Origins of International Factor Structures

Zhengyang Jiang and Robert Richmond
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Northwestern Kellogg and NYU Stern
Asset prices and economic quantities are difficult to connect

- Comovements in international asset prices.
  - Forbes and Rigobon (2002); Bekaert et al. (2009); Lustig et al. (2011); Verdelhan (2018)
- Comovements in international business cycles and trade.
  - Gregory and Head (1999); Kose et al. (2003); Imbs (2004); Burstein et al. (2008); Rose and Spiegel (2009)
- Relating asset prices to economic quantities.
  - Meese and Rogoff (1983); Backus and Smith (1993)

This Paper:
Use the global trade network to explain international co-movements and factor structures, both theoretically and empirically.
Global production and consumption network

We show how the global production and consumption network generates international movements in asset prices and business cycles.
Network closeness explains asset price and quantity correlations

- We define a network closeness measure based on trade linkages.
- We thereby bridge international trade to asset pricing.
Countries produce and consume distinct tradable goods

- $N$ countries. Each country produces a distinct tradable goods.
- Production function in country $i$

\[
X_i = A_i L_i^{\theta_i} \left( \prod_{j=1}^{N} X_{ij}^{w_{ij}} \right)
\]

- $A_i$ productivity, $L_i$ labor, $X_{ij}$ input from country $j$
- Log utility over aggregate consumption $C_i$:

\[
C_i = \prod_{j=1}^{N} C_{ij}^{v_{ij}}
\]
Countries productivity shocks can be correlated

- Productivity $A_i$ is the only exogenous shock

$$a_{i,t+1} = a_{i,t} + \varepsilon_{i,t+1}$$

- $\varepsilon_{t+1}$ are normally distributed and iid over time

- Shocks may be correlated across countries:

$$\mathbb{E}_t[\varepsilon_{t+1} \varepsilon'_{t+1}] = \Omega$$

- Our setting with log preference, Cobb-Douglas aggregation and i.i.d. shocks abstracts away from many interesting dynamics.
Markets are complete. Social planner maximizes:

\[
\sum_{i=1}^{N} \lambda_i \sum_{t=1}^{\infty} \exp(-\beta t) \log C_{i,t}.
\]

Subject to market clearing:

\[
\overline{X}_i = \overline{A}_i L_i^{\theta_i} \left( \prod_{j=1}^{N} X_{ij}^{w_{ij}} \right) = \sum_{j=1}^{N} (C_{ji} + X_{ji}),
\]

\[
\overline{L}_i = L_i.
\]
Output and consumption depend on the global network structure

\[ \overline{X}_i = A_i L_i^{\theta_i} \left( \prod_{j=1}^{N} X_{ij}^{w_{ij}} \right), \quad \overline{C}_i = \prod_{j=1}^{N} C_{ij}^{v_{ij}}; \]

- \( W \) is the matrix with element \( w_{ij} \). \( V \) is the matrix with element \( v_{ij} \).
- **Lemma**: The log production and consumption growth rates are
  \[ \Delta \overline{x}_{t+1} = (I - W)^{-1} \varepsilon_{t+1}, \]
  \[ \Delta \overline{c}_{t+1} = V(I - W)^{-1} \varepsilon_{t+1}. \]
- Leontief inverse aggregates across all direct and indirect trade linkages:
  \[ (I - W)^{-1} = I + W + W^2 + W^3 + \ldots. \]
Closeness measures the similarity in countries’ shock exposures

- Define network profile $H$ as
  \[ H \equiv V(I - W)^{-1} \]
  and $H_i$ is the vector of row $i$.
- Define the closeness between two countries $i$ and $j$ as
  \[ C(i, j) \equiv H_i \Omega H_j'. \]
- Define average closeness of country $i$ as:
  \[ \overline{C}(i) \equiv \frac{1}{N} \sum_{j=1}^{N} C(i, j). \]
Asset prices are easy to calculate

- Stock is the claim to local consumption. Let $r_{i,t+1}^{eq}$ denote the log cum-dividend return in the unit of local consumption goods.
- Let $e_{i,j,t}$ denote the log real exchange rate between consumption bundles.
- Let $\bar{e}_{i,t}$ denote the base currency factor:

$$\bar{e}_{i,t} = \frac{1}{N} \sum_{j=1}^{N} e_{i,j,t}.$$
Result 1: Closeness explains international co-movements

- Countries that are closer in the network have more correlated consumption growth rates and more correlated stock returns:

\[
\text{cov}(\Delta \bar{c}_{i,t}, \Delta \bar{c}_{j,t}) = C(i, j), \\
\text{cov}\left(r_{i,t}^{eq}, r_{j,t}^{eq}\right) = C(i, j).
\]

- Controlling for country-level fixed effects, closer countries also have more correlated base currency factor movements and less volatile bilateral real exchange rate movements:

\[
\text{cov}(\Delta \bar{e}_{i,t}, \Delta \bar{e}_{j,t}) = C(i, j) - \bar{C}(i) - \bar{C}(j) + \kappa^e, \\
\text{var}(\Delta e_{i,j,t}) = -2C(i, j) + C(i, i) + C(j, j).
\]
Result II: Trade Network Generates Common Factors

- \( V = \Omega = I \). Suppose the production network follows a core-peripheral structure:

\[
W_1 = (1 - \theta) \begin{bmatrix}
1 & 0 & 0 & 0 \\
\gamma & 1 - \gamma & 0 & 0 \\
\gamma & 0 & 1 - \gamma & 0 \\
\gamma & 0 & 0 & 1 - \gamma \\
\end{bmatrix}.
\]

- The covariance matrix of consumption growth or stock return, \( C = (I - W_1)^{-1}((I - W_1)^{-1})' \), has the following Cholesky decomposition:

\[
\text{chol}(C) = \begin{bmatrix}
a_1 & a_2 & a_2 & a_2 \\
0 & a_3 & 0 & 0 \\
0 & 0 & a_3 & 0 \\
0 & 0 & 0 & a_3 \\
\end{bmatrix},
\]

- The central country’s consumption growth becomes the common factor in the cross-section of countries. All other (peripheral) countries load equally on this common factor, and have no further pairwise comovements beyond that induced by this loading.
Result III: Trade Network Generates Regional Factors

- Suppose the productivity shocks load on systematic shocks \( u_t \) and idiosyncratic shocks \( \eta_t \):

\[
\varepsilon_t = \Psi u_t + H\eta_t.
\]

- The production network has a block structure. Each country only imports inputs from other countries in the same region:

\[
\omega_{ij} = \begin{cases} 
\omega_0, & \text{if } i = j, \\
\omega_1, & \text{if } i \neq j \text{ and } j \in R(i), \\
0, & \text{if } j \notin R(i),
\end{cases}
\]

- Then, idiosyncratic shocks within a region aggregate into a regional shock:

\[
\Delta \bar{c}_{i,t+1} = \sum_{k=1}^{K} \kappa_h^{\theta_i} \left( \theta_i \psi_{ik} + \sum_{j \in R(i)} \omega_1 \psi_{jk} \right) u_{k,t+1} + \kappa_h^{\omega_1} \left( \sum_{j \in R(i)} h_{jj} \eta_{j,t+1} \right) + \kappa_h^{\theta_i} h_{ii} \eta_{i,t+1}
\]
Data Sources

- Annual consumption data from World Bank’s World Development Indicators, 1973—2014.
- Gravity variables from CEPII.
Model quantities can be directly measured from WIOT

- Following the model, we estimate $W$ and $V$ from the import shares:

\[
\bar{X}_i = A_i L_i^\theta \left( \prod_{j=1}^{N} X_{ij}^{w_{ij}} \right) \Rightarrow w_{ij} = \frac{q_j X_{ij}}{q_i \bar{X}_i},
\]

\[
\bar{C}_i = \prod_{j=1}^{N} C_{ij}^{v_{ij}} \Rightarrow v_{ij} = \frac{q_j C_{ij}}{\sum_{k=1}^{N} q_k C_{ik}},
\]

where $q_j X_{ij}$ is the pecuniary value of imports from country $j$ to country $i$.

- We estimate $\Omega$ from

\[
\text{cov}(\Delta \bar{c}_i, t, \Delta \bar{c}_j, t) = \mathcal{C}(i, j) \equiv H_i \Omega H_j'
\]

where $H = V(I - W)^{-1}$. 
Different measures of closeness highlight different network components

\[ C^{\text{Consumption}}(i,j) = \{ V(I - W)^{-1}\Omega(V(I - W)^{-1})' \}_{i,j} \]  
(1)

\[ C^{\text{Exposure}}(i,j) = \{ \Omega \}_{i,j} \]  
(2)

\[ C^{\text{Network}}(i,j) = \{ V(I - W)^{-1}(V(I - W)^{-1})' \}_{i,j} \]  
(3)

\[ C^{\text{Production}}(i,j) = \{ (I - W)^{-1}((I - W)^{-1})' \}_{i,j} \]  
(4)

\[ C^{\text{ProductionFO}}(i,j) = \{ I + W + W' \}_{i,j} \]  
(5)
Closeness explains consumption and equity correlations

Define $\tilde{C}(i,j) = \frac{C(i,j)}{\sqrt{C(i,i)C(j,j)}}$.

$$corr(\Delta \bar{c}_{i,t}, \Delta \bar{c}_{j,t}) = \alpha + \beta \cdot \tilde{C}(i,j) + \varepsilon_{i,j},$$

$$corr\left(r^{eq}_{i,t}, r^{eq}_{j,t}\right) = \alpha + \beta \cdot \tilde{C}(i,j) + \varepsilon_{i,j}.$$
Closeness explains FX co-movements

Define $\tilde{C}(i,j) = C(i,j)/\sqrt{C(i,i)C(j,j)}$.

$$corr(\Delta \bar{e}_{i,t}, \Delta \bar{e}_{j,t}) = \delta_i + \delta_j + \beta \cdot \tilde{C}(i,j) + \varepsilon_{i,j},$$

$$std(\Delta e_{i,j,t}) = \delta_i + \delta_j + \beta \cdot \tilde{C}(i,j) + \varepsilon_{i,j}.$$

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*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
Currency factors

- A large literature studies currency factors constructed from currency portfolios
- Common factors:
  - \textit{HML} (carry): long in currencies with currently high interest rates, short in currencies with currently low interest rates
  - \textit{UHML} (unconditional carry): long in currencies with on-average high interest rates, short in currencies with on-average low interest rates
  - \textit{Dollar}: equal weighted portfolio of currencies vis-a-vis the dollar
  - \textit{PMC}: long in peripheral countries, short in central countries
- All of the above factors are some linear combination of exchange rates
- Currency factors explain common movements in exchange rates and price the cross-section of currencies.
- Are the co-movements implied by the network related to currency factors?
Similarity in co-variance structure

- Measure each currency’s loading on a currency factor:

$$\Delta \bar{e}_{i,t} = \alpha_i + \beta_i HML_t + \epsilon_{it}$$

- How much of the cross-sectional variation in currency’s factor loadings can be explained by closeness measures?

- For a covariance matrix $C$, each eigenvector/principal component $PC_n(C)$ can be interpreted as a currency portfolio

- Regress base factor’s loadings on the PC’s portfolio loadings

$$\beta_i = \alpha + \gamma_1 PC_{1,i}(C) + \gamma_2 PC_{2,i}(C) + \gamma_3 PC_{3,i}(C) + \epsilon_i.$$ 

- R-squared answers our question
Regress base factor loadings on PC loadings

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$$\beta_i = \alpha + \gamma_1 PC_{1,i}(C) + \gamma_2 PC_{2,i}(C) + \gamma_3 PC_{3,i}(C) + \varepsilon_i.$$
Network structure generates regional factors

- Approximate a block structure in the trade network using hierarchical clustering algorithm (Johnson (1967))
  - Inverse of network closeness $1/C^{\text{network}}(i,j)$ as a measure of distance.
  - Only uses data from WIOT.
- Partition countries into 3 clusters that are furthest apart.
- Build cluster factors as averages within each cluster.
- Measure factor loadings by regressing each quantity or asset prices on each factor.
Loadings on FX factors are higher within cluster
Loadings on equity factors tend to be higher within cluster
We develop a model of the global production and consumption network.

Closeness is the model-implied measure for international co-movements.

- Countries that are closer in this network have more correlated consumption growth, stock returns, and exchange rate movements.
- The structure of both the consumption and production network are important for understanding co-movements.
- The network generates factor structures in equity returns and exchange rate movements as found in the data.

Offers a network-based account of the origins of factor structures in international asset prices and economic quantities.


