positive and equal to the interest rate differential. This is a result of central countries being more exposed to common shocks to consumption growth, as shown in Proposition (1). On average, bad global shocks — which originate in the center of the network — increase central country marginal utility more. Higher marginal utility in bad times causes central country currencies to appreciate in bad times, making them a good consumption hedge and lowering their risk premia. Interest rates are also lower in central countries due to higher consumption growth variance.

The intuition from the normal case generalizes to any i.i.d. distribution of shocks z_{i2} in Equation (3) and i.i.d distribution of shocks y_{i2} in Equation (4). This is important because of work such as Chernov et al. (2012) and Brunnermeier et al. (2008) showing that currency investment strategies exhibit significant negative skewness. By incorporating higher order moments into the distribution of z_{i2}, such as skewness (Barro, 2006), currency risk premia will reflect these higher order moments. Exploiting the convexity of cumulant generating functions gives the following general proposition (the proof is in Appendix A).

Proposition 2. *For any two countries with $v_i > v_j$, the* log *currency risk premium for going long in currency j from country i and* log *interest rate differential satisfy*

$$\mathrm{E}\left[rx_{ij2}\right] = rf_{j1} - rf_{i1} > 0.$$

This proposition is the key takeaway from the model. Central countries have lower interest rates and lower currency risk premia than peripheral countries because their exchange rate tends to appreciate in high marginal utility states.

A final implication of the model is that Sharpe ratios in local currencies are higher in central countries than in peripheral countries. Specifically, define R_{i2}^E to be the excess return on an asset which pays off in the currency of country i. Then the following proposition holds:

Proposition 3. *Assume that the shocks are normally distributed for all i: $z_{i2} \overset{i.i.d}{\sim} \mathcal{N}(\mu_z, \sigma_z^2)$ and $y_{i2} \overset{i.i.d}{\sim} \mathcal{N}(\mu_y, \sigma_y^2)$. Then for any two countries with $v_i > v_j$, the maximum Sharpe ratios for excess returns in local currencies satisify:*

$$\underset{\{R_{i2}^E\}}{max} \frac{\mathrm{E}\left[R_{i2}^E\right]}{\sqrt{\mathrm{Var}\left[R_{i2}^E\right]}} > \underset{\{R_{j2}^E\}}{max} \frac{\mathrm{E}\left[R_{j2}^E\right]}{\sqrt{\mathrm{Var}\left[R_{j2}^E\right]}}.$$

2 Data and Empirical Trade Network Centrality

In this section, I test the predictions of Proposition (1), Proposition (2), and Proposition (3):

1. Central countries' consumption growth covaries more with global consumption growth than peripheral countries'.
2. Countries that are central in the global trade network have lower currency risk premia and lower interest rates than peripheral countries.
3. Local currency Sharpe ratios — paricularly in equity markets — are higher in central countries than in peripheral countries.

2.1 Data Sources

Daily spot and forward rates are from Barclay's and Reuter's[3]. The sample period is 1984 to 2013. A list of the 39 countries and the dates of data availability is in Table (B.1). I use one-month forward rates and convert daily observations to end-of-month series. All exchange rates are with respect to the U.S. Dollar. Consumer price indices used to calculate inflation are monthly from Barclay's and Reuter's. Data for Australia and New Zealand are only available quarterly, therefore I use interpolated monthly values.

I use q_{it} and f_{it} to denote the log spot and forward exchange rates in units of currency i per U.S. dollar. r_{it} is the 1-month log interest rate. Country indices are omitted anytime a value is with respect the U.S. Assuming that covered interest parity holds[4], forward spreads

[3]The data can be obtained through Datastream

[4]Akram et al. (2008) provide evidence that covered interest parity typically holds at daily frequencies. Due to large deviations from covered interest parity, some observations are omitted as specified in Appendix B. Additionally, Du et al. (2016) find large deviations from CIP after the financial crisis. Table (B.11) presents results limiting the sample to before the financial crisis. All results hold in this sample.

are equal to the interest rate differential: $f_{it} - q_{it} \approx r_{it} - r_t$. I calculate log risk premia for a U.S. investor going long in country i as

$$rx_{it+1} = r_{it} - r_t - \Delta q_{it+1} \approx f_{it} - q_{it+1}. \tag{33}$$

An investor who goes long in currency i at time t and divests at time $t+1$ receives the interest rate differential, less the appreciation of the home currency. All forward spreads and risk premia are annualized. I calculate real interest rate differentials from forward spreads by substracting expected inflation differentials. Expected inflation is calculated as lagged year-over-year change in log price indices following Atkeson and Ohanian (2001).

Bilateral trade data are from the International Monetary Fund's Direction of Trade Statistics. Data are annual from 1973 through 2013, covering 173 reporting countries. I use reported exports for each country, which are in current U.S. dollars "free on board." Current U.S. dollar GDP and population data are from the World Bank's World Development Indicators.

Real consumption data are from the Penn World Tables 7.1 (Heston et al., 2002). The data consists of real per capita GDP and consumption in international prices for 189 countries from 1950 to 2010.

Equity market returns are monthly in local currency from MSCI and are available on Datastream. Short-term interest rate data are 3-month yields from Global Financial Data. I use 3-month yields, rather than 1-month yields, to maximize sample coverage. The equity and yield data begin in January 1973 and end in December 2013. All returns and risk free rates are in logs. The list of countries that have equity and yield data that can be matched with the trade data is in Table (B.2).

For all datasets, I limit the sample to the 39 countries which foreign exchange data are available. For the euro area, I construct an aggregate with all countries that adopted the euro, beginning in 1999. Observations are omitted after a country secedes its currency to the euro. For robustness, I present results without using the euro aggregate in Table (B.7), results calculating centrality with all 173 countries in the trade data in Table (B.8), results omitting pegged currencies in Table (B.9), and results on a developed country subset in Table (B.10).

2.2 Empirical Trade Network Centrality

To determine each country's position in the trade network, I first construct a measure of the strength of trade ties between country pairs. I define bilateral trade intensity as

$$\widetilde{w}_{ijt} = \widetilde{w}_{jit} = \frac{\widetilde{X}_{ijt} + \widetilde{X}_{jit}}{\widetilde{Y}_{it} + \widetilde{Y}_{jt}}, \tag{34}$$

where $\widetilde{X}_{ijt}$ is the dollar value of exports from country i to country j at time t (equivalently the imports by j from i), and $\widetilde{Y}_{it}$ is the dollar GDP of country i at time t. Bilateral trade intensity measures the total trade between two countries, relative to their total GDP. This measure was first used in Frankel and Rose (1998) to explain business cycle correlations between countries.

Bilateral trade intensity is a natural generalization of the relation in Equation (20) of the model. The key insight of the model is that countries' heterogeneous trade links generate heterogeneous exposures to shocks which propagate through the trade network. I use this symmetric variant of Equation (20) to remain agnostic about the direction that shocks propagate. In the model, shocks only propagate downstream from exporters to importers due to the tractable Cobb-Douglas production technology. In general, shocks may propagate both upstream and downstream through the global trade network. For example, in a model with government demand shocks, Acemoglu et al. (2015) show that both upstream and downstream propagation occurs. Therefore, I focus on the symmetric variant, but also present results using normalized export weights, $\widetilde{w}_{ijt} = \frac{\widetilde{X}_{ijt}}{\widetilde{Y}_{it}+\widetilde{Y}_{jt}}$, and normalized import weights, $\widetilde{w}_{ijt} = \frac{\widetilde{X}_{jit}}{\widetilde{Y}_{it}+\widetilde{Y}_{jt}}$ in Table (B.5). The results are robust to the different specifications.

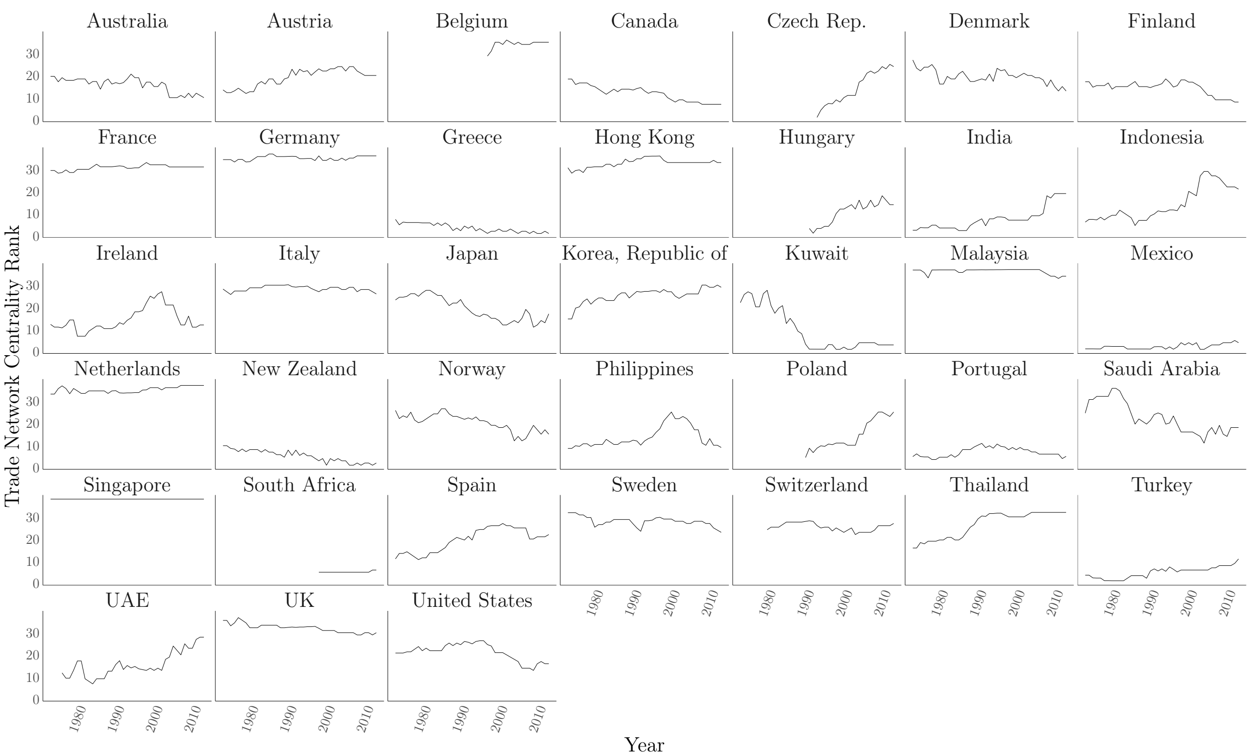
For each year, I construct an adjacency matrix, denoted $\widetilde{W}_t$, consisting of the bilateral trade intensities. Using the adjacency matrix, I calculate centrality for all countries each year as in Equation (23)[5]. To understand what trade network centrality is measuring, it helps to examine the weights in Equation (34). Trade links are stronger if bilateral trade represents a large proportion of countries' pair-wise total GDP. For example, New Zealand and Australia trade a significant amount of their total GDP with each other, which leads to a large bilateral trade intensity for these two countries. That said, they do not trade a significant proportion of pair-wise GDP with many other countries, such as the U.S. and Canada. Therefore, the weights with these larger countries will be smaller. In contrast, countries like the Netherlands and Singapore are home to some of the largest ports in the

[5] I use $1-\alpha = 1$. Varying $1-\alpha$ has almost no effect on the ranking of countries' centralities. For example, the minimum rank correlation (across years) of centralities calculated with $1-\alpha = 1$ and $1-\alpha = 0.1$ is 0.99.

world and are hubs for European, Asian, and global trade. On average, these countries will have high bilateral trade intensities with most countries in the world. It is important to remember that for each country, weights are calculated for all other countries in the sample. The centrality measure takes into account the global position of a country by considering a country to be central if it has strong trade links with countries that are themselves central.

Figure (3) shows the time series of centrality rankings. As predicted, Asian trade hubs such as Hong Kong and Singapore are the most central, while countries such as New Zealand are peripheral. Interestingly, despite an exponential increase in the level of global trade from 1973 to 2013, countries' relative centralities are a highly persistent. This persistence is why trade network centrality explains unconditional properties of countries, such as average interest rates and average currency risk premia.

Figure 3: Time Series of Centrality Ranking by Country



Rankings of countries' centrality in the global trade network by year. Centrality is alpha centrality of an adjacency matrix of yearly bilateral trade intensities — pair-wise total trade divided by total GDP. Rankings are normalized each year to between 1 and 39 (maximum number of countries in the sample). Trade data are annual reported exports from the IMF Direction of Trade Statistics and GDP data are from the World Bank, both in dollars. Data are annual from 1973 to 2013.

I begin by testing Proposition (2), where I show that central countries' currency risk premia and interest rates are lower than peripheral countries'. Table (1) presents regressions of forward spreads and risk premia on standardized trade network centrality. A one standard deviation increase in trade network centrality lowers forward spreads by 1.4% and currency risk premia by 0.8%, consistent with Proposition (2). The magnitude of these effects are large given that the cross-sectional standard deviation of average risk premia and interest rate differentials are 3.5% and 5.3% respectively.

I also present specifications with various controls in Table (1). First, central countries may be larger on average. Therefore, following Hassan (2013), I control for country size using countries' GDP shares. GDP share is a significant determinant of forward spreads and risk premia — a one standard deviation increase in GDP share lowers forward spreads by 0.9% and risk premia by 0.4%. That said, the centrality coefficient is effectively unchanged and the magnitude of the centrality effect is much larger than that of GDP share. Next, I control for a countries' total trade normalized by its GDP — a measure of trade openness. This is in contrast to centrality, which measures a country's importance for global trade. As an example, a country could have large trade to GDP because it trades a significant amount of its GDP with one country, but it will not typically be central. Consistent with the prediction that trade network centrality is what matters for risk premia and interest rates, controlling for trade to GDP does not impact the magnitude of the centrality coefficients.

I also control for the measure of trade specialization from Ready et al. (2013) in Table (B.3). In a bivariate regression, both trade network centrality and their measure of trade specialization remain significant determinants of the cross-section of currency risk premia.

Although trade network centrality is a highly persistent characteristic of countries, some countries do increase or decrease in centrality over time. An increase in a country's centrality could lead to a decrease in their risk premia and interest rate spread over time – vice-versa for a decrease in centrality. In Table (B.4) I test this hypothesis in regressions of risk premia and forward spreads on centrality, but including country fixed effects rather than time fixed effects as in Table (1). As predicted, the coefficients on centrality for risk premia and forward spreads are both negative. This suggests that as a country's centrality increases over time, its risk premia and interest rates do tend to decrease.

While country level interest rates and risk premia are important, the returns to the carry trade are a result of heterogeneous exposure to a global risk factor. To test this, I use portfolio sorts in the next section.

Table 1: Regressions for Risk Premia and Forward Spreads with Year Fixed Effects

	rx	rx	rx	$f-s$	$f-s$	$f-s$
Centrality	-0.849^{***}	-0.862^{***}	-0.982^{*}	-1.415^{**}	-1.442^{**}	-1.386^{*}
	(0.327)	(0.311)	(0.567)	(0.603)	(0.569)	(0.727)
GDP Share		-0.418			-0.886^{*}	
		(0.319)			(0.486)	
Trade to GDP			0.159			-0.036
			(0.539)			(0.664)
R^2	0.441	0.442	0.441	0.099	0.119	0.099
Num. obs.	644	644	644	645	645	645

Regressions of log risk premia rx_t and forward spreads $f_t - s_t$ on lagged standardized GDP share, standardized trade to GDP, and standardized trade network centrality, v_{it-1}. All specifications include year fixed effects. Excess returns and forward spreads are yearly averages of annualized observations. Centrality is Katz (1953) centrality of an adjacency matrix of yearly bilateral trade intensities pair-wise total trade divided by total GDP. GDP share is the fraction of world GDP for each country, where world GDP is the total GDP of all available countries in the sample for that year. Trade data are annual reported exports from the IMF Direction of Trade Statistics and annual GDP data are from the World Bank, both in dollars. For the euro area, I construct an aggregate with all countries that adopted the euro, beginning in 1999. Foreign exchange data are monthly from Barclay's and Reuter's for 39 countries from 1/1984 to 12/2013. Observations are omitted after a country secedes its currency to the euro. Standard errors in parentheses are clustered by country using Cameron et al. (2011). *, **, and *** denote significance at the 10%, 5%, and 1% levels respectively.

2.3 Carry Trade Risk Factors

Following Lustig and Verdelhan (2007) and Lustig et al. (2011), I sort currencies into portfolios. Portfolio sorts eliminate the idiosyncratic component of currency returns and uncover the common — undiversifiable — component of currency risk associated with the sorting variable. Sorting on forward spreads generates the standard cross-section of carry trade returns, while the innovation in this paper is sorting on trade network centrality. Table (2) reports the results. In each month t, currencies are sorted into 4 portfolios using three sorting variables: prior year trade network centrality, current forward spreads, and average forward spreads from 1984 to 1995. All sorting variables are observable at time t, making these sorts implementable trading strategies. Portfolios are rebalanced monthly, although trade network centralities are observed yearly and unconditional forward spreads are constant. Standard errors are calculated by bootstrapping 10,000 samples.

Panel A presents portfolios sorted on trade network centrality. Interest rates are monotonically increasing from the portfolio of peripheral countries to portfolio of central countries, producing an average spread in interest rates of 527 basis points. On average, peripheral country currencies depreciate by 57 basis points, while central country currencies appreciate by 129 basis points. Therefore, the 527 basis point interest rate differential translates to a 340 basis point spread in log excess returns. Central countries also have lower real interest rates. As with nominal interest rates, real interest rate differentials are monotonically increasing from central to peripheral portfolios with a spread between central and peripheral portfolios of 201 basis points. The annualized Sharpe ratio of a long peripheral, short central country portfolio is 0.56.

Panel A also presents evidence for Proposition (1), where I show that consumption growth covariances are increasing in centrality. To obtain a measure of consumption covariances, I regress each countries' per capita log consumption growth on world consumption growth using 20-year rolling windows

$$\Delta\widetilde{c}_{i\tau} = \alpha_{it} + \beta_{it}\Delta\widetilde{c}_{W\tau} + \epsilon_{i\tau} \quad \tau = t-19,\ldots,t. \tag{35}$$

Real per capita consumption is from the Penn World Table. I calculate log world per capita consumption, $\widetilde{c}_{Wt}$, by omitting each country i. The average consumption growth β is increasing from 0.09 for the portfolio of peripheral countries to 0.67 for the portfolio of central countries[6]. This finding shows that consumption growth in central countries is more correlated with world consumption growth. This is consistent with Proposition (1) and helps to explain the heterogeneity in consumption growth covariances found in papers such as Tesar (1995).

As a benchmark for the portfolio sorts on trade network centrality, in Panels B and C of Table (2) I sort currencies into portfolios on forward spreads. In Panel B, I sort on current forward spreads, which represent returns to the carry trade. In Panel C, I sort on average forward spreads, which represent unconditional returns to the carry trade. For the unconditional sorts, I use the average forward spread in the first part of the sample (1984-1995 as in Lustig et al. (2011)). Both sorts on current forward spreads and average forward spreads produce monotonic cross sections of currency risk premia. Neither currencies with currently high interest rates, nor currencies with on-average high interest rates, depreciate enough to offset the interest rate differential with the U.S.

[6]Standard errors for consumption growth betas are computed using a 20-year block bootstrap given that they are estimated using a rolling sample.

Table 2: Portfolios Sorted on Centrality and Forward Spreads

	Panel A: Trade Network Centrality				
	Peripheral	2	3	Central	PMC
Previous Centrality: v_{it-12}					
mean	1.06	1.10	1.16	1.33	-0.27
Forward Spread: $f_t - s_t$					
mean	5.57	1.39	1.26	0.31	5.27
std	1.23	0.58	0.58	0.54	1.23
se	0.23	0.11	0.11	0.10	0.23
Risk Premia: rx_t					
mean	5.00	3.15	1.93	1.60	3.40
std	7.87	10.10	7.46	6.05	6.05
se	1.46	1.88	1.39	1.14	1.13
Sharpe ratio					
mean	0.64	0.31	0.26	0.26	0.56
se	0.21	0.19	0.19	0.19	0.20
Real Interest Differential: $r_{it} - r_t$					
mean	2.76	1.04	0.77	0.76	2.01
std	0.55	0.54	0.58	0.62	0.72
se	0.10	0.10	0.11	0.11	0.13
Consumption Growth Coefficient: β_i					
mean	0.09	0.50	0.83	0.67	-0.58
se	0.24	0.05	0.07	0.03	0.24
	Panel B: Unconditional Forward Spread				
	Low	2	3	High	UHML^{FX}
Average Forward Spread (1984-1995)					
mean	-1.54	1.51	3.95	6.12	7.67
Forward Spread: $f_t - s_t$					
mean	-1.71	0.03	0.53	3.93	5.63
se	0.09	0.08	0.10	0.10	0.09
Risk Premia: rx_t					
mean	-1.25	0.03	0.77	3.11	4.36
std	6.12	6.69	9.22	12.05	10.16
se	1.45	1.59	2.19	2.83	2.38
Sharpe ratio					
mean	-0.20	0.00	0.08	0.26	0.43
se	0.24	0.24	0.24	0.24	0.25
	Panel C: Current Forward Spread				
	Low	2	3	High	HML^{FX}
Previous forward spread: $f_{t-1} - s_{t-1}$					
mean	-1.87	0.20	2.33	8.61	10.48
Forward Spread: $f_t - s_t$					
mean	-1.67	0.25	2.33	8.25	9.92
se	0.09	0.08	0.09	0.27	0.29
std	0.50	0.44	0.49	1.46	1.56
Risk Premia: rx_t					
mean	-1.01	1.80	3.99	4.63	5.65
se	1.31	1.30	1.49	1.87	1.53
std	7.11	7.05	8.10	10.16	8.32
Sharpe ratio					
mean	-0.14	0.26	0.49	0.46	0.68
se	0.18	0.19	0.19	0.20	0.20

Summary statistics of portfolios sorted on trade network alpha centrality v_{it}, current log forward spreads $f_t - s_t$, and average log forward spreads from 1/1984 to 12/1995. Each month t currencies are ranked on one of the 3 criteria and placed into 4 portfolios with equal weights. The last column is the difference between the high portfolio and the low portfolio. Log risk premia are $rx_t = f_{t-1} - s_{t-1} - \Delta s_t$. Real interest rate differentials are forward spreads less the expected inflation differential. Expected inflation is lagged year-over-year change in log CPI. Centrality v_{it} is Katz (1953) centrality of an adjacency matrix of yearly bilateral trade intensities — pair-wise total trade divided by total GDP. Mean, SD, and Sharpe ratios are annualized. Standard errors are from bootstrapping 10,000 samples. Trade data are annual reported exports from the IMF Direction of Trade Statistics and annual output data are GDP from the World Bank, both in dollars. For the euro area, I construct an aggregate with all countries that adopted the euro, beginning in 1999. Observations are omitted after a country secedes its currency to the euro. Foreign exchange data are monthly from Barclay's and Reuter's for 39 countries from 1/1984 to 12/2013.

To compare the returns of the three cross-sections in Table (2), I construct long-short risk factors (Lustig et al., 2011) for each sorting variable. I refer to the excess returns to the long-short trade network centrality strategy as PMC — peripheral minus central. The long-short risk factor from sorts on current forward spreads in Panel B is referred to as HML^{FX} — high minus low forward spread. Finally, the long-short risk factor from sorts in Panel C is referred to as $UHML^{FX}$ — unconditional HML^{FX}. Because the set of currently high interest rate currencies includes currencies with on-average high interest rates, the returns to HML^{FX} subsume the returns to $UHML^{FX}$. Importantly, HML^{FX} and $UHML^{FX}$ can be interpreted as risk factors in the sense that currencies with similar interest rates co-move.

Table (3) presents annualized summaries of the three risk factors. The first 3 columns are for all available data, while the last two columns match the sample period of PMC and HML^{FX} to $UHML^{FX}$. HML^{FX} has the highest annual return of 5.65% and a Sharpe ratio of 0.68. PMC and $UHML^{FX}$ have similar return profiles, although the Sharpe ratio of PMC is higher, due to lower volatility. Over the matched period, $UHML^{FX}$ (4.36%) makes up over half of the returns to HML^{FX} (7.22%). All strategies exhibit crash risk, with negative skewness and large maximum drawdowns. Interestingly, PMC appears to be less exposed to this risk, with a maximum drawdown of 15% compared to 25% for HML^{FX} and 33% for $UHML^{FX}$.

Table 3: Summary Statistics of Currency Risk Factors

	PMC	HML^{FX}	$UHML^{FX}$	PMC (2)	HML^{FX} (2)
Mean	3.40	5.65	4.36	4.04	7.22
SD	6.05	8.32	10.16	5.93	8.27
Sharpe Ratio	0.56	0.68	0.43	0.68	0.87
Skewness	− 0.05	− 0.05	− 0.08	− 0.06	− 0.05
Excess Kurtosis	− 0.40	− 0.61	0.18	− 0.22	− 0.58
Maximum Drawdown	0.15	0.25	0.33	0.14	0.20
N	348	359	216	216	216

Risk factors are constructed from excess returns of currencies sorted into 4 portfolios. PMC is from sorts of currencies on prior year trade network alpha centrality and goes long peripheral countries and short central countries. HML^{FX} is from sorts of currencies on currently observable log forward spreads $f_t - s_t$ and goes long high interest rate currencies and short low interest rate currencies. $UHML^{FX}$ is from sorts of currencies on average log forward spreads from 1/1984 to 12/1995 and goes long high average interest rate currencies and short low average interest rate currencies. Summaries for $UHML^{FX}$ are from 1/1996 to 12/2013. Summaries for PMC (2) and HML^{FX} (2) are also are calculated from 1996 to 2013 for comparison to $UHML^{FX}$. All portfolios are rebalanced monthly and moments are annualized. All moments are annualized. Mean and standard deviation are reported in percentage points. Centrality is alpha centrality of an adjacency matrix of yearly bilateral trade intensities — pair-wise total trade divided by total GDP. Trade data are annual reported exports from the IMF Direction of Trade Statistics and GDP from the World Bank, both in dollars. For the euro area, I construct an aggregate with all countries that adopted the euro, beginning in 1999. Observations are omitted after a country secedes its currency to the euro. Foreign exchange data are monthly from Barclays and Reuters for 39 countries from 1/1984 to 12/2013.

2.4 Cross-Sectional Asset Pricing (FX)

I next show that the returns to PMC can be used to explain the unconditional returns to the currency carry trade. If PMC can be used to explain the returns to the unconditional carry trade, it should co-move with and subsume the excess returns to $UHML^{FX}$. To test this hypothesis, I regress the benchmark risk factors, HML^{FX} and $UHML^{FX}$, on the centrality risk factor PMC

$$(U)HML_t^{FX} = \alpha + \beta PMC_t + \epsilon_t. \tag{36}$$

The results are presented in Table (4). PMC is highly correlated with $UHML^{FX}$, with a statistically significant β of 1.2. The unexplained excess returns, α, are statistically insignificant and are only 4 basis points annually. PMC is correlated with HML^{FX}, but an unexplained excess return still exist. Because HML^{FX} is constructed using conditional data in current forward spreads, while trade network centrality is and unconditional property of countries, this finding is not surprising.

Table 4: Explanatory Regressions for Benchmark Risk Factors

	HML^{FX}	$UHML^{FX}$
α	4.228^{***}	-0.493
	(1.561)	(1.985)
β	0.554^{***}	1.201^{***}
	(0.150)	(0.124)
Adj. R^2	0.164	0.488
Num. obs.	348	216

The regression specification is $fac_t = \alpha + \beta PMC_t + \epsilon_t$. fac_t is either HML_t^{FX} or $UHML_t^{FX}$ which are conditional and unconditional carry trade factors. HML_t^{FX} is long currently high forward spread countries and short currently low forward spread countries. $UHML_t^{FX}$ is from a sort on average forward spreads between 1/1984 and 12/1995 - long high forward spread, short low forward spread. PMC_t is long peripheral countries and short central countries. Centrality is calculated as alpha centrality for 39 developed and developing countries using bilateral trade intensity — pair-wise total trade divided by total GDP — as adjacency matrix weights. All factors are from sorts into 4 portfolios. Trade data are annual reported exports from the IMF Direction of Trade Statistics and annual GDP are from the World Bank, both in dollars. For the euro area, I construct an aggregate with all countries that adopted the euro, beginning in 1999. Observations are omitted after a country secedes its currency to the euro. Foreign exchange data are monthly from Barclays and Reuters for 39 countries from 1/1984 to 12/2013. Standard errors in parentheses are Newey and West (1986). *, **, and *** denote significance at the 10%, 5%, and 1% levels respectively.

Given that PMC explains the unconditional carry trade, a risk-based interpretation implies that low interest rate currencies will have lower loadings on PMC and high interest rate currencies will load more on PMC. Table (5) presents time series regressions of individual portfolio excess returns in Table (2) on PMC

$$rx_{it}^{fac} = \alpha_i + \beta_i PMC_t + \epsilon_{it} \quad t = 1, 2, \ldots, T, \tag{37}$$

where rx_{it}^{fac} is the excess return to portfolio $i = 1 \ldots 4$ and fac is either PMC, HML^{FX}, or $UHML^{FX}$, referring to the portfolios used in the construction of the three risk factors.

Panel A presents regressions of portfolios sorted on current forward spreads on PMC. The portfolios show monotonically increasing factors loadings from high to low interest rates, but unexplained returns are increasing and some are marginally significant. Currencies with currently high interest rates have a temporarily high loading on the HML^{FX} factor, which likely leads to the unexplained excess returns.

Panel B presents results for portfolios sorted on average forward spreads from 1984-1995. Factors loadings are monotonically increasing from low average interest rate portfolios to high average interest rate portfolios and unexplained excess returns are insignificant. This shows

Table 5: Time series regressions of portfolios on PMC

	Panel A: Current $f - s$			
	1	2	3	4
α_i	-0.579	2.067	3.771^{**}	3.649^{*}
	(1.563)	(1.481)	(1.765)	(1.953)
β_i	0.014	0.114	0.168	0.568^{***}
	(0.107)	(0.118)	(0.141)	(0.190)
Adj. R^2	-0.003	0.007	0.013	0.121
Num. obs.	348	348	348	348
	Panel B: Average $f - s$ (1984-1995)			
	1	2	3	4
α_i	-1.479	-1.636	-1.605	-1.972
	(1.456)	(1.539)	(2.349)	(2.511)
β_i	0.057	0.413^{***}	0.587^{***}	1.258^{***}
	(0.081)	(0.157)	(0.164)	(0.175)
Adj. R^2	-0.002	0.130	0.138	0.380
Num. obs.	216	216	216	216
	Panel C: Current Centrality			
	1	2	3	4
α_i	2.119	2.735	1.813	2.119
	(1.306)	(2.239)	(1.616)	(1.306)
β_i	0.847^{***}	0.122	0.034	-0.153
	(0.113)	(0.199)	(0.103)	(0.113)
Adj. R^2	0.422	0.002	-0.002	0.021
Num. obs.	348	348	348	348

The regression specification is $rx_{it}^{fac} = \alpha_i + \beta_i PMC_t + \epsilon_{it}$. rx_{it}^{fac} is the excess return to portfolio $i = 1 \dots 4$ and fac is either HML^{FX}, $UHML^{FX}$, or PMC, which refer to the portfolios used in the construction of the three risk factors. Portfolios are from sorts into quartiles based on current log forward spreads, HML^{FX}, average log forward spreads from 1984-1995, $UHML^{FX}$, and trade network alpha centrality, PMC. Centrality is Katz (1953) centrality of an adjacency matrix of yearly bilateral trade intensities — pair-wise total trade divided by total GDP. Trade data are annual reported exports from the IMF Direction of Trade Statistics and GDP data are from the World Bank, both in dollars. For the euro area, I construct an aggregate with all countries that adopted the euro, beginning in 1999. Observations are omitted after a country secedes its currency to the euro. Foreign exchange data is monthly from Barclays and Reuters for 39 countries from 1/1984 to 12/2013. Standard errors in parentheses are Newey and West (1986). *, **, and *** denote significance at the 10%, 5%, and 1% levels respectively.

that sorts on trade network centrality uncover a source of hetereogenity in unconditional exposure to carry risk.

Panel C presents results of portfolios sorted on alpha centrality, as in the construction of PMC. The portfolios have monotonically decreasing factor loadings from the peripheral portfolio to the central portfolio. Additionally, unexplained excess returns are statistically indistinguishable from zero. This implies that PMC can be used to explain the cross section of centrality sorted portfolios, as well as the average interest rate sorted portolfios of $UHML^{FX}$.

2.5 Cross-Sectional Asset Pricing (Equities)

Finally, I test Proposition (3) by sorting countries based upon their trade network centrality. I present the results in Table (6). As predicted, local currency equity market Shapre ratios are increasing from portfolio of peripheral countries to the portfolio of central countries. The average Sharpe ratio of equity markets in central countries is 0.35, while the average Sharpe ratio of equity markets in peripheral countries is 0.19.

Table 6: Portfolios Sorted on Centrality Ranking (Local Equity Market Returns)

	Trade Network Centrality				
	Peripheral	2	3	Central	PMC
Previous Centrality: v_{it-12}					
mean	1.07	1.10	1.14	1.30	0.24
Equity excess return: rx_t					
mean	3.29	2.41	4.76	6.27	2.98
std	17.08	15.53	16.11	18.10	13.92
se	2.70	2.45	2.54	2.85	2.18
Sharpe ratio					
mean	0.19	0.16	0.30	0.35	0.21
se	0.16	0.16	0.16	0.16	0.16

Summary statistics of portfolios of MSCI local currency equity indices. Each month t countries are ranked on previous year trade network centrality, v_{it-1}, and placed into 4 portfolios with equal weights. The last column is the difference between the portfolio of central countries and the portfolio of peripheral countries. Centrality is Katz (1953) centrality of an adjacency matrix of yearly bilateral trade intensities — pair-wise total trade divided by total GDP. Mean, SD, and Sharpe ratios are annualized. Standard errors are from bootstrapping 10,000 samples. Trade data are annual reported exports from the IMF Direction of Trade Statistics and annual output data are GDP from the World Bank, both in dollars. For the euro area, I construct an aggregate with all countries that adopted the euro, beginning in 1999. Equity market returns are in local currency from MSCI and interest rates are from Global Financial Data. Returns are in logs. The sample begins in January 1973 and end in December 2013.

3 Conclusion

I have shown that trade network centrality is a significant determinant of a country's unconditional interest rates and currency risk premia. This finding motivates a trading strategy of going long in the currencies of high interest rate countries by borrowing in the currencies of low interest rate countries. The returns to the associated risk factor PMC — peripheral minus central — subsume the unconditional returns to the carry trade.

The empirical findings arise in an international model with network-based production. Shocks that originate in the center of the production network impact global consumption more than shocks that originate in the periphery. Additionally, shocks have a greater impact on the consumption of the country where they originate, causing central countries' consumption to covary more with global consumption growth. This higher exposure to common consumption growth risk causes central country currencies to appreciate in high marginal utility states, resulting in lower currency risk premia and interest rates.

Based upon the predictions of the model, I have presented two additional empirical findings. First, central countries' consumption growth covaries more with global consumption growth than peripheral countries'. Second, equity market Sharpe ratios in local currencies' are increasing in trade network centrality.

My findings shed light on fundamental sources of risk exposure across countries. Understanding variation in risk exposure leads to a better understanding of why interest rates differ across countries and why some currencies are fundamentally riskier than others. More broadly, I make a connection between international asset prices and quantities — an important relation that has had tenuous success.

References

Acemoglu, D., U. Akcigit, and W. Kerr (2015). Networks and the macroeconomy: An empirical exploration. Technical report, National Bureau of Economic Research.

Acemoglu, D., V. M. Carvalho, A. Ozdaglar, and A. Tahbaz-Salehi (2012). The network origins of aggregate fluctuations. *Econometrica 80*(5), 1977–2016.

Ahern, K. (2012). Network centrality and the cross section of stock returns. *Unpublished Manuscript, University of Southern California*.

Akram, Q. F., D. Rime, and L. Sarno (2008). Arbitrage in the foreign exchange market: Turning on the microscope. *Journal of International Economics 76*(2), 237–253.

Alvarez, F., A. Atkeson, and P. J. Kehoe (2009). Time-varying risk, interest rates, and exchange rates in general equilibrium. *The Review of Economic Studies 76*(3), 851–878.

Atkeson, A. and L. E. Ohanian (2001). Are phillips curves useful for forecasting inflation? *Federal Reserve bank of Minneapolis quarterly review 25*(1), 2–11.

Backus, D., M. Chernov, and S. Zin (2014). Sources of entropy in representative agent models. *The Journal of Finance 69*(1), 51–99.

Backus, D. K., S. Foresi, and C. I. Telmer (2001). Affine term structure models and the forward premium anomaly. *The Journal of Finance 56*(1), 279–304.

Backus, D. K. and G. W. Smith (1993). Consumption and real exchange rates in dynamic economies with non-traded goods. *Journal of International Economics 35*(3), 297–316.

Bansal, R. (1997). An exploration of the forward premium puzzle in currency markets. *Review of Financial Studies 10*(2), 369–403.

Bansal, R. and I. Shaliastovich (2012). A long-run risks explanation of predictability puzzles in bond and currency markets. *Review of Financial Studies*, hhs108.

Baqaee, D. R. and E. Farhi (2017). The macroeconomic impact of microeconomic shocks: Beyond hulten's theorem. Technical report, National Bureau of Economic Research.

Barro, R. J. (2006). Rare disasters and asset markets in the twentieth century. *The Quarterly Journal of Economics*, 823–866.

Barrot, J.-N., E. Loualiche, and J. Sauvagnat (2016). The globalization risk premium.

Barrot, J.-N. and J. Sauvagnat (2016). Input specificity and the propagation of idiosyncratic shocks in production networks. *The Quarterly Journal of Economics*, qjw018.

Bekaert, G. (1996). The time variation of risk and return in foreign exchange markets: A general equilibrium perspective. *Review of Financial Studies 9*(2), 427–470.

Bekaert, G. and C. R. Harvey (1995). Time-varying world market integration. *The Journal of Finance 50*(2), 403–444.

Betts, C. M. and T. J. Kehoe (2008). Real exchange rate movements and the relative price of non-traded goods. Technical report, National Bureau of Economic Research.

Billingsley, P. (2008). *Probability and measure*. John Wiley & Sons.

Bilson, J. F. (1978). Rational expectations and the exchange rate. *The Economics of Exchange Rates: Selected Studies*, 75–96.

Bonacich, P. and P. Lloyd (2001). Eigenvector-like measures of centrality for asymmetric relations. *Social networks 23*(3), 191–201.

Brunnermeier, M. K., S. Nagel, and L. H. Pedersen (2008). Carry trades and currency crashes. Technical report, National Bureau of Economic Research.

Burstein, A., M. Eichenbaum, and S. Rebelo (2006). The importance of nontradable goods' prices in cyclical real exchange rate fluctuations. *Japan and the World Economy 18*(3), 247–253.

Burstein, A. and G. Gopinath (2014). *International Prices and Exchange Rates*, Volume 4, pp. 391–451. Elsevier. Preliminary January 2013. Prepared for the Handbook of International Economics, Vol. IV.

Cameron, A. C., J. B. Gelbach, and D. L. Miller (2011). Robust inference with multiway clustering. *Journal of Business & Economic Statistics 29*(2).

Chernov, M., J. J. Graveline, and I. Zviadadze (2012). Crash risk in currency returns. *Available at SSRN 2023440*.

Colacito, R. and M. Croce (2011). Risks for the long-run and the real exchange rate. *Journal of Political Economy 119*(1).

Della Corte, P., S. J. Riddiough, and L. Sarno (2013). Currency premia and global imbalances. *Unpublished manuscript, Imperial College and City University*.

Du, W., A. Tepper, and A. Verdelhan (2016). Covered interest rate parity deviations in the post-crisis world. *Available at SSRN 2768207*.

Dumas, B. and B. Solnik (1993). The world price of foreign exchange risk. Technical report, National Bureau of Economic Research.

Engel, C. (1999, June). Accounting for U.S. Real Exchange Rate Changes. *Journal of Political Economy 107*(3), 507–538.

Fama, E. F. (1984). Forward and spot exchange rates. *Journal of Monetary Economics 14*(3), 319–338.

Fama, E. F. and J. D. MacBeth (1973). Risk, return, and equilibrium: Empirical tests. *The Journal of Political Economy*, 607–636.

Ferson, W. E. and C. R. Harvey (1993). The risk and predictability of international equity returns. *Review of financial Studies 6*(3), 527–566.

Frankel, J. A. and A. K. Rose (1998). The endogenity of the optimum currency area criteria. *The Economic Journal 108*(449), 1009–1025.

Gabaix, X. and M. Maggiori (2014). International liquidity and exchange rate dynamics. Technical report, National Bureau of Economic Research.

Hansen, L. P. and R. Jagannathan (1991). Implications of security market data for models of dynamic economies. *Journal of political economy 99*(2), 225–262.

Harvey, C. R. (1991). The world price of covariance risk. *The Journal of Finance 46*(1), 111–157.

Hassan, T. A. (2013). Country size, currency unions, and international asset returns. *The Journal of Finance 68*(6), 2269–2308.

Hassan, T. A. and R. C. Mano (2013). Forward and spot exchange rates in a multi-currency world. *Fama-Miller Working Paper*.

Heston, A., R. Summers, and B. Aten (2002). Penn world table. *Center for International Comparisons at the University of Pennsylvania*.

Katz, L. (1953). A new status index derived from sociometric analysis. *Psychometrika 18*(1), 39–43.

Lettau, M., M. Maggiori, and M. Weber (2014). Conditional risk premia in currency markets and other asset classes. *Journal of Financial Economics 114*(2), 197–225.

Lewis, K. K. (1995). What can explain the apparent lack of international consumption risk sharing? Technical report, National Bureau of Economic Research.

Long, J. B. and C. I. Plosser (1983). Real business cycles. *The Journal of Political Economy*, 39–69.

Lustig, H., N. Roussanov, and A. Verdelhan (2011). Common risk factors in currency markets. *Review of Financial Studies*, hhr068.

Lustig, H. and A. Verdelhan (2007). The cross section of foreign currency risk premia and consumption growth risk. *American Economic Review 97*(1), 89–117.

Maggiori, M. (2011). Financial intermediation, international risk sharing, and reserve currencies. *Working Paper*.

Martin, I. W. (2013). Consumption-based asset pricing with higher cumulants. *The Review of Economic Studies 80*(2), 745–773.

Negishi, T. (1960). Welfare economics and existence of an equilibrium for a competitive economy. *Metroeconomica 12*(2-3), 92–97.

Newey, W. K. and K. D. West (1986). A simple, positive semi-definite, heteroskedasticity and autocorrelationconsistent covariance matrix.

Obstfeld, M. (1994). Are industrial-country consumption risks globally diversified? Technical report, National Bureau of Economic Research.

Ready, R., N. Roussanov, and C. Ward (2013). Commodity trade and the carry trade: A tale of two countries. Technical report, National Bureau of Economic Research.

Shambaugh, J. C. (2004). The effect of fixed exchange rates on monetary policy. *The Quarterly Journal of Economics*, 301–352.

Shea, J. (2002). Complementarities and comovements. *Journal of Money, Credit, and Banking 34*(2), 412–433.

Solnik, B. H. (1974). An equilibrium model of the international capital market. *Journal of economic theory 8*(4), 500–524.

Stockman, A. C. and L. L. Tesar (1990). Tastes and technology in a two-country model of the business cycle: Explaining international comovements. Technical report, National Bureau of Economic Research.

Stockman, A. C. and L. L. Tesar (1995). Tastes and technology in a two-country model of the business cycle: Explaining international comovements. *The American Economic Review 85*(1), pp. 168–185.

Tesar, L. L. (1993). International risk-sharing and non-traded goods. *Journal of International Economics 35*(1), 69–89.

Tesar, L. L. (1995). Evaluating the gains from international risksharing. In *Carnegie-Rochester Conference Series on Public Policy*, Volume 42, pp. 95–143. Elsevier.

Verdelhan, A. (2010). A habit-based explanation of the exchange rate risk premium. *The Journal of Finance 65*(1), 123–146.

A Model Appendix

This appendix provides derivations of the key equations in the theoretical model.

A.1 Definitions of Constants

I define $\mathbf{1}$ as the vector of ones and $\boldsymbol{I}$ as the identity matrix — both are assumed to be of the appropriate dimension. The following constants are used throughout the paper. Their derivations can be found below.

$$
\begin{aligned}
\Gamma &= \left(\boldsymbol{I} - (1-\alpha)W'\right)^{-1}\left((1-\theta)\mathbf{1}\right),\\
a_i &= \alpha \log\left(\frac{\Gamma_i \alpha}{\rho\theta + \Gamma_i \alpha}\right) + (1-\alpha)\sum_{j=1}^{N} w_{ij} \log\left(\frac{\Gamma_i (1-\alpha) w_{ij}}{\Gamma_j}\right),\\
b_i &= \theta\rho \log\left(\frac{\rho\theta}{\rho\theta + \Gamma_i \alpha}\right) + \frac{1-\theta}{N}\sum_{j=1}^{N} \log\left(\frac{1-\theta}{N\Gamma_j}\right),\\
d_i &= b_i + \frac{1-\theta}{N}\left(\left(\boldsymbol{I} - (1-\alpha)W\right)^{-1} a\right)' \mathbf{1},\\
F_t &= \frac{(1-\theta)\alpha}{N}\left(\sum_{j=1}^{N} v_j z_{jt}\right).
\end{aligned}
$$

A.2 Derivation of Tradables Production

Starting with the social planners problem and taking first order conditions with respect to C_{jit} and X_{jit} gives Equation (18) and Equation (19), reproduced here:

$$C_{jit} = \frac{(1-\theta)}{N\Psi_{it}}, \tag{A.1}$$

$$X_{jit} = \frac{\Psi_{jt}\overline{X}_{jt}(1-\alpha)w_{ji}}{\Psi_{it}}. \tag{A.2}$$

Substituting Equation (A.1) and Equation (A.2) into the resource constraint for country i tradables given in Equation (16) implies

$$
\begin{aligned}
\overline{X}_{it} &= \sum_{j=1}^{N} X_{jit} + \sum_{j=1}^{N} C_{jit}\\
&= \sum_{j=1}^{N} \frac{\Psi_{jt}\overline{X}_{jt}(1-\alpha)w_{ji}}{\Psi_{it}} + \sum_{j=1}^{N} \frac{(1-\theta)}{N\Psi_{it}}.
\end{aligned}
$$

Using the definition $\Gamma_{it} = \overline{X}_{it}\Psi_{it}$ and rearranging gives

$$\Gamma_{it} = (1-\alpha)\left(\sum_{j=1}^{N} \Gamma_{jt} w_{ji}\right) + (1-\theta)\mathbf{1}.$$

Stacking into vectors, defining $\Gamma_t = [\Gamma_{1t}, \ldots, \Gamma_{Nt}]'$, and solving results in

$$\begin{aligned}\Gamma_t &= (1-\alpha)W'\Gamma_t + (1-\theta)\mathbf{1} \\ &= \left(\boldsymbol{I} - (1-\alpha)W'\right)^{-1}\left((1-\theta)\mathbf{1}\right).\end{aligned}$$

This shows that Γ_{it} is a time-invariant function of the model parameters. Therefore, I omit the subscript and define $\Gamma_t = \Gamma$.

First order conditions with respect to L^N_{it} and L^T_{it} give

$$L^N_{it} = \frac{\rho\theta}{G_{it}}, \tag{A.3}$$

$$L^T_{it} = \frac{\Psi_{it}\overline{X}_{jt}\alpha}{G_{it}} = \frac{\Gamma_i\alpha}{G_{it}}. \tag{A.4}$$

Plugging these FOCs into the labor market clearing gives

$$1 = L^N_{it} + L^T_{it} = \frac{\rho\theta}{G_{it}} + \frac{\Gamma_i\alpha}{G_{it}} \implies G_{it} = \rho\theta + \Gamma_i\alpha \tag{A.5}$$

Redefining Equation (A.2) in terms of Γ_i and substituting it into the log tradables production function in Equation (8) gives

$$\begin{aligned}\log\left(\overline{X}_{it}\right) &= \log\left((Z_{it})^\alpha \left(L^T_{it}\right)^\alpha \prod_{j=1}^N (X_{ijt})^{(1-\alpha)w_{ij}}\right) \\ &= \alpha\log Z_{it} + \alpha\log L^T_{it} + (1-\alpha)\sum_{j=1}^N w_{ij}\log\left(X_{ijt}\right) \\ &= \alpha\log Z_{it} + \alpha\log\left(\frac{\Gamma_i\alpha}{\rho\theta + \Gamma_i\alpha}\right) + (1-\alpha)\sum_{j=1}^N w_{ij}\log\left(\frac{\Gamma_i(1-\alpha)w_{ij}}{\Gamma_j}\overline{X}_{jt}\right) \\ &= \alpha\log Z_{it} + a_i + (1-\alpha)\sum_{j=1}^N w_{ij}\log\overline{X}_{jt},\end{aligned}$$

where the constant a_i is defined as:

$$a_i = \alpha\log\left(\frac{\Gamma_i\alpha}{\rho\theta + \Gamma_i\alpha}\right) + (1-\alpha)\sum_{j=1}^N w_{ij}\log\left(\frac{\Gamma_i(1-\alpha)w_{ij}}{\Gamma_j}\right).$$

Stacking into vectors and solving gives

$$\begin{aligned}\overline{x}_t &= \alpha z_t + a + (1-\alpha)W\overline{x}_t \\ &= \left(\boldsymbol{I} - (1-\alpha)W\right)^{-1}\left(\alpha z_t + a\right),\end{aligned}$$

where $\overline{x}_t = \left[\log(\overline{X}_{1t}), \ldots, \log(\overline{X}_{Nt})\right]'$, $z_t = [\log(Z_{1t}), \ldots, \log(Z_{Nt})]'$, and $a = [a_1, \ldots, a_N]'$. This is Equation (21).

A.3 Derivation of Consumption Baskets

Defining Equation (18) in terms of Γ_i gives

$$\begin{aligned}C_{jit} &= \frac{(1-\theta)}{N\Psi_{it}} \\ &= \frac{(1-\theta)}{N\Gamma_i}\overline{X}_{it}\end{aligned} \tag{A.6}$$

Taking log of Equation (15) gives

$$\begin{aligned}\log \overline{C}_{it} &= \log\left(\left((Z_{it})^{\rho}\left(L_{it}^{N}\right)^{\rho}(Y_{it})^{1-\rho}\right)^{\theta}\prod_{j=1}^{N}(C_{ijt})^{\frac{(1-\theta)}{N}}\right) \\ &= \theta\left(\rho z_{it} + \rho\log\left(L_{it}^{N}\right) + (1-\rho)y_{it}\right) + \frac{1-\theta}{N}\sum_{j=1}^{N}\log C_{ijt} \\ &= \theta\left(\rho z_{it} + \rho\log\left(\frac{\rho\theta}{\rho\theta + \Gamma_i\alpha}\right) + (1-\rho)y_{it}\right) + \frac{1-\theta}{N}\sum_{j=1}^{N}\log\left(\frac{1-\theta}{N\Gamma_j}\overline{X}_{jt}\right) \\ &= \theta\left(\rho z_{it} + (1-\rho)y_{it}\right) + b_i + \frac{1-\theta}{N}\sum_{j=1}^{N}\overline{x}_{jt},\end{aligned}$$

where the third equality replaces C_{ijt} with Equation (A.6), and b_i is a constant defined as:

$$b_i = \theta\rho\log\left(\frac{\rho\theta}{\rho\theta + \Gamma_i\alpha}\right) + \frac{1-\theta}{N}\sum_{j=1}^{N}\log\left(\frac{1-\theta}{N\Gamma_j}\right).$$

Defining $\overline{c}_t = \left[\log(\overline{C}_{1t}), \ldots, \log(\overline{C}_{Nt})\right]'$, $y_t = [\log(Y_{1t}), \ldots, \log(Y_{Nt})]'$, $b = [b_1, \ldots, b_N]'$, stacking into a vector, and plugging in the production vector Equation (21) gives Equation

(22):

$$
\begin{aligned}
\overline{c}_t &= \theta\left(\rho z_t + (1-\rho)y_t\right) + b + \frac{1-\theta}{N}\overline{x}_t'\mathbf{1} \\
&= \theta\left(\rho z_t + (1-\rho)y_t\right) + b + \frac{1-\theta}{N}\left(\left(\boldsymbol{I} - (1-\alpha)W\right)^{-1}(\alpha z_t + a)\right)'\mathbf{1} \\
&= \theta\left(\rho z_t + (1-\rho)y_t\right) + \frac{1-\theta}{N}\left(\left(\boldsymbol{I} - (1-\alpha)W\right)^{-1}(\alpha z_t)\right)'\mathbf{1} + d \\
&= \theta\left(\rho z_t + (1-\rho)y_t\right) + \frac{(1-\theta)\alpha}{N}\left(z_t'\left(\boldsymbol{I} - (1-\alpha)W'\right)^{-1}\mathbf{1}\right) + d,
\end{aligned}
$$

where d is a vector of constants with elements given by

$$
d_i = b_i + \frac{1-\theta}{N}\left(\left(\boldsymbol{I} - (1-\alpha)W\right)^{-1}a\right)'\mathbf{1}. \tag{A.7}
$$

Defining alpha centrality for country i as

$$
v_i = \left[(\boldsymbol{I} - (1-\alpha)W')^{-1}\mathbf{1}\right]_i, \tag{A.8}
$$

log consumption at time t for country i, given in Equation (24), is

$$
\begin{aligned}
\overline{c}_{it} &= \theta\left[\rho z_{it} + (1-\rho)y_{it}\right] + \frac{(1-\theta)\alpha}{N}\left(\sum_{j=1}^{N} v_j z_{jt}\right) + d_i \\
&= \theta\left[\rho z_{it} + (1-\rho)y_{it}\right] + F_t + d_i,
\end{aligned}
$$

where F_t is given by

$$
F_t = \frac{(1-\theta)\alpha}{N}\left(\sum_{j=1}^{N} v_j z_{jt}\right).
$$

A.4 Proof of Proposition (1)

Using Equation (24) and that $z_{i1} = \log(Z_{i1}) = \log(1) = 0$ and $y_{i1} = \log(Y_{i1}) = \log(1) = 0$, change in log consumption in country i is given by

$$
\Delta\overline{c}_{it} = \theta\left(\rho z_{i2} + (1-\rho)y_{i2}\right) + \frac{(1-\theta)\alpha}{N}\left(\sum_{j=1}^{N} v_j z_{j2}\right). \tag{A.9}
$$

Average global consumption growth is given by

$$\widehat{\Delta \bar{c}_2} = \left(\frac{1}{N} \sum_{j=1}^{N} \left(\theta\rho + v_j \alpha (1-\theta) \right) z_{j2} \right) + \left(\frac{\theta(1-\rho)}{N} \sum_{j=1}^{N} y_{j2} \right).$$

I define σ_z^2 as the variance of z_{i2} for all i. Using that time 2 shocks are i.i.d, as in Equation (3) and Equation (4), the covariance of country i consumption growth with world average consumption growth is:

$$\mathrm{Cov}(\Delta \bar{c}_{it}, \widehat{\Delta \bar{c}_2}) - \mathrm{Cov}(\Delta \bar{c}_{jt}, \widehat{\Delta \bar{c}_2}) = \frac{\sigma_z^2}{N} \theta\rho\alpha(1-\theta)(v_i - v_j).$$

This immediately implies Proposition (1).

A.5 Proof of Proposition (2)

I first show the currency log risk premia equal log interest rate differentials. Equation (29) implies that $E\left[\Delta q_{ij2}\right] = E\left[m_{i2}\right] - E\left[m_{j2}\right]$. The log IMRS in each country is given in Equation (28):

$$m_{i2} = \delta - \theta\left(\rho z_{i2} + (1-\rho) y_{i2}\right) - \frac{(1-\theta)\alpha}{N} \left(\sum_{j=1}^{N} v_j z_{j2} \right).$$

Using that z_{i2} and y_{i2} are i.i.d. for all i implies $E\left[\Delta q_{ij2}\right] = 0$. Therefore, currency risk premia are equal to interest rate differentials: $E\left[rx_{ij2}\right] = rf_{j1} - rf_{i1}$. Therefore, I focus on interest rate differentials for the remainder of the proof.

Expanding the log interest rate differential from Equation (30) gives

$$\begin{aligned}
rf_{j1} - rf_{i1} &= \log E\left[M_{i2}\right] - \log E\left[M_{j2}\right] \\
&= \log E\left[e^{m_{i2}}\right] - \log E\left[e^{m_{j2}}\right] \\
&= \log E\left[e^{\delta - \theta(\rho z_{i2} + (1-\rho) y_{i2}) - \frac{(1-\theta)\alpha}{N} \left(\sum_{k=1}^{N} v_k z_{k2} \right)} \right] - \log E\left[e^{\delta - \theta(\rho z_{j2} + (1-\rho) y_{j2}) - \frac{(1-\theta)\alpha}{N} \left(\sum_{k=1}^{N} v_k z_{k2} \right)} \right] \\
&= \left(K_z\left(-\frac{(1-\theta)\alpha}{N} v_j \right) - K_z\left(-\theta\rho - \frac{(1-\theta)\alpha}{N} v_j \right) \right) \qquad \text{(A.10)} \\
&\quad - \left(K_z\left(-\frac{(1-\theta)\alpha}{N} v_i \right) - K_z\left(-\theta\rho - \frac{(1-\theta)\alpha}{N} v_i \right) \right), \qquad \text{(A.11)}
\end{aligned}$$

where the last inequality uses the fact that z_{i2} and y_{i2} are i.i.d. and defines the cumulant generating function of z_{i2} as $K_z(h) = \log E\left[e^{hz}\right]$. Cumulant generating functions have nice properties that make them useful for asset pricing[7]. In particular, the expression assuming normality of z_{i2} in Equation (32) follows directly from the fact that $K_z(h) = \mu_z h + \sigma_z^2 h^2/2$ when z is normally distributed.

To show in general that $rf_{j1} > rf_{i1}$ when $v_i > v_j$, I exploit the (strict) convexity and differentiability of cumulant generating functions (see Billingsley (2008)). Starting from the term in Equation (A.11), assuming without loss of generality that $v_i > v_j$, and rewriting as an integral gives

$$\begin{aligned}
K_z\left(-\frac{(1-\theta)\alpha}{N}v_i\right) - K_z\left(-\theta\rho - \frac{(1-\theta)\alpha}{N}v_i\right) \\
&= \int_{-\theta\rho-\frac{(1-\theta)\alpha}{N}v_i}^{-\frac{(1-\theta)\alpha}{N}v_i} K_z'(h)\ \mathrm{d}h \\
&= \int_{-\theta\rho-\frac{(1-\theta)\alpha}{N}v_j}^{-\frac{(1-\theta)\alpha}{N}v_j} K_z'\left(h + \frac{(1-\theta)\alpha}{N}v_j - \frac{(1-\theta)\alpha}{N}v_i\right)\ \mathrm{d}h \\
&< \int_{-\theta\rho-\frac{(1-\theta)\alpha}{N}v_j}^{-\frac{(1-\theta)\alpha}{N}v_j} K_z'(h)\ \mathrm{d}h \\
&= K_z\left(-\frac{(1-\theta)\alpha}{N}v_j\right) - K_z\left(-\theta\rho - \frac{(1-\theta)\alpha}{N}v_j\right).
\end{aligned}$$

The inequality comes from the fact that for a non-degenerate distribution, the cumulant generating function K_z is strictly convex. This implies that if $x > y$ then $K_z'(x) > K_z'(y)$. The above shows that when $v_i > v_j$ Equation (A.11) is greater than Equation (A.10). Therefore, $rf_{j1} - rf_{i1} > 0$. Because interest rate differentials equal currency risk premia, $E\left[rx_{ij2}\right] > 0$, proving Proposition (2).

[7]See Backus et al. (2014) and Martin (2013) for recent examples.

A.6 Proof of Proposition (3)

The assumption that $z_{i2} \overset{i.i.d}{\sim} \mathcal{N}(\mu_z, \sigma_z^2)$ and $y_{i2} \overset{i.i.d}{\sim} \mathcal{N}(\mu_y, \sigma_y^2)$ for all i implies that the SDFs in Equation (28) are normally distributed with some variances $\sigma^2_{\mathrm{m_i}}$. For normally distributed $m_{i2} = \log(M_{i2})$ the following equality holds:

$$\frac{\sqrt{\mathrm{Var}\left[M_{i2}\right]}}{\mathrm{E}\left[M_{i2}\right]} = \sqrt{e^{\sigma^2_{m_i}} - 1}. \tag{A.12}$$

Calculation of the variance of the SDF in Equation (28) shows $v_i > v_j$ implies $\sigma^2_{m_i} > \sigma^2_{m_j}$. Combining Equation (A.12) with $\sigma^2_{m_i} > \sigma^2_{m_j}$ implies:

$$\frac{\sqrt{\mathrm{Var}\left[M_{j2}\right]}}{\mathrm{E}\left[M_{j2}\right]} = \sqrt{e^{\sigma^2_{m_j}} - 1} < \sqrt{e^{\sigma^2_{m_i}} - 1} = \frac{\sqrt{\mathrm{Var}\left[M_{i2}\right]}}{\mathrm{E}\left[M_{i2}\right]}. \tag{A.13}$$

Following Hansen and Jagannathan (1991), the Euler equation for assets paying off in the currency of country i, $E\left[M_{i2} R^E_{j2}\right] = 0$, implies that

$$\frac{\mathrm{E}\left[R^E_{i2}\right]}{\sqrt{\mathrm{Var}\left[R^E_{i2}\right]}} \leq \frac{\sqrt{\mathrm{Var}\left[M_{i2}\right]}}{\mathrm{E}\left[M_{i2}\right]}. \tag{A.14}$$

Since the maximum Sharpe ratio occurs when Equation (A.14) holds with equality, Equation (A.14) and Equation (A.13) imply Proposition (3).

B Empirical Appendix (For Online Publication)

This appendix contains data descriptions, additional empirical tests, and robustness checks.

B.1 Data Description (FX)

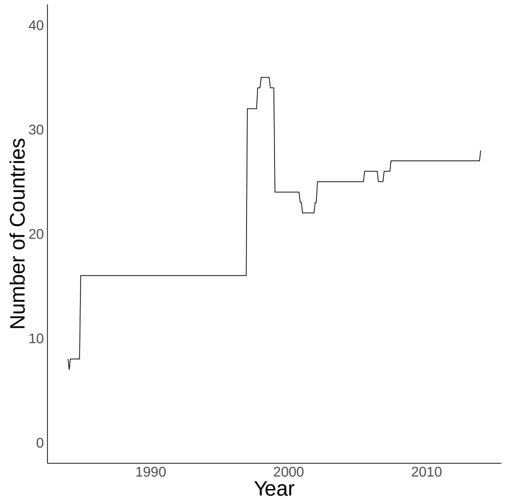
Table (B.1) reports the sample of countries that I have FX data for and which I can calculate trade network centrality. Figure (B.1) shows how the size of the sample changes over time. Following Lustig et al. (2011) I omit the following observations due to large deviations from covered interest parity: South Africa in August 1985, Malaysia from September 1998 to June 2005, Indonesia from January 2001 to May 2007, Turkey from November 2000 to November 2001, and United Arab Emirates from July 2006 to November 2006.

Table B.1: Sample of Countries with FX Data and Trade Data

Country	Start Date	End Date
Australia	Dec 1984	Dec 2013
Austria	Jan 1997	Dec 1998
Belgium	Jan 1997	Dec 1998
Canada	Dec 1984	Dec 2013
Czech Republic	Jan 1997	Dec 2013
Denmark	Dec 1984	Dec 2013
Europe	Jan 1999	Dec 2013
Finland	Jan 1997	Dec 1998
France	Jan 1984	Dec 1998
Germany	Jan 1984	Dec 1998
Greece	Jan 1997	Dec 1998
Hong Kong	Jan 1984	Dec 2013
Hungary	Oct 1997	Dec 2013
India	Oct 1997	Dec 2013
Indonesia	Jan 1997	Dec 2013
Ireland	Jan 1997	Dec 1998
Italy	Mar 1984	Dec 1998
Japan	Jan 1984	Dec 2013
Korea, Republic of	Feb 2002	Dec 2013
Kuwait	Jan 1997	Dec 2013
Malaysia	Dec 1984	Dec 2013
Mexico	Jan 1997	Dec 2013
Netherlands	Jan 1984	Dec 1998
New Zealand	Dec 1984	Dec 2013
Norway	Dec 1984	Dec 2013
Philippines	Jan 1997	Dec 2013
Poland	Feb 2002	Dec 2013
Portugal	Jan 1997	Dec 1998
Saudi Arabia	Jan 1997	Dec 2013
Singapore	Dec 1984	Dec 2013
South Africa	Jan 1998	Dec 2013
Spain	Jan 1997	Dec 1998
Sweden	Dec 1984	Dec 2013
Switzerland	Jan 1984	Dec 2013
Thailand	Jan 1997	Dec 2013
Turkey	Jan 1997	Dec 2013
United Arab Emirates	Jan 1997	Dec 2013
United Kingdom	Jan 1984	Dec 2013
United States	Jan 1984	Dec 2013

This table reports the sample of countries that have both trade data and foreign exchange data. Trade data are annual reported exports from 1973 to 2013 from the IMF Direction of Trade Statistics. Annual GDP is from the World Bank in dollars. Observations are omitted after a country secedes its currency to the euro. Foreign exchange data are monthly from Barclay's and Reuter's for 39 countries from 1/1984 to 12/2013.

Figure B.1: Number of Countries in Combined Dataset



This figure plots the number of countries that have both trade data and foreign exchange data across time. Trade data are annual reported exports from 1973 to 2013 from the IMF Direction of Trade Statistics. Annual GDP is from the World Bank. Foreign exchange data are monthly from Barclay's and Reuter's for 39 countries from 1/1984 to 12/2013.

B.2 Data Description (Equity)

Table (B.2) reports the sample of countries that I have equity market data, yeilds data, and which I can calculate trade network centrality.

Table B.2: Sample of Countries with Equity, Yield, and Trade Data

Country	Start Date	End Date
Australia	Jan 1973	Dec 2013
Austria	Jan 1973	Dec 1990
Canada	Jan 1973	Dec 2013
Czech Republic	Dec 1994	Dec 2013
Denmark	Jan 1976	Dec 2013
Europe	Jan 1999	Dec 2013
France	Jan 1973	Dec 1998
Germany	Jan 1973	Dec 1998
Hong Kong	Jun 1991	Dec 2013
Hungary	Dec 1994	Dec 2013
India	Jan 1993	Dec 2013
Ireland	Dec 1987	Dec 1998
Italy	Jan 1973	Dec 1998
Japan	Jan 1973	Dec 2013
Malaysia	Dec 1987	Dec 2013
Netherlands	Jan 1973	Dec 1998
New Zealand	Dec 1987	Dec 2013
Norway	Jan 1984	Dec 2013
Philippines	Dec 1987	Dec 2013
Poland	Dec 1992	Dec 2013
Portugal	Dec 1987	Dec 1998
Singapore	Dec 1987	Dec 2013
South Africa	Jan 1998	Dec 2013
Spain	Jul 1982	Dec 1998
Sweden	Jan 1973	Dec 2013
Switzerland	Jan 1980	Dec 2013
Thailand	Jan 1997	Dec 2013
United Kingdom	Jan 1973	Dec 2013
United States	Jan 1973	Dec 2013

This table reports the sample of countries that have equity, yields, and trade data. Trade data are annual reported exports from 1973 to 2013 from the IMF Direction of Trade Statistics. Annual GDP is from the World Bank in dollars. Equity market returns are monthly in local currency from MSCI and are available on Datastream. Short-term interest rate data are 3-month yields from Global Financial Data.

B.3 Controlling for Ready, Roussanov, Ward (2016)

Table (B.3) presents regressions controlling for the measure in Ready et al. (2013). To replicate their measure, I classify a SITC2 group as complex or basic following the classification given in their paper. Also, I assume that any good in SITC2 group is basic if more than half of the SITC4 codes classified in that group are classified as basic. The sample begins in 1988 for the same sample of countries in their paper.

Table B.3: Explanatory Regressions for Risk Premia and Forward Spreads Controlling for Ready, Roussanov, Ward (2016)

	rx	rx	rx	$f-s$	$f-s$	$f-s$
Centrality	-0.686^{**}		-0.548^{**}	-0.933^{***}		-0.827^{***}
	(0.275)		(0.264)	(0.290)		(0.289)
RRW		0.753^{***}	0.790^{***}		0.866^{**}	0.543
		(0.248)	(0.246)		(0.437)	(0.399)
R^2	0.480	0.471	0.482	0.195	0.179	0.217
Num. obs.	518	518	504	518	518	504

Regressions of log risk premia rx_t and forward spreads $f_t - s_t$ on standardized GDP share, standardized trade to GDP, and standardized trade network centrality, v_{it}. All specifications include time fixed effects. Excess returns and forward spreads are yearly averages of annualized observations. Centrality is Katz (1953) centrality of an adjacency matrix of yearly bilateral trade intensities pair-wise total trade divided by total GDP. GDP share is the fraction of world GDP for each country, where world GDP is the total GDP of all available countries in the sample for that year. Trade data are annual reported exports from the IMF Direction of Trade Statistics and annual GDP data are from the World Bank, both in dollars. For the euro area, I construct an aggregate with all countries that adopted the euro, beginning in 1999. Foreign exchange data are monthly from Barclay's and Reuter's for 39 countries from 1/1988 to 12/2013. Observations are omitted after a country secedes its currency to the euro. Standard errors in parentheses are clustered by country using Cameron et al. (2011). *, **, and *** denote significance at the 10%, 5%, and 1% levels respectively.

B.4 Time Series Variation in Centrality

In Table (B.4) I present regressions of risk premia and forward spreads on trade network centrality, including country fixed effects. Although not statistically significant, the sign of the coefficients suggests that as a country becomes more central in the global trade network, its interest rates and currency risk premia tend to decrease.

Table B.4: Explanatory Regressions for Risk Premia and Forward Spreads

	rx	$f - s$
Centrality	-1.345	-0.945
	(0.884)	(0.670)
R^2	0.053	0.524
Num. obs.	655	664

Regressions of log risk premia rx_t and forward spreads $f_t - s_t$ on standardized trade network centrality, v_{it}. All specifications include country fixed effects. Excess returns and forward spreads are yearly averages of annualized observations. Centrality is Katz (1953) centrality of an adjacency matrix of yearly bilateral trade intensities pair-wise total trade divided by total GDP. Trade data are annual reported exports from the IMF Direction of Trade Statistics and annual GDP data are from the World Bank, both in dollars. For the euro area, I construct an aggregate with all countries that adopted the euro, beginning in 1999. Foreign exchange data are monthly from Barclay's and Reuter's for 39 countries from 1/1984 to 12/2013. Observations are omitted after a country secedes its currency to the euro. Standard errors in parentheses are clustered by country using Cameron et al. (2011). *, **, and *** denote significance at the 10%, 5%, and 1% levels respectively.

B.5 Sorts with Alternative Network Weights

For robustness, Table (B.5) presents portfolios sorted on alpha centrality using three different network weights. For comparison, Panel A presents network weights measured as total trade normalized by total output as in Table (2). Panel B presents results with network weights measured as exports normalized by total output. Panel C presents results with network weights measured as imports normalized by total output. All results are consistent with Table (2). Measuring trade link strength with imports rather than exports produces higher returns and Sharpe ratios, which implies that the model mechanism may operate more through importing relationships.

Table B.5: Portfolio Sorts Using Alternative Network Weights

	Panel A: Total Trade Network Weights				
	Peripheral	2	3	Central	PMC
Previous Centrality: v_{it-12}					
mean	1.06	1.10	1.16	1.33	− 0.27
Forward Spread: $f_t - s_t$					
mean	5.57	1.39	1.26	0.31	5.27
std	1.23	0.58	0.58	0.54	1.23
se	0.23	0.11	0.11	0.10	0.23
Risk Premia: rx_t					
mean	5.00	3.15	1.93	1.60	3.40
std	7.87	10.10	7.46	6.05	6.05
se	1.46	1.88	1.39	1.14	1.13
Sharpe ratio					
mean	0.64	0.31	0.26	0.26	0.56
se	0.21	0.19	0.19	0.19	0.20
Consumption Growth Coefficient: β_i					
mean	0.09	0.50	0.83	0.67	− 0.58
se	0.24	0.05	0.07	0.03	0.24

	Panel B: Export Network Weights				
	Peripheral	2	3	Central	PMC
Previous Centrality: v_{it-12}					
mean	1.03	1.04	1.07	1.14	− 0.11
Forward Spread: $f_t - s_t$					
mean	4.75	2.06	1.25	0.52	4.23
std	1.25	0.86	0.52	0.52	1.27
se	0.23	0.16	0.10	0.10	0.23
Risk Premia: rx_t					
mean	4.82	3.14	1.85	1.89	2.93
std	7.33	10.10	7.59	6.27	5.64
se	1.35	1.86	1.40	1.16	1.05
Sharpe ratio					
mean	0.66	0.31	0.24	0.30	0.52
se	0.20	0.19	0.19	0.19	0.20
Consumption Growth Coefficient: β_i					
mean	0.12	0.46	0.81	0.68	− 0.56
se	0.23	0.05	0.05	0.03	0.23

	Panel C: Import Network Weights				
	Peripheral	2	3	Central	PMC
Previous Centrality: v_{it-12}					
mean	1.03	1.05	1.07	1.15	−0.12
Forward Spread: $f_t - s_t$					
mean	5.77	1.11	1.71	−0.12	5.89
std	1.22	0.58	0.58	0.45	1.26
se	0.23	0.11	0.11	0.08	0.23
Risk Premia: rx_t					
mean	4.98	2.39	2.64	1.65	3.33
std	7.87	9.59	8.40	5.36	5.84
se	1.46	1.79	1.56	1.00	1.07
Sharpe ratio					
mean	0.63	0.25	0.31	0.31	0.57
se	0.21	0.19	0.19	0.19	0.20
Consumption Growth Coefficient: β_i					
mean	0.50	0.11	0.67	0.78	−0.28
se	0.07	0.32	0.04	0.04	0.09

Summary statistics of portfolios sorted on trade network alpha centrality v_{it} using different network weights. For each month t currencies are ranked trade network centrality and sorted into four portfolios. Log risk premia are $rx_t = f_{t-1} - s_t$. Centrality v_{it} is alpha centrality of an adjacency matrix with elements that are either total trade, exports, or imports — all normalized by pair-wise total GDP. Means and standard deviations are annualized. Sharpe ratios are the annualized mean divided by the annualized standard deviation. Standard errors are from bootstrapping 10,000 samples. Trade data are annual reported exports from the IMF Direction of Trade Statistics and GDP data are from the World Bank, both in dollars. For the euro area, I construct an aggregate with all countries that adopted the euro, beginning in 1999. Observations are omitted after a country secedes its currency to the euro. Foreign exchange data are monthly from Barclay's and Reuter's for 39 countries from 1/1984 to 12/2013.

B.6 Sorts on Average Rank

Due to the possibility of structural changes in the trade network as countries enter and exit the sample and as the euro is introduced, I report portfolio sorts using prior year trade network centrality in Panel A of Table (2). That said, trade network centrality is an unconditional property of countries, so results should be robust to sorting on the full sample average of countries' trade network centrality. Table (B.6) presents portfolios sorts using the full sample average of countries' trade network centrality ranking. Results are consistent with those found in the main text.

B.7 Sorts without Euro Aggregate

Table (B.7) presents portfolio sorts on data omitting the euro area aggregate and maintaining the euro countries after 1999. FX observations are still dropped for currencies that secede to the euro. All results are consistent with Table (2). Currency risk premia and interest rates are decreasing in centrality and consumption growth coefficients are increasing in centrality.

B.8 Sorts Using Centrality Constructed with All Countries

Table (B.8) presents portfolio sorts using a centrality measure constructed using all trade data available from the IMF's Direction of Trade Statistics. FX observations are still dropped for currencies that secede to the euro. As in Table (2), currency risk premia and interest rates are decreasing in centrality. The consumption growth coefficients are also increasing in centrality.

Table B.6: Portfolios Sorted on Full Sample Average Centrality Ranking

	Panel A: Trade Network Centrality				
	Peripheral	2	3	Central	PMC
Average Centrality Rank					
mean	9.69	16.92	23.14	30.29	-20.61
Forward Spread: $f_t - s_t$					
mean	5.31	1.83	0.78	0.26	5.05
std	0.12	0.06	0.05	0.05	0.13
se	0.22	0.10	0.08	0.10	0.23
Risk Premia: rx_t					
mean	3.56	2.38	0.89	1.76	1.80
std	8.00	8.52	7.33	8.05	6.28
se	1.45	1.55	1.34	1.47	1.15
Sharpe ratio					
mean	0.44	0.28	0.12	0.22	0.29
se	0.20	0.19	0.18	0.18	0.19
Real Interest Differential: $r_{it} - r_t$					
mean	2.33	0.65	0.48	1.10	1.24
std	0.06	0.06	0.05	0.07	0.06
se	0.11	0.11	0.09	0.12	0.11
Consumption Growth Coefficient: β_i					
mean	0.38	0.40	0.85	0.99	-0.60
se	0.15	0.09	0.09	0.04	0.17

Summary statistics of portfolios sorted on full sample average trade network alpha centrality ranking. For each month t currencies are ranked according to their countries' average ranking throughout the sample and placed into four portfolios with equal weights. Rankings each period are normalized to be between 1 and 39 (maximum number of countries in the sample) so that they are comparable across time. The last column is the difference between the high portfolio and the low portfolio. Log risk premia are $rx_t = f_{t-1} - s_{t-1} - \Delta s_t$. Centrality is Katz (1953) centrality of an adjacency matrix of yearly bilateral trade intensities — pair-wise total trade divided by total GDP. Means and standard deviations are annualized. Sharpe ratios are the annualized mean divided by the annualized standard deviation. Trade data are annual reported exports from the IMF Direction of Trade Statistics and GDP data are from the World Bank, both in dollars. For the euro area, I construct an aggregate with all countries that adopted the euro, beginning in 1999. Observations are omitted after a country secedes its currency to the euro. Foreign exchange data are monthly from Barclay's and Reuter's for 39 countries from 1/1984 to 12/2013.

Table B.7: Portfolios Sorted on Centrality (No Euro Aggregate)

	Panel A: Trade Network Centrality				
	Peripheral	2	3	Central	PMC
Previous Centrality: v_{it-12}					
mean	1.07	1.13	1.18	1.36	-0.28
Forward Spread: $f_t - s_t$					
mean	5.54	1.56	1.59	0.04	5.50
std	1.26	0.56	0.59	0.51	1.25
se	0.23	0.10	0.11	0.09	0.23
Risk Premia: rx_t					
mean	4.71	2.85	2.63	1.60	3.11
std	7.42	9.30	8.47	6.02	5.89
se	1.38	1.72	1.57	1.12	1.09
Sharpe ratio					
mean	0.63	0.31	0.31	0.27	0.53
se	0.20	0.19	0.19	0.19	0.19
Real Interest Differential: $r_{it} - r_t$					
mean	2.79	1.09	0.96	0.58	2.21
std	0.54	0.58	0.56	0.58	0.62
se	0.10	0.11	0.10	0.11	0.12
Consumption Growth Coefficient: β_i					
mean	0.08	0.56	0.56	0.85	-0.77
se	0.24	0.03	0.07	0.08	0.32

Summary statistics of portfolios sorted on trade network centrality v_{it}. Centrality is calculated only on country observations and does not include an aggregate for the euro area. Each month t currencies are ranked on their prior year trade network centrality. The last column is the difference between the high portfolio and the low portfolio. Log risk premia are $rx_t = f_{t-1} - s_{t-1} - \Delta s_t$. Real interest rate differentials are forward spreads less the expected inflation differential. Expected inflation is lagged year-over-year change in log CPI. Centrality v_{it} is Katz (1953) centrality of an adjacency matrix of yearly bilateral trade intensities — pair-wise total trade divided by total GDP. Mean, SD, and Sharpe ratios are annualized. Standard errors are from bootstrapping 10,000 samples. Trade data are annual reported exports from the IMF Direction of Trade Statistics and annual output data are GDP from the World Bank, both in dollars. Foreign exchange data are monthly from Barclay's and Reuter's for 39 countries from 1/1984 to 12/2013.

Table B.8: Portfolios Sorted on Centrality Constructed with All Trade Data

	Panel A: Trade Network Centrality				
	Peripheral	2	3	Central	PMC
Previous Centrality: v_{it-12}					
mean	1.11	1.17	1.25	1.49	-0.38
Forward Spread: $f_t - s_t$					
mean	4.42	2.46	1.83	0.07	4.35
std	1.06	0.87	0.58	0.48	1.12
se	0.20	0.16	0.11	0.09	0.21
Risk Premia: rx_t					
mean	3.56	3.72	3.02	1.56	1.99
std	7.79	8.31	9.62	5.49	5.76
se	1.45	1.54	1.79	1.02	1.07
Sharpe ratio					
mean	0.46	0.45	0.31	0.28	0.35
se	0.20	0.19	0.19	0.19	0.19
Real Interest Differential: $r_{it} - r_t$					
mean	2.58	1.18	1.26	0.30	2.28
std	0.50	0.61	0.59	0.56	0.66
se	0.09	0.11	0.11	0.10	0.12
Consumption Growth Coefficient: β_i					
mean	0.28	0.59	0.65	0.49	-0.21
se	0.18	0.07	0.03	0.09	0.17

Summary statistics of portfolios sorted on trade network centrality v_{it}. Centrality is calculated using all 173 reporting countries in the IMF DOTS. Each month t currencies are ranked on their prior year trade network centrality. The last column is the difference between the high portfolio and the low portfolio. Log risk premia are $rx_t = f_{t-1} - s_{t-1} - \Delta s_t$. Real interest rate differentials are forward spreads less the expected inflation differential. Expected inflation is lagged year-over-year change in log CPI. Centrality v_{it} is Katz (1953) centrality of an adjacency matrix of yearly bilateral trade intensities — pair-wise total trade divided by total GDP. Mean, SD, and Sharpe ratios are annualized. Standard errors are from bootstrapping 10,000 samples. Trade data are annual reported exports from the IMF Direction of Trade Statistics and annual output data are GDP from the World Bank, both in dollars. Foreign exchange data are monthly from Barclay's and Reuter's for 39 countries from 1/1984 to 12/2013.

B.9 Sorts Omitting Pegs

Table (B.9) presents portfolio sorts using a subset of observations which omits currency pegs. The pegs classification is from Shambaugh (2004) and I omit currency-month observations if a currency is classified as pegged to any other currency. FX observations are still dropped for currencies that secede to the euro. As in Table (2), currency risk premia and interest rates are decreasing in centrality. The consumption growth coefficients are also increasing in centrality.

Table B.9: Portfolios Sort Omitting Pegged Currencies

	Panel A: Trade Network Centrality				
	Peripheral	2	3	Central	PMC
Previous Centrality: v_{it-12}					
mean	1.06	1.10	1.14	1.34	-0.28
Forward Spread: $f_t - s_t$					
mean	7.01	1.69	1.95	0.69	6.31
std	1.75	0.88	0.65	0.65	1.80
se	0.33	0.16	0.12	0.12	0.33
Risk Premia: rx_t					
mean	5.05	2.85	3.09	1.88	3.17
std	8.72	11.09	9.08	6.73	8.07
se	1.63	2.07	1.69	1.25	1.49
Sharpe ratio					
mean	0.58	0.26	0.34	0.28	0.39
se	0.20	0.19	0.19	0.19	0.19
Real Interest Differential: $r_{it} - r_t$					
mean	2.97	1.06	1.23	1.19	1.78
std	0.56	0.65	0.52	0.67	0.78
se	0.10	0.12	0.10	0.12	0.14
Consumption Growth Coefficient: β_i					
mean	0.34	0.45	0.66	0.66	-0.32
se	0.08	0.05	0.03	0.06	0.12

Summary statistics of portfolios sorted on trade network alpha centrality v_{it} using a subset of currencies which are not pegged. For each month t currencies are ranked trade network centrality and sorted into four portfolios. Log risk premia are $rx_t = f_{t-1} - s_t$. Centrality v_{it} is alpha centrality of an adjacency matrix with elements that are either total trade, exports, or imports — all normalized by pair-wise total GDP. Means and standard deviations are annualized. Sharpe ratios are the annualized mean divided by the annualized standard deviation. Standard errors are from bootstrapping 10,000 samples. Trade data are annual reported exports from the IMF Direction of Trade Statistics and GDP data are from the World Bank, both in dollars. Foreign exchange data are monthly from Barclay's and Reuter's for 39 countries from 1/1984 to 12/2013. Data on currency pegs is from Shambaugh (2004).

B.10 Sorts on Developed Subset

Table (B.10) presents portfolio sorts using a subset of developed countries: Australia, Austria, Belgium, Canada, Denmark, Europe, France, Germany, Hong Kong, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Singapore, South Korea, Spain, Sweden, Switzerland, and United Kingdom. FX observations are still dropped for currencies that secede to the euro. As in Table (2), currency risk premia and interest rates are decreasing in centrality. The consumption growth coefficients are no longer monotonically increasing in centrality, although a large spread remains between central and peripheral portfolios.

Table B.10: Portfolio Sorts With Developed Subset

	Panel A: Trade Network Centrality				
	Peripheral	2	3	Central	PMC
Previous Centrality: v_{it-12}					
mean	1.08	1.11	1.16	1.38	-0.30
Forward Spread: $f_t - s_t$					
mean	1.88	0.48	1.11	-0.54	2.43
std	0.72	0.58	0.65	0.45	0.85
se	0.13	0.11	0.12	0.08	0.16
Risk Premia: rx_t					
mean	3.69	2.80	2.29	1.83	1.86
std	8.53	9.88	8.70	6.33	6.73
se	1.57	1.84	1.62	1.19	1.24
Sharpe ratio					
mean	0.43	0.28	0.26	0.29	0.28
se	0.19	0.19	0.19	0.19	0.19
Real Interest Differential: $r_{it} - r_t$					
mean	1.91	0.93	0.99	0.46	1.45
std	0.54	0.54	0.55	0.84	1.00
se	0.10	0.10	0.10	0.16	0.19
Consumption Growth Coefficient: β_i					
mean	0.73	0.49	0.94	1.05	-0.32
se	0.05	0.05	0.09	0.04	0.09

Summary statistics of portfolios sorted on trade network alpha centrality v_{it} using a subset of developed country currencies. For each month t currencies are ranked trade network centrality and sorted into four portfolios. Log risk premia are $rx_t = f_{t-1} - s_t$. Centrality v_{it} is alpha centrality of an adjacency matrix with elements that are either total trade, exports, or imports — all normalized by pair-wise total GDP. Means and standard deviations are annualized. Sharpe ratios are the annualized mean divided by the annualized standard deviation. Standard errors are from bootstrapping 10,000 samples. Trade data are annual reported exports from the IMF Direction of Trade Statistics and GDP data are from the World Bank, both in dollars. For the euro area, I construct an aggregate with all countries that adopted the euro, beginning in 1999. Observations are omitted after a country secedes its currency to the euro. Foreign exchange data are monthly from Barclay's and Reuter's for 39 countries from 1/1984 to 12/2013.

B.11 Sorts on Sample Ending in 2007

Table (B.11) presents portfolio sorts using a subset of the data that ends in 2007 due to deviations from covered interest parity documented by Du et al. (2016). As in Table (2), currency risk premia and interest rates are decreasing in centrality. Consumption growth coefficients are also increasing in centrality as in Table (2).

Table B.11: Portfolio Sorts With Sample Ending in 2007

	Panel A: Trade Network Centrality				
	Peripheral	2	3	Central	PMC
Previous Centrality: v_{it-12}					
mean	1.06	1.10	1.15	1.32	-0.25
Forward Spread: $f_t - s_t$					
mean	5.97	1.39	1.21	0.02	5.95
std	1.35	0.64	0.64	0.57	1.30
se	0.28	0.13	0.13	0.12	0.27
Risk Premia: rx_t					
mean	6.16	3.79	2.61	1.62	4.54
std	6.51	9.41	7.81	5.78	5.72
se	1.36	1.93	1.62	1.19	1.19
Sharpe ratio					
mean	0.95	0.40	0.33	0.28	0.79
se	0.22	0.21	0.21	0.21	0.22
Real Interest Differential: $r_{it} - r_t$					
mean	2.93	1.01	0.92	0.80	2.13
std	0.56	0.57	0.60	0.68	0.76
se	0.12	0.12	0.13	0.14	0.16
Consumption Growth Coefficient: β_i					
mean	0.14	0.51	0.79	0.71	-0.57
se	0.13	0.02	0.04	0.02	0.13

Summary statistics of portfolios sorted on trade network alpha centrality v_{it} using a sample that ends in 2007. For each month t currencies are ranked trade network centrality and sorted into four portfolios. Log risk premia are $rx_t = f_{t-1} - s_t$. Centrality v_{it} is alpha centrality of an adjacency matrix with elements that are either total trade, exports, or imports — all normalized by pair-wise total GDP. Means and standard deviations are annualized. Sharpe ratios are the annualized mean divided by the annualized standard deviation. Standard errors are from bootstrapping 10,000 samples. Trade data are annual reported exports from the IMF Direction of Trade Statistics and GDP data are from the World Bank, both in dollars. For the euro area, I construct an aggregate with all countries that adopted the euro, beginning in 1999. Observations are omitted after a country secedes its currency to the euro. Foreign exchange data are monthly from Barclay's and Reuter's for 39 countries from 1/1984 to 12/2013.

B.12 Correlation of Risk Factors

The correlation table of the currency risk factors is in Table (B.12).

Table B.12: Correlation of Currency Risk Factors

	PMC	HML^{FX}	$UHML^{FX}$
PMC	1.00		
HML^{FX}	0.41	1.00	
$UHML^{FX}$	0.70	0.65	1.00

Risk factors are constructed from excess returns of currencies sorted into four portfolios. PMC is from sorts on prior year trade network alpha centrality — long peripheral countries and short central countries. HML^{FX} is from sorts of currencies on currentl log forward spreads $f_t - s_t$ — long high interest rate currencies and short low interest rate currencies. $UHML^{FX}$ is from sorts of currencies on average log forward spreads from 1/1984 to 12/1995. Summaries for $UHML^{FX}$ are calculated from 1/1996 to 12/2013. All moments are annualized. Trade data are annual reported exports from the IMF Direction of Trade Statistics and annual GDP data are from the World Bank, both in dollars. Observations are omitted after a country secedes its currency to the euro. Foreign exchange data are monthly from Barclays and Reuters for 39 countries from 1/1984 to 12/2013.