Trade Cost, Knowledge Linkages and Economic Growth

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Preliminary. Comments are welcome!

Observations

- Some inventions enhance general purpose technology (GPT) that can be easily applied to innovations in other sectors; Others create sector-specific knowledge.
- Rich countries tend to concentrate more of their innovate and export in GPT sectors.
- Regions with lower trade cost also concentrate more innovation in GPT sectors.

Contribution

- Empirically,
  - Measure sectoral technology's generality based on cross-sector patent citation data connected technology network, or product space.
  - show that a country grows faster if its initial export composition contains more GPT goods.
  - (to be done) countries export or innovate more in GPT sectors after trade liberalization.

- Theoretically, in a two-country multi-sector model with productivity difference, we try to explain that
  - why a more productive country specializes its R&D in GPT sectors.
  - why real income difference can be much larger than the productivity difference.
  - how trade cost enlarges the real income difference.

Literature

- Hausmann, Hwang and Rodrik (2005), Hidalgo, Klinger, Barabasi and Hausman (2007), Nunn (2007), Levchenko (2009)
- Hsieh and Klenow (2005) Feenstra and Kee (2004)
- Bernard, Redding and Schott (2009)

Authority Weight and Hub Weight

- We construct pure knowledge-based measures using *cross-sector* patent citation data: 476 technological classes

- *authority weight (aw)* and *hub weight (hw)*, (Kleinberg's algorithm, 1998)

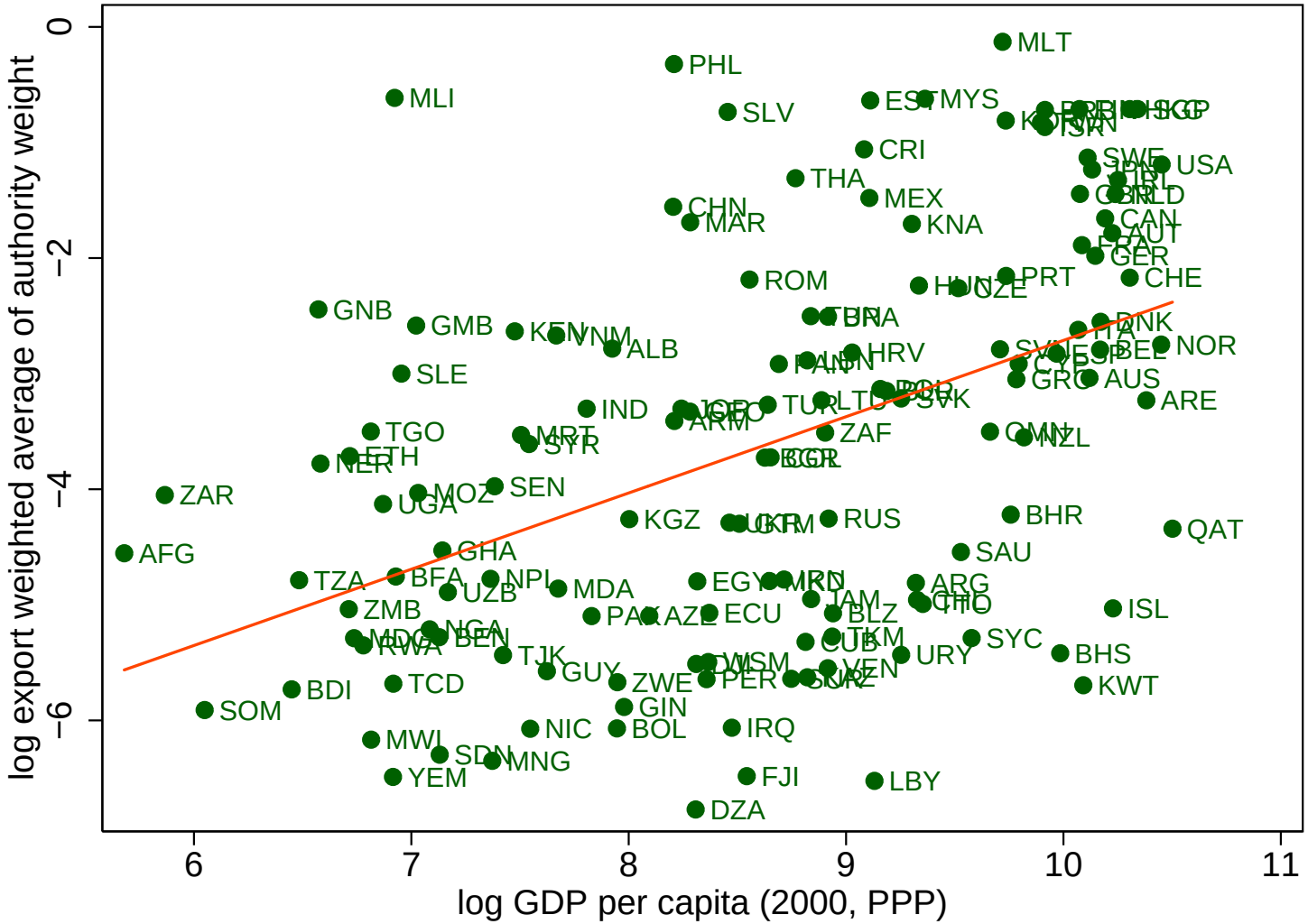
$$
\begin{aligned}
aw^i &= \lambda^{-1} \sum_j W^{ij} hw^j \\
hw^i &= \mu^{-1} \sum_j W^{ji} aw^j
\end{aligned}
$$

$$
W^{ij} = \begin{cases} 1, \text{ if } j \text{ is citing } i \\ 0, \text{otherwise} \end{cases}
$$

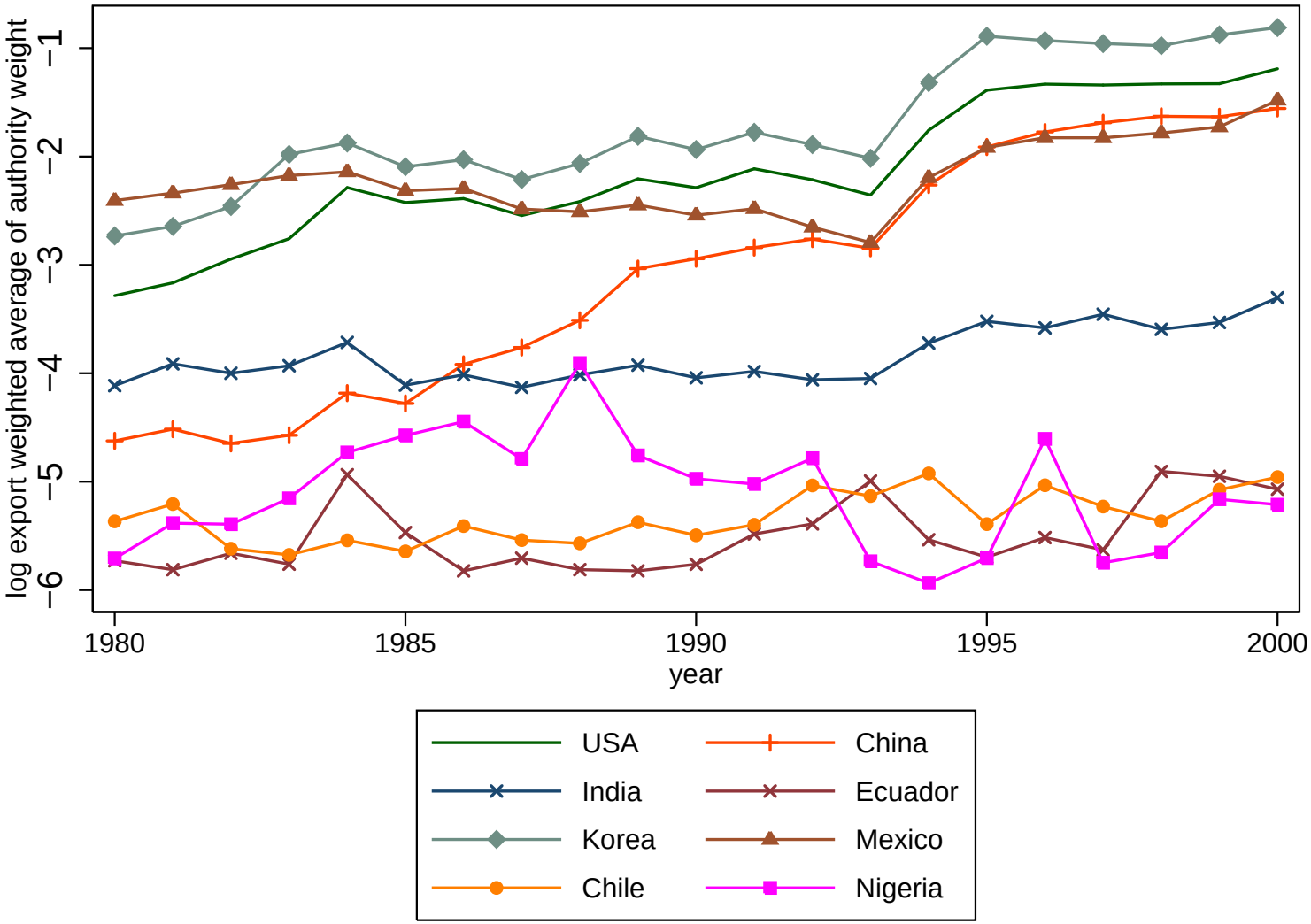
Sample of Top Five Most Connected Technological Categories

year	category	names	authority weight
1999	438	Semiconductor device manufacturing: process	0.85278
1999	257	Active solid-state devices (e.g., transistors, solid-state diodes)	0.46518
1999	370	Multiplex communications	0.17430
1999	361	Electricity: electrical systems and devices	0.06167
1999	365	Static information storage and retrieval	0.04785
1989	514	Drug, bio-affecting and body treating compositions	0.93968
1989	424	Drug, bio-affecting and body treating compositions	0.29949
1989	428	Stock material or miscellaneous articles	0.05668
1989	604	Surgery	0.05495
1989	435	Chemistry: molecular biology and microbiology	0.05422
1979	123	Internal-combustion engines	0.99720
1979	514	Drug, bio-affecting and body treating compositions	0.04112
1979	60	Power plants	0.03811
1979	261	Gas and liquid contact apparatus	0.02636
1979	73	Measuring and testing	0.02058

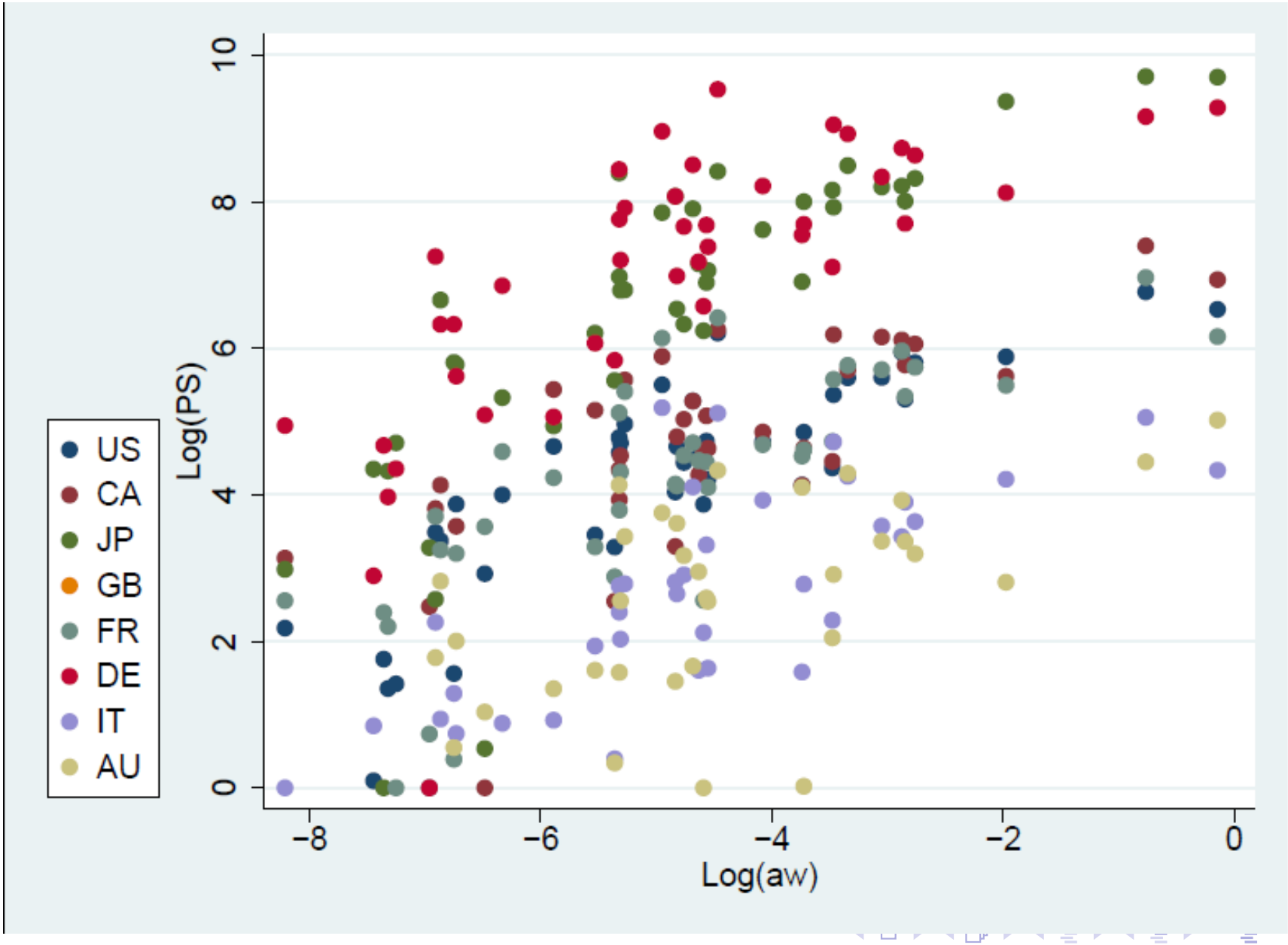
Richer Countries Export more GPT Goods



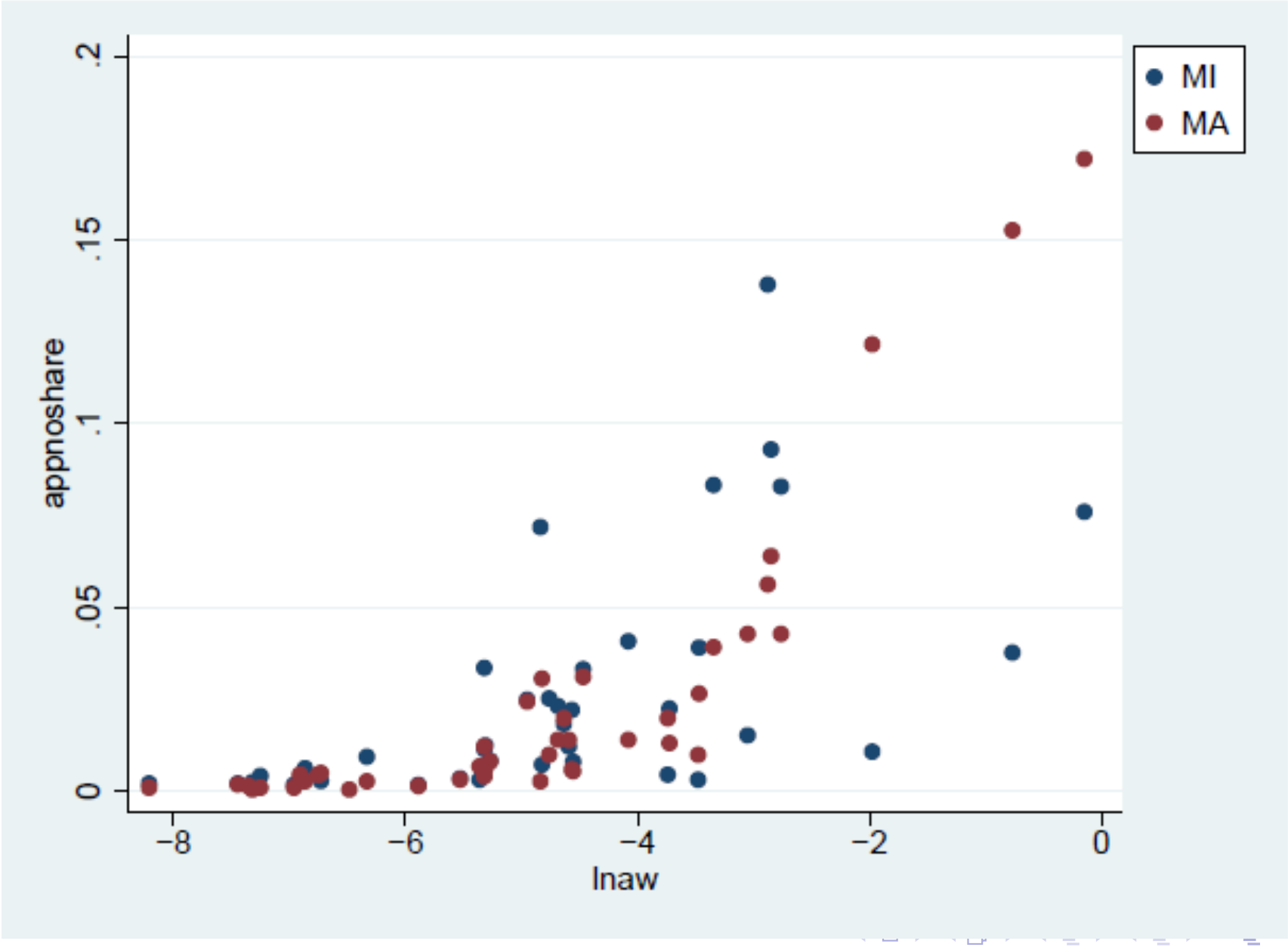
Example of eight selected countries



Richer Countries Innovate more GPT Goods



Coastal Regions Innovate More in GPT Sectors



Model

A two-country multi-sector firm innovation model with the following key elements:

- Heterogeneous knowledge linkages between sectors.
- Home country has higher labor productivity than foreign country.
- Productivity difference causes R&D specialization.

Consumers

- Goods:
- Final good

$$C = \left(\sum_{i=1}^{K} Q_i^{\frac{\delta-1}{\delta}} \right)^{\frac{\delta}{\delta-1}} \tag{1}$$

- Sectoral goods

$$Q^i = \left(\int_0^{I^i + I^{i*}} x^i(k)^{\frac{\sigma-1}{\sigma}} dk \right)^{\frac{\sigma}{\sigma-1}}, \tag{2}$$

Intermediate Good Firms

- The domestic market price of domestic good k in sector i is

$$p^i(k) = \frac{\sigma}{\sigma - 1}\frac{1}{\phi}$$

- The foreign market price of domestic good k in sector i is

$$p^{i*}(k) = \frac{\sigma}{\sigma - 1}\frac{\tau}{\phi}$$

where τ is the iceberg trade cost and e is exchange rate: one unit of home country currency is worth e unit of foreign currency.

- The sales quantity at domestic and foreign markets are

$$\mathsf{x}^i_{k,d} = \frac{s^i E}{P^i}\left(\frac{p_k}{P^i}\right)^{-\sigma} \tag{3}$$

$$\mathsf{x}^i_{k,x} = \frac{s^i E^*}{eP^{i*}}\left(\frac{p^*_k}{P^{i*}}\right)^{-\sigma}. \tag{4}$$

Price indices

- The home price index of sector i is

$$P^i = \frac{\sigma}{\sigma - 1}[I^i(\frac{1}{\phi})^{1-\sigma} + I^{i*}(\frac{\tau}{\phi^* e})^{1-\sigma}]^{1/(1-\sigma)}$$

- The foreign price index of sector i is

$$P^{i*} = \frac{\sigma}{\sigma - 1}[I^i(\frac{\tau}{\phi})^{1-\sigma} + I^{i*}(\frac{1}{\phi^* e})^{1-\sigma}]^{1/(1-\sigma)}$$

- Aggregate price indices are

$$P = \left(\sum_{i=1}^{K} P_i^{1-\delta}\right)^{\frac{1}{1-\delta}}$$

$$P^* = \left(\sum_{i=1}^{K} P_{i*}^{1-\delta}\right)^{\frac{1}{1-\delta}}$$

Multi-Product Firms

- Innovation: a process of increasing number of goods in one sector using existing knowledge in all sectors.
- Production: monopolistic competitive firms
- Innovation is subject to a mean-zero i.i.d. shock

All-sector Firm's R&D Decision

$$\max_{\left\{R_{f,t}^{ij}\right\}_{i,j\in\{1,2,\ldots,K\}}} V(\boldsymbol{z}_{f,t}) = \sum_{j=1}^{K} \frac{\pi^j}{I_t^j} z_{f,t}^j - \sum_{i=1}^{K}\sum_{j=1}^{K} R_{f,t}^{ij} + \frac{V(\boldsymbol{z}_{f,t+1})}{1+r} \tag{5}$$

subject to the knowledge capital accumulation condition in every sector

$$z_{f,t+1}^i = z_{f,t}^i + \Delta z_{f,t}^i, \tag{6}$$

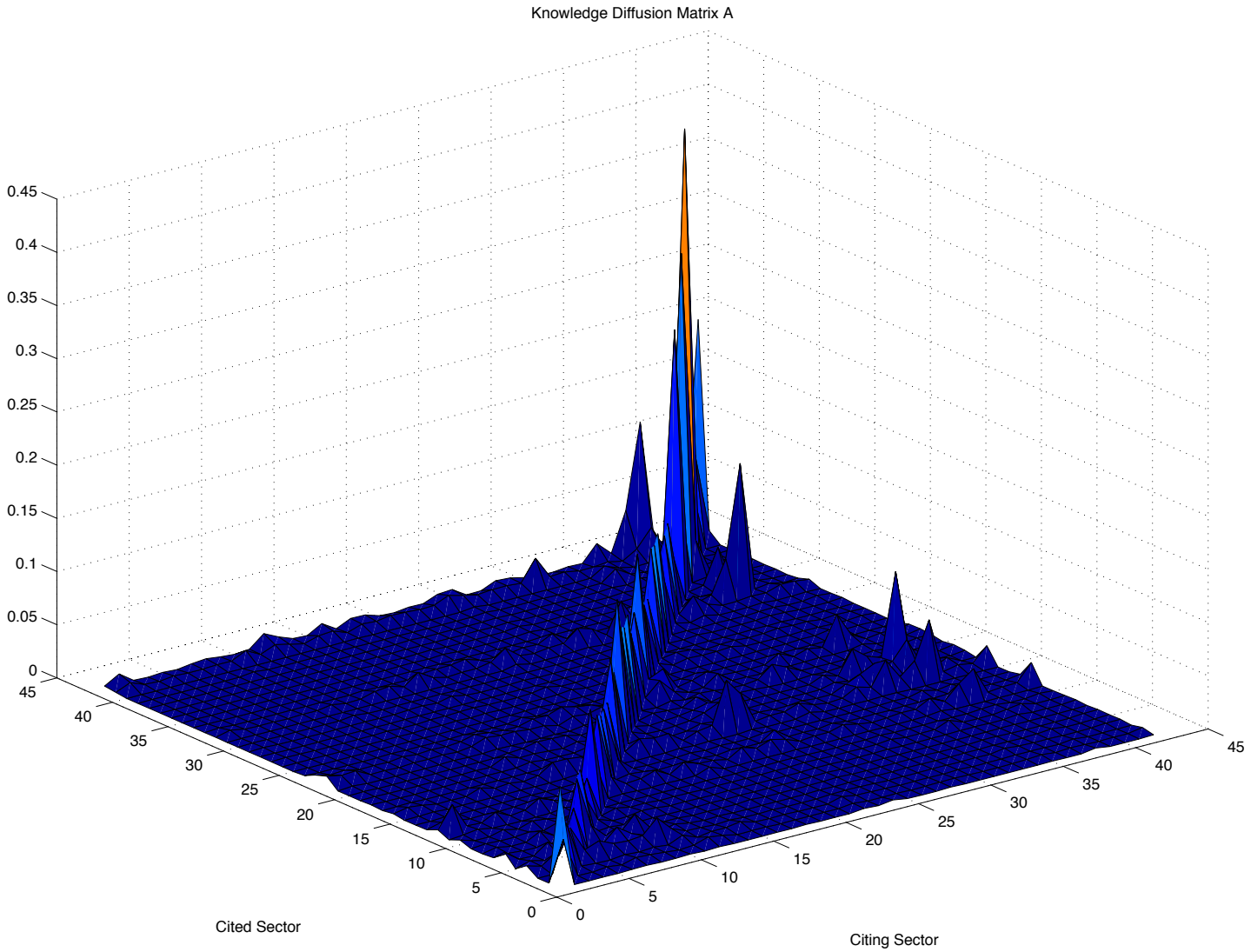
where the incremental innovation is

$$\Delta z_{f,t}^i = \sum_{j=1}^{K} A^{ij} \left(\bar{z}_t^i R_{f,t}^{ij}\right)^{\alpha} \left(z_{f,t}^j + \gamma \bar{z}_t^j\right)^{1-\alpha} \tag{7}$$

where A^{ij} denotes the $(i,j)^{th}$ element of knowledge linkage matrix $\mathbf{A}_{K\times K}$; γ governs the relative effectiveness of public knowledge to private knowledge in innovations.

Knowledge Diffusion Matrix A

In the data, $A^{ij} = \frac{\text{Outward Citation}^{ij}}{\text{Outward Citation}^{i}} / \frac{\text{Inward Citation}^{j}}{\text{Inward Citation}}$



Firm Value

The value of a firm is a linear combination of its knowledge capital in all the sectors it is producing in:

$$V(\mathbf{z}_{f,t}) = \sum_{j=1}^{K} v^j \frac{z_{f,t}^j}{I_t^j} + u$$

- The marginal value of more innovation in sector j

$$v^j = (1-\rho)^{-1}(\pi^j + \sum_{i=1}^{K} \omega^{ij})$$

- The rent from public knowledge

$$u = \sum_{j=1}^{K} (1-\rho)^{-1} \sum_{i=1}^{K} \omega^{ij} \frac{\gamma}{M^j},$$

- Marginal value of j's knowledge in producing i:

$$\omega^{ij} = \frac{I^j}{I^i} \frac{1-\alpha}{\alpha} \left(A^{ij} \alpha \rho v^i \right)^{\frac{1}{1-\alpha}} (M^i)^{\frac{\alpha}{1-\alpha}}$$

General Equilibrium

$\mathbf{v}_{K\times 1}$, $\mathbf{v}^*_{K\times 1}$, $(\mathbf{I}/I^1)_{(K-1)\times 1}$, $(\mathbf{I}^*/I^1)_{K\times 1}$, M, M^*, g, and e are determined by the following equations:

- Patent value functions

$$\frac{v^j}{M} = (1-\rho)^{-1}\left[\frac{\pi^j}{M} + \sum_{i=1}^{K}\frac{1-\alpha}{\alpha}\frac{I^j}{I^i}\left(\frac{A^{ij}\alpha\rho v^i}{M}\right)^{\frac{1}{1-\alpha}}\right] \tag{8}$$

$$\frac{v^{j*}}{M^*} = (1-\rho)^{-1}\left[\frac{\pi^{j^*}}{M^*} + \sum_{i=1}^{K}\frac{1-\alpha}{\alpha}\frac{I^{j^*}}{I^{i*}}\left(\frac{A^{ij^*}\alpha\rho v^{i^*}}{M^*}\right)^{\frac{1}{1-\alpha}}\right] \tag{9}$$

- Growth rates of innovation

$$g = \sum_{j=1}^{K}\left[A^{ij\frac{1}{1-\alpha}}\left(\frac{\alpha\rho v^i}{M}\right)^{\frac{\alpha}{1-\alpha}}\right]\frac{I^j}{I^i}(1+\gamma\frac{\bar{z}^{wj}}{\bar{z}^j}) \tag{10}$$

$$g = \sum_{j=1}^{K}\left[A^{ij*\frac{1}{1-\alpha}}\left(\frac{\alpha\rho v^{i*}}{M^*}\right)^{\frac{\alpha}{1-\alpha}}\right]\frac{I^{j*}}{I^{i*}}(1+\gamma\frac{\bar{z}^{wj}}{\bar{z}^{j*}}) \tag{11}$$

General Equilibrium

- Free entry conditions

$$F = \sum_{j=1}^{K} \left[\frac{v^j}{M} - (1-\rho)^{-1} \frac{\pi^j}{M} \right] \gamma \frac{\bar{z}^{wj}}{\bar{z}^j} \tag{12}$$

$$\frac{F^*}{e} = \sum_{j=1}^{K} \left[\frac{v^{j*}}{M^*} - (1-\rho)^{-1} \frac{\pi^{j^*}}{M^*} \right] \gamma \frac{\bar{z}^{wj}}{\bar{z}^{j*}}, \tag{13}$$

- Trade balance condition

$$\sum_{i=1}^{K} \frac{E^* \left(\frac{P^{*i}}{P^*} \right)^{1-\delta} I^i}{I^i + I^{i*} \left(\frac{\phi}{\phi^* \tau e} \right)^{1-\sigma}} = \sum_{i=1}^{K} \frac{E \left(\frac{P^i}{P} \right)^{1-\delta} I^{i*}}{I^{i*} + I^i \left(\frac{\phi^* e}{\phi \tau} \right)^{1-\sigma}}. \tag{14}$$

Real Income Levels

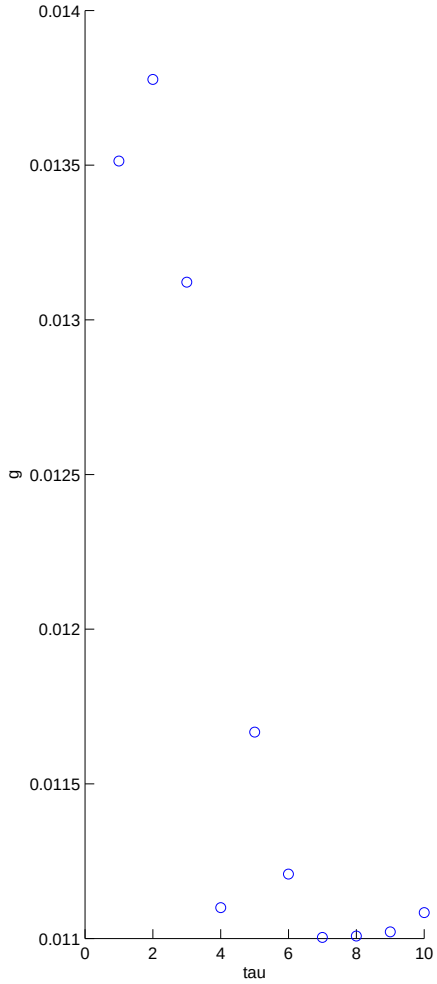
- Home real income

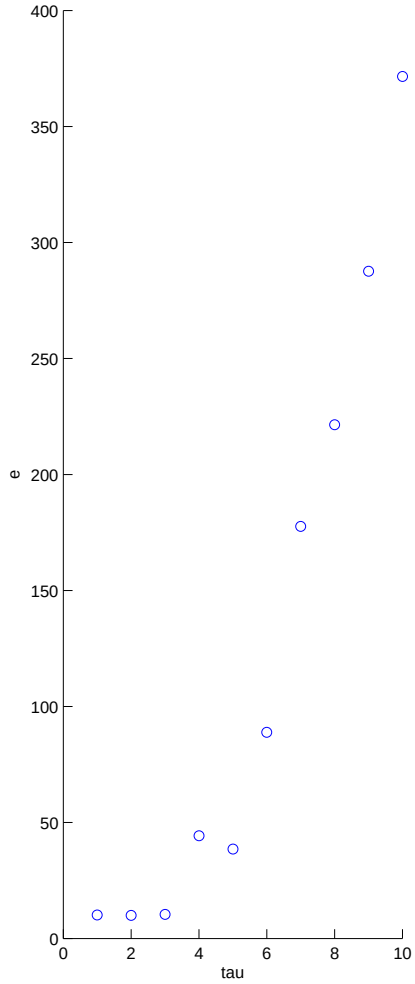
$$\frac{E/L}{P} = \frac{1 + r\sum_{i=1}^{K} v^i/L}{B\prod_{i=1}^{K}\left(\frac{\sigma}{\sigma-1}\left[I^i\left(\frac{1}{\phi}\right)^{1-\sigma} + I^{i*}\left(\frac{\tau}{\phi^* e}\right)^{1-\sigma}\right]^{1/(1-\sigma)}\right)^{s^i}},$$

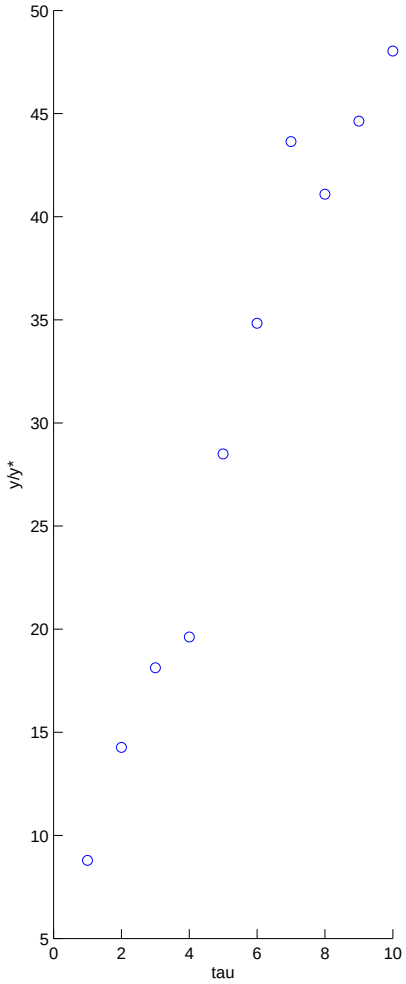
- Foreign real income

$$\frac{E^*/L^*}{P^*} = \frac{\frac{1}{e} + r\sum_{i=1}^{K} v^{*i}/L^*}{B\prod_{i=1}^{K}\left(\frac{\sigma}{\sigma-1}\left[I^i\left(\frac{\tau e}{\phi}\right)^{1-\sigma} + I^{i*}\left(\frac{1}{\phi^*}\right)^{1-\sigma}\right]^{1/(1-\sigma)}\right)^{s^i}}.$$

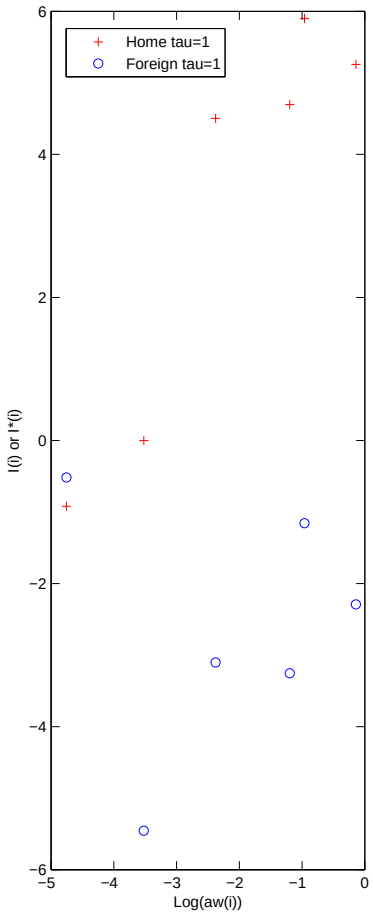
The Open Economy under Different Trade Cost

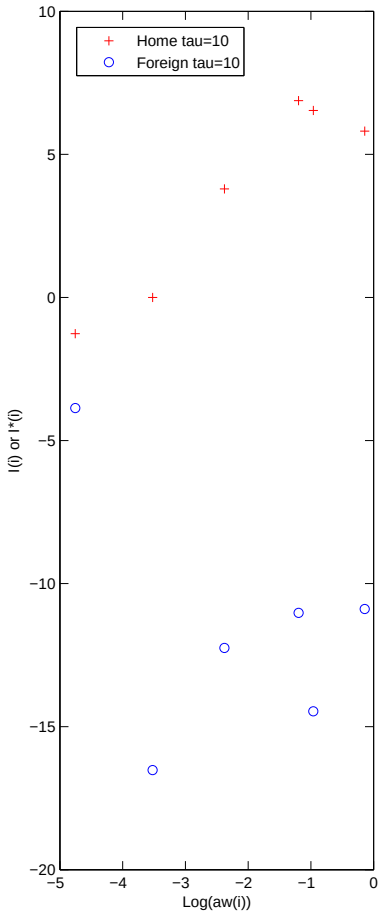


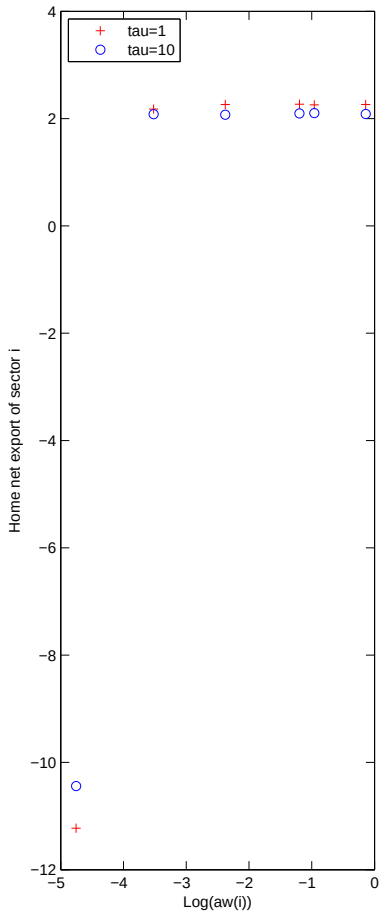




Trade Pattern







Final Remarks

- Patent data and trade data show that rich countries innovate and export more goods in general purpose technology sectors.
- Patent price consists of two components: the discounted future monopolistic profit in self-sector and the value as knowledge capital to create new patents in all related sectors.
- In the more productive home country, a patent's value as knowledge capital appreciates more in GPT sectors, because it has broader applications in other sectors and benefits from the greater profit from all knowledge using sectors.
- Home country invests a larger share of R&D fund in GPT sectors than foreign.
- Home's better RD resource allocation enlarges the income gap that originates from productivity difference.
- Trade liberalization encourages firms to concentrate R&D resources in GPT sectors, which provides knowledge spillovers to the rest of economy and promotes growth.