Capital Flows in Global Value Chains

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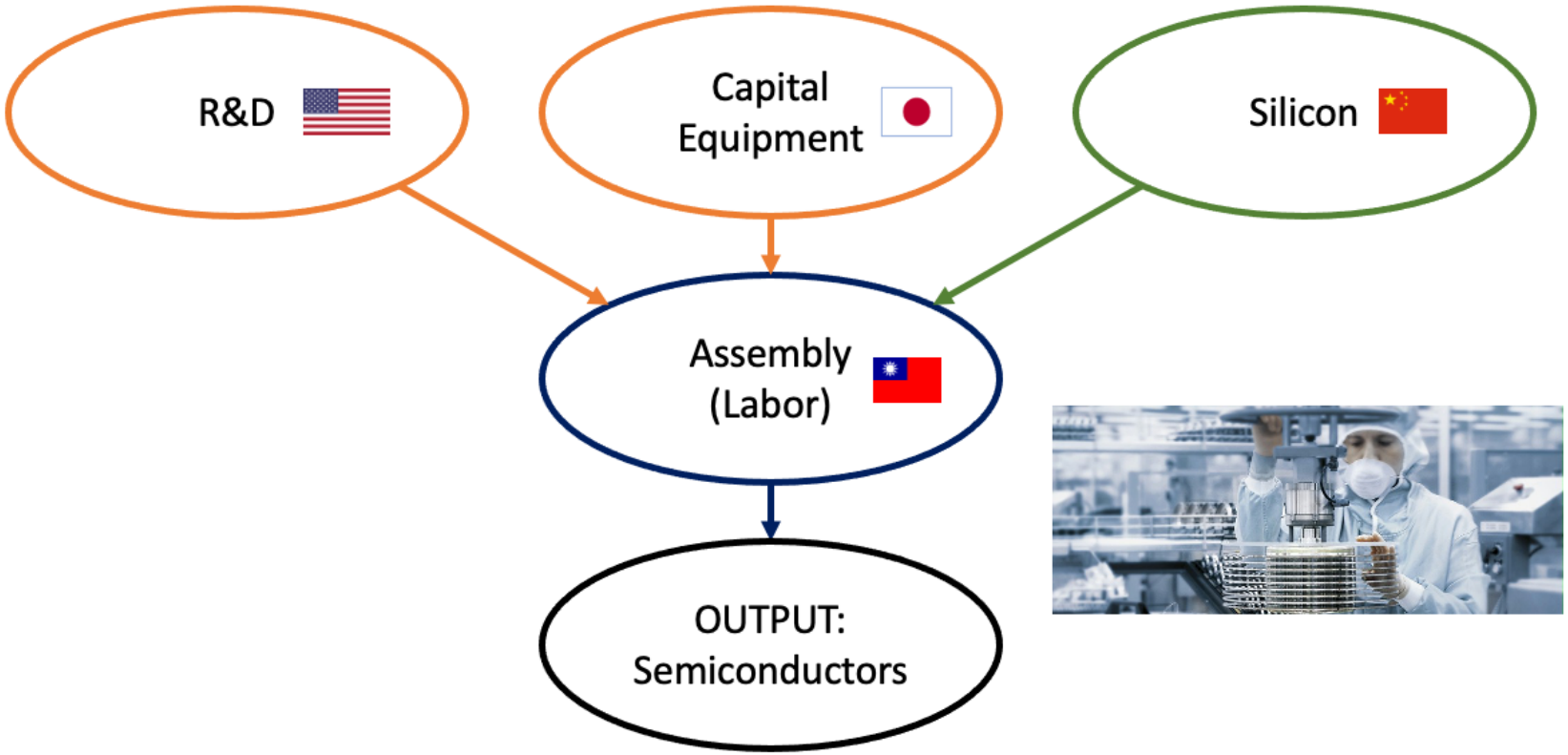
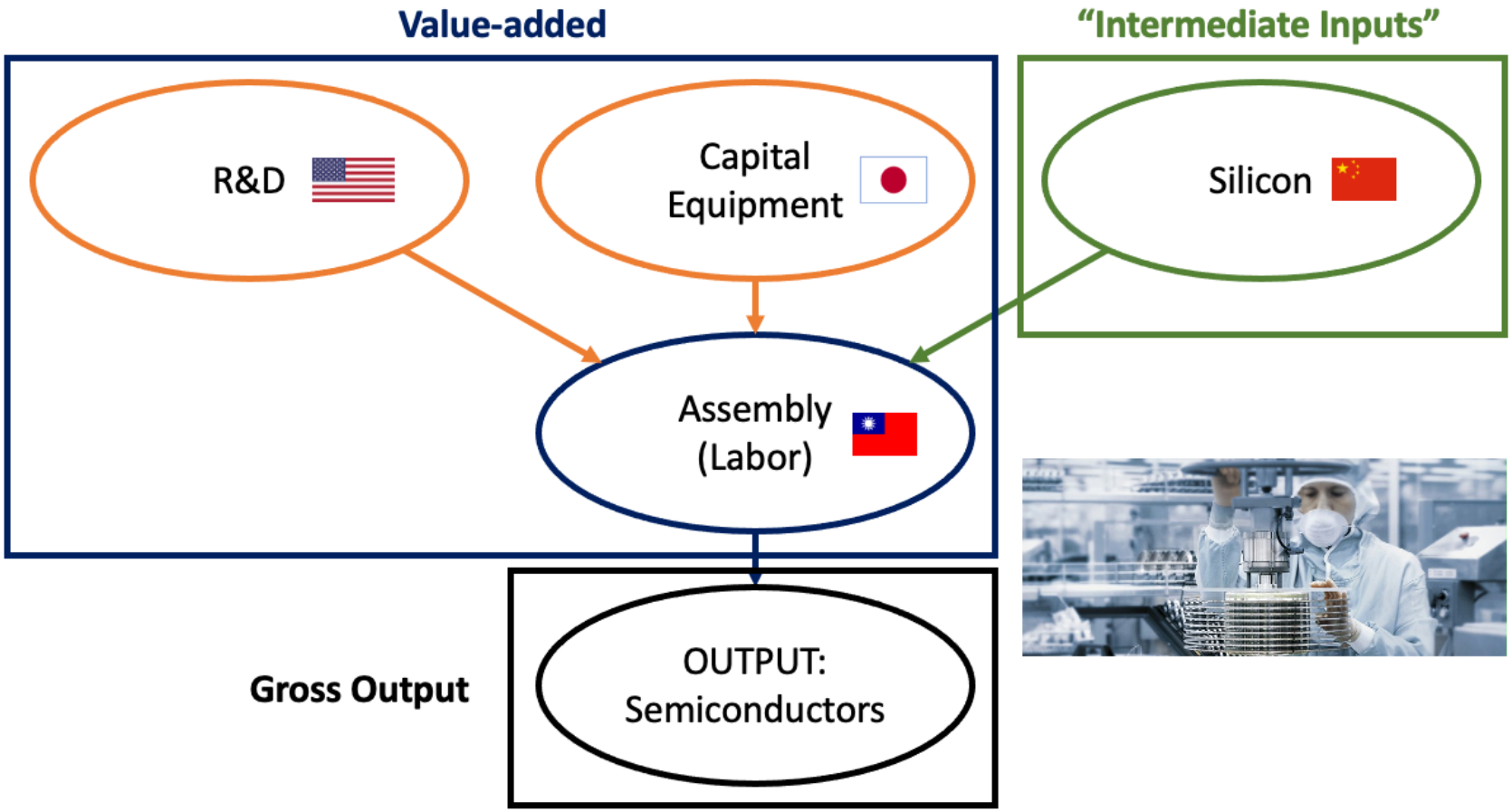
Motivation: A Semiconductor GVC



- Capital assets are durable intermediate inputs
- Capital is just as traded as expensed intermediate inputs

Motivation: A Semiconductor GVC



- Two challenges for accounting for capital in GVCs
  1. Measurement: supply $\rightarrow$ use links typically not in national accounts
  2. Dynamics: investment depends on expectations of tomorrow

This Paper

- A unified framework for quantifying production linkages (GVCs)
  - Treat capital services symmetrically with intermediates

- Theory: open economy dynamic general equilibrium model
  - Focus on long-run steady state outcomes
  - Same quantitative machinery as existing static models
  - Different calibration of production function parameters

- Measurement: capital coefficients $\leftarrow$ investment flows
  - Rental Payments to Capital $\Longleftrightarrow$ Value of New Investment
  - US BEA Capital Flow Tables
  - World Input-Output Tables

- Quantification: **new** production linkages from supply & use of capital
  - $\rightarrow$ more than **double** the gains from trade liberalization
  - $\rightarrow$ amplification is greater in capital-intensive industries
  - $\rightarrow$ both capital intensity in use, and in supply

Related Literature

- Quantitative models calibrated using (W)IOTs
  currently do not consider capital as an intermediate input
  - Production networks: Carvalho & Tahbaz-Salehi '19
  - Gravity models of trade: Costinot & Rodriguez-Clare '14
  - GVC models: Antràs & Chor '21

- Existing research on trade in capital:
  focus on one type of capital at a time
  - Physical capital e.g. Eaton & Kortum '01
  - Knowledge capital e.g. Keller and Yeaple '13

- Multi-sector RBC models:
  give fair treatment to capital but focus is on short-term fluctuations
  - Eaton et al. '16; Atalay, '17; vom Lehn & Winberry, '21

- National Accounting
  - Growth accounting with intangibles: Corrado et al. '05
  - Capitalization explains the decline of the labor share: Koh et al. '20
  - Capitalization leads to double-counting: Hulten '79, Barro '21

Illustration:
Accounting in an Island Economy

Economy (A): Rods are Intermediate Inputs

Table 1: Fishing Rods as Intermediate Goods

	Rods	Fish	Consumption	Investment	Output
Rods	0	$\frac{1}{2}L$	0	0	$\frac{1}{2}L$
Fish	0	0	L	0	L
Labor	$\frac{1}{2}L$	$\frac{1}{2}L$			
Capital	0	0			
Output	$\frac{1}{2}L$	L			

- GDP $= L$
- $\mathrm{d}\log$ GDP $= \frac{1}{2}\,\mathrm{d}\log$ Productivity shock in Rods

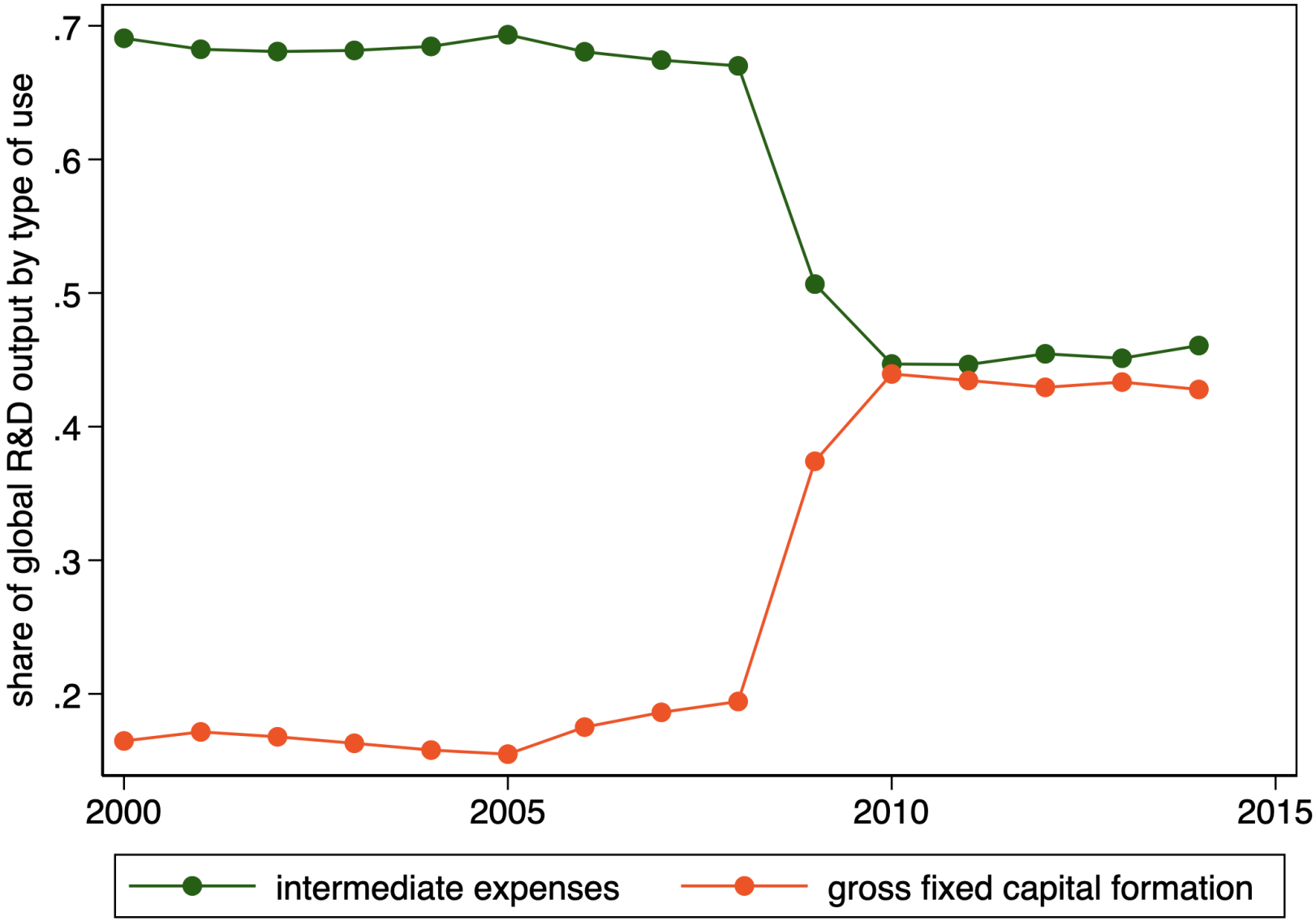
Economy (B): Rods are Capital Inputs

Table 2: Input-Output Table of Economy (B): Fishing Rods as Capital Goods

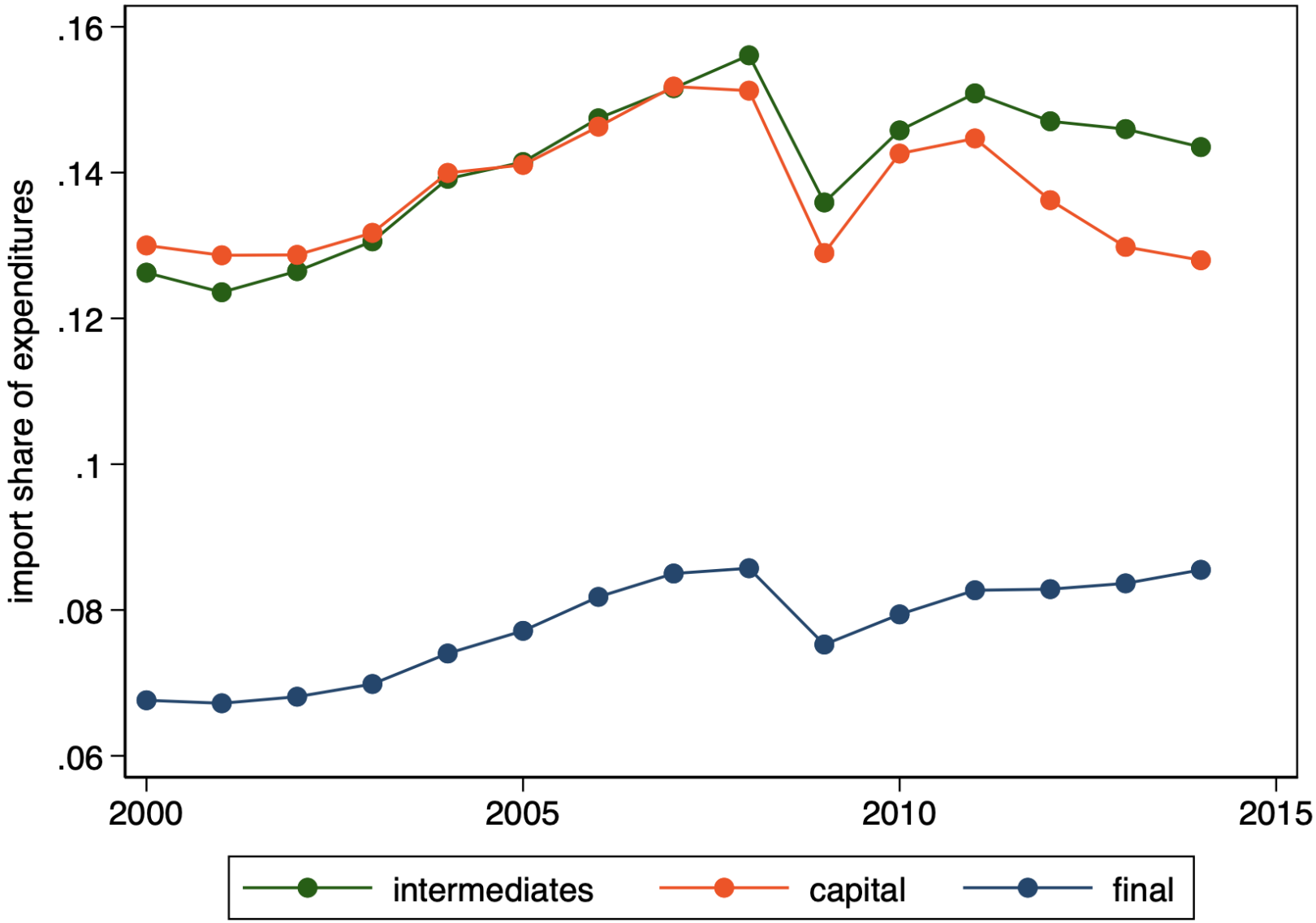
	Rods	Fish	Consumption	Investment	Output
Rods	0	0	0	$\frac{1}{2}L$	$\frac{1}{2}L$
Fish	0	0	L	0	L
Labor	$\frac{1}{2}L$	$\frac{1}{2}L$			
Capital	0	$\frac{1}{2}L$			
Output	$\frac{1}{2}L$	L			

- "GDP" $= 1.5L$, (not L)
- $\mathrm{d}\log$ "GDP" $= \frac{1}{3}\,\mathrm{d}\log$ Productivity shock in Rods, (not $\frac{1}{2}$, nor $\frac{2}{3}$)

The Capitalization of R&D in National Accounts



Capital is as Traded as Intermediates



Theoretical Framework

Closed Economy: Preferences and Technology

- Household: standard intertemporal preferences

$$U = \sum_{t=1}^{\infty} \beta^t u(C_t)$$

  - Euler equation pins down r^f: rate of return on storing final good

$$1 + r^f = \frac{1}{\beta},$$

- $j, k = 1, ..., J$ industries
- Production functions are Cobb Douglas over intermediates **and** capital:

$$q_j = A_j \cdot l^{\beta_j^L} \prod_{k=1}^{J} m_k^{\beta_{jk}^M} \prod_{k=1}^{J} \kappa_k^{\beta_{jk}^K}, \qquad \forall j = 1, ..., J.$$

- Capital accumulation: depreciation and investment

$$K_{j,t+1} = (1 - \delta_j) K_{j,t} + I_{j,t} \qquad \forall j$$

Investment Flows $\iff$ Value Added by Capital

- Let $V_{jt} \equiv$ net present asset value of a unit of capital j at the start of t:

$$V_{jt} = r_{jt} + \frac{1}{1 + r_t^f}(1 - \delta_j) V_{j,t+1}$$

- Steady state:
  - $V_{jt} = V_{j,t+1} = V_j$
  - Investment replaces depreciated capital $I_j = \delta_j K_j$

- By no-arbitrage: return on final good $1 + r^f =$ return on j

$$1 + r^f = \frac{V_j}{P_j} = \frac{r_j}{P_k(1 - \frac{1}{1+r_t^f}(1 - \delta_j))} \implies P_j = \frac{r_j}{r^f + \delta_j}$$

- Investment $\iff$ return payments to capital, for each asset type j:

$$P_j I_j = \frac{\delta_j}{r^f + \delta_j} r_j K_j \qquad \forall j$$

Closed Economy Steady State

1. The labor market clears
$$L = \sum_k \beta_k^L X_k,$$
2. Markets for capital services clear for each asset type j:
$$r_j K_j = \sum_k \beta_{kj}^K X_k \qquad \forall j,$$
3. Investment in each type of capital achieves the required rate of return
$$P_j I_j = \frac{\delta_j}{r^f + \delta_j} r_j K_j \qquad \forall j,$$
4. Output markets clear in each industry
$$X_j = \sum_k \left(\beta_{kj}^M + \frac{\delta_j}{r^f + \delta_j} \beta_{kj}^K \right) X_k + \alpha_j \left(L + \sum_j \sum_k \frac{r^f}{r^f + \delta_j} \beta_{kj}^K X_k \right).$$

Proposition 1: Shock Propagation in Autarky

- Impact of an unanticipated permanent productivity shock $\mathrm{d}\log A_j$
- Outcome = per-period steady state welfare = real final consumption C

$$\mathrm{d}\log C = \boldsymbol{\alpha}'(\boldsymbol{I} - \boldsymbol{B})^{-1}\,\mathrm{d}\log \boldsymbol{A},$$

  - $\boldsymbol{\alpha}$ is a industry-vector of final spending shares,
  - $\boldsymbol{I}$ is the identity matrix,
  - $\boldsymbol{B}$ a $K \times K$ matrix with elements $\boldsymbol{B}_{jk}$ given by

$$\boldsymbol{B}_{jk} = \beta_{jk}^{M} + \beta_{jk}^{K}.$$

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- **Corollary:** Domar weights (Hulten 1978) no longer sufficient statistics

$$\frac{\boldsymbol{X}}{L} = (\boldsymbol{I} - \boldsymbol{\Upsilon})^{-1}\boldsymbol{\alpha},$$

where $\boldsymbol{\Upsilon}$ is a modified 'Leontief'-style matrix with elements $\boldsymbol{\Upsilon}_{jk}$ given by

$$\boldsymbol{\Upsilon}_{kj} = \beta_{kj}^{M} + \frac{\delta_j}{r^f + \delta_j}\beta_{kj}^{K} + \alpha_j\left(\sum_{j'}\frac{r^f}{r^f + \delta_{j'}}\beta_{kj'}^{K}\right) \neq \boldsymbol{B}_{jk}$$

Back-of-envelope math

- Why the doubling?
- Take a one-sector economy
- Only counting intermediate expenses: $B = 0.5$

$$\begin{aligned} \mathrm{d}\log C &= \boldsymbol{\alpha}'(\boldsymbol{I} - \boldsymbol{B})^{-1}\,\mathrm{d}\log \boldsymbol{A} \\ \mathrm{d}\log C &= (1 - \frac{1}{2})^{-1}\,\mathrm{d}\log A \\ &= 2\,\mathrm{d}\log A \end{aligned}$$

- Counting both intermediate expenses and capitalized investments: $B = 0.75$

$$\begin{aligned} \mathrm{d}\log C &= (1 - \frac{3}{4})^{-1}\,\mathrm{d}\log A \\ &= 4\,\mathrm{d}\log A \end{aligned}$$

- **Key Takeaway**: in theoretical framework: capital is treated symmetrically as intermediate expenses

Open Economy Steady State

- Let $i, n = 1, ..., N$ denote countries
- **Assumptions (for now):**
  Financial autarky. No FDI. Exogenous Imbalances (transfers).

1. The labor market clears in each country i

$$w_i L_i = \sum_k \beta_{ik}^L X_{ik}, \qquad \forall i,$$

2. Markets for capital services clear for each asset type j in each country i:

$$r_{ij} K_{ij} = \sum_k \beta_{ikj}^K X_{ik} \qquad \forall i, j,$$

3. Investment in each type of capital achieves the required rate of return

$$P_{ij} I_{ij} = \frac{\delta_{ij}}{r^f + \delta_{ij}} r_j K_j \qquad \forall j,$$

Open Economy Steady State (continued)

4. Output markets clear in each industry j in each country i:

$$X_{ij} = \sum_n \pi_{nij} \left[\sum_k \left(\beta^M_{nkj} + \frac{\delta_{nj}}{r^f_n + \delta_{nj}} \beta^K_{nkj} \right) X_{nk} + \alpha_{nj} \left(w_n L_n + D_n + \sum_j \sum_k \frac{r^f_n}{r^f_n + \delta_{nj}} \beta^K_{nkj} X_{nk} \right) \right],$$

5. Import shares take the constant-elasticity form:

$$\pi_{nij} = \frac{(\tau_{nij} c_{ij})^{-\theta_j}}{\sum_{i'} (\tau_{ni'j} c_{i'j})^{-\theta_j}},$$

6. Unit costs of production in each country i in industry j

$$c_{ij} = A^{-1}_{ij} w_i^{\beta^L_{ij}} \prod_k P_{ik}^{\beta^M_{ijk} + \beta^K_{ijk}} \eta_{ij},$$

7. The consumption price index of industry k in n:

$$P_{nk} = \left(\sum_i (\tau_{nij} c_{ij})^{-\theta_j} \right)^{-\frac{1}{\theta_j}}.$$

Quantitative Results

Data and Calibration

- WIOT, 2007 (+ socioeconomic data for labor shares β_{ij}^{L})
- Aggregation: 33 countries, 33 industries
- Trade elasticities: Caliendo-Parro and C-RC and $\theta_j = 5$ for $j \in$ services

- Data from the WIOT:
  - Labor incomes $w_i L_i$
  - Gross output X_{ij}
  - Import shares π_{nij}
  - Intermediate input use M_{ijk}
  - When costs are expensed: we see supplying and using industry $k \to j$

$$\beta_{ijk}^{M} = \frac{M_{ijk}}{X_{ij}}$$

  - When costs are capitalized: we only see total value-added on capital:

$$\beta_{ij}^{CAP} = \frac{VA_{ij} - w_i L_i}{X_{ij}}$$

- To find β_{ijk}^{K} need to link up $k \to j$ in use of capital services:

Data and Calibration: US BEA Capital Flows Tables

Use Table. Commodities Used by Industries and Final Uses

		INDUSTRIES [1]							
		Natural resources and mining	Construction	Manufacturing	Trade, transportation, and utilities	Information	Services	Total interme-diate use	P co tion
COMMODITIES [1]	Natural resources and mining								
	Construction								
	Manufactured products								
	Trade, transportation, and utilities								
	Information								
	Services								
	Noncomparable imports								
	Total intermediate inputs								
VALUE ADDED	Compensation of employees								
	Indirect business tax and nontax liability								
	Other value added [2]								
	Total								
TOTAL INDUSTRY OUTPUT									

Source: Meade et al. (2003): Business Investment by Industry in the U.S. Economy for 1997

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		INDUSTRIES [1]							FINAL USE (GDP)							
		Natural resources and mining	Construction	Manufacturing	Trade, transportation, and utilities	Information	Services	Total interme-diate use	Personal consump-tion expend-itures	Private fixed investment	Change in business inventories	Exports of goods and services	Imports of goods and services	Government consumption expenditures and gross investment	GDP	TOTAL COMMODITY OUTPUT
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Capital Flow Table. Distribution of New Equipment and Structures to Using Industries

		INDUSTRIES [1]						
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	Manufactured products							
	Trade, transportation, and utilities							
	Information							
	Services							
	Noncomparable imports							
TOTAL INDUSTRY USE OF NEW EQUIPMENT AND STRUCTURES								

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	Trade, transportation,							
	Information							
	Services							
	Noncomparable imports							
TOTAL INDUSTRY USE OF NEW EQUIPMENT AND STRUCTURES								

New private fixed investment by type of new commodity

Distribution of new private fixed investment across industries

Source: Meade et al. (2003): Business Investment by Industry in the U.S. Economy for 1997

Data and Calibration

- Theory provides a link between investment and value added by capital input, for each asset type k in each using industry j

$$P_k I_k = \frac{\delta_k}{r^f + \delta_k} r_k K_k \qquad \forall k$$

- US BEA Capital Flow Tables, 1997

$$\beta^K_{ijk} = \beta^{CAP}_{ij} \frac{\beta^{K,'97}_{US,jk}}{\beta^{VA,'97}_{US,j}}$$

$$= \beta^{CAP}_{ij} \frac{r_{US,k} K_{US,jk}}{\sum_{k'} r_{US,k'} K_{US,jk'}} = \beta^{CAP}_{ij} \frac{P_{US,k} I_{US,jk} \frac{r^f_{US} + \delta_{US,k}}{\delta_{US,k}}}{\sum_{k'} P_{US,k'} I_{US,jk'} \frac{r^f_{US} + \delta_{US,k'}}{\delta_{US,k'}}},$$

- BEA Depreciation rates by asset type: $\delta_{US,j}$
- Global "risk-free" rate: $r^f = r^f_{US} = 0.03$

Trade Liberalization Counterfactual

- **10% Trade Liberalization** across all Countries and Industries
- **Proposition:** Standard Hat Algebra to solve for **Exact Changes**

- Per-period steady-state real consumption (welfare):

$$\hat{C}_n = \frac{\hat{w}_n \hat{L}_n w_n L_n + D_n + \sum_j \sum_k \frac{r_n^f}{r_n^f + \delta_{nj}} \beta_{nkj}^K X'_{nk}}{w_n L_n + D_n + \sum_j \sum_k \frac{r_n^f}{r_n^f + \delta_{nj}} \beta_{nkj}^K X_{nk}} \prod_k \hat{P}_{nk}^{-\alpha_{nk}}$$

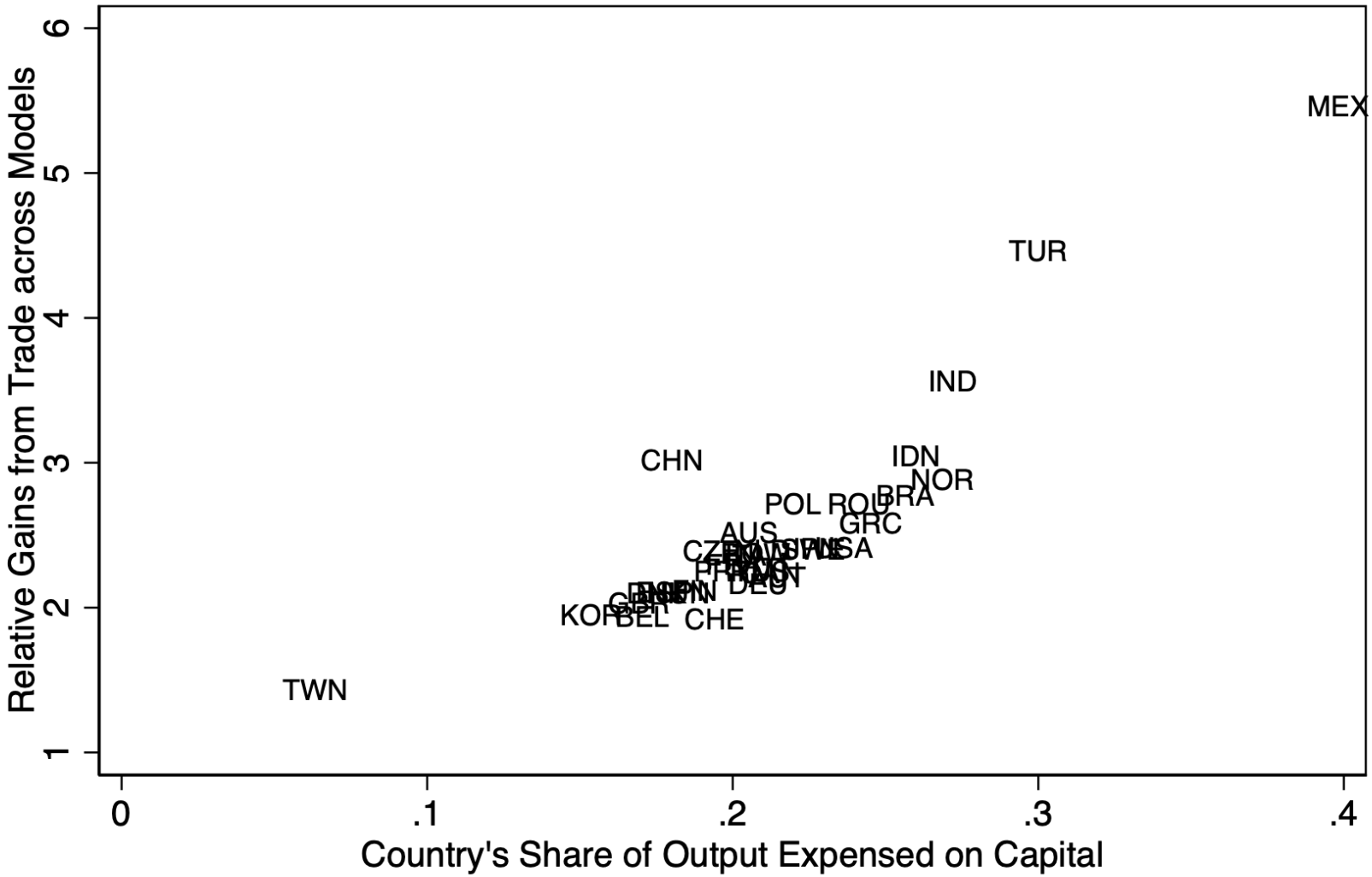
$$= s_n^{LD} \cdot \underbrace{\frac{\hat{w}_n \hat{L}_n w_n L_n + D_n}{(w_n L_n + D_n) \prod_k \hat{P}_{nk}^{\alpha_{nk}}}}_{\text{real labor income (\& transfers)}} + (1 - s_n^{LD}) \cdot \underbrace{\frac{\sum_k \mu_{nk} \hat{X}_{nk}}{\prod_k \hat{P}_{nk}^{\alpha_{nk}}}}_{\text{real capital gains}},$$

- Compare welfare impacts across two models calibrated to the same data
  1. Capital is primary input; Investment is final use
  2. Rental services from capital assets are intermediate inputs

Gains from Trade: Comparison across Models

Gains from Trade: Comparison across Models

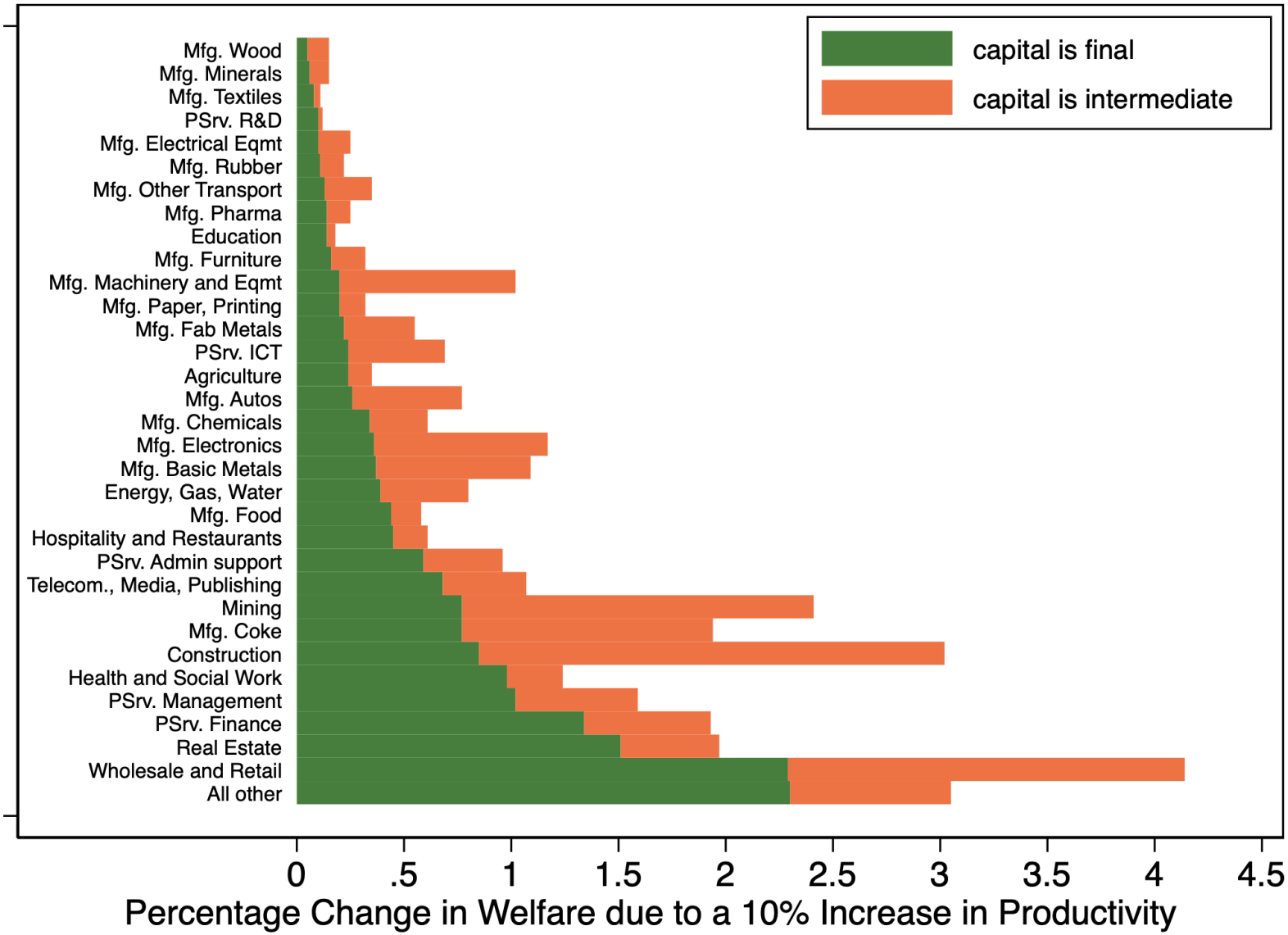
"Missing Gains" increase with Capital Intensity in Use



The relative gains from trade liberalization (10% worldwide reduction in trade costs) are computed as the ratio of the welfare gains from treating capital as intermediates versus treating capital as final goods

▸ Capital intensity inversely correlated with intermediate intensity

Impact of Industry-level Productivity Shocks in the U.S.



▸ Amplification effect increases with capital intensity in supply

Conclusion

- Hard to measure supply $\rightarrow$ use of capital assets across industries
- Disconnect between reality and how our models are calibrated

- Conceptual framework: dynamic GE model
  - (often-implicit) rental of capital is an intermediate expense
  - comparable steady-state equilibrium conditions to static model
  - same solution method, just different calibration

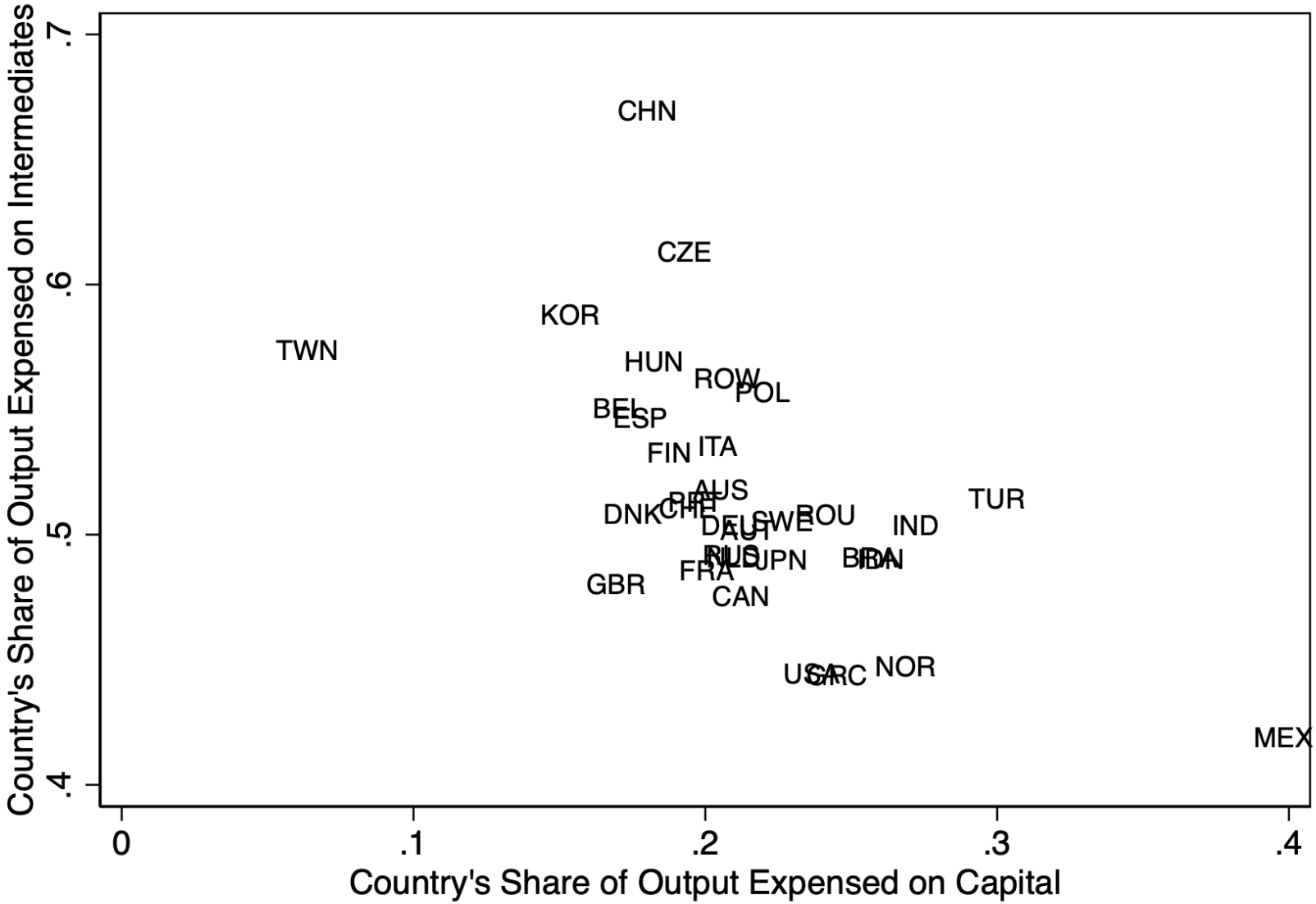
- Quantitative results: how important are these missing linkages?
  - Incorporate capital into GVCs more than doubles shock propagation
  - Biggest amplification for capital-intensive industries & countries

- Looking ahead:
  - Theory: dynamics along the adjustment to new steady state
  - Measurement: can we do better? What about IPP?
  - Multinationals, FDI, and endogenous imbalances?
  - Tax-shifting incentives for capitalization v. expenses?

Appendix Slides

Capital Shares negatively correlated with Intermediate Shares

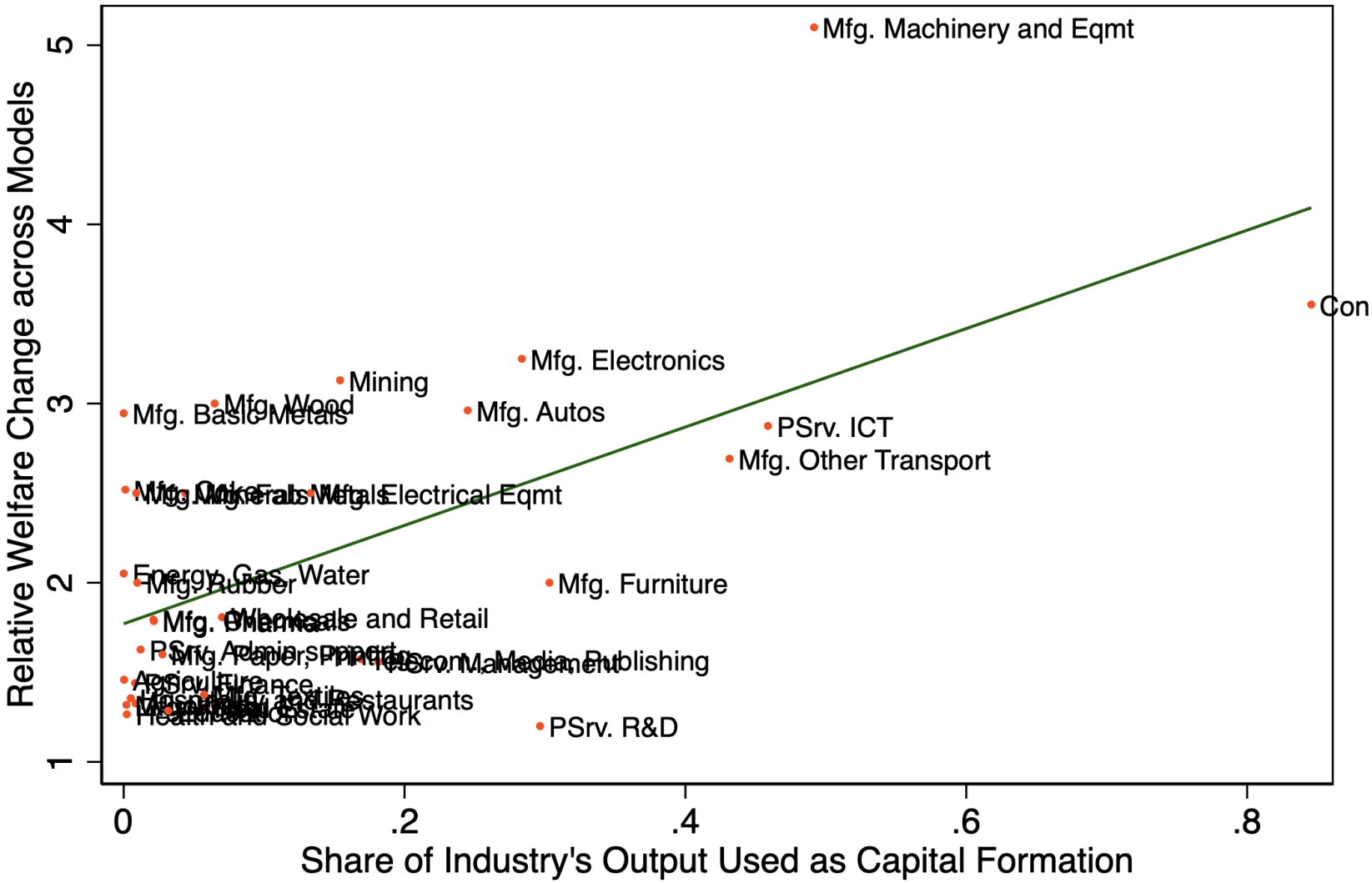
Back



t-statistic is -4.09

Capital Intensity in supply explains extra productivity impact

Back



Relative Welfare Gains for the US are computed under a 10% Productivity shock under (i) assuming capital is final use and (ii) assuming capital is intermediate. t-stat = 4.24