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Innovation and Manufacturing Offshoring with Fully Endogenous Productivity Growth

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Introduction

- Although R&D has traditionally concentrated in advanced countries, in recent years firms have begun to shift innovation offshore to emerging economies.
- For example, the U.S. is the largest R&D performer (NSF 2016) in terms of gross domestic expenditure, but has exhibited trade deficits in R&D services with a number of emerging economies over the last decade.
- Destinations include Brazil, China, India, Russia, Singapore, and Taiwan (Hausmann et al. 2007; Puga and Trefler 2010; Santos-Paulino et al. 2014)
- Trade deficits with China and India grew at average annual rates of 23% and 17% between 2006 and 2014 to become US$2.2 billion and US$2.9 billion in 2015 (BEA 2016).

Introduction

There is a growing empirical literature that studies the links between R&D offshoring, innovation performance, and economic growth.

Empirical evidence at the firm level:

- Nieto and Rodríguez (2011) and Bertrand and Mol (2013): firms that offshoring R&D are more likely to introduce new products.
- Rodríguez and Nieto (2016): positive relationship between innovation offshoring and sales growth.

Motivation

Empirical evidence at the aggregate level:

- D'Agostino et al. (2013): OECD regions with firms that offshore innovation to emerging economies have more patent applications.
- Castellani and Peiri (2013): European regions with a greater number of outward oriented R&D investment projects exhibit higher growth rates for labor productivity.

Related Literature

- Ekholm and Hakkala (2007) develop a two-country general-equilibrium model of trade in which firms locate production and R&D independently.
- There are a number of papers considering the relationship between innovation-based growth and offshoring. For example, Martin and Ottaviano (1999), Gao (2007), Naghavi and Ottaviano (2009, 2010).
- These papers do not consider R&D offshoring. Innovation is either tied to the location of entry or agglomerates fully in the advanced country because of localized knowledge spillovers.
- Davis (2013) studies a variety expansion model of R&D offshoring; but no link between offshoring patterns and growth.

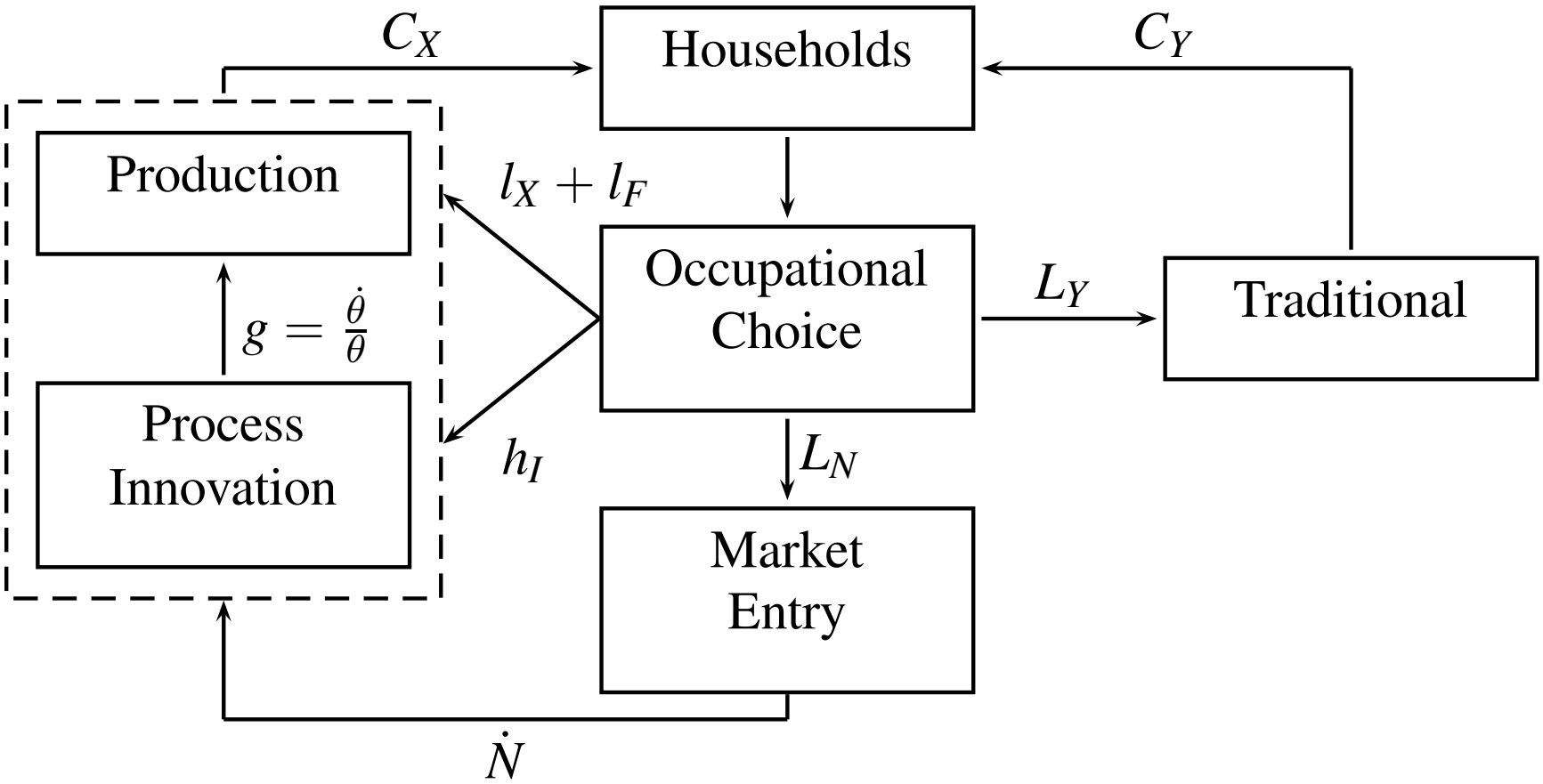
This paper

- Firm-level investment in process innovation to improve labor productivity in production drives economic growth.
- The occupational choice of skilled-differentiated workers into low-skilled employment in production and high-skilled employment in innovation.
- Manufacturing firms shift production and innovation independently between countries in order to minimize costs.
- A tension arises between access to technical knowledge and low-cost high-skilled labor in the location decision for R&D.

Model Framework

- Two symmetric countries – except for asset wealth.
- Home (asset wealthy) and Foreign (asset poor)
- Occupational choice: low-skilled (L) or high-skilled employment (H)
- Monopolistically competitive firms produce for domestic and export markets and invest in process innovation
- Production and innovation are located independently with the aim of minimizing costs
- Iceberg trade costs and incomplete knowledge spillovers between countries

Model Framework



Households

- Lifetime utility:

$$U = \int_0^{\infty} e^{-\rho t} \left(\alpha \ln C_X(t) + (1-\alpha) \ln C_Y(t)\right) dt.$$

- The composite price index for manufacturing goods is

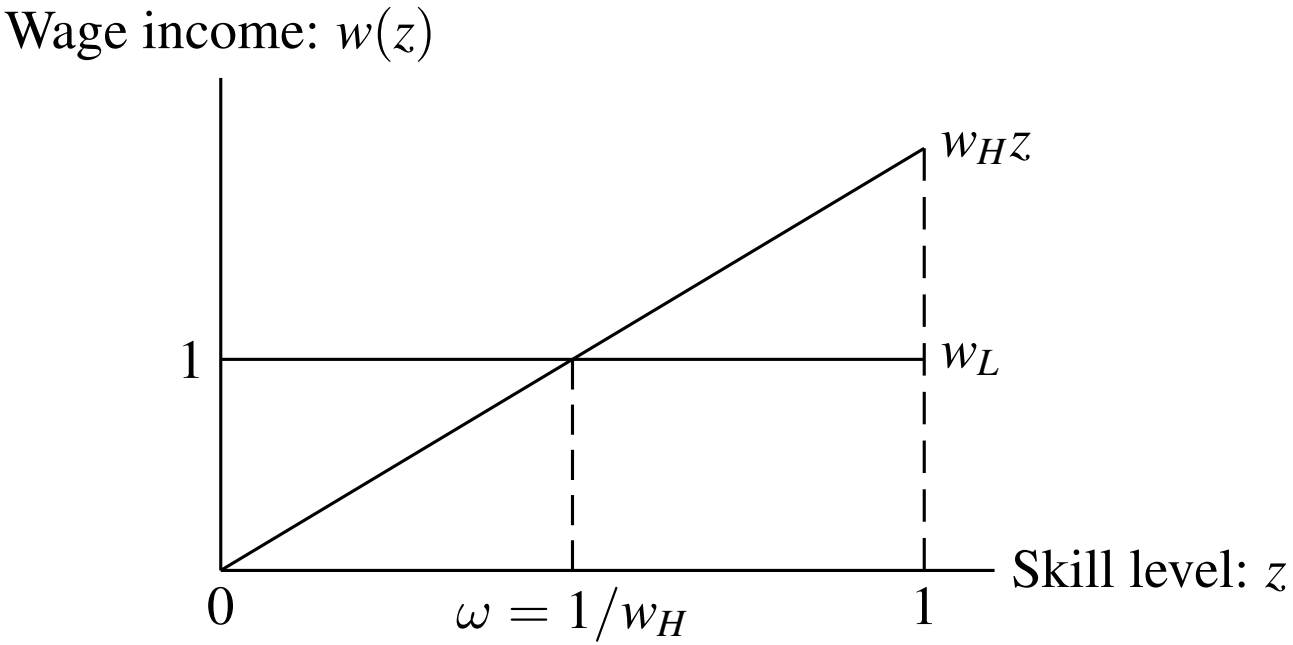
$$P_X = \left(\int_0^{N} {p_{Xi}}^{1-\sigma} di + \int_0^{N^*} \left(\zeta p_{Xj}^*\right)^{1-\sigma} dj \right)^{\frac{1}{1-\sigma}}.$$

- The demand for varieties i and j in home are

$$c_i = \alpha p_{Xi}^{-\sigma} P_X^{\sigma-1} E, \qquad c_j = \alpha (\zeta p_{Xj})^{-\sigma} P_X^{\sigma-1} E.$$

Occupational choice

- Symmetric population sizes and uniform skill distributions.



- The effective low-skilled and high-skilled labor supplies are $L = \omega Z$ and $H = (1 - \omega^2)Z/2$.
- National labor income, conditional on employment levels, is $I(\omega) = w_L L + w_H H = (1 + \omega^2)Z/(2\omega)$.

Manufacturing

- Production technology: $x = \theta^{\gamma} l_X$
- Profit: $\Pi = \pi - w_H h_I - l_F$, where $\pi = p_X x - l_X$
- Process innovation: $\dot{\theta} = k\theta h_I$, where $k = s_X + \delta(1 - s_X)$
- Firm value: $V(t) = \int_t^{\infty} e^{-\int_t^{\tau}(r(\tau')+\lambda)d\tau'} \Pi(\tau) d\tau$
- Price is a standard markup over unit cost: $p_X = \sigma/((\sigma - 1)\theta^{\gamma})$
- The cost of process innovation is captured by $p_I = w_H/(k\theta)$

Production shares

- The asset wealthy country's share of production that equates operating profits on sales is ($\pi = \pi^*$):

$$s_X \equiv \frac{N}{N_W} = \frac{E - \varphi E^*}{(1-\varphi)E_W} = \underbrace{\frac{\alpha\rho(b - \varphi b^*)}{1-\varphi}}_{\text{Relative investment income}} + \underbrace{\frac{(1-\alpha\rho)(I - \varphi I^*)}{(1-\varphi)I_W}}_{\text{Relative labor income}}$$

- I is national labor income.
- $b \equiv B/(B + B^*) > 1/2$ is the asset-wealthy country's share of total asset wealth.

Production shares

- The asset wealthy country's share of production that equates the unit costs of process innovation ($p_I = p_I^*$):

$$s_X = \underbrace{\frac{w_H - \delta w_H^*}{(1-\delta)(w_H + w_H^*)}}_{\text{Relative high-skilled wages}} = \frac{\omega^* - \delta\omega}{(1-\delta)(\omega + \omega^*)}$$

- Strength of knowledge spillovers: $k = (1+\delta)\omega^*/(\omega + \omega^*)$

Labor Market Equilibrium

- Share locus:

$$\underbrace{\frac{\alpha\rho(b-\varphi(1-b))}{1-\varphi}+\frac{(1-\alpha\rho)(I-\varphi I^*)}{(1-\varphi)I_W}}_{\text{Equalized operating profits } (\pi=\pi^*)}=\underbrace{\frac{\omega^*-\delta\omega}{(1-\delta)(\omega+\omega^*)}}_{\text{Equalized innovation costs } (p_I=p_I^*)}$$

Labor Market Equilibrium

- Level of market entry ($n = N_W/(\alpha E_W)$):
  - Process innovation and the high-skilled labor market:

$$n_H = \frac{(\sigma-1)\gamma\omega k}{\sigma(\rho+\lambda)} - \frac{(1-\alpha\rho)(H/\omega + H^*/\omega^*)\omega k}{\alpha(\rho+\lambda)I_W}$$

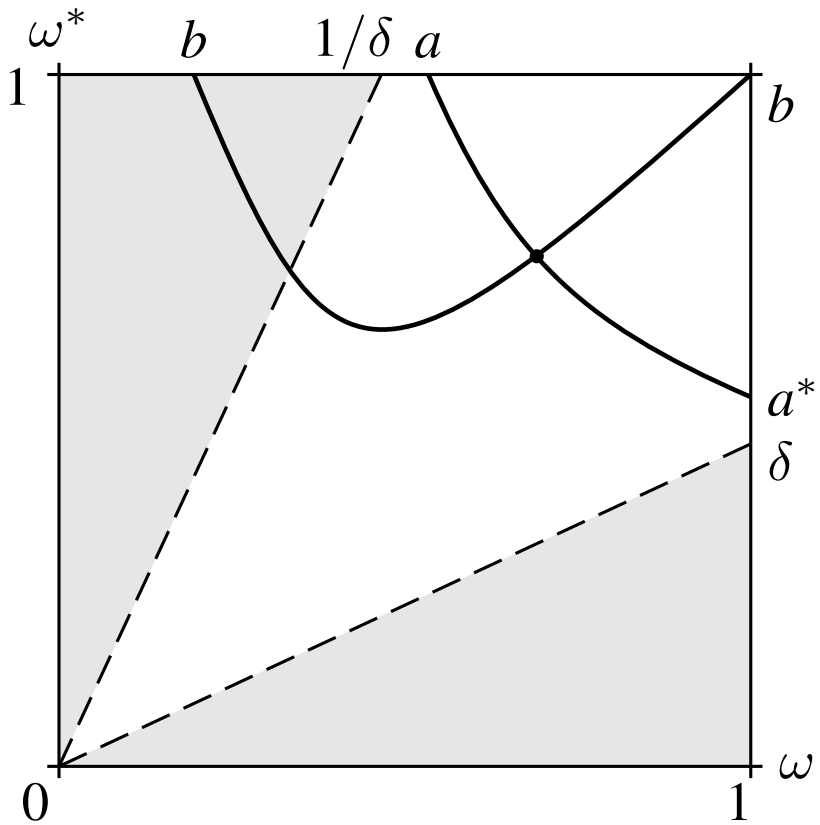
  - Market entry and the low-skilled labor market:

$$n_L = \frac{2(1-\alpha\rho)(L+L^*)}{\alpha l_F I_W} - \frac{\sigma-\alpha}{\alpha\sigma l_F} - \frac{\lambda}{l_F}$$

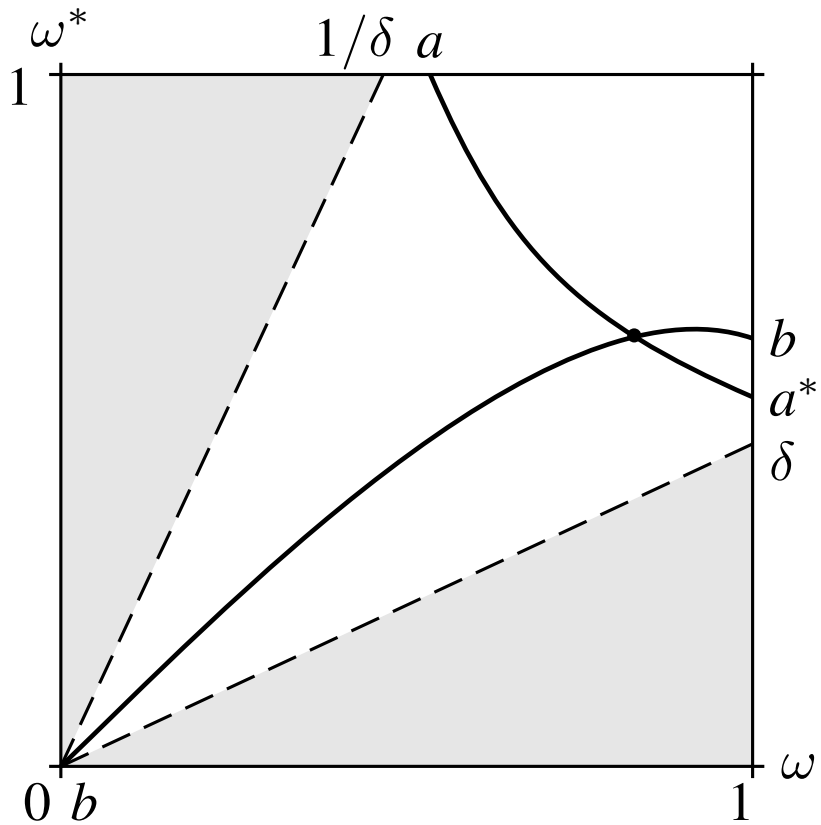
- Investment locus: $n_H = n_L$.

Location Patterns

- *aa* is the investment locus and *bb* is the share locus



(a) $\varphi < \varphi_B$



(b) $\varphi > \varphi_B$

Equilibrium Location Patterns

Proposition 1

(i) If $\varphi < \varphi_B$, the asset-wealthy country has larger shares of industry and innovation, with the full concentration of industry for $\varphi \in (\varphi_X, \varphi_B)$ and of innovation for $\varphi \in (\varphi_I, \varphi_B)$.

(ii) If $\varphi > \varphi_B$, the asset-poor country has larger shares of industry and innovation, with the full concentration of industry for $\varphi \in (\varphi_B, \varphi_X^*)$ and of innovation for $\varphi \in (\varphi_B, \varphi_I^*)$,

where

$$\varphi_B \equiv \frac{\delta + \omega\omega^* + (1-\delta)(b^* - \omega\omega^* b)\alpha\rho}{1 + \delta\omega\omega^* - (1-\delta)(b^* - \omega\omega^* b)\alpha\rho},$$

with positive values for both the numerator and denominator since $1 > \alpha\rho$. There exists a threshold $\overline{\delta}$ such that $\varphi_I < \varphi_X$ and $\varphi_I^* > \varphi_X^*$ for $\delta < \underline{\delta}$, but $\varphi_I \geq \varphi_X$ and $\varphi_I^* \leq \varphi_X^*$ for $\delta \geq \underline{\delta}$.

Intuition

- Raise the asset wealthy country's share of asset wealth ($b \uparrow$)

$$\overbrace{\underbrace{\frac{\alpha\rho(b-\varphi(1-b))}{1-\varphi}}_{\text{Investment income effect}}+\underbrace{\frac{(1-\alpha\rho)(I-\varphi I^*)}{(1-\varphi)I_W}}_{\text{Labor income effect}}}^{s_X \text{ for } \pi=\pi^*}=\overbrace{\underbrace{\frac{\omega^*-\delta\omega}{(1-\delta)(\omega+\omega^*)}}_{\text{Innovation cost effect}}}^{s_X \text{ for } p_I=p_I^*}$$

  - For $\varphi < \varphi_B$, $\quad b \uparrow \Rightarrow k/k^* \Uparrow$ and $w_H/w_H^* \uparrow \Rightarrow p_I < p_I^*$. Firms relocate production and innovation to the asset wealthy country until $p_I = p_I^*$.
  - For $\varphi > \varphi_B$, $\quad b \uparrow \Rightarrow k/k^* \uparrow$ and $w_H/w_H^* \Uparrow \Rightarrow p_I > p_I^*$. Firms relocate production and innovation to the asset poor country until $p_I = p_I^*$.

Offshoring Patterns in Manufacturing

- The asset wealthy country's share of manufacturing is

$$s_X = \frac{\omega^* - \delta\omega}{(1-\delta)(\omega+\omega^*)}$$

- The direction of net offshoring flows in manufacturing:

$$S_X \equiv b - s_X = \frac{(b+\delta b^*)\omega - (b^*+\delta b)\omega^*}{(1-\delta)(\omega+\omega^*)}$$

- When $S_X > 0$ net offshoring flows from the asset wealthy home country to the asset poor foreign country.
- When $S_X < 0$ net offshoring flows from the asset poor country to the asset wealthy country.

Manufacturing Offshoring

Proposition 2

Net offshoring in manufacturing flows from the asset-wealthy country to the asset-poor country for $\varphi \notin (\varphi_{XO}, \varphi_B)$,

and from the asset-poor country to the asset-wealthy country for $\varphi \in (\varphi_{XO}, \varphi_B)$, where $\varphi_{XO} \in (0, \varphi_X)$.

Offshoring Patterns in Innovation

- The asset wealthy country's share of innovation is

$$s_I = \frac{w_H H}{w_H H + w_H^* H^*} = \frac{(1-\omega^2)\omega^*}{(1-\omega^2)\omega^* + (1-\omega^{*2})\omega}$$

- The direction of net offshoring flows in innovation

$$S_I \equiv b - s_I = \frac{b\omega(1-\omega^{*2}) - b^*\omega^*(1-\omega^2)}{(1-\omega^2)\omega^* + (1-\omega^{*2})\omega}$$

- When $S_I > 0$ net offshoring flows from the asset wealthy home country to the asset poor foreign country.
- When $S_I < 0$ net offshoring flows from the asset poor country to the asset wealthy country.

Proposition 3

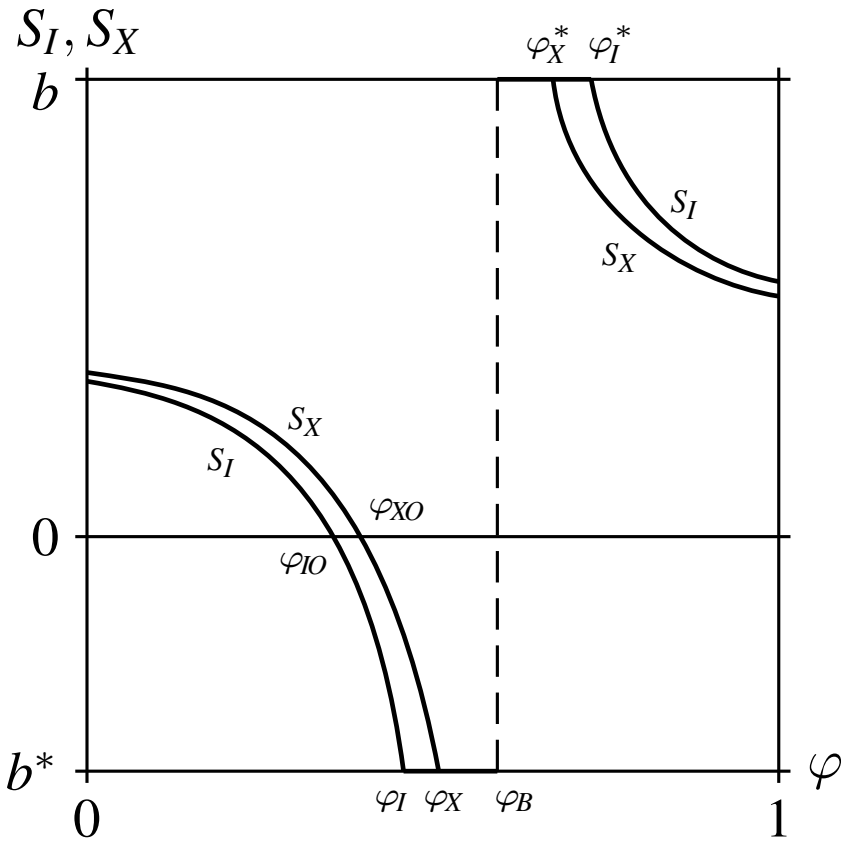
When $\delta < \overline{\delta}$, net offshoring in innovation flows from the asset-wealthy country to the asset-poor country for $\varphi \notin (\varphi_{IO}, \varphi_B)$,

and from the asset-poor country to the asset-wealthy country for $\varphi \in (\varphi_{IO}, \varphi_B)$, where $\underline{\delta} < \overline{\delta}$ and $\varphi_{IO} \in (0, \varphi_I)$.

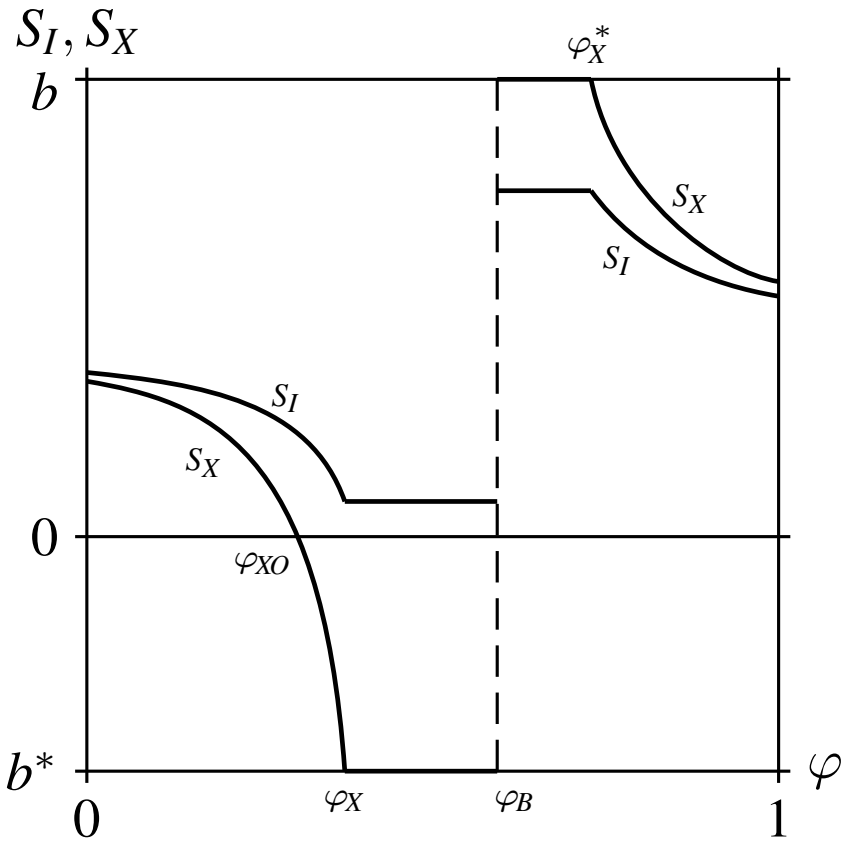
When $\delta > \overline{\delta}$, net offshoring in innovation always flows from the asset-wealthy country to the asset-poor country.

Offshoring Patterns

- $S_X \equiv b - s_X$ and $S_I \equiv b - s_I$



(a) $\delta < \underline{\delta} < \overline{\delta}$



(b) $\delta > \overline{\delta} > \underline{\delta}$

Market Entry and Productivity Growth

- The total level of market entry is

$$n = \frac{(\nu - \rho - \lambda)\omega k}{\omega k l_F - \rho - \lambda}$$

where $\nu = (1 - (\sigma - 1)\gamma)/\sigma$ and $\nu > \rho + \lambda$.

- The rate of productivity growth is

$$g = \frac{(\sigma - 1)\gamma\omega k}{\sigma n} - \rho - \lambda = \frac{(\sigma - 1)\gamma(\omega k l_F - \rho - \lambda)}{\sigma(\nu - \rho - \lambda)} - \rho - \lambda$$

Industry Concentration and Process Innovation

- The unit cost of process innovation $p_I = 1/(\omega k\theta)$ is increasing with the concentration of industry as the cost of rising high-skilled wages always dominates the benefits of improved knowledge spillovers from production to innovation.
- Therefore, an increase in the concentration of industry in either the asset-wealthy country or the asset-poor country leads to greater market entry and slower growth.

Trade Costs and Process Innovation

Proposition 4

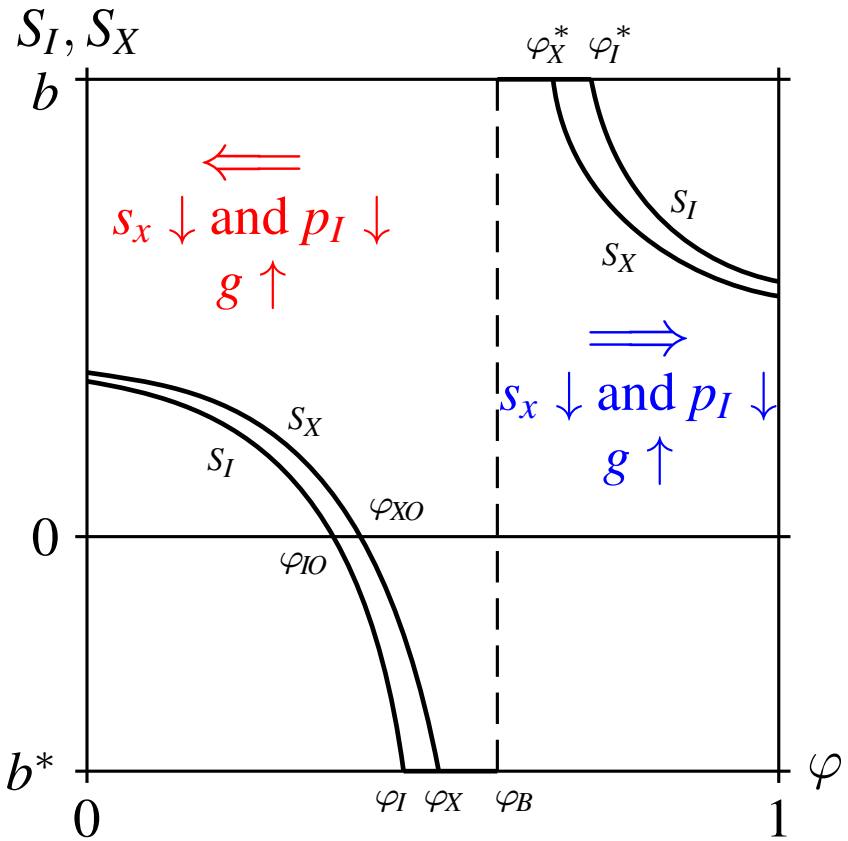
A reduction in trade costs decreases net offshoring flows from the asset-wealthy country to the asset-poor country,

while raising market entry and dampening productivity growth for $\varphi < \varphi_B$,

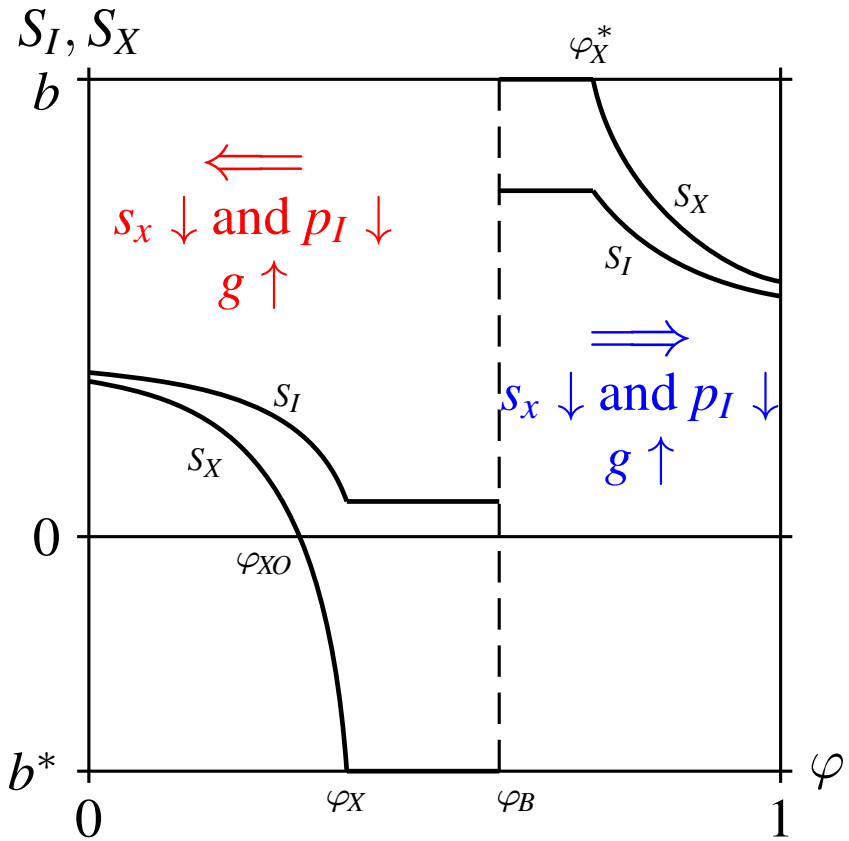
but lowering market entry and accelerating productivity growth for $\varphi > \varphi_B$.

Effects of Changes in Trade Costs

- $S_X \equiv b - s_X$ and $S_I \equiv b - s_I$



(a) $\delta < \underline{\delta} < \overline{\delta}$



(b) $\delta > \overline{\delta} > \underline{\delta}$

Knowledge Diffusion and Process Innovation

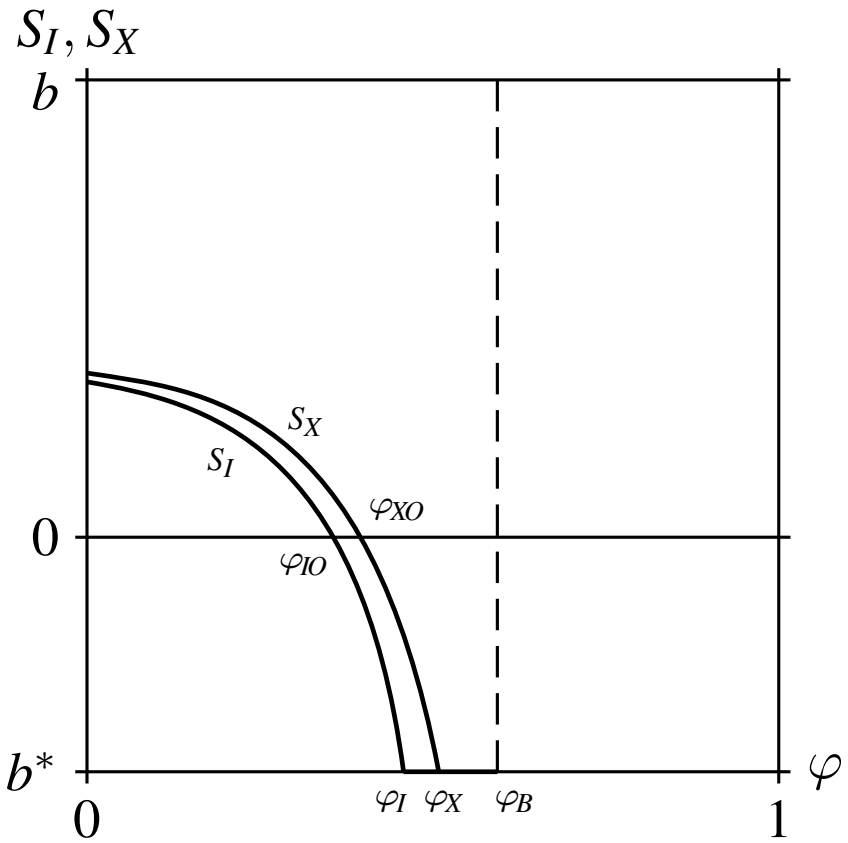
Proposition 5

An improvement in the degree of knowledge diffusion reduces market entry and accelerates productivity growth for $\varphi < \varphi_B$,

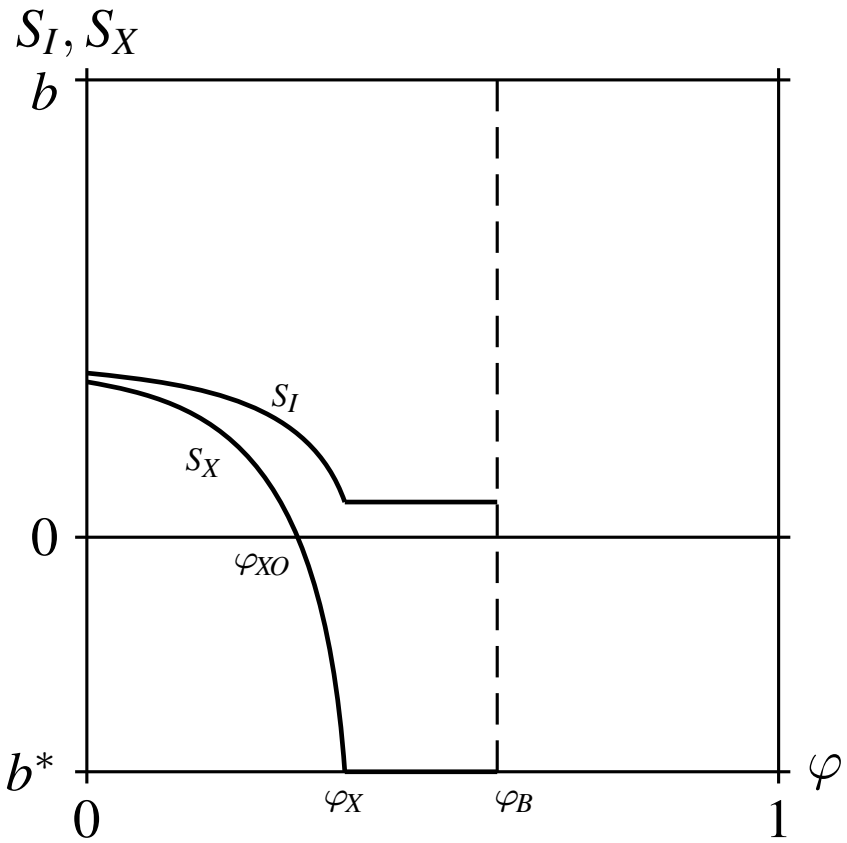
but has ambiguous effects on market entry and productivity growth for $\varphi > \varphi_B$.

Effects of Improved Knowledge Diffusion

- $S_X \equiv b - s_X$ and $S_I \equiv b - s_I$
- For $\varphi < \varphi_B$, we have $\delta \uparrow \Longrightarrow S_X \uparrow, S_I \uparrow$ and $g \uparrow$



(a) $\delta < \underline{\delta} < \overline{\delta}$



(b) $\delta > \overline{\delta} > \underline{\delta}$

Conclusions

We investigate the relationship between the innovation offshoring patterns and productivity growth.

- Long-run equilibrium with innovation activity dispersed across countries.
- When trade costs and knowledge diffusion are high (low), the asset wealthy (poor) country has a larger market and greater shares of innovation and manufacturing.
- Net offshoring in innovation and manufacturing may flow in either direction between the asset wealthy country and the asset poor country, depending on trade costs and the degree of knowledge diffusion.
- Increases in innovation offshoring from the asset wealthy country to the asset poor country coincide with a faster rate of productivity growth.