CURRENCY COMOVEMENT, GRAVITY AND BILATERAL LINKAGES

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ABSTRACT

Gravity variables capture country level differences in exposure to global shocks. Currencies of countries which are geographically distant and culturally different have larger differences in exposure to global shocks and as such comove less. The explanatory power of gravity for currency comovement is also present in trade flows and financial linkages. Predicted values of trade flows and foreign debt holdings contain around 80% of the explanatory power of gravity variables for currency comovement.

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I. INTRODUCTION

An increasing body of work in the international finance literature has shown that a factor structure exists in foreign exchange markets, where a small number of common risk factors are responsible for explaining a large percentage of variation in exchange rates. This approach is the foreign exchange equivalent of the factor models that are used to explain returns in stock markets (Fama and French 1993). Explaining exchange rates with a factor structure has mainly been motivated by the empirical disconnection between exchange rate changes and macroeconomic variables (Meese and Rogoff 1983, Backus and Smith 1993, Kollmann 1995, Engel and West 2005). Amongst these disconnections, the one which has drawn the most attention is the violation of uncovered interest rate parity (UIP), which is the simple non-arbitrage condition that exchange rate changes should reflect interest rate differentials (Hansen and Hodrick 1980, Bilson 1981, Fama 1984). This leads to the carry trade, which is both widely studied in academia and implemented in foreign exchange markets.

However, while we largely understand the determinants of factor loadings in stock markets, there has been limited work exploring the determinants of factor loadings in foreign exchange markets. Lustig and Richmond (2019) show that the distance between countries, measured by gravity variables commonly used in the international trade and finance literature (Isard and Peck 1954, Bergstrand 1985), determines the degree of currency comovement. On average, countries that are closer to each other will have similar exposures to common shocks, and have currencies with higher degrees of comovement. Their results are strong and are exempt to endogeneity issues due to the pre-determined nature of gravity variables.

Gravity variables have been long shown to explain cross-sectional differences in international trade, foreign asset holdings and cross-border bank claims quite well. In this paper, I show that it is specifically because of gravity variables explanatory power for international trade and financial linkages that results in their relationship to currency comovement. Using a two-stage regression and applying gravity as instruments for trade flows, foreign equity holdings, foreign debt holdings and cross border bank claims, I find that the fitted values of bilateral trade flows and foreign debt holdings contain around 70% of the explanatory power that gravity has for currency comovement. Richmond (2018) and Richmond and Jiang (2019) find that global trade networks generate a factor structure in foreign exchange markets. My results show that simple bilateral trade flows also contain relevant information for currency comovement, while bilateral financial linkages, particularly foreign debt holdings are just as important.

The results in this paper show that international trade, foreign asset holdings and cross border bank claims are important channels through which global shocks are propagated throughout the global economy. More intensive trade, foreign asset holdings and cross border bank claims cause partner countries to have similar exposures to global shocks, and thus have currencies that comove more.

The rest of the paper is as follows. Part II gives a simple theoretical framework for currency comovement. Part III describes the data. Part IV shows the explanatory power of gravity for unconditional currency comovement. Part V uses gravity as an instrument for trade flows, foreign asset holdings and cross-border bank claims on currency comovement. Part VI shows results by year and country. Part VII concludes.

II. FRAMEWORK

To guide this paper's empirical results, I present a simple theory of exchange rate comovement under a standard asset pricing framework following Frachot (1996), Backus, Foresi, and Telmer

(2001), Hodrik and Vassalou (2002), Brennan and Xia (2006), Lustig, Roussanov, and Verdelhan (2011, 2014), Verdelhan (2018) and Lustig and Verdelhan (2019).

This line of work emphasizes the determination of exchange rates in financial markets, differing from the unsuccessful attempts at explicitly connecting exchange rate movements to macroeconomic determinants. (Hansen and Hodrik 1980, Bilson 1981, Fama 1984, Meese and Rogoff 1983, Backus and Smith 1993, Kollmann 1995, Engel and West 2005).

For domestic and foreign investors in country i holding foreign asset A^i, intertemporal utility maximizing requires their Euler equations to satisfy the following conditions:

$$(1) \qquad E_t\left[M_{t+1}R_{t+1}^i \frac{s_t^i}{s_{t+1}^i}\right] = 1$$

and

$$(2) \qquad E_t\left[M_{t+1}^i R_{t+1}^i\right] = 1$$

Where M_{t+1} and M_{t+1}^i is the nominal stochastic discount factor (intertemporal marginal rate of substitution, or IMRS) of the domestic and foreign investor i respectively; R_{t+1}^i is the return on foreign asset A^i measured in foreign currency units; and s_t^i is the bilateral exchange rate expressed as foreign currency units per domestic currency.

If markets are complete, then the stochastic discount factor is unique for each country.[1] As such, exchange rate movements can be simply expressed as

$$(3) \qquad \frac{s_{t+1}^i}{s_t^i} = \frac{M_{t+1}}{M_{t+1}^i}$$

[1] Notably, a separate line of work explains exchange rates emphasizing the non-completeness of markets where exchange rate risk cannot be completely traded away by market participants and is instead borne by risk-neutral global financial intermediaries with limited risk-bearing capacity. that many papers suggest that markets are not complete, and foreign exchange risk is not completely tradable (Hau and Rey, 2005; Gabaix and Maggiori, 2015; Camanho, Hau and Rey, 2018). Integrating these two strands of the literature could be promising.

Taking logs on both sides of the equation, this implies that bilateral exchange rate movement can be expressed as the difference between the stochastic discount factor of the domestic investor and the foreign investor.

$$(4) \qquad \Delta s_{t+1}^{i} = m_{t+1} - m_{t+1}^{i}$$

The domestic currency appreciates against the foreign currency ($\Delta s_{i,t+1} > 0$) when the domestic country experiences an adverse shock, and the marginal utility of wealth is relatively higher in the domestic country. In this sense, a domestic investor who speculates in a foreign currency is betting on the difference between her IMRS and that of the foreign investor. (Lustig and Verdelhan 2006)

With equation (4), we can now explain bilateral exchange rate movements by studying the log stochastic discount factors m_{t+1} and m_{t+1}^{i}.

I follow Lustig and Verdelhan (2019) in presenting a multiple-factor linear SDF model, assuming that: (1) the log stochastic discount factors are linear in local and global shocks (Cox, Ingersoll, and Ross 1985) and (2) there is no time variation in the price or quantity of risk. Assumption (2) is used to generate a clear, tractable model for the empirical results, and can be relaxed for a more general setting.

The log stochastic discount factors of the domestic and foreign investor are then given by

$$(5) \qquad -m_{t+1} = \alpha + \chi\sigma^{2} + \sum_{k=1}^{M} \xi_{k}\sigma_{k}^{g,2} + \tau\sigma u_{t+1} + \sum_{k=1}^{M} \gamma_{k}\, u_{k,t+1}^{g}$$

and

$$(6) \qquad -m_{t+1}^{i} = \alpha^{i} + \chi^{i}\sigma^{i,2} + \sum_{k=1}^{M} \xi_{k}^{i}\, \sigma_{k}^{g,2} + \tau^{i}\sigma^{i}u_{t+1}^{i} + \sum_{k=1}^{M} \gamma_{k}^{i}\, u_{k,t+1}^{g}$$

Where u_{t+1} and u_{t+1}^{i} are respectively country specific (local) shocks for the domestic country and foreign country i. $u_{k,t+1}^{g}$ are M common (global) shocks. The local shocks and global shocks are Gaussian in nature, with zero mean and unit variance.

As such, the bilateral exchange rate between foreign currency i and the domestic currency can be expressed as the difference in exposure to global and local shocks:

$$(7) \quad \Delta s_{t+1}^{i} = (\alpha^{i} - \alpha) + (\chi^{i}\sigma^{i,2} - \chi\sigma^{2}) + \sum_{k=1}^{M}(\xi_{k}^{i} - \xi_{k})\,\sigma_{k}^{g,2} + (\tau^{i}\sigma^{i}u_{t+1}^{i} - \tau\sigma u_{t+1}) + \sum_{k=1}^{M}(\gamma_{k}^{i} - \gamma_{k})\,u_{t+1}^{g}$$

Pioneering work by Lustig, Verdelhan and Roussanov (2011), Verdelhan (2018) and Richmond (2019) show that forming currency portfolios based on dollar βs (dollar factor), interest rates (carry factor) and trade centrality captures global shocks. Here, I allow for M common shocks without explicitly identifying them, though in the appendix I include results based on three explicit risk factors: dollar, carry and momentum.

The base factor for the domestic currency is constructed as the simple average of the exchange rate movements of all currencies:

$$(8) \quad \Delta base_{t+1} = \frac{1}{N}\sum_{i=1}^{N}\Delta s_{t+1}^{i}$$

$$= (\bar{\alpha} - \alpha) + (\overline{\chi\sigma^{2}} - \chi\sigma^{2}) + \sum_{k=1}^{K}(\bar{\xi}_{k} - \xi_{k})\,\sigma_{k}^{g,2} + (\overline{\tau\sigma u_{t+1}} - \tau\sigma u_{t+1}) + \sum_{k=1}^{K}(\overline{\gamma_{k}} - \gamma_{k})\,u_{t+1}^{g}$$

The bar terms are the averages of the parameters for all foreign currencies. By the law of large numbers, the average of the local shocks $\overline{\tau\sigma u_{t+1}}$ tends to zero, which gives:

$$(9) \quad \lim_{N\to\infty}\Delta base_{t+1} = (\bar{\alpha} - \alpha) + (\overline{\chi\sigma^{2}} - \chi\sigma^{2}) + \sum_{k=1}^{M}(\bar{\xi}_{k} - \xi_{k})\,\sigma_{k}^{g,2} - \tau\sigma u_{t+1} + \sum_{k=1}^{M}(\overline{\gamma_{k}} - \gamma_{k})\,u_{t+1}^{g}$$

For each individual foreign currency i, its β with the domestic currency is then:

$$(10) \quad \beta^{i} = \frac{Cov(\Delta s_{t+1}^{i}, \lim_{N\to\infty}\Delta base_{t+1})}{Var(\lim_{N\to\infty}\Delta base_{t+1})} = \frac{\tau^{2}\sigma^{2} + \sum_{k=1}^{M}(\gamma_{k}^{i} - \gamma_{k})(\overline{\gamma_{k}} - \gamma_{k})\sigma^{g,2}}{\tau^{2}\sigma^{2} + \sum_{k=1}^{M}(\overline{\gamma_{k}} - \gamma_{k})^{2}\sigma^{g,2}}$$

With regards to the βs, I make three quick intuitive observations.

First, for a given domestic (base) country, a larger β^i for foreign currency i implies a larger difference in exposure to global shocks between the domestic currency (γ_k) and the foreign currency (γ_k^i). Hence, larger β^is imply lower degrees of currency comovement between the domestic currency and the foreign currency.

Second, for each domestic (base) currency, the mean β for all foreign currency is 1 by construction. In other words, currency comovement between foreign currency i and the domestic currency is normalized by the average degree of comovement for all other foreign currencies with the domestic currency.

Third, $\beta = 1$ when $\gamma_k^i = \overline{\gamma_k}$. In other words, currency i has the average level of comovement against the domestic currency when country i's exposure to global shocks is equal to the average exposure of all other foreign currencies.

III. DATA

This section gives a description of the data used in this paper, namely exchange rates, gravity variables and bilateral linkages.

III.A. Spot exchange rates and currency comovement estimation

End of day spot exchange rates, denoted as foreign currency against the US dollar is obtained from Global Financial Data for 46 currencies from April 1973 to December 2018. The currencies of countries that adopted the euro are dropped from the sample following the introduction of the Euro in January 1999, except for Greece, which adopted the Euro on January 2001. Log spot rate changes are winsorized at the 1% and 99% levels to avoid excessive monthly exchange rate movements driven by hyperinflation.

Unconditional currency comovement are estimated from the regression $\Delta s_{i,j,t} = \alpha_{i,j} + \beta_{i,j}\Delta Base_{j,t} + \varepsilon_{i,j,t}$. Where $\Delta Base_{j,t} = \frac{1}{N-1}\sum_{k\neq i}\Delta s_{k,j,t}$ is the average appreciation of base currency j at time t relative to all available currencies, excluding currency i. Unconditional currency comovement ($\beta_{i,j}$) between base currency j and foreign currency i are estimated over three different sample periods.

Monthly currency comovement β_{τ} are estimated from the regression $\Delta s_{i,j,t} = \alpha_{i,j} + \beta_{i,j,\tau}\Delta Base_{j,t} + \varepsilon_{i,j,t}$, for $t = \tau - 59, \dots \tau$ .Where $Base_{j,t} = \frac{1}{N-1}\sum_{k\neq i}\Delta s_{k,j,t}$ is the average appreciation of base currency j at month t relative to all available currencies, excluding foreign currency i. Yearly currency comovements are calculated as the average of the respective monthly currency comovement βs.

III.B. Gravity variables

Following Lustig and Richmond (2019), I obtain gravity variables which are used to measure distance between economies.

Distance: Population weighted average distance in kilometers between large cities of each country pair. (Mayer and Zignago, 2011)

Shared Language: Common language is 1 if a language is spoken by at least 9% of the population in both countries. (Mayer and Zignago, 2011)

Shared Legal: Shared legal is 1 if country pair had the same legal origins. (Porta et al., 2007)

Colonial Link: Is 1 if country pair had common colonizer after 1945. (Mayer and Zignago, 2011)

Resource similarity: I follow Lustig and Richmond (2017), and obtain a list of natural resources for each country from the CIA world factbook. Using this list, a vector of natural resource dummy's is constructed. For each entry in the vector, the value is 1 if the country had the resource and 0 otherwise. Resource similarity between a country pair is the cosine similarity of the vectors of resource dummy variables.

III.C. Bilateral linkage measures

There are four intensity measures used in the paper: bilateral trade flows, foreign equity holdings, foreign debt holdings and foreign bank claims.

Bilateral trade flows are constructed following the international trade literature (Bergstrand, 1985; Anderson and Wincoop, 2004), where:

$$trade\ flow_{ij,T} = \frac{total\ trade_{ij,T}}{\sqrt{GDP_{i,T} \times GDP_{j,T}}} \times 100\%$$

To construct the trade flow measures, bilateral trade statistics for each country pair are obtained from the Center for International Data (CID) pre-2000, and appended with data from the World Integrated Trade Solution (WITS) Trade States post 2000.[2] GDP data, measured in current US dollars, are obtained from the World Bank world development indicators dataset.

Bilateral equity and debt holding are constructed following Lustig and Richmond (2019), though they are inspired by Portes and Rey (2000), and Portes, Rey and Oh (2001), where:

$$\text{asset holding intensity}_{\text{ij,T}} = \frac{asset\ holding_{ij,T}}{\sqrt{MktCap_{i,T} \times MktCap_{j,T}}} \times 100\%$$

$$\text{asset holding}_{\text{ij,T}} = \text{i's asset holdings in j in year T} + \text{j's asset holdings in i in year T}$$

[2] When using the WITS data, I follow the procedure proposed by the CID and place priority on import data rather than export data. For example, when measuring how much country A imports from country B, I use import data from country A rather than export data from country B. If import data is missing however, then export data is utilized. Furthermore, I merged West Germany's trade data pre-1991 with Germany's trade data post-1991 to obtain a single data series.

To construct the equity and debt holdings, bilateral holdings are obtained from the International Monetary Fund's Coordinated Portfolio Investment Survey (CPIS). Asset holdings are broken down into equity and investment funds shares, long-term debt instruments, and short-term debt instruments. End-December series are available from 2001-2018.

Bank claims are constructed using cross border bank claim data from the Bank of International Settlements (BIS):

$$Foreign\ bank\ claims_{\mathrm{ij,T}} = \frac{crossborder\ bank\ claims_{\mathrm{ij,T}}}{\sqrt{MktCap_{i,T} \times MktCap_{j,T}}} \times 100\%$$

Where $cross - border\ bank\ claims_{ij,T}$ measures the cross-border bank claims of source country i banks in host country j in year T. The data provided at the BIS is at the quarterly frequency starting from 2001, but I utilize the annual frequency to match with the trade, equity holding and debt holding intensities.

IV. UNCONDITIONAL CURRENCY COMOVEMENT AND GRAVITY

I start the empirical results of this paper by replicating the main finding in Lustig and Richmond (2019), namely that gravity variables do very well in explaining the cross section of unconditional currency comovement.

Insert Table 1 Here

Table 1 presents the summary statistics for unconditional currency comovement βs and gravity variables.

Unconditional currency comovement is estimated over three different periods: April 1973 – December 2014 which corresponds to the sample period of Lustig and Richmond (2019); April 1973 – December 2018 which extends and updates the sample period; and January 2001 –

December 2018 which focuses on the period for which country holdings of foreign assets are available through the Coordinated Portfolio Investment Survey (CPIS). The number of estimated βs decreases for the last sample period, as 11 European currencies are dropped from the sample following the adoption of the Euro in January 1999.

Insert Table 2 Here

Table 2 presents the results for regressing unconditional currency comovement on gravity variables.

Column (1) presents the original results from Lustig and Richmond, while Column (2) presents my replication results over the same time period. The results are quantitatively the same. The mean values of currency comovement βs are 1 by construction. Comparing across Column (1) and (2), doubling the distance between a base country and a foreign country decreases currency comovement by 14.2% - 16.3%. All else equal, speaking a common language increases currency comovement by slightly more than 11%, sharing a land border increases currency comovement by 11.5% - 12.8%, and having a common colonizer in the past increases currency comovement by about 23%. The standard deviation of resource similarity is 0.15, combined with the coefficient of -0.146 (-0.139), implies that a one standard deviation increase in resource similarity increases currency comovement by 2.1% - 2.2%. All coefficients are in the direction as expected and are statistically significant apart from legal origin. Commonality and closeness imply higher degrees of currency comovement (lower βs), while difference and distance imply lower degrees of currency comovement (higher βs). Referring to the β measure in the theory part of the paper, this suggests that geographical distance, links through land borders and historical colonial relationships, and differences in language, legal systems and resources capture cross country differences in exposure to global shocks.

Column (3) presents the results for the extended sample period up to December 2018 and reassuringly produce very similar results.

Column (4) presents the results focusing on the sample period for which country holdings on foreign assets are available through CPIS. The biggest difference in sample construction is the dropping out of 11 European currencies that were replaced with the Euro. Overall, the gravity variables now explain 11.3% of the variation in cross-sectional currency comovement, less than half compared to the sample periods starting from 1973. Apart from historical colonial links, the explanatory power of all gravity variables decreases both economically and statistically. Only distance, common language and historical colonial links remain statistically significant. Doubling the distance between a country pair now decreases currency comovement by 11%, compared to 16% for all sample countries. The magnitude of the coefficient on shared language is halved and is now only statically significant at the 10% level. Sharing a land border and resource similarity are no longer significantly correlated with unconditional currency comovement. The only gravity variable that increases in explanatory power is colonial links. Together, the difference of the results in column (4) compared to the first three columns suggest that European countries are an important driver of the relationship between unconditional currency comovement and gravity. This is not surprising. European countries are geographically close and share land borders, while their economies are also closely linked through trade and financial linkages, leading to higher degrees of currency comovement. Despite this, the coefficients are still in the predicted direction, reassuring us that the variation in currency comovement captured by the gravity variables is not solely due to European countries.

V. CURRENCY COMOVEMENT, GRAVITY AND BILATERAL LINKAGES

V.A. The trade and financial channel of gravity

Section IV shows that gravity variables capture a significant portion of cross-country exposures to global shocks, allowing them to explain unconditional currency comovements very well. And yet, it is rather difficult to imagine gravity variables directly determining exposure to global shocks, and thus causing currency comovement. For example, the fact that Singapore and the United States lie on both sides of the Pacific, does not directly cause their residents to have differential exposure to global shocks.

Rather, the effects of gravity variables must be manifesting through the actions of economic agents that bring their stochastic discount factors closer together. In other words, gravity variables impact the decisions of economic agents, and the actions of these agents cause countries to be more or less tied to one another, causing differential exposures to global shocks, and driving currency comovement. Two channels come to mind: the international trade channel and international finance channel.

Indeed, gravity variables first gained prominence in their capacity to explain international trade patterns, and this is one of the most robust empirical findings in the literature (Bergstrand 1985, Frankel and Romer 1999, Anderson and Wincoop 2004). Here, gravity measures proxy for shipping and transportation costs, resulting in less bilateral trade for geographically distant and culturally different countries.

Gravity variables have also been shown to successfully explain international asset holdings and bank claims. (Portes and Rey 2000, Portes, Rey and Oh 2001, Lane and Milesi-Ferretti 2004, Houston, Lin, and Ma 2012, Karolyi, Sedunov, and Taboada 2018). In the setting of financial linkages, gravity variables proxy for informational asymmetries that lead investors to hold relatively larger portions of their foreign portfolios in closer and more culturally similar countries. Thus, for international trade, countries that are geographically closer and culturally similar trade more, and thus have more similar exposures to global shocks. For international asset holdings, countries that are closer and more similar have larger bilateral foreign asset holdings, more risk sharing, and more similar exposures to global shocks.

Table 3 presents the summary statistics for rolling sample estimates of currency comovement as well as trade and financial linkages. Monthly currency comovement is estimated over a 60 month rolling window, requiring at least 55 observations. Yearly currency comovement is then calculated as the average monthly currency comovement for a given year.

Insert Table 3 Here

For each bilateral linkage variable, I also present summary statistics for the same variable but excluding countries that adopted the Euro.

V.B. Yearly currency comovement and gravity variables

To test whether gravity variables influence currency comovement through international trade and financial linkages. I start by checking the explanatory power of gravity variables for yearly currency comovement.

Insert Table 4 Here

Column (1) presents the rolling sample regressions from Lustig and Richmond (2019), while Column (2) presents the replication results over the same sample period. Similar to the full sample regressions, the coefficients from my replication match closely to the original results. The number of observations and the adjusted R^2 of the regression differ, indicating an additional screening measure that Lustig and Richmond apply to their regression, most likely intended to drop extreme outliers. As shown in column (3), extending the results to December 2018 generate largely similar outcomes.

Column (4) restricts the rolling sample regressions to 2001 through 2018, which corresponds to the period that country level foreign asset holdings are available through the CPIS. Once again, the difference in the rolling sample results generated by the post 2001 sample compared to the sample through 1973 is quite similar to that for the full sample results in Table 2. Aside from colonial link, all gravity variables have less explanatory power for currency comovement.

The results in column (5) are generated from the same sample period as column (4), but with the additional restriction that foreign asset holding data is non-missing. This restriction lowers the number of observations from 21,420 to 9,144, but increases the adjusted R^2 by more than 50%. Given that foreign asset holding data is missing for country pairs with very low or zero bilateral asset holdings, this tentatively suggests that the gravity has stronger explanatory power for currency comovement for countries that have more risk sharing through cross-border asset holdings. I apply this additional restriction, because it allows me in later results to examine the portion of gravity's explanatory power for currency comovement that trade and financial linkages capture.

Table 5 presents a first pass on the correlation between bilateral linkages and currency comovement. Column (1) redisplays the results of regressing yearly currency comovement on gravity variables. Column (2) – (5) presents the correlation between bilateral linkages and yearly currency comovement for the sample period 2001 – 2018. Similar to Lustig and Richmond (2018), international trade, cross-border asset holdings and cross-border bank flows are negatively correlated with yearly currency comovement. By itself, trade flows do quite well in explaining currency comovement. A 1% increase in bilateral trade increases currency comovement by 5.1%. This suggests that trade and financial linkages do contain relevant information on differential exposures to global shocks between countries. However, these linkages provide very limited information on top of the gravity variables, as measured by the increase in adjusted R^2. Another thing to notice is the addition of gravity variables, lowers the coefficients for all linkages variables while the coefficients for the gravity variables remain unchanged.

V.C. Gravity variables as instruments for bilateral linkages

On the surface, this would seem to suggest that linkage variables do not add additional information on top of the gravity variables, and are relatively unimportant for understanding currency comovement. Yet, upon closer inspection, given that international trade and financial linkages can be explained as linear combinations of the gravity variables, we would not expect them to provide further information that is not contained in the gravity variables.

As such, I propose the use of gravity variables as instruments for bilateral linkages and currency comovement. Table 6, Panel A presents the results of regressing trade flows, foreign asset holdings and foreign bank claims on gravity variables.

Insert Table 6 Panel A Here

Similar to the respective international trade and finance literature, gravity variables do very well in explaining cross-sectional variation in international trade and asset holdings. For international trade, the gravity variables proxy for costs of transportation. Countries that are geographically distant and culturally different trade less. Doubling the distance between a country pair decreases trade flows by around 0.78% and is significant at the 1% level. Speaking a common language, sharing a land border increase bilateral trade flows by 0.87% and 2.3% respectively, which is very large economically given that average trade flows are about 0.94%. They are also highly statistically significant at the 1% level. The coefficients on common legal system, colonial link and resource similarity are in the expected direction, though only colonial link is significant at the 10% level. Combined, gravity variables explain slightly less than 30% of international trade flows.

For international financial linkages, foreign countries that are more distant and different entail larger information asymmetries for a foreign investor and lead to less cross-border asset holdings and bank claims. Distance has a very strong effect on bilateral asset holdings and cross border bank claims. Doubling the distance between two countries decreases foreign equity holdings, foreign debt holdings and cross border bank claims by 0.71%, 2.33% and 0.99% respectively, which is 55%, 109%, 66% of the respective mean values. Speaking a common language lowers information barriers and leads to more asset trade and bank loans. Once again, the explanatory power of gravity for the financial linkages are quite strong, particular for foreign debt holdings and cross border bank claims.

Insert Table 6, Panel B Here

Next, I regress yearly currency comovement on the fitted values of trade flows and financial linkages. The fitted values of trade flows, foreign asset holdings and cross border bank claims do a good job in explaining yearly currency comovement. Richmond (2019) finds that trade networks explain currency comovement and cross country correlations in stock market returns. He also finds the gravity effect on currency comovement manifests itself through global trade network. Similarly, the predicted values of trade networks on gravity variables explain 10.8% of yearly currency comovement, or about 75% of the explanatory power that gravity variables have. Interestingly, fitted cross-border debt holdings have very close explanatory power at 9.9%, or 70% of the explanatory power of gravity variables. Equity holdings and cross border bank claims are slightly lower at 6.9% (49% of gravity) and 4.2% (30% of gravity).

Yet the question remains for why regressions using the raw values of trade flows, asset holdings and bank claims do so poorly. This is likely due to these measures being noisy. For cross border asset holdings, it has been shown that after controlling for information asymmetries, there is evidence of the diversification incentive, that is to say, investors tend to hold more assets in countries with business cycles less correlated with their country of domicile. This effect would lead to closer countries having less bilateral asset holdings and larger degrees of currency comovement.

VI. RESULTS BY YEAR AND COUNTRY

Figures 1 – 3 focus on sub-sample results for each individual year and country in the sample.

Insert Figures 1 – 3 Here

Figures 1A – 1D plots the explanatory power ($Adjusted\ R^2$) of gravity, fitted trade flows, fitted foreign debt holdings and fitted foreign equity holdings on currency comovement by year. Across the gravity and fitted bilateral linkage measures, the time trends are quite similar. Strikingly, the explanatory power of these four variables drop off following the 2008 Global Financial Crisis. Despite trending upwards, they have not recovered to pre-crisis levels. This suggests that the Global Financial Crisis significantly altered country exposures to global shocks and thus currency comovement.

Figure 2 shows the explanatory power that gravity has for currency comovement, captured by fitted trade flows, fitted debt holdings and fitted equity holdings. Overall, fitted trade flows and fitted debt holdings tend to capture around 80% of the relevant information in gravity variables.

On the other hand, fitted equity holdings do the worst, though it is interesting that fitted equity holdings contained 90% of the relevant information in gravity variables in 2001, around 10% more than either fitted trade flows or fitted debt holdings.

Figure 3 shows the results of regressing yearly currency comovement on gravity and fitted linkages by country. As expected European countries are explained quite well across gravity variables, fitted trade flows, fitted debt holdings and equity holdings. More interesting are countries such as New Zealand, Mexico and South Africa, where gravity variables do very well in explaining currency comovement, but none of the fitted bilateral linkage variables seem to have much explanatory power.

VII. CONCLUSION

Gravity variables cause currency comovement through their effects on bilateral trade flows, foreign asset holdings and cross-border bank claims. Fitted values of bilateral trade flows and foreign debt holdings contain around 70% of the explanatory power that gravity variables have for currency comovement. Financial linkages are just as important as trade flows in generating common exposures to global shocks, and driving currency comovement.

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Table 1

Full Sample Summary Statistics

	N	Mean	Median	Sd	Min	Max
Currency Comovement β (1973 – 2014)	2,070	1.01	1.03	0.36	-0.0003	2.18
Currency Comovement β (1973 – 2018)	2,070	1.02	1.03	0.35	-0.0003	2.17
Currency Comovement β (2001 – 2018)	1,190	0.99	1.02	0.35	-0.63	2.03
Log Distance	2,070	8.62	9.00	0.93	5.08	9.88
Common Language	2,070	0.13	0	0.34	0	1
Shared Legal	2,070	0.29	0	0.45	0	1
Shared Border	2,070	0.04	0	0.19	0	1
Resource Similarity	2,070	0.21	0.21	0.18	0	1
Colonial Link	2,070	0.02	0	0.15	0	1

Summary statistics of unconditional currency comovement and gravity data. Unconditional currency comovement β are estimated from the regression $\Delta s_{i,j,t} = \alpha_{i,j} + \beta_{i,j}\Delta Base_{j,t} + \varepsilon_{i,j,t}$. Where $\Delta Base_{j,t} = \frac{1}{N-1}\sum_{k\neq i}\Delta s_{k,j,t}$ is the average appreciation of base currency j at time t relative to all available currencies, excluding currency i. Unconditional currency comovement are estimated over three different sample periods.

Log distance is the population weighted average distance in kilometers between large cities of the country pair. Common language is 1 if a language is spoken by at least 9% of the population in both countries. Shared legal is 1 if the country pair had the same legal origins. Shared border is 1 is the country pair share a land border. Resource similarity is the cosine similarity of the vectors of resource dummy variables for the country pair.

The sample has 24 developed and 23 developing economies classified by the MSCI in August 2015. End of month spot rates are obtained from Global Financial Data for April 1973 to December 2018. Spot rates for countries that adopted the Euro are dropped starting January 1999.

Table 2

Full Sample Regressions with Currency Comovement on Gravity

	(1) Lustig & Richmond	(2) 1973-2014	(3) 1973-2018	(4) 2001-2018
Log Distance	0.142***	0.163***	0.165***	0.111***
	(0.038)	(0.030)	(0.030)	(0.026)
Shared Language	-0.111***	-0.112***	-0.111***	-0.059*
	(0.035)	(0.037)	(0.036)	(0.033)
Shared Legal	-0.006	0.004	0.006	-0.036
	(0.027)	(0.025)	(0.024)	(0.030)
Shared Border	-0.128***	-0.115**	-0.110**	-0.016
	(0.040)	(0.049)	(0.047)	(0.052)
Colonial Link	-0.233**	-0.226***	-0.223***	-0.276***
	(0.101)	(0.076)	(0.074)	(0.087)
Resource Similarity	-0.146***	-0.139***	-0.136***	-0.095
	(0.064)	(0.038)	(0.039)	(0.085)
Adjusted R^2	0.232	0.237	0.244	0.113
Num. obs.	2,070	2,070	2,070	1,190

Results from the regression: $\beta^*_{i,j} = \theta + \mu \boldsymbol{G}_{i,j} + e_{i,j}$.Unconditional currency comovement $\beta^*_{i,j}$ are estimated from the regression $\Delta s_{i,j,t} = \alpha_{i,j} + \beta_{i,j}\Delta Base_{j,t} + \varepsilon_{i,j,t}$. $\boldsymbol{G}_{i,j}$ is a vector of gravity variables. Log distance is the population weighted average distance in kilometers between large cities of the country pair. Common language is 1 if a language is spoken by at least 9% of the population in both countries. Shared legal is 1 if the country pair had the same legal origins. Shared border is 1 is the country pair share a land border. Resource similarity is the cosine similarity of the vectors of resource dummy variables for the country pair.

Column (1) is the regression result from Lustig and Richmond (2019). Column (2) is the replication result over the same sample period as Lustig and Richmond. Column (3) is the result over the extended sample period. Column (4) is the result over the sample period for which bilateral asset holdings are available through the Coordinated Portfolio Investment Survey (CPIS).

The sample has 24 developed and 23 developing economies classified by the MSCI in August 2015. End of month spot rates are obtained from Global Financial Data for April 1973 to December 2018. Standard errors double clustered at the country (i) and base country (j) level are in parenthesis. * p<0.05, ** p<0.01, *** p<0.001.

Table 3

Rolling Sample Summary Statistics

	N	Mean	Median	Sd	Min	Max
Currency Comovement β $(1973-2014)$	62,600	0.99	1.01	0.52	-1.57	2.98
Currency Comovement β $(1973-2018)$	67,360	0.99	1.01	0.51	-1.57	2.98
Currency Comovement β $(2001-2018)$	21,420	0.99	1.02	0.42	-1.28	2.56
Trade Flows/GDP (%)	37,234	0.94	0.34	2.03	0	42.33
Trade Flows/GDP (%), non Euro	21,394	0.91	0.29	2.24	0	42.33
Foreign Equity Holding/MktCap (%)	19,690	1.29	0.27	3.52	0	87.90
Foreign Equity Holding/MktCap (%), non Euro	9,144	0.84	0.18	1.73	0	18.26
Foreign Debt Holding/MktCap (%)	19,690	2.56	0.37	6.72	0	132.78
Foreign Debt Holding/MktCap (%), non Euro	9,144	0.75	0.16	1.54	0	15.88
Foreign Bank Claims/GDP (%)	13,835	1.51	0.25	4.04	0	69.71
Foreign Bank Claims/GDP (%), non Euro	5,276	1.45	0.17	4.99	0	67.71

Summary statistics of yearly currency comovement and bilateral linkages. Monthly currency comovement β_τ are estimated from the regression $\Delta s_{i,j,t} = \alpha_{i,j} + \beta_{i,j,\tau}\Delta Base_{j,t} + \varepsilon_{i,j,t}$, for $t = \tau - 59, \ldots \tau$.Where $Base_{j,t} = \frac{1}{N-1}\sum_{k\neq i}\Delta s_{k,j,t}$ is the average appreciation of base currency j at time t relative to all available currencies, excluding currency i. Yearly currency comovements are calculated as the average of the respective monthly currency comovement βs.

Trade Flows is bilateral trade obtained from World Integrated Trade Solution and Center for International Data, standardized by country pair nominal GDP. Foreign Equity and Debt holdings are bilateral holdings obtained from the Coordinated Portfolio Investment Survey (CPIS), and standardized by country pair stock market capitalization. Foreign bank claims are cross border bank claims for base country j on foreign country i obtained from the Bank of International Settlements (BIS), and standardized by country pair nominal GDP. Summary statistics for the bilateral linkages are also presented excluding countries that adopted the Euro.

The sample has 24 developed and 23 developing economies classified by the MSCI in August 2015. End of month spot rates are obtained from Global Financial Data for April 1973 to December 2018. Spot rates for countries that adopted the Euro are dropped starting January 1999.

Table 4

Rolling Sample Regressions with Currency Comovement on Gravity

	(1) Lustig & Richmond	(2) 1973 - 2014	(3) 1973 - 2018	(4) 2001 - 2018	(5) CPIS
Log Distance	0.142***	0.140***	0.139***	0.108***	0.148***
	(0.041)	(0.035)	(0.033)	(0.026)	(0.028)
Shared Language	-0.123***	-0.131***	-0.128***	-0.078**	-0.057
	(0.040)	(0.041)	(0.039)	(0.034)	(0.038)
Shared Legal	-0.020	-0.032	-0.030	-0.040	-0.079**
	(0.030)	(0.031)	(0.030)	(0.034)	(0.032)
Shared Border	-0.123**	-0.118**	-0.109**	-0.064	0.059
	(0.050)	(0.054)	(0.051)	(0.067)	(0.048)
Colonial Link	-0.284***	-0.285***	-0.275***	-0.316***	-0.088
	(0.083)	(0.071)	(0.070)	(0.082)	(0.077)
Resource Similarity	-0.171***	-0.142***	-0.136***	-0.093	-0.020
	(0.064)	(0.039)	(0.040)	(0.073)	(0.070)
Adjusted R^2	0.117	0.098	0.097	0.092	0.142
Num. obs.	59,654	62,600	67,360	21,420	9,144

Results from the regression: $\beta^*_{i,j,T} = \theta + \mu \boldsymbol{G}_{i,j,T} + e_{i,j,T}$. Yearly currency comovement $\beta^*_{i,j,T}$ are the averages of monthly currency comovements estimated from the regression $\Delta s_{i,j,t} = \alpha_{i,j} + \beta_{i,j,\tau} \Delta Base_{j,t} + \varepsilon_{i,j,t}$, for $t = \tau - 59, \dots \tau$. $\boldsymbol{G}_{i,j}$ is a vector of gravity variables. Log distance is the population weighted average distance in kilometers between large cities of the country pair. Common language is 1 if a language is spoken by at least 9% of the population in both countries. Shared legal is 1 if the country pair had the same legal origins. Shared border is 1 is the country pair share a land border. Resource similarity is the cosine similarity of the vectors of resource dummy variables for the country pair.

Column (1) is the regression result from Lustig and Richmond (2019). Column (2) is the replication result over the same sample period as Lustig and Richmond. Column (3) is the result over the extended sample period. Column (4) is the result over the sample period for which bilateral asset holdings are available through the Coordinated Portfolio Investment Survey (CPIS). Column (5) is the result for the sample where bilateral asset holdings provided by the CPIS are non-missing.

The sample has 24 developed and 23 developing economies classified by the MSCI in August 2015. End of month spot rates are obtained from Global Financial Data for April 1973 to December 2018. Standard errors double clustered at the country (i) and base country (j) level are in parenthesis. * p<0.05, ** p<0.01, *** p<0.001.

Table 5

Rolling Sample Regressions with Currency Comovement on Bilateral Linkages and Gravity

	(1) Gravity	(2) Trade Flows	(3) Equity Holding	(4) Debt Holding	(5) Bank Claims	(6) Gravity +Trade Flows	(7) Gravity +Equity Holding	(8) Gravity +Debt Holding	(9) Gravity +Bank Holding
Log Distance	0.148***					0.140***	0.150***	0.149***	0.132***
	(0.028)					(0.030)	(0.028)	(0.028)	(0.045)
Shared Language	-0.057					-0.047	-0.060	-0.057	-0.039
	(0.038)					(0.034)	(0.041)	(0.039)	(0.087)
Shared Legal	-0.079**					-0.078**	-0.080**	-0.079**	-0.065
	(0.032)					(0.032)	(0.033)	(0.032)	(0.047)
Shared Border	0.059					0.085	0.054	0.058	0.141
	(0.048)					(0.079)	(0.046)	(0.048)	(0.090)
Colonial Link	-0.088					-0.032	-0.086	-0.087	
	(0.077)					(0.079)	(0.078)	(0.077)	
Resource Similarity	-0.020					-0.024	-0.024	-0.020	0.023
	(0.070)					(0.072)	(0.063)	(0.069)	(0.177)
Trade Flows/GDP (%)		-0.051***				-0.009			
		(0.009)				(0.008)			
Foreign Equity Holding/MktCap (%)			-0.014				0.004		
			(0.013)				(0.007)		
Foreign Debt Holding/MktCap (%)				-0.025*				0.001	
				(0.015)				(0.005)	
Foreign Bank Claims/GDP (%)					-0.010**				-0.005
					(0.005)				(0.004)
Adjusted R^2	0.141	0.049	0.004	0.010	0.032	0.144	0.142	0.142	0.081
Num. obs.	9,144	9,144	9,144	9,144	3,226	9,144	9,144	9,144	3,226

Results from the regression: $\beta^*_{i,j,T} = \theta + \mu \boldsymbol{G}_{i,j} + Intensity_{i,j,T} + e_{i,j,T}$. Monthly base factor loadings β_τ are estimated from the regression $\Delta s_{i,j,t} = \alpha_{i,j} + \beta_{i,j,\tau} Base_{j,t} + \varepsilon_{i,j,t}$, for $t = \tau - 59, \dots \tau$.Where $\Delta Base_{j,t} = \frac{1}{N-1} \sum_{k \neq i} \Delta s_{k,j,t}$ is the average appreciation of currency *j* at time *t* relative to all available currencies, excluding currency i. Yearly base factor loadings are calculated as the average of the respective monthly base factor loadings.

$\boldsymbol{G}_{i,j}$ is a set of gravity variables. Log distance is the population weighted average distance in kilometers between large cities of the country pair. Common language is 1 if a language is spoken by at least 9% of the population in both countries. Shared legal is 1 if the country pair had the same legal origins. Shared border is 1 is the country pair share a land border. Resource similarity is the cosine similarity of the vectors of resource dummy variables for the country pair.

Trade Flows is bilateral trade obtained from World Integrated Trade Solution and Center for International Data, standardized by country pair nominal GDP. Foreign Equity and Debt holdings are bilateral holdings obtained from the Coordinated Portfolio Investment Survey (CPIS), and standardized by country pair stock market capitalization. Foreign bank claims are cross border bank claims for base country *j* on foreign country *i* obtained from the Bank of International Settlements (BIS), and standardized by country pair nominal GDP.

Table 6, Panel A

Linkages on Gravity Variables

	(1) Trade Flow	(2) Equity Holding	(3) Debt Holding	(4) Bank Claims
Log Distance	-0.781***	-0.705***	-2.330***	-0.991***
	(0.130)	(0.268)	(0.603)	(0.227)
Shared Language	0.872**	1.359***	0.937	1.427*
	(0.353)	(0.457)	(0.782)	(0.852)
Shared Legal	0.124	-0.097	0.434	0.710
	(0.110)	(0.172)	(0.402)	(0.524)
Shared Border	2.258***	1.344***	3.915***	2.707**
	(0.602)	(0.163)	(1.285)	(1.057)
Colonial Link	1.832*	-1.075	-3.300***	-2.355***
	(0.967)	(0.692)	(1.143)	(0.616)
Resource Similarity	-0.488	1.366***	0.552	-0.365
	(0.420)	(0.401)	(0.494)	(0.629)
Adjusted R^2	0.299	0.091	0.200	0.157
Num. obs.	37,234	19,690	19,690	13,835

Results from the regression: $Linkage_{i,j,T} = \theta + \mu \boldsymbol{G}_{i,j} + y_T + e_{i,j,T}$.
$\boldsymbol{G}_{i,j}$ is a set of gravity variables. Log distance is the population weighted average distance in kilometers between large cities of the country pair. Common language is 1 if a language is spoken by at least 9% of the population in both countries. Shared legal is 1 if the country pair had the same legal origins. Shared border is 1 is the country pair share a land border. Resource similarity is the cosine similarity of the vectors of resource dummy variables for the country pair.
Trade Flows is bilateral trade obtained from World Integrated Trade Solution and Center for International Data, standardized by country pair nominal GDP. Foreign Equity and Debt holdings are bilateral holdings obtained from the Coordinated Portfolio Investment Survey (CPIS), and standardized by country pair stock market capitalization. Foreign bank claims are cross border bank claims for base country j on foreign country i obtained from the Bank of International Settlements (BIS), and standardized by country pair nominal GDP.

Table 6, Panel B

Rolling Sample Loadings and Fitted Intensities

	(1) Trade Flow	(2) Equity Holding	(3) Debt Holding	(4) Bank Holding	(5) Trade and Asset Holding	(6) Gravity
Trade Flows/GDP (%)	-0.118***				-0.087***	
	(0.024)				(0.022)	
Foreign Equity Holding/MktCap (%)		-0.105***			0.030***	
		(0.029)			(0.005)	
Foreign Debt Holding/MktCap (%)			-0.048***		-0.028**	
			(0.010)		0.014	
Foreign Bank Claims/GDP (%)				-0.073**		
				(0.030)		
Log Distance						0.148***
						(0.028)
Shared Language						-0.057
						(0.038)
Shared Legal						-0.079**
						(0.032)
Shared Border						0.059
						(0.048)
Colonial Link						-0.088
						(0.077)
Resource Similarity						-0.020
						(0.070)
Adjusted R^2	0.108	0.069	0.099	0.067	0.116	0.141
Num. obs.	9,144	9,144	9,144	3,226	9,144	9,144

Results from the regression: $\beta^*_{i,j,T} = \theta + \widetilde{Intensity}_{i,j,T} + e_{i,j,T}$. Monthly base factor loadings β_τ are estimated from the regression $\Delta s_{i,j,t} = \alpha_{i,j} + \beta_{i,j,\tau} Base_{j,t} + \varepsilon_{i,j,t}$, for $t = \tau - 59, \dots \tau$.Where $Base_{j,t} = \frac{1}{N-1}\sum_{k\neq i} \Delta s_{k,j,t}$ is the average appreciation of currency *j* at time *t* relative to all available currencies, excluding currency i. Yearly base factor loadings are calculated as the average of the respective monthly base factor loadings. Intensity measures are fitted values from the regression: $Intensity_{i,j,T} = \theta + \mu \boldsymbol{G}_{i,j} + y_T + e_{i,j,T}$.

Figure 1

Yearly R^2

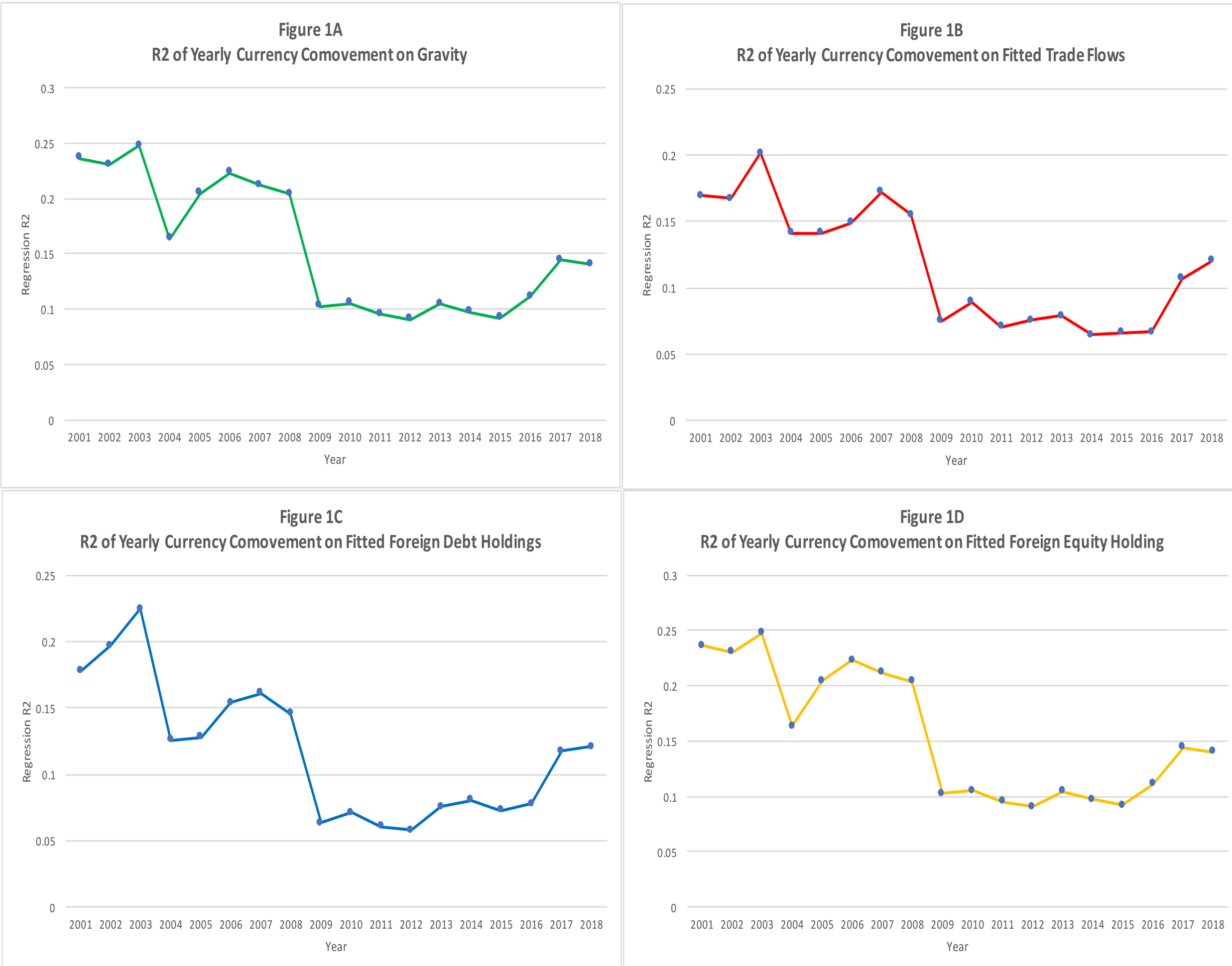

Figure 1: Plots of yearly R^2 from regression $\beta^*_{i,j,T} = \theta + \mu \boldsymbol{G}_{i,j,T} + e_{i,j,T}$ and $\beta^*_{i,j,T} = \theta + \widetilde{Intensity}_{i,j,T} + e_{i,j,T}$. Yearly base factor loadings are calculated as the average of the respective monthly base factor loadings. Intensity measures are fitted values from the regression: $Intensity_{i,j,T} = \theta + \mu \boldsymbol{G}_{i,j} + y_T + e_{i,j,T}$.

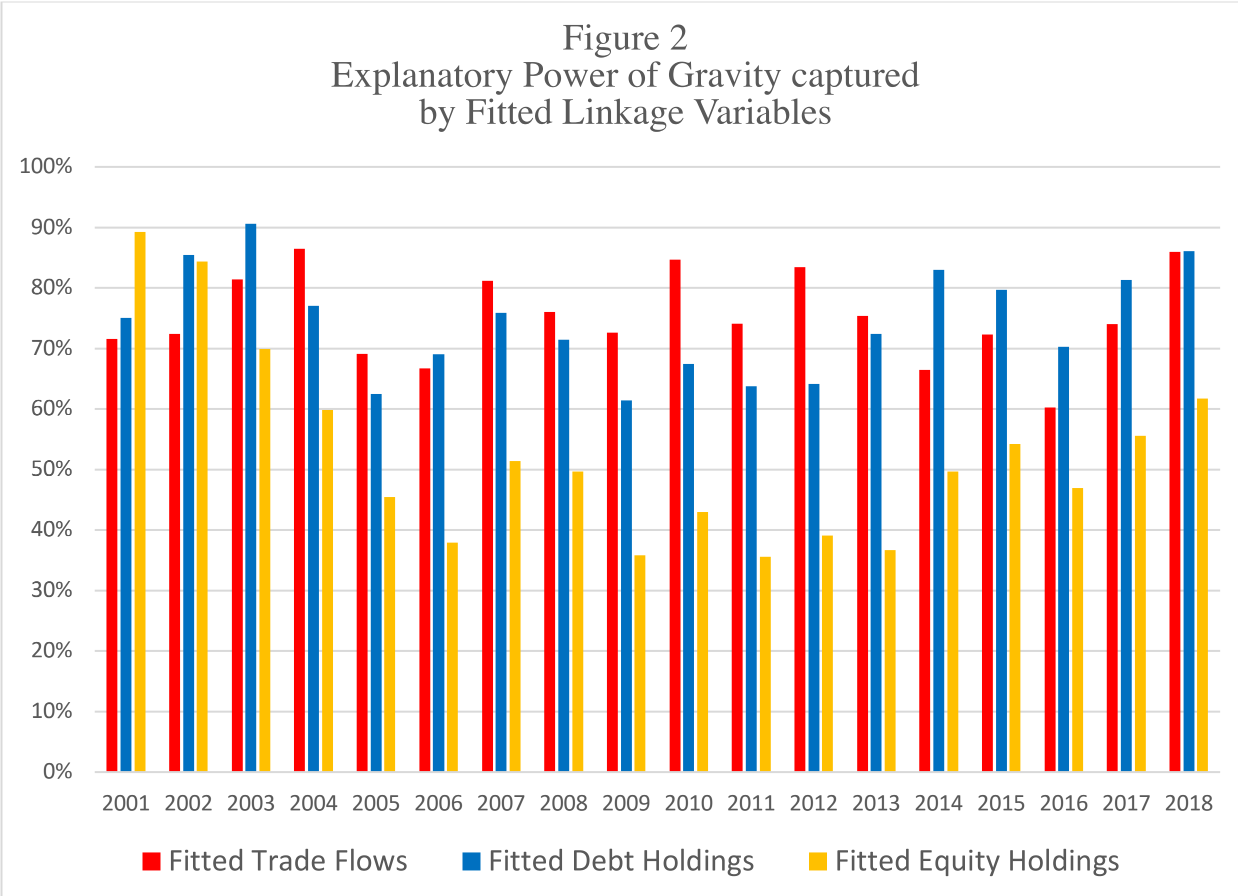

Figure 2: R2 of yearly currency comovement on fitted linkage variables/R2 of yearly currency comovement on gravity. R^2 from regression $\beta^*_{i,j,T} = \theta + \mu \boldsymbol{G}_{i,j,T} + e_{i,j,T}$ and $\beta^*_{i,j,T} = \theta + \widetilde{Intensity}_{i,j,T} + e_{i,j,T}$. Yearly base factor loadings are calculated as the average of the respective monthly base factor loadings. Intensity measures are fitted values from the regression: $Intensity_{i,j,T} = \theta + \mu \boldsymbol{G}_{i,j} + y_T + e_{i,j,T}$.

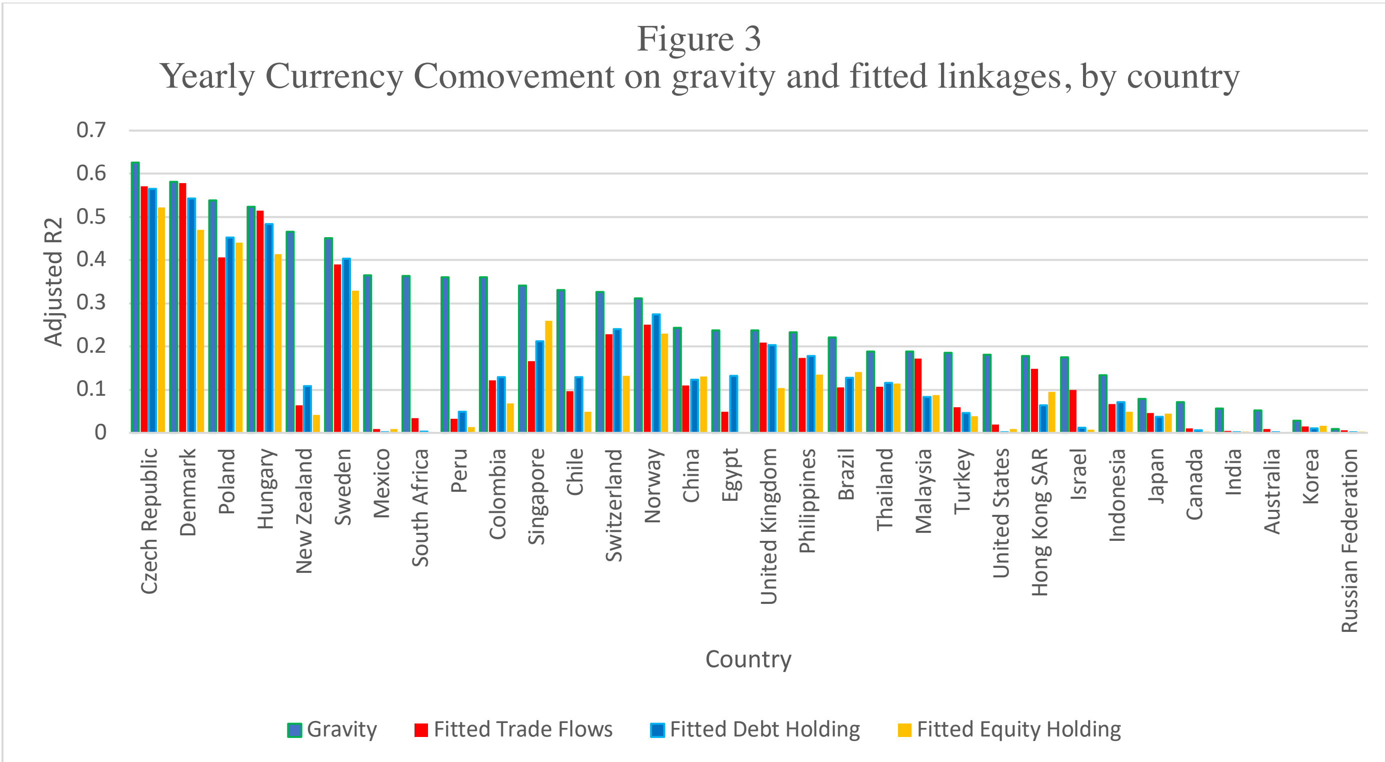

Figure 3: R2 of yearly currency comovement on gravity and fitted linkage variables. R^2 from regression $\beta^*_{i,j,T} = \theta + \mu \boldsymbol{G}_{i,j,T} + e_{i,j,T}$ and $\beta^*_{i,j,T} = \theta + \widetilde{Intensity}_{i,j,T} + e_{i,j,T}$. Yearly base factor loadings are calculated as the average of the respective monthly base factor loadings. Intensity measures are fitted values from the regression: $Intensity_{i,j,T} = \theta + \mu \boldsymbol{G}_{i,j} + y_T + e_{i,j,T}$.