International Portfolio Investments with Trade Networks

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Motivation

- Foreign portfolio investments are sizable
  - FPI: $53.4 trillion. FDI: $36.4 trillion.
- Country equity and bond portfolios are heterogeneous ▸ More
- What are the determinants of international portfolio investments?
  - Large home bias literature, but 2-country or symmetric models inadequate to explain composition of external investments.

This paper

1. Solve for the optimal bond and equity portfolios in a workhorse $N-$country RBC model.
    - closed-form solution $\rightarrow$ analytical insights
2. Model features realistic trade networks:
    - Preferences for consumption and investment goods
    - International production input-output (IO) linkages
3. Characterize how
    1. international shocks propagate on trade networks
    2. holding the “right” portfolios helps hedge against these shocks

Summary of findings

- Theory: optimal portfolios in closed form
  1. Equity portfolio determined by network demand exposure - International Domar Weights
  2. Bond portfolio determined by an expenditure switching matrix
- Empirics:
  1. Network equity portfolio explains half of variation in data
     - robust to controlling for gravity factors
  2. Network equity portfolio resolves “distance puzzle”
  3. Indirect linkages matter, not just direct trade links
  4. Trade networks explain asset home bias, in levels and changes

Related Literature

- International portfolio and international risk sharing
    - Lucas (1982), French and Porterba (1991), Baxter & Jermann (1997), Obstfeld and Rogoff (2001), Fitzgerald (2012), Portes and Rey (2005), Lane & Milesi-Ferretti (2008), Coeurdacier, Kollman, and Martin (2010), Heathcote & Perri (2013), Coeurdacier & Gourinchas (2016), Engel & Matsumoto (2009), Osaka & van Wincoop (2012).
- Network in domestic macro + finance
    - Macro: Domar (1961), Hulten (1978), Long & Plosser (1983), Gabaix (2011), Acemoglu et. al. (2012), Baqaee & Farhi (2019).
    - Finance: Herskovic (2018, 2020), Gofman et. al. (2020), Babus & Kondor (2018)
- Network in open economy
    - Johnson & Noguera (2012), Johnson (2014), Richmond (2019), Richmond & Jiang (2019), Farhi and Baqaee (2020), Chang et. al. (2020), di Giovanni and Hale (2022)

Outline

Environment

- N countries. Each country produces a country-specific intermediate good

$$Y_i = Z_i^Y \left[L_i^{\theta} K_i^{1-\theta}\right]^{1-\gamma} \left(\sum_{j=1}^{N} \omega_{ij}^{\frac{1}{\varepsilon}} X_{ij}^{1-\frac{1}{\varepsilon}}\right)^{\frac{\gamma\varepsilon}{\varepsilon-1}}$$

  and a final good, used for domestic consumption and investment:

$$G_i = \left[\sum_{j=1}^{N} \xi_{ij}^{\frac{1}{\varepsilon}} G_{ij}^{1-\frac{1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}}.$$

- Capital accumulation: $K_{i,+1} = (1-\delta)K_i + Z_i^K I_i$
- Optimal investment:

$$V_t(K_{i,t}) = \max_{I_{i,t}} \quad \underbrace{r_{i,t}K_{i,t} - Q_{i,t}I_{i,t}}_{\text{profit } \Pi} + \mathbb{E}_t\left[\Theta_{i,t+1}V_{t+1}\left(K_{i,t+1}\right)\right]$$

Assets and Preferences

- $2N$ assets:
  - Equity i pays out country-i capital's profit
  - Bond i pays 1 out 1 unit of intermediate good i each period
- Household: maximize discounted lifetime utility

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t u(C_{i,t})$$

subject to budget constraint:

$$Q_{i,t}C_{i,t} + PR_{i,t} = W_{i,t}L_{i,t} + \sum_j \left(\Lambda_{ij,t}\Pi_{j,t} + B_{ij,t}P_{j,t}\right)$$

where the portfolio rebalancing term equals

$$PR_{i,t} = \sum_j P^E_{j,t}\Delta\Lambda_{ij,t+1} + \sum_j P^B_{j,t}\Delta B_{ij,t+1}.$$

Market clearing

- Final goods:

$$C_{i,t} + I_{i,t} = G_{i,t}$$

- Intermediate goods:

$$Y_{i,t} = \sum_j \left(G_{ji,t} + X_{ji,t}\right)$$

- Equities:

$$\sum_i \Lambda_{ij,t} = 1.$$

- Bonds:

$$\sum_i B_{ij,t} = 0.$$

Solution Method

- Solve for steady-state portfolio:

$$\Lambda_t(S_t) = \Lambda + \Lambda_t'(\bar{S}) \cdot (S_t - \bar{S}) + ...$$

  by approximating the Euler equation to second order and other equations to first-order
  - Samuelson (1970), Dereveux and Sutherland (2011), Engel & Matsumoto (2009).
- With $2N$ assets and $2N$ shocks, markets are complete. Back out portfolios that support full risk-sharing.
  - Coeurdacier, Kollman, Martin (2010), Coeurdacier & Rey (2013), Coeurdacier & Gourinchas (2016).

IO matrices

- Define consumption share matrix:

$$\Xi_{ij} = \frac{P_j G_{ij}}{Q_i G_i} = \frac{i\text{'s final expenditure on good } j}{i\text{'s total final expenditure}}$$

- Define intermediate input share matrix:

$$\Omega_{ij} = \frac{P_j X_{ij}}{P_i^X X_i} = \frac{i\text{'s interm. expenditure on good } j}{i\text{'s total expend. on interm. inputs}}$$

- Ξ and Ω come from data (WIOD), referred to as “trade networks”

IO accounting: Expenditure $\rightarrow$ Income

Lemma
For trade networks (Ω_t, Ξ_t), we have:

$$\widetilde{GDP}_t = \underbrace{(1-\gamma)\widetilde{Y}_t}_{\text{value-added}} = M_t \underbrace{\widetilde{G}_t}_{\text{expenditure}},$$

where

$$M_t = (1-\gamma)\left[I - \gamma\Omega_t'\right]^{-1}\Xi_t'$$

is an $N \times N$ matrix of international Domar weights. ▸ Derivation

- M_{ij} = value-added content in final good j produced by sector i.
- Johnson and Noguera (2012): trade in value-added
- M not directly observable, but computable from trade shares.

IDW in the data

Origin	Dest.	Intermediate	Final	Scaled IDWs
Japan	China	1.61%	2.31%	5.57%
Japan	US	0.99%	0.49%	2.64%
Japan	Australia	1.00%	0.10%	1.50%

Table 1: IDWs vs bilateral trade shares for Japan

Data: World Input-Output Database (WIOD).

- Japan exports more indirectly than directly to key destinations.

Decomposing International Risks

Lemma
Log-linearizing the model around the steady state, we have

$$\widehat{GDP}_t = \overline{M}\left(\widehat{\widetilde{C}}_t + \widehat{\widetilde{I}}_t\right) - \overline{M}^P \widehat{p}_t,$$

where $\overline{M}$ is the matrix of IDWs and $\overline{M}^P$ captures expenditure switching.

- Any set of shocks affects country incomes mainly through fluctuations in investment $\widehat{\widetilde{I}}$ and relative price $\widehat{p}$.

Optimal Equity Portfolio Hedges Investment Risk

$$\widehat{GDP}_t = \overline{M}\left(\widehat{\widetilde{C}}_t + \widehat{\widetilde{I}}_t\right) - \overline{M}_P \widehat{p}_t$$

- Consider a particular realization of investment $\widehat{\widetilde{I}}$
  - Effect of investment on labor income: $\widehat{\widetilde{L}} = \theta\overline{M} \cdot \widehat{\widetilde{I}}$
  - Effect of investment on financial income:

$$\Lambda \underbrace{\alpha\overline{M}\widehat{\widetilde{I}}}_{\text{capital income}} - \Lambda \underbrace{\widehat{\widetilde{I}}}_{\text{lower dividend}}$$

- Optimal equity portfolio hedges labor income risk for all realizations of $\widehat{\widetilde{I}}$:

$$\theta M + \alpha\Lambda M - \Lambda = 0 \Rightarrow \Lambda = \theta M \left[I - \alpha M\right]^{-1}$$

- IDWs first-order determinant of equity portfolios ▸ Intuition

Optimal Equity Portfolio Hedges Relative Price Risk

- TOT risk on labor and equity income:

$$\frac{\partial GNI}{\partial p} = \frac{\partial GNI}{\partial GDP} \cdot \frac{\partial \mathrm{GDP}}{\partial p}$$
$$= -\left[I - \alpha\left(I - \Lambda\right)\right] \cdot \overline{M}_P$$

  with
  $\overline{M}^P = (\varepsilon - 1)(1 - \gamma)\left[I - \gamma\overline{\Omega}'\right]^{-1}\left(D_Y - \overline{\Xi}' D_G \overline{\Xi} - \overline{\Omega}' D_X \overline{\Omega}\right)$.
- Optimal TOT-hedging bonds:

$$\widetilde{B}^P = [I - \alpha(I - \Lambda)] \cdot \overline{M}_P$$

- When $\varepsilon > 1$, long domestic bonds because these bonds pay higher return when domestic income is low.
- A higher level of equity home bias implies a higher domestic bond position because GNI and GDP more closely linked.

Extensions

- The framework is flexible and can allow for:
  - Adding a non-traded sector
  - Multiple intermediate goods in each country
  - Heterogeneity in production (i.e. $(\alpha_i, \theta_i, \gamma_i)$ vary by *i*)
  - Non-CES production (similar first-order behaviors)

Explaining external equity investments I

- International production network from World Input - Output Database.
  - 28 EU countries and 14 other major countries (inc. emerging markets), and ROW.
  - Data: country-sector level. Aggregate at country level to get Ω and Ξ.
- Portfolio investment from Coordinated Portfolio Investment Survey (IMF).
  - 200+ countries, 2001-2018
  - CPIS data restated from residency to nationality (Coppola et al., 2021).
- Gravity variables: CEPII, Eikon Refinitiv. Capital controls from Fernandez et al. (2016)

Explaining external equity investments II

- Trade networks Ω and Ξ from WIOD $\rightarrow$ optimal network portfolio Λ
- Network portfolio predicted by theory:

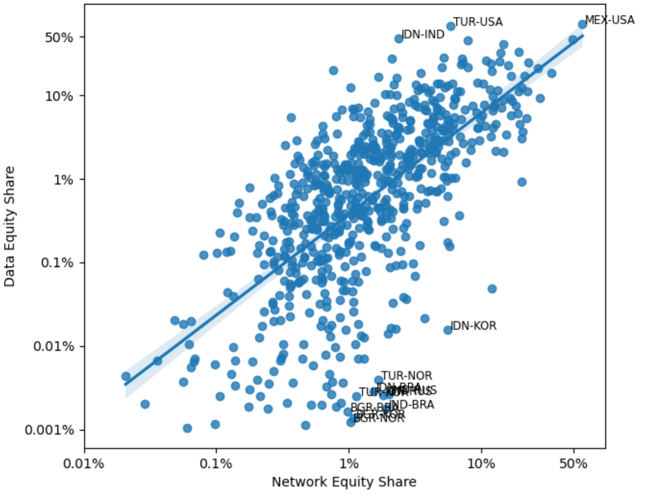
$$\text{network equity share}_{ij} = \frac{\Lambda_{ij} \cdot P_S^j}{\sum_{j \neq i} \Lambda_{ij} P_S^j}$$

- Observed portfolio from the data:

$$\text{data equity share}_{ij} = \frac{\text{Equity investment into } j \text{ by } i}{\text{Total external equity investment of } i}$$

- Drop country pairs for which equity share $< 10^{-5}$.

Network Portfolio vs. Data



Baseline regression results

	Dependent variable: CPIS Equity share$_{ij}$ (log)		
Network	1.19 (0.05)		
Market cap, origin		0.06 (0.04)	0.19 (0.03)
Market cap, destination		0.77 (0.04)	0.89 (0.04)
Distance			-0.76 (0.06)
Const	-0.05 (0.09)	-7.04 (0.34)	-5.72 (0.35)
N	684	684	684
Adj-R^2	0.48	0.41	0.51

Data: WIOD and CPIS. Year: 2007. All variables are in log form.

Network, controlling for gravity factors

	Dependent variable: CPIS Equity Share	
Network		0.92 (0.11)
Market cap, orig	0.13 (0.06)	0.15 (0.06)
Market cap, dest	0.97 (0.07)	0.07 (0.14)
Distance	-0.72 (0.08)	-0.10 (0.10)
Capital control, orig	-0.34 (0.08)	-0.36 (0.07)
Capital control, dest	-0.14 (0.10)	-0.13 (0.10)
N	684	684
Adj-R^2	0.56	0.59

Data: WIOD and CPIS. Year: 2007. Each regression includes a set of other gravity variables: market cap/GDP, contiguity, common language, joint EU membership, WTO membership, and US dummies.

Partial R-sq = 0.08

Isolate Indirect Linkages

- How important are indirect linkages?
- Compare against alternative measures for direct trade:
  1. Direct trade portfolio: same theory, but ignore trade in intermediate and higher order terms

$$\Lambda = \theta M + h.o.t \approx \theta \Xi' + h.o.t.$$

  2. Obstfeld - Rogoff (2001): import share of origin ($\Lambda = \Xi$)
  3. Trade intensity: Total trade / $\left(GDP_i + GDP_j\right)$
  4. Familiarity: Trade share of origin

Isolate Indirect Linkages: Result

	Dependent variable: CPIS Equity Share					
Network	1.19					1.03
Direct		0.26				-0.13
O-R			0.84			0.00
Trade Intensity				0.81		0.15
Familiarity					0.98	0.14
Constant	-0.01	-1.76	-0.39	2.71	-0.21	-0.10
N	684	684	684	684	684	684
Adj. R^2	0.48	0.02	0.341	0.25	0.45	0.49

*Estimates in red are significant at the 1% level, and insignificant otherwise.

Equity Home Bias Revisit

- Large literature on asset home bias. How well does our theory explain the level of home bias across countries? Changes over time?
- Home bias = share of domestic asset in total investment portfolio

$$EHB_i = \frac{\text{Investment in Dom. Assets}_i}{\text{Total Investment}_i}$$

- CPIS only has external investment. Infer

$$\text{Investment in Dom. Assets}_i = Mkcap_i - \text{Holding by Foreigners}$$

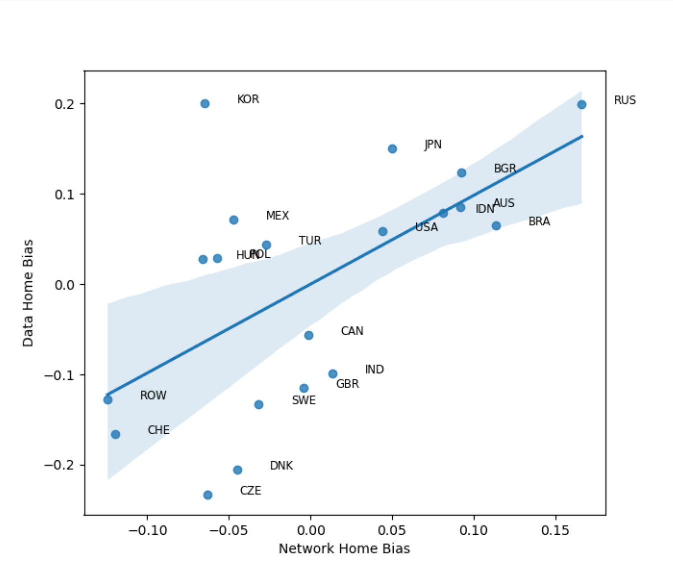
Explaining Equity Home Bias

	Data EHB
	Level
Network	0.98 (0.25)
Market cap	-0.10 (0.03)
Capital control	0.46 (0.09)
Constant	0.66 (0.13)
N	20
Adj. R^2	0.73

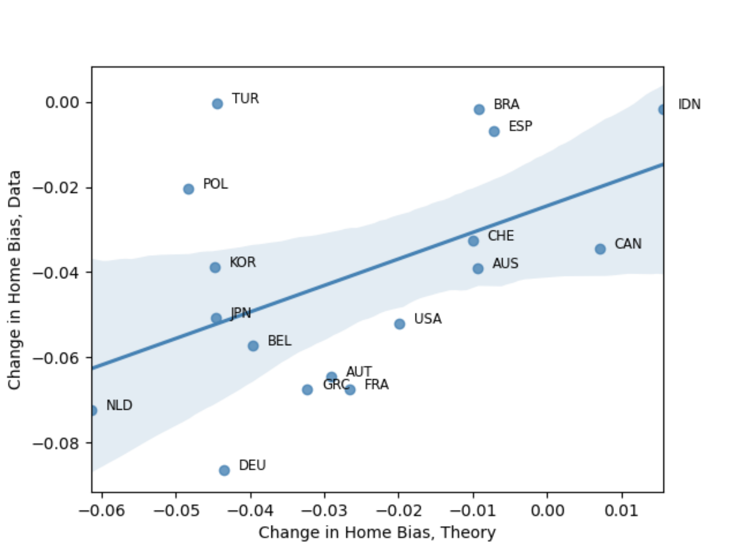
Data: WIOD and CPIS.

Partial R^2 of network = 0.32

Explaining Equity Home Bias: Level



Explaining Equity Home Bias: Changes



R^2 = 0.14. Slope = 1.15.

Conclusion

- Theory of optimal portfolios to hedge against international risks
- Network portfolio explains the data well, is robust to gravity controls, and resolves the distance puzzle
- Future developments:
    - Nominal frictions & pricing regimes
    - Portfolios under incomplete markets
    - Leverage exogenous shocks to trade structure to find more causal evidences

Thank you!

Heterogeneity in external portfolios

	USA	GBR	JPN	CAN	FRA	DEU
Origin: USA	-	0.99	-0.04	0.41	0.14	0.25
GBR	0.11	-	-0.10	-0.43	0.52	0.99
JPN	0.22	0.02	-	-0.28	-0.02	-0.11
DEU	-0.38	1.21	-0.70	-0.58	2.12	-
THA	-0.55	0.09	-0.76	-0.94	-0.69	-0.48
BRA	0.34	-0.52	-0.98	-0.84	-0.69	-0.60

Table 2: $\frac{\text{data portfolio share}}{\text{destination market cap share}} - 1$

Back

Expenditure switching

- The linearized market clearing condition is given by:

$$(1-\gamma)\widehat{\widetilde{Y}} = M\widehat{\widetilde{G}} - M_P\left(\widehat{q}+\widehat{e}\right),$$

where

$$M_P = (\varepsilon-1)(1-\gamma)\left[I-\gamma\Omega'\right]^{-1}\left(\Xi'\Phi_G\Xi+\gamma\Omega'\Phi_Y\Omega-\Phi_Y\right)$$

- When $\varepsilon = 1$: no expenditure switching effect.
- First term: higher price $\rightarrow$ lower demand in final sector.
- Second term: higher price $\rightarrow$ lower demand in intermediate sector.
- Third term: higher price $\rightarrow$ higher revenue per unit sold.

International Business Cycle: C vs. I

Country	$sd(c)$	$sd(i)$	$sd(i)/sd(c)$
USA	0.009	0.043	4.9
UK	0.014	0.054	3.9
Japan	0.014	0.051	3.6
Germany	0.010	0.049	4.8
France	0.013	0.040	3.1
China	0.036	0.146	4.1
Turkey	0.035	0.111	3.2
Sample Average	0.042	0.124	3.5

Table 3: Standard deviation of consumption and investment ▸ Back

Data: Penn World Table 9.1. Author's calculations. Series are HP-filtered.

International Domar Weights: Derivation

- Without intermediate inputs

$$\widetilde{Y} = \Xi' \widetilde{G}$$

- With intermediate inputs

$$\widetilde{Y} = \Xi' \widetilde{G} + \gamma \Omega' \widetilde{Y}$$

- Total effect (direct + indirect):

$$(1-\gamma)\widetilde{Y} = (1-\gamma) \underbrace{\left[I - \gamma\Omega'\right]^{-1}}_{\text{Leontief inverse}} \Xi' \widetilde{G} = M\widetilde{G}$$

Optimal Equity Portfolio Intuition

- Optimal equity portfolio $\Lambda = \theta M \left[I - \alpha M\right]^{-1}$ to the first order:

$$\Lambda = \theta M + h.o.t$$

- Hold more shares if more "exposed" (measured by IDWs) to investment fluctuations
    - Seems to be true in the data (later).
- Induced by negative correlation between financial income $rK{-}I$ and labor income wL.
    - Heathcote and Perri (2013): $cor(rK{-}I, wL) \in [-0.5, 0.1]$.
- Models without investment: $cor(rK, wL)$ usually positive.