Global Trade

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Outline

- Trade and Trade Data
- International Friends and Enemies
- Neoclassical Growth in an Interdependent World

Trade and Trade Data

Modern World Trade Data

- United Nations COMTRADE Database
  - Raw source for trade data by country-partner for HS 6-digit products
- CEPII BACI Trade Database
  - Bilateral trade data by country-partner for HS 6-digit products
  - Harmonized HS92 Classification (1995-2023)
  - Also HS96, HS02, HS07, HS12, HS17, HS22
- CEPII GRAVITY Trade Database
  - Aggregate bilateral trade data by country-partner from multiple sources from 1948-2020
  - Data on bilateral distance and other country-partner characteristics to estimate a gravity equation
- NBER World Trade Database
  - Bilateral trade data by country-partner and disaggregated product from 1962-2000 (Feenstra et al. 2005)
- IMF Direction of Trade Statistics (DOTS)
  - Aggregate bilateral trade data by country-partner from 1948 onwards

World Input-Output Data

- World Input Output Database (WIOID)
  - World input-output tables for 43 countries and the rest of the world
  - Data for 56 sectors are classified according to the International Standard Industrial Classification revision 4 (ISIC Rev. 4)

- EORA Global Supply Chain Database
  - Inter-sectoral transfers amongst 15,909 sectors across 190 countries from 1990-2022
  - Warning: Substantial imputation

- Trade in Value Added (TiVA)
  - Tracks the origins of value added in exports, imports and final demand for the years 1995-2020 for 76 countries

Modern World Tariff Data

- United Nations TRAINS Database
  - Raw source for tariff data by country-partner and product
- World Integration Trade Solutions (WITS) Database
  - Web access to download the TRAINS data
- Feodora Teti Global Tariff Database
  - Corrects issues with the imputation of tariffs in the WITS data
  - Now the frontier sources for accurate modern world tariff data

Trade Concordances

- Peter Schott's Website has a number of useful concordances
  - Standard International Classification (SIC)
  - Harmonized System (HS)
  - North American Industry Classification (NAICS)

- Forum for Research in Empirical International Trade (FREIT) has a number of useful concordances

Historical World Trade Data

- Federico-Tena World Trade Historical Database
  - Annual series of trade by polity from 1800 to 1938 which sum as series for continent and world (Federico and Tena-Junguito 2019)
- CEPII TRADHIST
  - 1.9 million bilateral trade flows, 42,000 observations on total imports and exports, and 14,000 observations for GDP and exchange rates, for a 188-year period spanning 1827-2014 (Fouquin and Hugot 2016)
- RICardo Project
  - Trade between Nations from 1800 to 1938 (Dedinger and Girard 2017)

US Trade and Tariff Data

- Peter Schott's Website
  - US HS-level imports and exports
- Replication datasets for studies of the Trump Tariffs
  - Mary Amiti, Stephen J. Redding and David Weinstein (2019) "The Impact of the 2018 Trade War on U.S. Prices and Welfare," *Journal of Economic Perspectives*, 33(4), 187-210.
  - Amiti, Mary, Stephen J. Redding and David Weinstein (2020) "Who's Paying for the U.S. Tariffs? A Longer Term Perspective," *American Economic Association*, Papers and Proceedings, 110, 541–546.
  - Fajgelbaum, Pablo D., Pinelopi K. Goldberg, Patrick J. Kennedy, and Amit K. Khandelwal (2020) "The Return to Protectionism," *Quarterly Journal of Economics*, 135(1), 1-55.
  - Fajgelbaum, Pablo D., Pinelopi K. Goldberg, Patrick J. Kennedy, Amit K. Khandelwal and Dalia Taglioni (2024) "The US-China Trade War and Global Reallocations," *American Economic Review: Insights*, 6(2), 295-312.

Code and Other Resources

- Kleinman, Benny, Stephen J. Redding and Ernest Liu (2024) "International Friends and Enemies," *American Economic Journal: Macroeconomics*, 16(4), 350-85.
  - https://www.internationalfriendsandenemies.com/home
  - Replication data and code
  - Interactive maps and network graphs of income and welfare exposure

- Kleinman, Benny, Stephen J. Redding and Ernest Liu (2023) "Dynamic Spatial General Equilibrium," *Econometrica*, 91(2), 385-424.
  - https://stephenredding.github.io/
  - Replication data and code
  - Model toolkit

International Friends and Enemies

- Kleinman, Benny, Stephen J. Redding and Ernest Liu (2024) "International Friends and Enemies," *American Economic Journal: Macroeconomics*, 16(4), 350-85.

Motivation

- Changes in the relative economic size of countries are often accompanied by shifts in the balance of political power
  - "Throughout history, anxiety about decline and shifting balances of power has been accompanied by tension and miscalculation ... Traditionally the test of a great power was its strength in war. Today, however, the definition of power is losing its emphasis on military force ... The factors of technology ... and economic growth are becoming more significant in international power." (*Nye 1990*, pp. 153-4)

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- As countries becomes more more economically dependent on a trade partner, do they realign politically towards that trade partner?
- We use network measures of economic exposure to foreign productivity growth from constant elasticity trade models
  - A country is an economic friend (enemy) of a trade partner if its productivity growth raises (reduces) the partner's real income

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- Combine with a variety of measures of political alignment
  - United Nations voting, strategic rivalries, formal alliances

This Paper

- Countries can undertake political actions that raises the productivity of their trade partners but incur utility costs
  - More sensitive a country's real income to a partner's productivity, greater incentive to undertake these political actions
- Key empirical challenge is that economic exposure depends on trade flows which could be endogenous to political alignment
- Address this empirical challenge using two sources of quasi-experimental variation
  - China's emergence into the global economy following its domestic supply-side reforms in 1978 (Autor et al. 2013)
  - Reduction in cost of air travel, which affects trade partners with different air distances relative to sea distances unevenly (Feyrer 2019)
- Increases in economic dependence on a trade partner predicted by our instruments lead to political realignment towards that partner
- Our theory-based economic exposure measure dominates simpler measures of trading relationships between countries

Related Literature

- International political economy
  - Scott (1955), Cohen (1960), Nye (1990), Signorino & Ritter (1999), Thompson (2001), Kuziemko & Werker (2006), Meyersson et al. (2008), Guiso, Sapienza & Zingales (2009), Colaresi et al. (2010), Head et al. (2010), Häge (2011), Head & Mayer (2013), Nunn & Qian (2014), Bailey et al. (2017), Aghion et al. (2018), Dicaprio & Sokolova (2018), Bao, Liu, Qiu & Zhu (2019)
- Empirical literature on war and trade
  - Polachek (1980), Polachek and McDonald (1992), Mansfield (1995), Barbieri (2002), Blomberg & Hess (2006), Martin et al. (2008), Glick & Taylor (2010)
- Empirical literature on China's emergence and IVs for trade
  - Frankel & Romer (1999), Rodriguez & Rodrik (2001), Autor, Dorn & Hanson (2013, 2016), Brunnermeier et al. (2018), Feyrer (2019)
- Quantitative trade models and sufficient statistics for welfare
  - Armington (1969), Jones & Scheinkman (1977), Wilson (1980), Eaton and Kortum (2002), Arkolakis, Costinot & Rodriguez-Clare (2012), Caliendo & Parro (2015), Adão, Costinot & Donaldson (2017), Adão, Arkolakis and Esposito (2019), Baqaee & Farhi (2019), Huo, Levchenko & Pandalai-Nayar (2019)

Constant Elasticity Armington

- Indirect utility function

$$u_n = \frac{w_n}{\left[\sum_{i=1}^{N} p_{ni}^{-\theta}\right]^{-\frac{1}{\theta}}}, \qquad \theta = \sigma - 1, \qquad \sigma > 1$$

- Expenditure share

$$s_{ni} = \frac{p_{ni}^{-\theta}}{\sum_{m=1}^{N} p_{nm}^{-\theta}}, \qquad p_{ni} = \frac{\tau_{ni} w_i}{z_i}$$

- Market clearing

$$w_i \ell_i = \sum_{n=1}^{N} s_{ni} w_n \ell_n$$

- Numeraire

$$\sum_{n=1}^{N} w_n \ell_n = 1, \qquad \sum_{n=1}^{N} q_n = 1, \qquad q_n \equiv w_n \ell_n$$

General Equilibrium

- General equilibrium reduces to a system of N equations in $\{w_n\}_{n=1}^N$

$$w_i \ell_i = \sum_{n=1}^{N} \frac{\left(\tau_{ni} w_i / z_i\right)^{-\theta}}{\sum_{m=1}^{N} \left(\tau_{nm} w_m / z_m\right)^{-\theta}} w_n \ell_n$$

- Excess demand system in which country wages are gross substitutes
  - There exists a unique equilibrium wage vector that solves this system (Alvarez and Lucas 2007; Allen, Arkolakis and Takahashi 2020)
- Exact-hat algebra counterfactuals (Dekle et al. 2007)
  - Denote counterfactual values by a prime (x'), initial values without a prime (x), and relative changes by a hat ($\hat{x} \equiv x'/x$)
  - Given exogenous counterfactual changes in productivities $\{\hat{z}_i\}$, rewrite the system of counterfactual equilibrium conditions as

$$w_i \ell_i \hat{w}_i \hat{\ell}_i = \sum_{n=1}^{N} \frac{s_{ni} \left(\hat{w}_i\right)^{-\theta} \left(\hat{z}_i\right)^{\theta}}{\sum_{m=1}^{N} s_{nm} \left(\hat{w}_m\right)^{-\theta} \left(\hat{z}_m\right)^{\theta}} w_n \ell_n \hat{w}_n \hat{\ell}_n$$

- Analogous results throughout the class of constant elasticity trade models (Arkolakis et al. 2012)

Exact-hat Algebra

- Real income exposure can be measured using exact-hat algebra
- Start at the observed equilibrium in the data and undertake a counterfactual for a productivity shock in one country

$$\ln \hat{w}_i = \left(\frac{\theta}{\theta+1}\right) \ln \hat{z}_i + \frac{1}{\theta+1} \ln \left[\sum_{n=1}^{N} t_{in} \frac{\hat{w}_n}{\sum_{m=1}^{N} s_{nm} \hat{w}_m^{-\theta} \hat{z}_m^{\theta}} \right]$$

$$\ln \widehat{u}_i = \ln \hat{w}_i + \frac{1}{\theta} \ln \left[\sum_{n=1}^{N} s_{in} \hat{w}_n^{-\theta} \hat{z}_n^{\theta} \right]$$

- s_{ni} : share of expenditure of importer n on exporter i
- $t_{in} = s_{ni} w_n \ell_n / w_i \ell_i$: share of income of exporter i from importer n
- Repeat for a productivity shock in each country and populate matrix $\boldsymbol{U}_{ik} = \ln \widehat{u}_i / \ln \widehat{z}_k$, where $\ln \widehat{x}_i \simeq \mathrm{d} \ln x_i$ for small x_i
- Corresponds to an arc elasticity for a given assumed magnitude of the productivity shock ($\widehat{z}_k$)

Linearization

- Totally differentiating market clearing and indirect utility

$$\text{(income exposure)} \qquad \mathrm{d}\ln w_i = \sum_{n=1}^{N} t_{in}\left(\mathrm{d}\ln w_n + \theta\left(\sum_{h=1}^{N} s_{nh}\left[\mathrm{d}\ln w_h - \mathrm{d}\ln z_h\right] - \left[\mathrm{d}\ln w_i - \mathrm{d}\ln z_i\right]\right)\right)$$

$$\text{(welfare exposure)} \qquad \mathrm{d}\ln u_n = \mathrm{d}\ln w_n - \sum_{i=1}^{N} s_{ni}\left[\mathrm{d}\ln w_i - \mathrm{d}\ln z_i\right]$$

- Bilateral friend-enemy income and welfare exposures obtained from matrix inversion (row i, column n) back

$$\underbrace{\mathrm{d}\ln \boldsymbol{w}}_{\text{income effect}} = \underbrace{\boldsymbol{T}\,\mathrm{d}\ln \boldsymbol{w}}_{\text{market-size effect}} + \underbrace{\theta \boldsymbol{M} \times \left(\mathrm{d}\ln \boldsymbol{w} - \mathrm{d}\ln \boldsymbol{z}\right)}_{\text{cross-substitution effect}}$$

$$\underbrace{\mathrm{d}\ln \boldsymbol{u}}_{\text{welfare effect}} = \underbrace{\mathrm{d}\ln \boldsymbol{w}}_{\text{income effect}} - \underbrace{\boldsymbol{S}\left(\mathrm{d}\ln \boldsymbol{w} - \mathrm{d}\ln \boldsymbol{z}\right)}_{\text{price index effect}}$$

$$\boldsymbol{T}_{in} = t_{in} \equiv \frac{s_{ni} w_n \ell_n}{w_i \ell_i}, \qquad \boldsymbol{M}_{in} = \left[\boldsymbol{T}\boldsymbol{S} - \boldsymbol{I}\right]_{in} = \sum_{h=1}^{N} t_{ih} s_{hn} - 1_{n=i}, \qquad \boldsymbol{S}_{ni} = s_{ni}$$

Matrix Inversion

- Re-arranging the wage equation:

$$\frac{1}{\theta+1}\,\mathbf{d}\ln\mathbf{w} = \frac{1}{\theta+1}\mathbf{T}\,\mathbf{d}\ln\mathbf{w} + \frac{\theta}{\theta+1}\mathbf{M}\left(\mathbf{d}\ln\mathbf{w} - \mathbf{d}\ln\mathbf{z}\right)$$

$$\frac{1}{\theta+1}\left(\mathbf{I}-\mathbf{T}-\theta\mathbf{M}\right)\,\mathrm{d}\ln\mathbf{w} = -\frac{\theta}{\theta+1}\mathbf{M}\,\mathrm{d}\ln\mathbf{z}$$

- Now use $\mathbf{M} = \mathbf{TS} - \mathbf{I}$

$$\frac{1}{\theta+1}\left(\mathbf{I}-\mathbf{T}-\theta\mathbf{TS}+\theta\mathbf{I}\right)\,\mathrm{d}\ln\mathbf{w} = -\frac{\theta}{\theta+1}\mathbf{M}\,\mathrm{d}\ln\mathbf{z},$$

$$\left(\mathbf{I}-\frac{\mathbf{T}+\theta\mathbf{TS}}{\theta+1}\right)\,\mathrm{d}\ln\mathbf{w} = -\frac{\theta}{\theta+1}\mathbf{M}\,\mathrm{d}\ln\mathbf{z}$$

- Using world GDP as numeraire, which implies $\mathbf{Q}\,\mathrm{d}\ln\mathbf{w} = 0$:

$$\left(\mathbf{I}-\frac{\mathbf{T}+\theta\mathbf{TS}}{\theta+1}+\mathbf{Q}\right)\,\mathrm{d}\ln\mathbf{w} = -\frac{\theta}{\theta+1}\mathbf{M}\,\mathrm{d}\ln\mathbf{z}$$

Exposure Measures

- The elasticities of each country's income with respect to productivity shocks in any country satisfy:

$$\mathrm{d}\ln \boldsymbol{w} = \boldsymbol{W}\,\mathrm{d}\ln \boldsymbol{z}$$

$$\boldsymbol{W} \equiv -\frac{\theta}{\theta+1}\left(\boldsymbol{I}-\boldsymbol{V}\right)^{-1}\boldsymbol{M}, \qquad \boldsymbol{V} \equiv \frac{\boldsymbol{T}+\theta\boldsymbol{T}\boldsymbol{S}}{\theta+1} - \boldsymbol{Q}$$

- The elasticities of each country's welfare with respect to a productivity shock in any country satisfy:

$$\mathrm{d}\ln \boldsymbol{u} = \boldsymbol{U}\,\mathrm{d}\ln \boldsymbol{z}$$

$$\boldsymbol{U} \equiv \left(\boldsymbol{I}-\boldsymbol{S}\right)\boldsymbol{W}+\boldsymbol{S}.$$

Multi-Industry IO (CP)

- Analogous matrix representation for multi-sector model with input-output linkages following Caliendo and Parro (2015)

$$\underbrace{\mathrm{d}\ln \boldsymbol{w}}_{\text{income effect}} = \underbrace{\boldsymbol{T}\,\mathrm{d}\ln \boldsymbol{w}}_{\text{market size effect}} + \underbrace{\boldsymbol{\theta M}}_{\text{substitution effect}} \times \underbrace{\left(\mathrm{d}\ln \boldsymbol{w} - \mathrm{d}\ln \boldsymbol{z}\right)}_{\text{change in costs}}$$

$$\underbrace{\mathrm{d}\ln \boldsymbol{u}}_{\text{welfare effect}} = \underbrace{\mathrm{d}\ln \boldsymbol{w}}_{\text{income effect}} - \underbrace{S\left(\mathrm{d}\ln \boldsymbol{w} - \mathrm{d}\ln \boldsymbol{z}\right)}_{\text{change in price indices}}$$

$$\boldsymbol{S}_{ni} \equiv \sum_{h=1}^{N}\sum_{k=1}^{K} \alpha_n^k s_{nh}^k \Lambda_{hi}^k$$

$$\boldsymbol{T}_{in} \equiv \sum_{h=1}^{N}\sum_{k=1}^{K} \Pi_{ih}^k \vartheta_{hn}^k$$

$$\boldsymbol{M}_{in} \equiv \sum_{h=1}^{N}\sum_{k=1}^{K}\sum_{o=1}^{N} \Pi_{io}^k \left(\vartheta_{oh}^k + \sum_{j=1}^{N} \Theta_{oh}^{kj}\right) \Upsilon_{hon}^k$$

Economic Data

- International trade data
  - United Nations COMTRADE data
  - NBER World Trade Database 1970-2012
- Income, population and distance data
  - CEPII Gravity Database 1970-2012
- Preferential Trade Agreements (PTAs)
  - World Bank's Content of Deep Agreements database 1958-2012
- Input-output matrix
  - Caliendo and Parro (2015)
- Robustness test using EORA database

Model Inversion

- Recover productivity and trade cost shocks from the trade data
- Recover trade costs from the Head-Ries formula

$$\frac{x_{nit}}{x_{nnt}} = \frac{w_{it}^{-\theta} z_{it}^{\theta} \left(\tau_{nit}\right)^{-\theta}}{w_{nt}^{-\theta} z_{nt}^{\theta} \left(\tau_{nnt}\right)^{-\theta}},$$

$$\left(\frac{x_{nit}}{x_{nnt}} \frac{x_{int}}{x_{iit}}\right)^{\frac{1}{2}} = \left(\frac{\tau_{nit}}{\tau_{nnt}} \frac{\tau_{int}}{\tau_{iit}}\right)^{-\frac{\theta}{2}}.$$

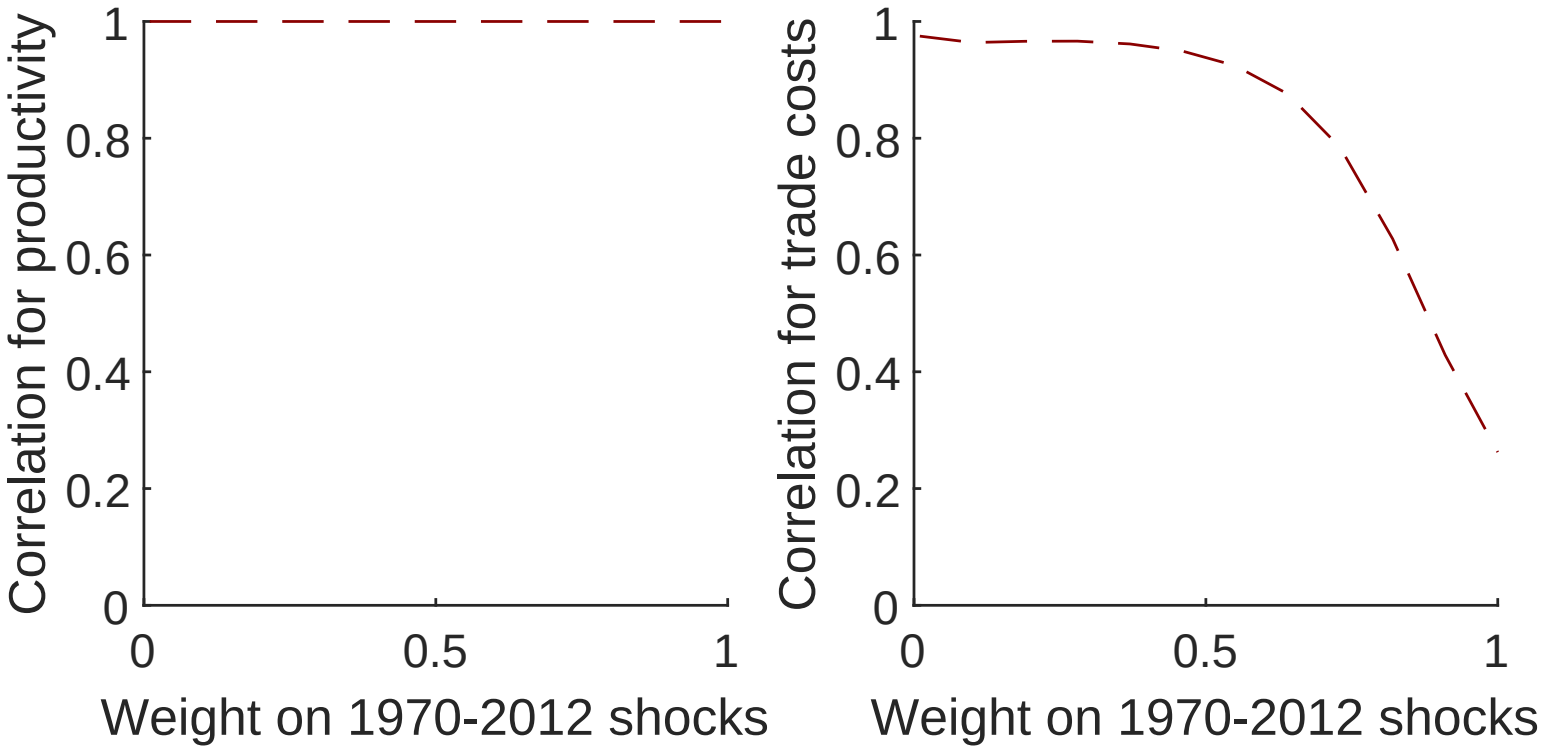
$$\left(\frac{\hat{x}_{nit}}{\hat{x}_{nnt}} \frac{\hat{x}_{int}}{\hat{x}_{iit}}\right)^{\frac{1}{2}} = \left(\hat{\tau}_{nit} \hat{\tau}_{int}\right)^{-\frac{\theta}{2}}.$$

- Recover changes in productivity that rationalize changes in income given changes in trade costs from market clearing

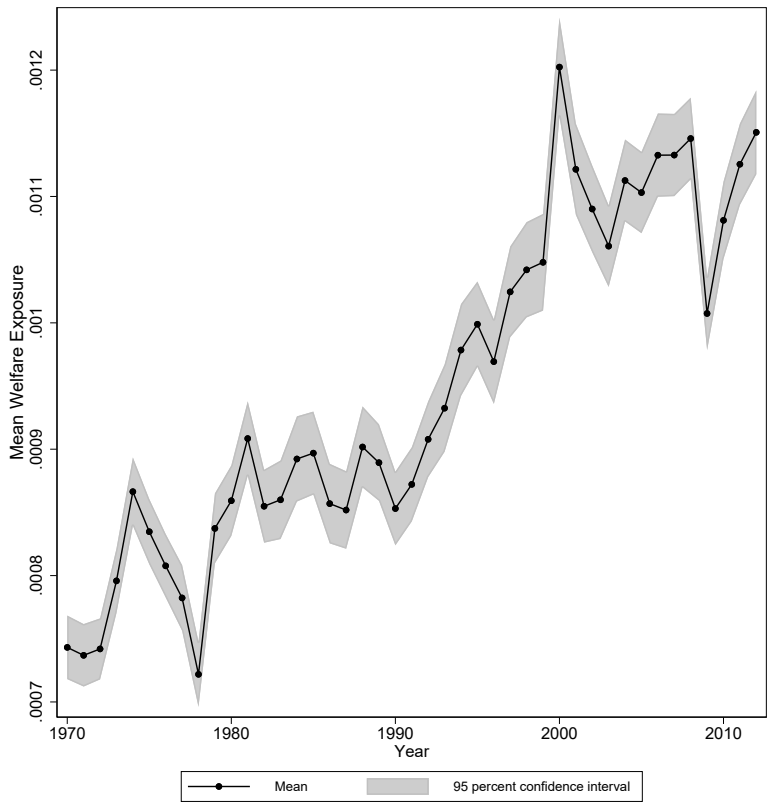
$$\hat{w}_{it} w_{it} \hat{\ell}_{it} \ell_{it} = \sum_{n=1}^{N} \frac{s_{nit} \hat{\tau}_{nit}^{-\theta} \left(\hat{w}_{it} / \hat{z}_{it}\right)^{-\theta}}{\sum_{\ell=1}^{N} s_{n\ell t} \hat{\tau}_{n\ell t}^{-\theta} \left(\hat{w}_{\ell t} / \hat{z}_{\ell t}\right)^{-\theta}} \hat{w}_{nt} w_{nt} \hat{\ell}_{nt} \ell_{nt}$$

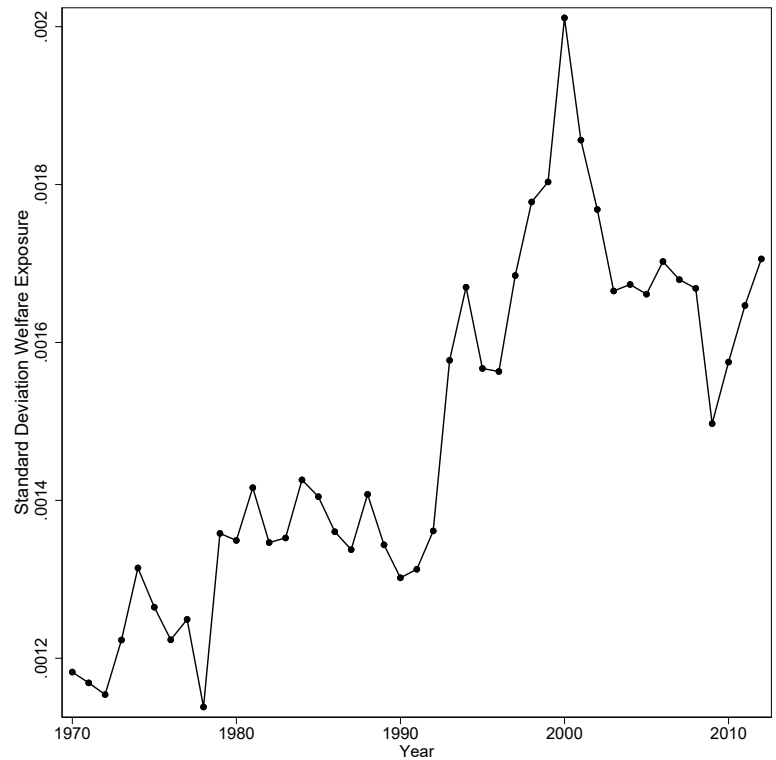
Non-linear and Linear Predictions

- Correlation between log changes in welfare in the non-linear model and our linearization ($\theta = 5$)



Global Welfare Exposure





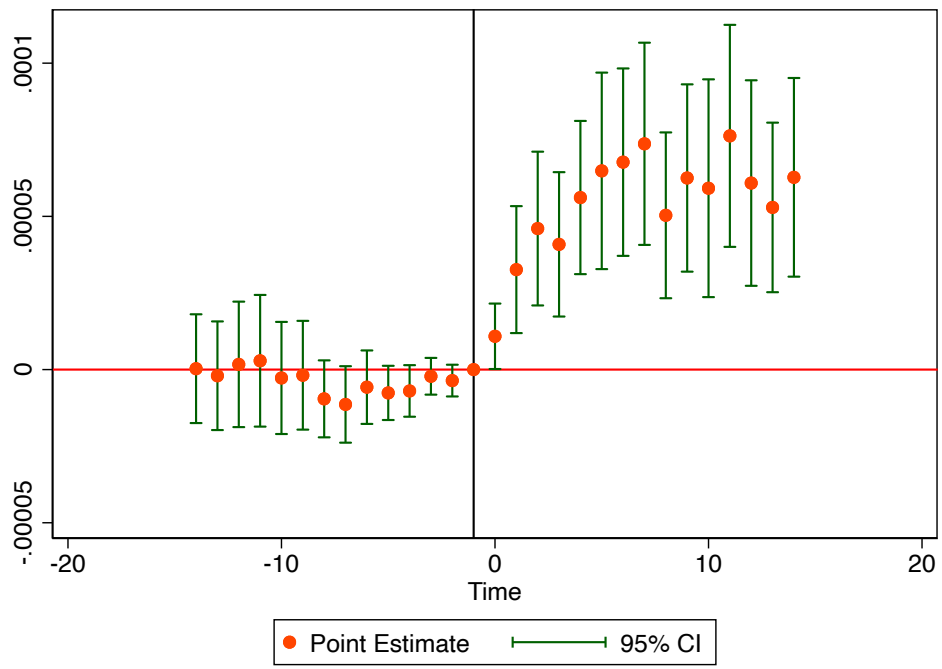
- Growing mean and dispersion of welfare exposure, consistent with increasing globalization over our sample period

Validation Check

- Use event-study specification to check that our real income exposure measure successfully detects increases in economic interdependence following the formation of Preferential Trade Agreements (PTAs)

$$U_{nit}^{IO} = \sum_{s \in \{S_-, S_+\}} \beta_s (\mathbb{I}_{ni}^{PTA} \times \mathbb{I}_s) + \xi_{ni} + d_{ct} + h_{nit},$$

- Demonstrate robustness to alternative event-study estimators



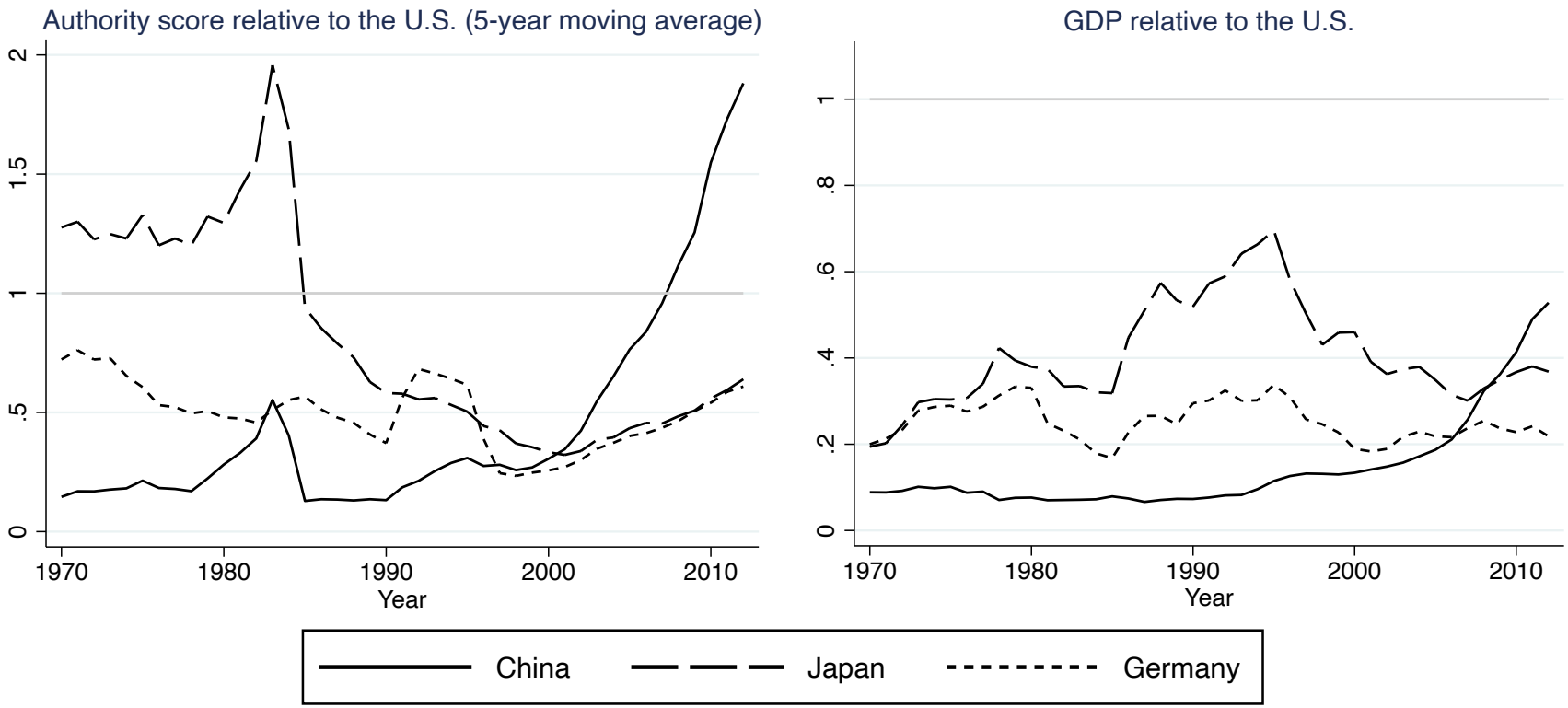
Hub and Authority Scores

- Generalizations of centrality measures for symmetric networks
- Authority score: captures the importance of a country as a source of real income shocks for other countries
- Hub score: summarizes the sensitivity of a country's real income to shocks in other countries

$$a_i = \lambda \sum_{n=1}^{N} \boldsymbol{U}_{ni} h_n, \qquad h_n = \mu \sum_{i=1}^{N} \boldsymbol{U}_{ni} a_i$$

- where λ and μ are scaling constants equal to inverse norms of vectors $\boldsymbol{a} \equiv [a_i]$ and $\boldsymbol{h} \equiv [h_n]$
- Substituting the definition of $\boldsymbol{h}$ into the definition of $\boldsymbol{a}$, these hub and authority scores are the dominant eigenvector of $\boldsymbol{U}\boldsymbol{U}'$ and $\boldsymbol{U}'\boldsymbol{U}$, respectively, such that $\boldsymbol{a} \propto \boldsymbol{U}'\boldsymbol{U}\boldsymbol{a}$ and $\boldsymbol{h} \propto \boldsymbol{U}\boldsymbol{U}'\boldsymbol{h}$
- A country is an authority if it has a strong connection with hubs, and it is a hub if it has a strong connection with authorities

Welfare Authority and GDP



Empirical Strategy

- Key empirical challenge: bilateral real income exposure depends on bilateral trade, which is endogenous to bilateral political alignment
  - Could be reverse causality from political alignment to real income exposure or omitted third variables could affect both

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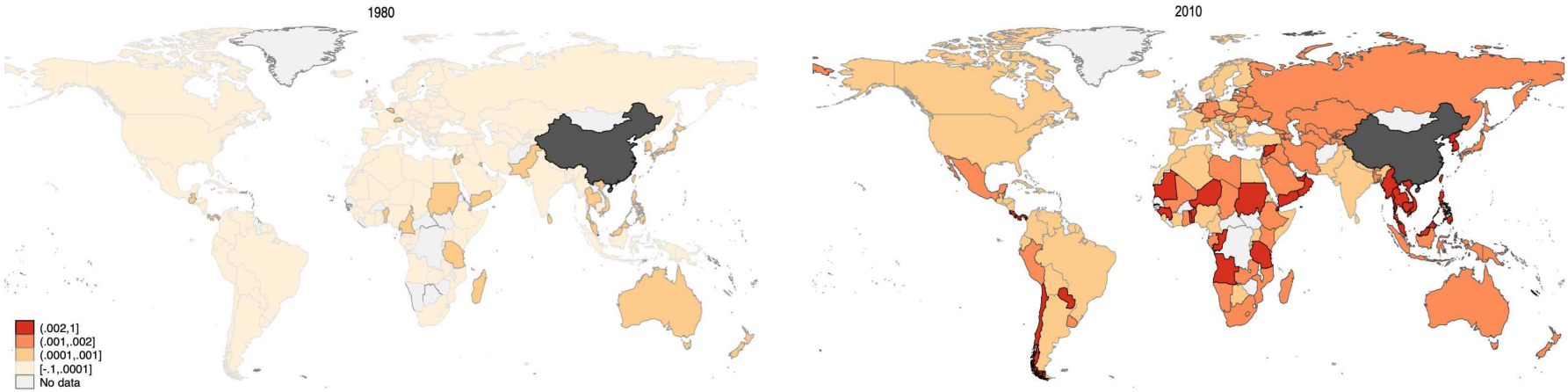
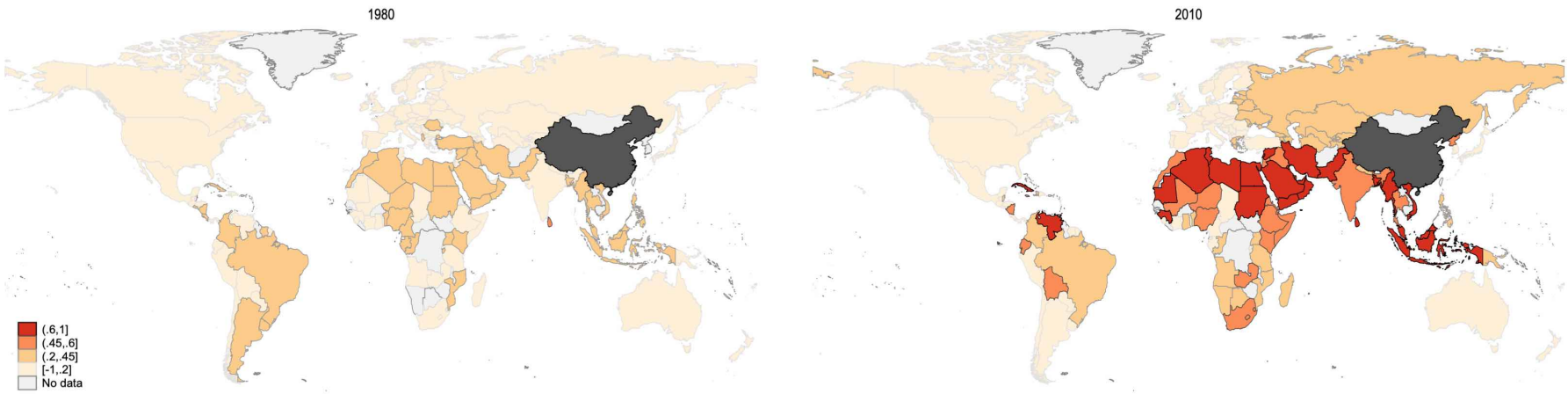
- Secular reduction in the cost of air travel (Feyrer 2019)
  - From 1955-2004, cost of moving goods by air fell by a factor of 10
  - Position of land messes generates large differences in bilateral distances by sea versus great circle distances by air
  - Countries with large sea distances relative to air distances benefit more from reduction in cost of air travel

China Shock

Top panel: welfare exposure to China's productivity growth by country, 1980 and 2010



Bottom panel: voting similarity (κ) to China in the United Nation's General Assembly, 1980 and 2010



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- Find ↑ economic friendship causes ↑ political friendship
- Theory-based exposure measure dominates simpler measures
- Major changes in the relative economic size of countries (e.g. China) lead to large-scale changes in the balance of political power

Neoclassical Growth in an Interdependent World

- Kleinman, Benny, Ernest Liu, Stephen J. Redding and Motohiro Yogo (2024) “Neoclassical Growth in an Interdependent World," *NBER Working Paper*, 31951

Motivation

- Closed-economy neoclassical growth model remains a key benchmark for thinking about cross-country income dynamics
- In the closed-economy, each country converges to its own steady-state level of income per capita (conditional convergence)
- Open economy versions of this model often make strong assumptions about substitutability and/or frictions in goods and capital markets
  - Goods are assumed to be homogeneous across countries or trade is assumed to be costless
  - Capital is assumed to be homogeneous, implying large net capital flows to arbitrage away differences in rates of return
- We generalize the neoclassical growth model to allow for costly trade and capital flows with imperfect substitutability
- We simultaneously model
  1. Intra-temporal goods trade subject to trade frictions
  2. Intra-temporal capital allocations subject to capital market frictions
  3. Intertemporal consumption-savings choices (and current account)

This Paper

- We show that our framework is consistent with a number of features of observed data on trade flows and capital holdings
  - Gravity equation for trade in goods and capital holdings
  - Determinate predictions for gross and net capital holdings
  - Relatively low capital flows to capital-scarce countries
  - Home bias in trade and capital flows
  - Correlation of domestic saving and investment (Feldstein-Horioka)
- Generalize existing dynamic exact-hat algebra techniques for counterfactuals to allow for bilateral trade and capital holdings
- Linearize the model to obtain closed-form solution for transition path
- Goods trade and capital holdings interact to shape the speed of convergence to steady-state in neoclassical growth model
- Since our framework incorporates bilateral trade and capital holdings and intertemporal consumption-saving, it is well suited to counterfactuals for both goods and capital market integration
  - Decoupling of China and the United States

Related Literature

- Neoclassical models of growth
  - Ramsey (1928), Solow (1956), Swan (1956), Barro (1991), Mankiw et al. (1992), King & Rebelo (1993), Ventura (1997), Acemoglu & Ventura (2002)
- Quantitative international trade
  - Arkolakis et al. (2012), Adão et al. (2019), Baqaee & Farhi (2019), Huo et al. (2019), Barthelme et al. (2019), Kleinman et al. (2020, 2021)
  - Ju et al. (2014), Reyes-Heroles (2016), Eaton et al. (2016), Ravikumar et al. (2019)
- International finance and macroeconomics
  - Global imbalances and capital flows: Lucas (1990), Obstfeld & Rogoff (1996, 2000), Jin (2012), Gourinchas & Rey (2007), Gourinchas & Jeanne (2006, 2013), Maggiori et al. (2020), Auclert et al. (2020), Coppola et al. (2021), Atkeson et al. (2022)
  - Imperfect substitutability in capital markets: Koijen and Yogo (2019, 2020), Auclert et al. (2022) and Maggiori (2021)
  - International propagation of shocks: Backus et al. (1992), Kose et al. (2003), Cravino & Levchenko (2017), di Giovanni et a. (2022)
  - Home bias and international diversification: Obstfeld (1994), Cole & Obstfeld (1991), Martin and Rey (2004, 2006), Engel & Maysumoto (2009), Mendoza et al. (2009), Heathcote & Perri (2013), Coeurdacier & Gourichas (2016), Pellegrino et al. (2021), Jiang et al. (2022), Chau (2022), Hu (2022), Kucheryavyy (2022)
  - Gravity equation in finance: Portes & Rey (2005)

Model Setup

- Economy consists of many countries n, $i \in \{1, \ldots, N\}$
- Time is discrete and indexed by $t \in \{0, \ldots, \infty\}$
- Each country supplies a differentiated good that is produced using labor and capital under constant returns to scale
- Markets are perfectly competitive
- Goods can be traded subject to bilateral trade costs
- Representative agent in each country endowed with labor ℓ_n
- At the beginning period t, representative agent in each country inherits a stock of wealth a_{nt}
- Wealth can be allocated to each country subject to capital market frictions and idiosyncratic shocks to returns
- Beginning period t: choose wealth allocation across countries and make consumption-saving decisions
- Beginning period $t + 1$: investment returns realized, depreciation occurs, and wealth again allocated across countries
- No aggregate uncertainty and perfect foresight

Intertemporal Preferences

- In country n, the mass ℓ_n of representative consumers solve

$$\max_{\{c_{nt},k_{nit}\}} \sum_{s=0}^{\infty} \beta^{t+s} \frac{c_{nt+s}^{1-1/\psi}}{1-1/\psi}$$

$$\text{s.t.} \quad p_{nt} c_{nt} + p_{nt} \sum_{i=1}^{N} a_{nit+1} = \left(p_{nt}\left(1-\delta\right) + v_{nt}\right) \sum_{i=1}^{N} a_{nit} + w_{nt} \ell_n$$

$$\text{Or equivalently s.t.:} \quad c_{nt} + a_{nt+1} = \mathcal{R}_{nt} a_{nt} + \frac{w_{nt} \ell_n}{p_{nt}}$$

- δ is depreciation rate; v_{nt} is return to capital; p_{nt} is consumption price index; $\mathcal{R}_{nt} = 1 - \delta + v_{nt}/p_{nt}$ is real gross return to investment
- Consumption is linear function of current wealth (Angeletos 2007)

$$c_{nt} = \varsigma_{nt} \left(\mathcal{R}_{nt} a_{nt} + \frac{w_{nt} \ell_n}{p_{nt}} + h_{nt} \right)$$

- where ς_{nt} is defined recursively as

$$\varsigma_{nt}^{-1} = 1 + \beta^{\psi} \phi_{nt+1}^{\psi} \mathcal{R}_{nt+1}^{\psi-1} \varsigma_{nt+1}^{-1}$$

Capital Allocation Within Each Period

- Each unit of capital subject to idiosyncratic shocks to returns (φ_{nit})
  - Search and acquisition costs, regulatory and productivity shocks
- Iceberg capital market frictions: $\kappa_{nit} > 1$ for $i \neq n$; $\kappa_{nnt} = 1$
- Return to a unit of capital invested from source n in host i:

$$\frac{\varphi_{nit} r_{it}}{\kappa_{nit}}, \qquad \varphi \sim e^{-\eta_{it}\varphi^{-\epsilon}}, \qquad \epsilon > 1$$

- η_{it} controls average host capital returns (e.g., property rights)
- Bilateral capital investments satisfy a gravity equation

$$b_{nit} = \frac{a_{nit}}{a_{nt}} = \frac{\left(\eta_{it} r_{it} / \kappa_{nit}\right)^{\epsilon}}{\sum_{h=1}^{N} \left(\eta_{ht} r_{ht} / \kappa_{nht}\right)^{\epsilon}}, \qquad \epsilon > 1$$

- Expected = realized return to capital is equalized across hosts i

$$v_{nit} = v_{nt} = \gamma \left[\sum_{h=1}^{N} \left(\eta_{ht} r_{ht} / \kappa_{nht}\right)^{\epsilon} \right]^{\frac{1}{\epsilon}}, \qquad \gamma \equiv \Gamma\left(\frac{\epsilon - 1}{\epsilon}\right)$$

- No aggregate uncertainty (continuous measure of units of capital)

Production and Trade

- Consumption and investment bundles follow CES (Armington):

$$c_{nt} = \left[\sum_{i=1}^{N} \left(c_{nit} \right)^{\frac{\theta}{\theta+1}} \right]^{\frac{\theta+1}{\theta}}, \qquad \theta = \sigma - 1, \qquad \sigma > 1$$

- Country n's expenditure share on good i:

$$s_{nit} = \frac{\tau_{nit} p_{it}^{-\theta}}{\sum_{h=1}^{N} \tau_{nht} p_{ht}^{-\theta}}$$

- Prices

$$p_{nit} = \frac{\tau_{nit} w_{it}^{\mu_i} r_{it}^{1-\mu_i}}{z_{it}}, \qquad p_{nt} = \left[\sum_{i=1}^{N} p_{nit}^{-\theta} \right]^{-1/\theta}$$

- Total payments for capital used in country i are proportional to payments for labor:

$$\sum_{n=1}^{N} v_{nt} a_{nit} = r_{it} k_{it} = \frac{1-\mu_i}{\mu_i} w_{it} \ell_i, \qquad k_{it} = \sum_{n=1}^{N} \gamma \eta_{it} b_{nit}^{-\frac{1}{\epsilon}} a_{nit}$$

Steady-State Equilibrium

- Steady-state equilibrium of the model:
  - Time-invariant values of the state variables $\{a_n^*\}_{n=1}^N$ and the other endogenous variables of the model $\{w_n^*, r_n^*, s_{ni}^*, v_{nt}^*, b_{ni}^*\}_{n=1}^N$
  - Given time-invariant values of country fundamentals $\{\ell_n, z_n, \eta_n\}_{n=1}^N$ and $\{\tau_{ni}, \kappa_{ni}\}_{n,i=1}^N$ (set $\phi_{nt} = 1$ for all n, t)
  - Denote the steady-state values of variables by an asterisk

- Steady-state gross real return to capital ($\mathcal{R}_n^*$) and the steady-state saving rate (ς_n^*) are inversely related to discount factor (β):

$$\mathcal{R}_n^* = \frac{1}{\beta}, \qquad \varsigma_n^* = 1 - \beta$$

- Common steady-state realized real return to capital (v_n^* / p_n^*):

$$\frac{v_n^*}{p_n^*} = \beta^{-1} - 1 + \delta$$

Linearization

- Suppose we observe population ($\boldsymbol{\ell}$), wealth ($\boldsymbol{a_t}$) and the trade and capital share matrices ($\boldsymbol{S}$, $\boldsymbol{T}$, $\boldsymbol{B}$, $\boldsymbol{X}$) of the economy at time $t = 0$
- Suppose that the economy is on a convergence path toward a steady-state with constant fundamentals ($\boldsymbol{z}$, $\boldsymbol{\eta}$, $\boldsymbol{\tau}$, $\boldsymbol{\kappa}$)
- Use a tilde above a variable to denote a log deviation from this initial steady-state (e.g., $\widetilde{a}_{it+1} = \ln a_{it+1} - \ln a_i^*$)
- Totally differentiating the general equilibrium conditions of the model around this unobserved initial steady-state, holding constant countries' labor endowment
- Obtain a system of linear equations that fully characterizes the economy's transition path up to first-order

Linearized Transition Path

Proposition

Suppose that the economy at time $t = 0$ is on a convergence path toward an initial steady state with constant fundamentals $(\boldsymbol{z}, \boldsymbol{\eta}, \boldsymbol{\tau}, \boldsymbol{\kappa})$. At time $t = 0$, agents learn about one-time, permanent shocks to fundamentals $(\widetilde{\boldsymbol{f}} \equiv \begin{bmatrix} \widetilde{\boldsymbol{z}} & \widetilde{\boldsymbol{\eta}} & \widetilde{\boldsymbol{\kappa}}^{in} & \widetilde{\boldsymbol{\kappa}}^{out} & \widetilde{\boldsymbol{\tau}}^{in} & \widetilde{\boldsymbol{\tau}}^{out} \end{bmatrix}')$ from time $t = 1$ onwards. There exists a $N \times N$ transition matrix $(\boldsymbol{P})$ and a $N \times N$ impact matrix $(\boldsymbol{R})$ such that the model's transition dynamics up to first-order have a closed-form solution of the form:

$$\widetilde{\boldsymbol{a}}_t = \boldsymbol{P}\widetilde{\boldsymbol{a}}_{t-1} + \boldsymbol{R}\widetilde{\boldsymbol{f}}.$$

The transition matrix $\boldsymbol{P}$ satisfies:

$$\boldsymbol{P} = \boldsymbol{U}\boldsymbol{\Lambda}\boldsymbol{U}^{-\mathbf{1}},$$

where $\boldsymbol{\Lambda}$ is a diagonal matrix of N stable eigenvalues $\{\lambda_k\}_{k=1}^{N}$ and $\boldsymbol{U}$ is a matrix stacking the corresponding N eigenvectors $\{\boldsymbol{u}_k\}_{k=1}^{N}$. The impact matrix $(\boldsymbol{R})$ is given by:

$$\boldsymbol{R} = \left(\boldsymbol{\Psi}\boldsymbol{P} + \boldsymbol{\Psi} - \boldsymbol{\Gamma}\right)^{-1}\boldsymbol{\Pi},$$

where $(\boldsymbol{\Psi}, \boldsymbol{\Gamma}, \boldsymbol{\Theta}, \boldsymbol{\Pi})$ are matrices of parameters from the system of second-order difference equations in the wealth state variables.

Data & Parameterization

- National Income Accounts (Penn World Tables)
- International Trade (UN COMTRADE)
- Capital Holdings (CPIS & Global Capital Allocation Project)
- Standard values for model parameters

Parameter		Value
Discount rate	β	0.95
Intertemporal elasticity of substitution	ψ	0.2
Depreciation rate	δ	0.05
Trade elasticity	θ	5
Investment elasticity	ϵ	4

- Labor share (μ_i) equals observed value for each country in the Penn World Tables data

Gravity

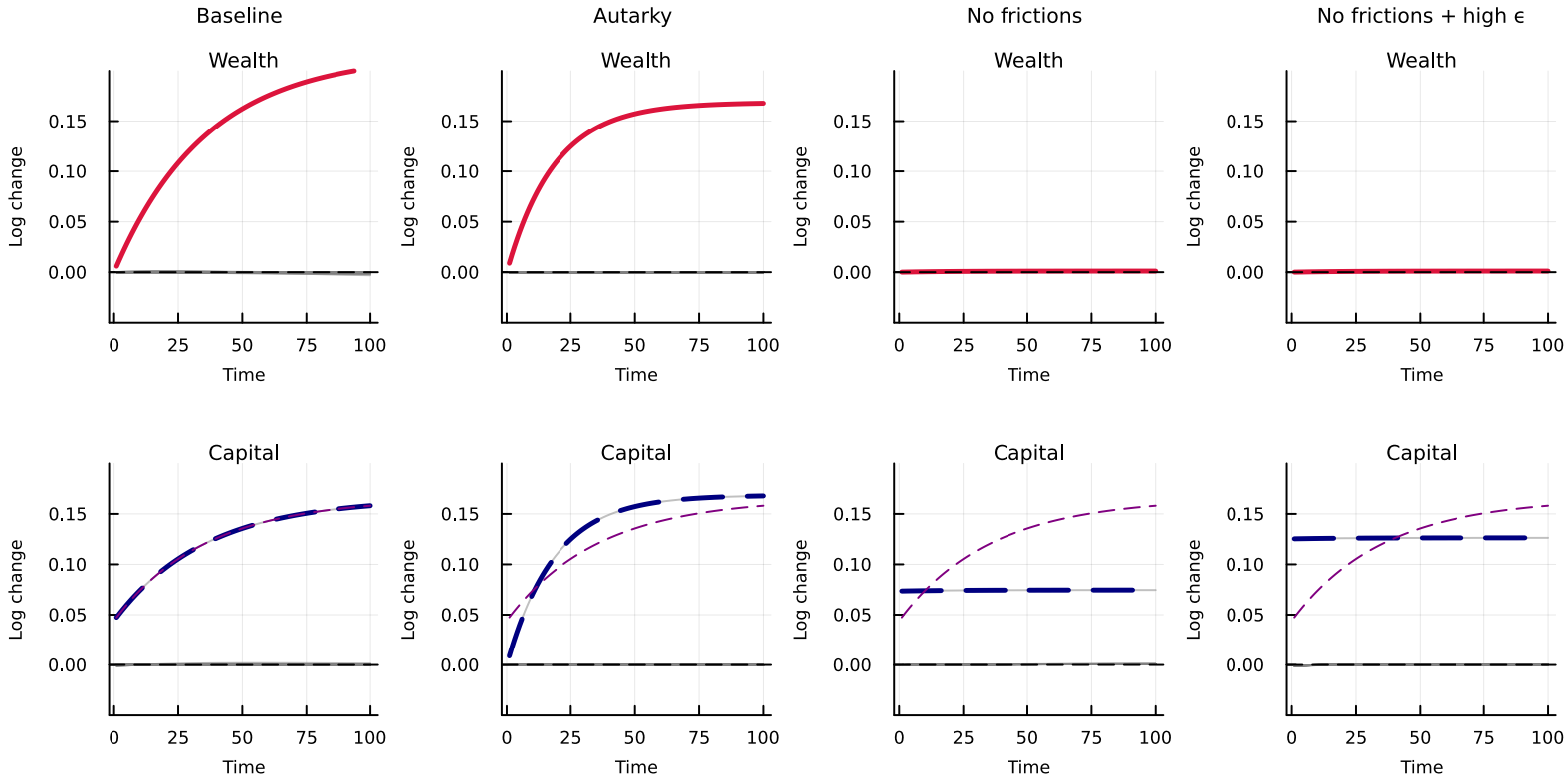
- Fixed effects gravity equation estimation

$$\ln X_{ni} = \vartheta_n^M + \vartheta_i^X + \delta \ln \text{dist}_{ni} + u_{ni},$$

	(1) Log Trade	(2) Trade	(3) Log Capital	(4) Capital
Distance	-1.18	-0.79	-1.41	-0.63
	(0.02)	(0.03)	(0.05)	(0.05)
Estimator	OLS	PPML	OLS	PPML
Observations	2,069	2,070	2,042	2,070
R^2	0.88		0.82	
Pseudo R^2		0.91		0.92

- Gravity equation provides a good fit to observed data on bilateral international trade and capital holdings

Small Country Productivity Shock



- Impulse response to a 10 percent productivity shock to Belgium

Counterfactuals

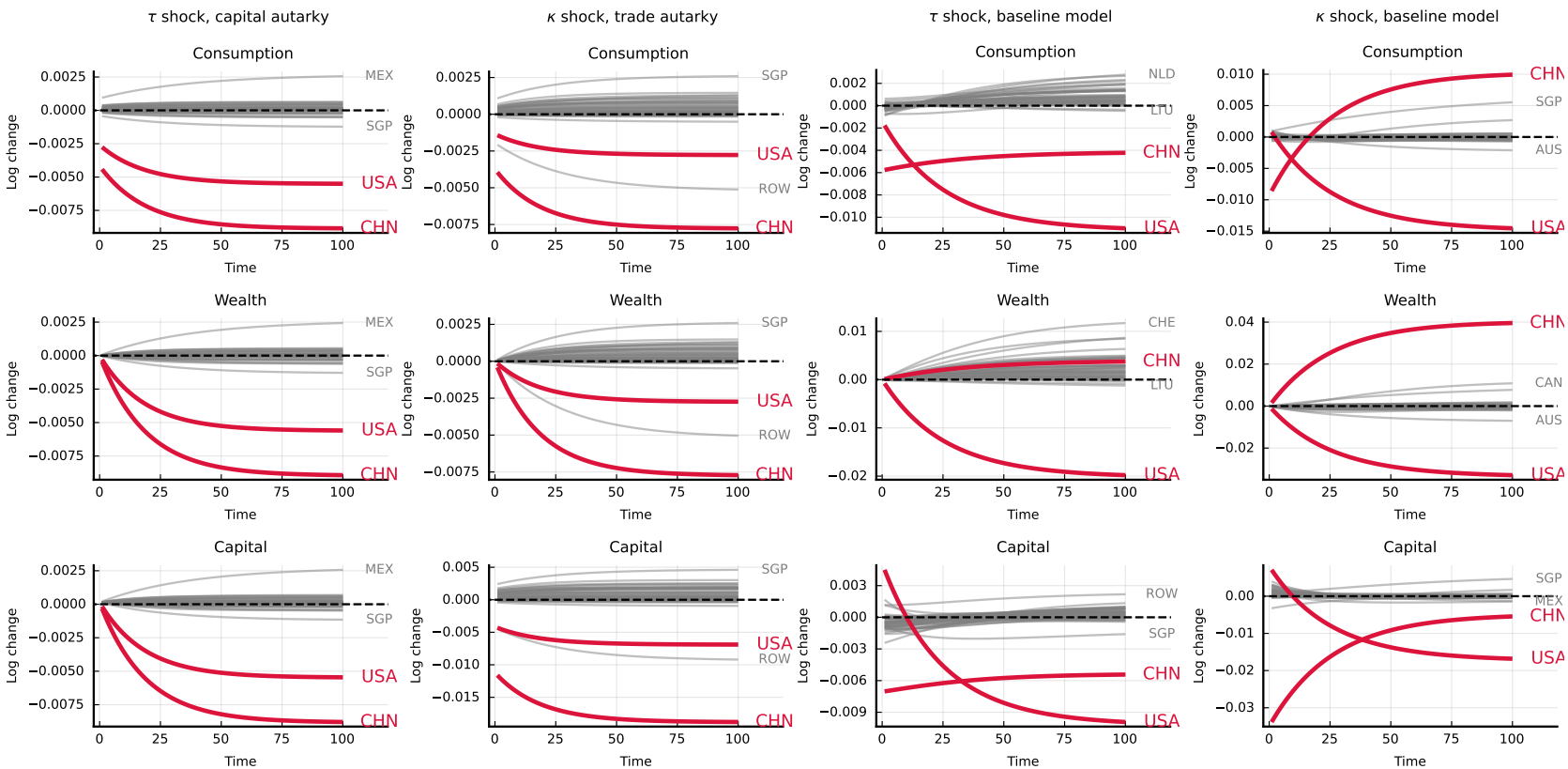
- New framework for evaluating policies that involve disintegration in both goods and capital markets (e.g., U.S.-China decoupling)

- Start at the observed equilibrium in the data and undertake counterfactuals for changes in goods and capital frictions
  - 50 percent increase in US-China trade frictions
  - 50 percent increase in US-China capital frictions

- Undertake these counterfactuals in
  - Special case of model with goods openness (and capital autarky)
  - Baseline model with goods and capital openness

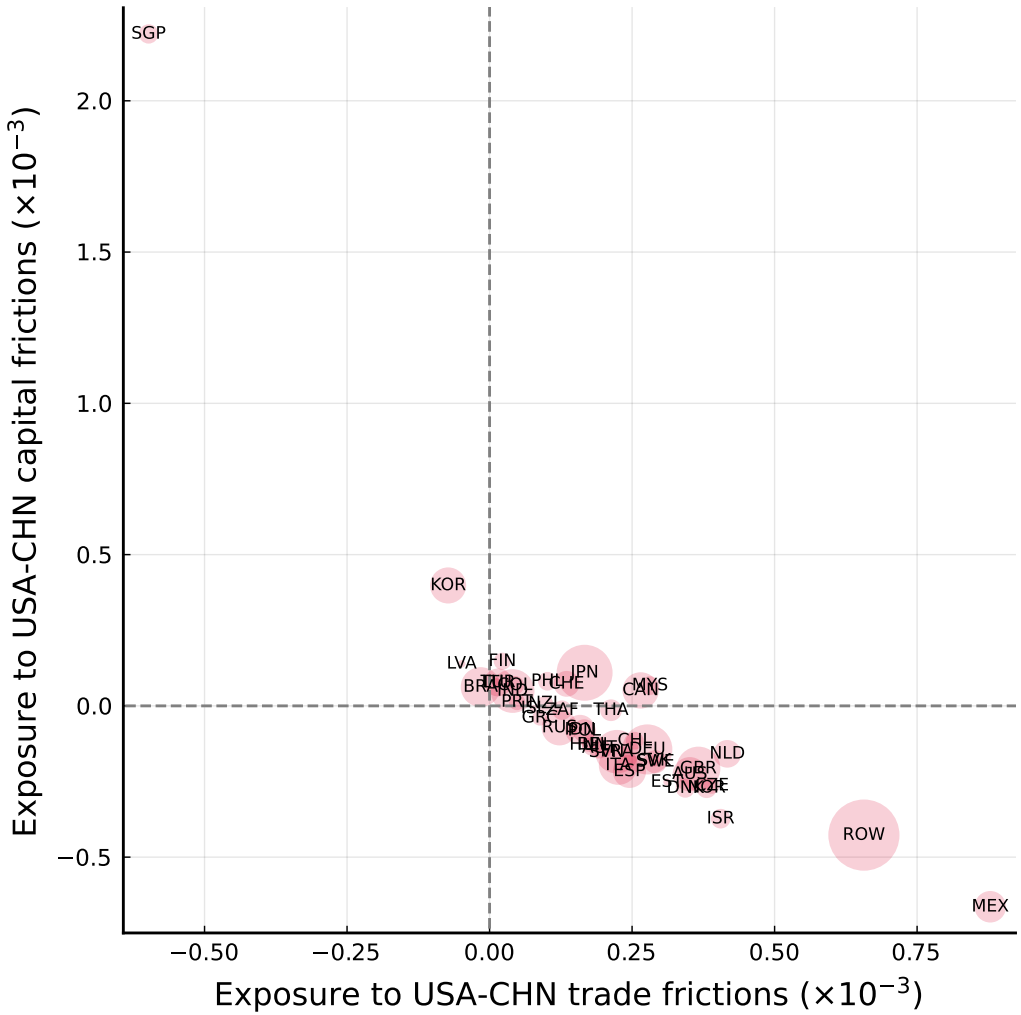
Increase US-China Trade/Capital Frictions

- Baseline model and special cases with either goods or capital autarky



Capital v Trade Frictions

- Different incidences across countries of higher U.S.-China capital versus trade frictions



Conclusions

- We generalize the open economy neoclassical model to allow for costly trade in goods and capital flows and imperfect substitutability
- We simultaneously model
  1. Intra-temporal goods trade subject to trade frictions
  2. Intra-temporal capital allocations subject to capital market frictions
  3. Intertemporal consumption-savings choice (hence current account)
- We show that our framework is consistent with a number of features of observed data on trade flows and capital holdings
  - Gravity equation for trade in goods and capital holdings
  - Determinate predictions for gross and net capital holdings
  - Relatively low capital flows to capital-scarce countries
- Goods trade and capital holdings interact to shape speed of convergence to steady-state
  - New implications for impulse responses to productivity shocks
  - Goods openness & capital autarky: faster convergence than closed NGM
  - Capital openness & goods autarky: faster convergence than closed NGM
  - Goods & capital openness: slower convergence than closed NGM
- Interaction of goods trade and capital holdings is consequential for the counterfactual impact of US - China decoupling

Thank You

Lecture Material

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