Queen Mary
University of London

Macro for Policy

Endogenous Growth Theory (part 2)

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Agenda

1. The Solow model in continuous time
2. Endogenous growth model 1: AK model (learning-by-doing)
3. **Endogenous growth model 2: Romer's R&D model**
4. **Endogenous growth model 3: Schumpeterian growth model**
   - Aghion-Howitt model
   - The inverted-U shape
     (Aghion, Philippe, Nick Bloom, Richard Blundell, Rachel Griffith and Peter Howitt. "Competition And Innovation: An Inverted-U Relationship," Quarterly Journal of Economics, 2005)
   - Distance to Frontier
     (Aghion, Philippe, Nick Bloom, Richard Blundell, Rachel Griffith and Peter Howitt. "Distance to Frontier, Selection, and Economic Growth," Journal of the European Economic Association, 2006)

Romer's R&D model

- Model R&D specifically, which is driven by monopoly rents.
- *Externalities from production at the individual level lead to technical progress at the aggregate level.*

→ Monopolistic rents (sub-optimal)
→ Room for policy makers to affect the growth rate of GDP

Overview:

- ***Final goods producer –*** combining intermediate goods

- ***Intermediate goods producers –*** buy patents to produce intermediate goods

- ***R&D sector –*** where new ideas are created used to produce intermediate goods

Romer's R&D model: Final goods producer

- *The production function:* $Y = L_Y^{1-\alpha}(x_1^\alpha + x_2^\alpha + \cdots + x_A^\alpha) = L_Y^{1-\alpha} A x^\alpha$

- *Profit maximization leads to demand curve:* $\pi = L_Y^{1-\alpha} A x^\alpha - w_Y L_Y - APx$

$$w_Y = (1-\alpha) L_Y^{-\alpha} A x^\alpha$$

$$p = \alpha L_Y^{1-\alpha} x^{\alpha-1}$$

Romer's R&D model: Intermediate goods producers

"Monopoly power with price markup"

- *The profit function:* $\pi = p(x)x - rx = \alpha L_Y^{1-\alpha} x^{\alpha} - rx$

- *Profit maximization yields positive profits (prospects for R&D):*

$$\alpha\alpha L_Y^{1-\alpha} x^{\alpha-1} = r$$

$$\alpha p = r \rightarrow p = \underbrace{\frac{1}{\alpha}}_{markup} \underbrace{r}_{marginal\ cost}$$

$$\pi = p(x)x - rx = rx\left(\frac{1-\alpha}{\alpha}\right)$$

Romer's R&D model: Innovation

- *New ideas are created by R&D (researchers and scientists' effort):*

$$\dot{A} = BL_A A$$

- *The value of creating new ideas:*

$$V = \sum_{t=0}^{\infty} \frac{1}{(1+r)^t} \pi = \frac{\pi}{r} = x\left(\frac{1-\alpha}{\alpha}\right)$$

$$w_A = BAV = BA\left(\frac{1-\alpha}{\alpha}\right)x$$

Romer's R&D model: Equilibrium

- *Wages are equalized between goods-producing sector and R&D sector*

$$w_Y = w_A$$

$$(1-\alpha)L_Y^{-\alpha}Ax^{\alpha} = BA\left(\frac{1-\alpha}{\alpha}\right)x$$

$$\text{-----}\rightarrow L_Y = \frac{r}{\alpha}\frac{1}{B}$$

Romer's R&D model: endogenized technological progress

Growth is driven by R&D effort (driven by monopolistic rents)

- *The growth rate of ideas:*

$$\frac{\dot{A}}{A} = BL_A = B(L - L_Y) = BL - BL_Y = BL - \frac{r}{\alpha}$$

The basic Aghion-Howitt model

- the economy is populated by a continuum of mass L of individuals
- each individual is endowed with one unit flow of labor per unit of time
- she or he can devote either to manufacturing an intermediate input or to research and development (R&D).

Output and innovation

- A final output (Y) is produced at any time using an intermediate input (y), according to

$$\boldsymbol{Y_t = A_t y_t^{\alpha}} \qquad (\mathbf{1})$$

- A_t denotes the current quality of the input
- A_t will be multiplied by γ when a new innovation occurs implying that $A_{t+1} = \gamma A_t$ upon new innovation
- Innovations arrive at the probability γz_t

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  - y denotes the amount of labor in manufacturing the intermediate input
  - z is the amount of labor devoted to R&D

Labor market clearing

$$\boldsymbol{y_t + z_t = L_t} \qquad \boldsymbol{(2)}$$

- y_t denotes the amount of labor working in manufacturing the intermediate input
- z_t is the amount of labor devoted to R&D
- L_t denotes the total labor supply

The expected growth rate

$$E[g_t] = E\left[log(\frac{Y_{t+1}}{Y_t})\right] = \gamma z_t log(\gamma) \qquad (2)$$

- $\frac{Y_{t+1}}{Y_t} = \frac{A_{t+1}}{A_t} = \frac{\gamma A_t}{A_t} = \gamma$
  if innovation occur, which happens with the probability λz_t

Prediction 1

The turnover rate λz is positively correlated with the growth rate g.

- a higher productivity of the R&D technology as measured by λ
- or a larger size of innovations γ
- or a larger size of the population L

has a positive effect on aggregate R&D

Competition and growth

- Policy concern in UK and Europe that productivity levels and growth rates are

- UK and EU strengthening competition regimes The Government has placed competition policy at the heart of its strategy to close the productivity gap. UK

- What is the theoretical and empirical evidence basis for these policies?

Competition and growth

Evidence from conventional wisdom, theory and empirics on the impact of competition appears contradictory

- Competition effect: ... from Adam Smith to Richard Caves: the belief that competition is good, rests on the idea that competition exerts downward pressure on costs, reduces slack and provides incentives for efficient organisation of production... (Nickell, 1996 JPE)

- Schumpeterian effect: ....anti-trust discourages innovation (Bill Gates and lawyers, frequently) Economic theory often supports the Schumpeterian effect of a negative competition effect on innovation

Depending on the market structure: the model

The economy contains many industries with two firms, which are either:

- ”neck-and-neck” as firms have the same technology
- ”leader-follower” as firms have different technologies

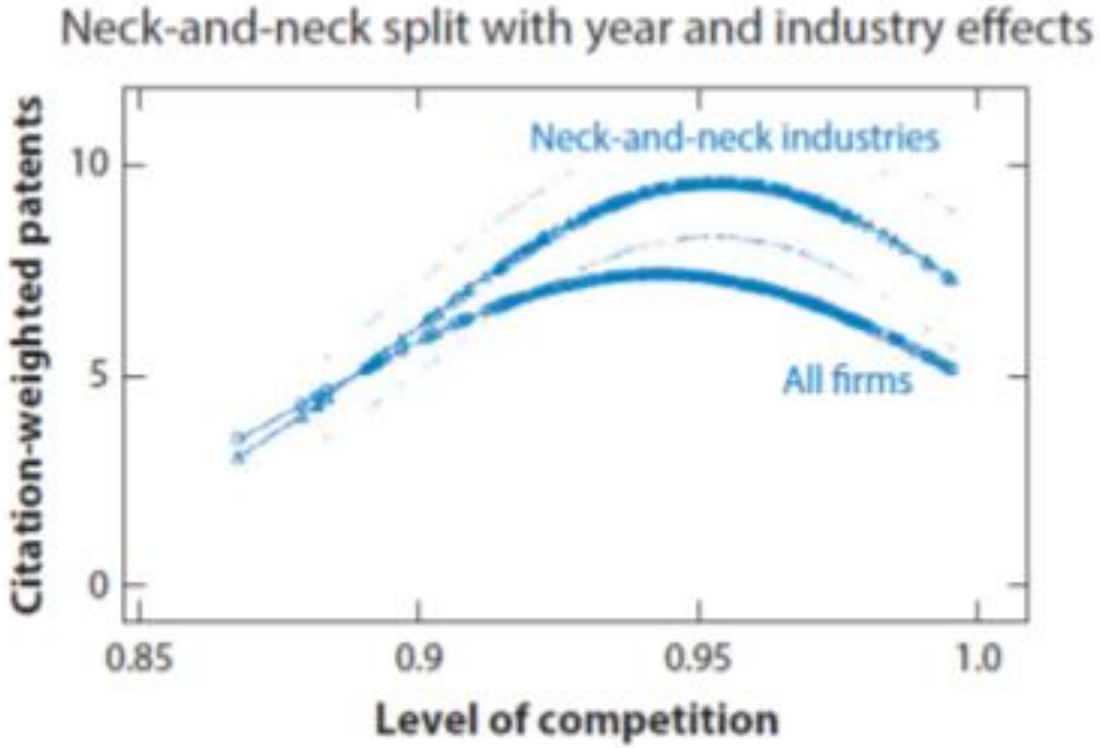
- in sectors that are neck-and-neck, product market competition will make life more difficult for neck-and-neck firms and encourage them to innovate in order to acquire a lead over their rival in the sector (escape-competition effect).

- conversely, in sectors that are leader-follower, increased product market competition will discourage innovation by laggard firms as they do not put much weight on the prospect of becoming a leader (the Schumpeterian effect)

  - under low competition neck-and-neck firms undertake little innovation, leading to an equilibrium with mainly neck-and-neck industries
  - under high competition neck-and-neck firms undertake a lot of innovation, leading to an equilibrium with mainly leader-follower industries

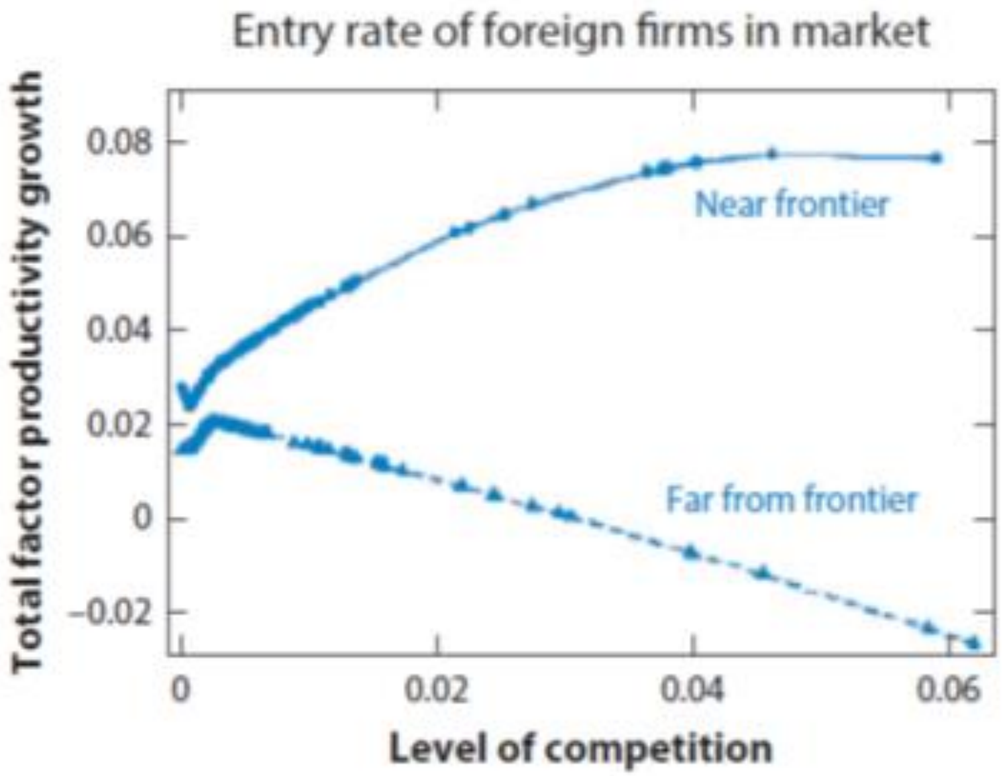
The inverted-U shape

- The relationship between competition and innovation follows an inverted-U pattern, and the average technological gap within a sector increases with competition.



Distance from the frontier

- More intense competition enhances innovation in frontier firms but may discourage it in nonfrontier firms.



Innovation Versus Imitation 1

Acemoglu et al. (2006) and more remotely Nelson and Phelps (1966)

$$\boldsymbol{A_{t+1} = \mu_n \gamma A_t + \mu_m \bar{A}_t} \qquad \boldsymbol{(3)}$$

- $\boldsymbol{A_{t+1}}$ the future (domestic) productivity in period $t + 1$
- $\boldsymbol{A_t}$ the current (domestic) productivity in period t
- $\boldsymbol{\bar{A}_t}$ the current world frontier productivity in period t
- $\boldsymbol{\mu_n}$ the fraction of sector innovates
- $\boldsymbol{\mu_m}$ the fraction of sector imitates

Innovation Versus Imitation 2

From equation (3),

$$A_{t+1} = \mu_n \gamma A_t + \mu_m \bar{A}_t \quad (4)$$

$$A_{t+1} - A_t = \mu_n \gamma A_t - \mu_n A_t + \mu_m \bar{A}_t - \mu_m A_t \quad (5)$$

$$\frac{A_{t+1} - A_t}{A_t} = \mu_n(\gamma - 1) + \mu_m \frac{\bar{A}_t}{A_t} - \mu_m \quad (6)$$

$$\frac{A_{t+1} - A_t}{A_t} = \mu_n(\gamma - 1) + \mu_m(a_t^{-1} - 1) \quad (7)$$

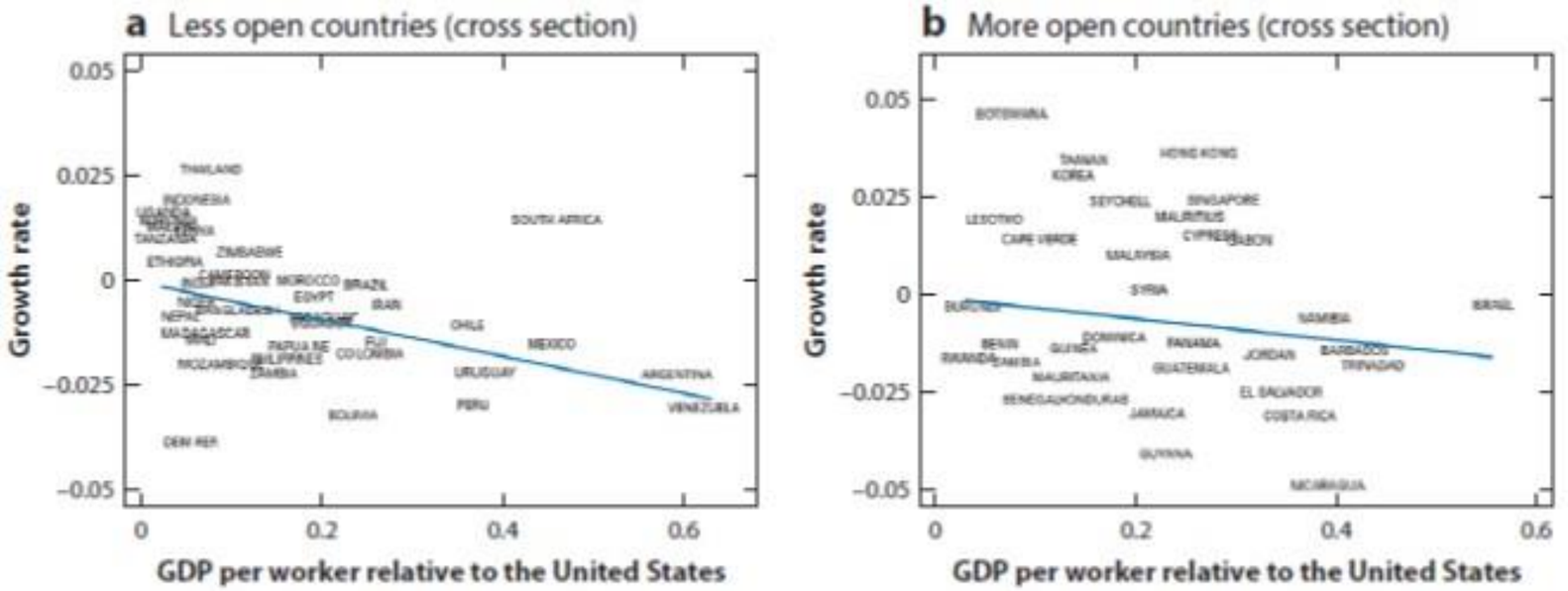
$a_t = \frac{A_t}{\bar{A}_t}$: the country's degree of frontierness

The country's degree of frontierness

$$g_t = \frac{A_{t+1} - A_t}{A_t} = \mu_n(\gamma - 1) + \mu_m(a_t^{-1} - 1)$$

Prediction: The closer to the frontier an economy is (the closer to one the proximity variable a is) the more is growth driven by "innovation-enhancing" rather than "imitation-enhancing" policies or institutions.

– Average growth should decrease more rapidly as a country approaches the world frontier when openness is low.



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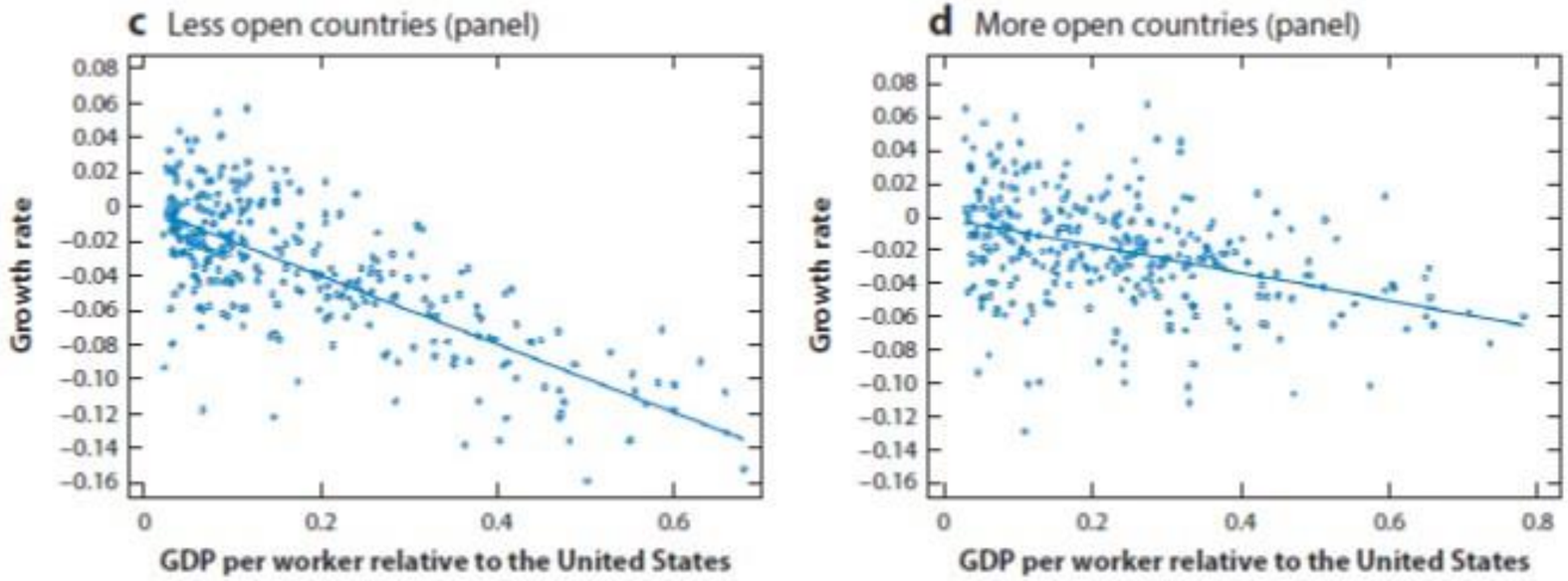
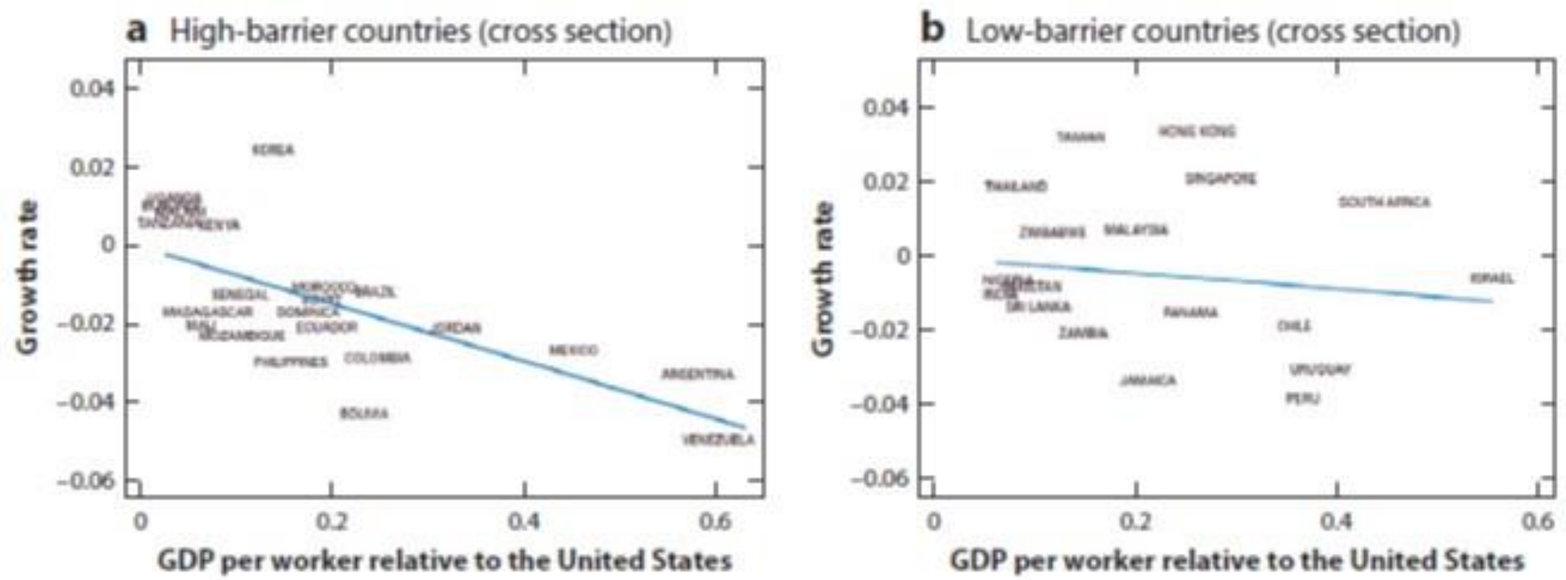


– High entry barriers become increasingly detrimental to growth as a country approaches the frontier



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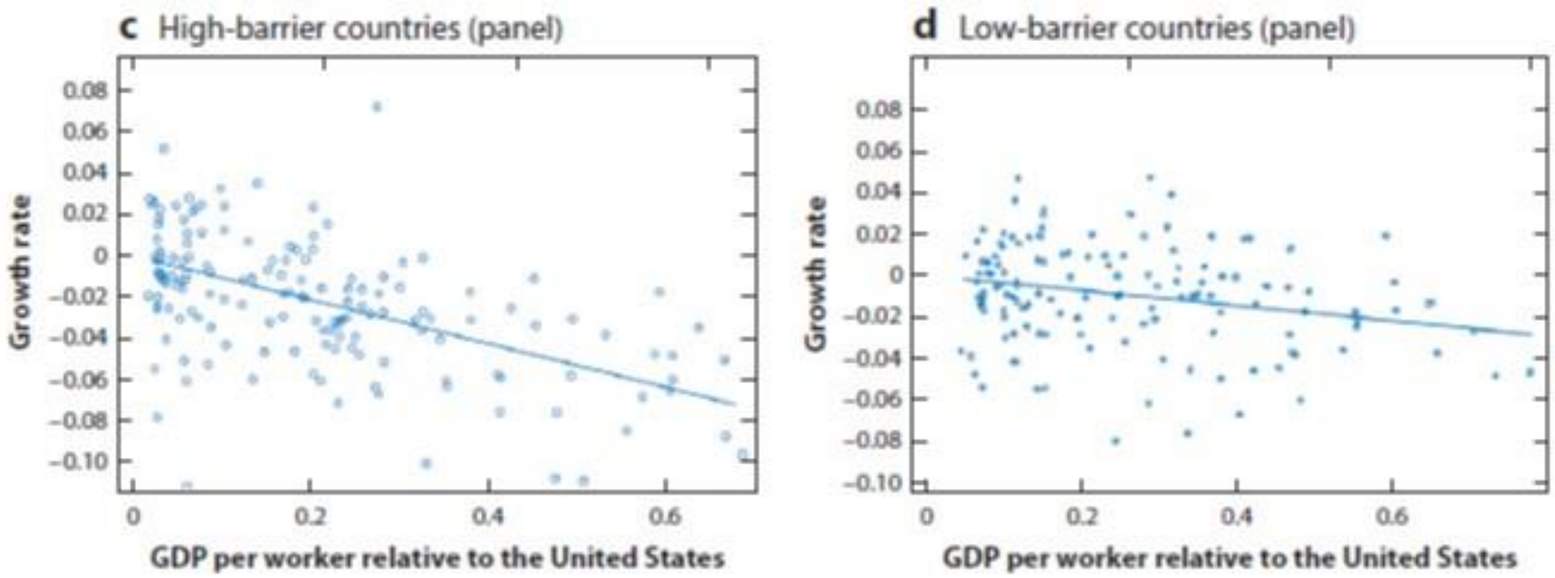
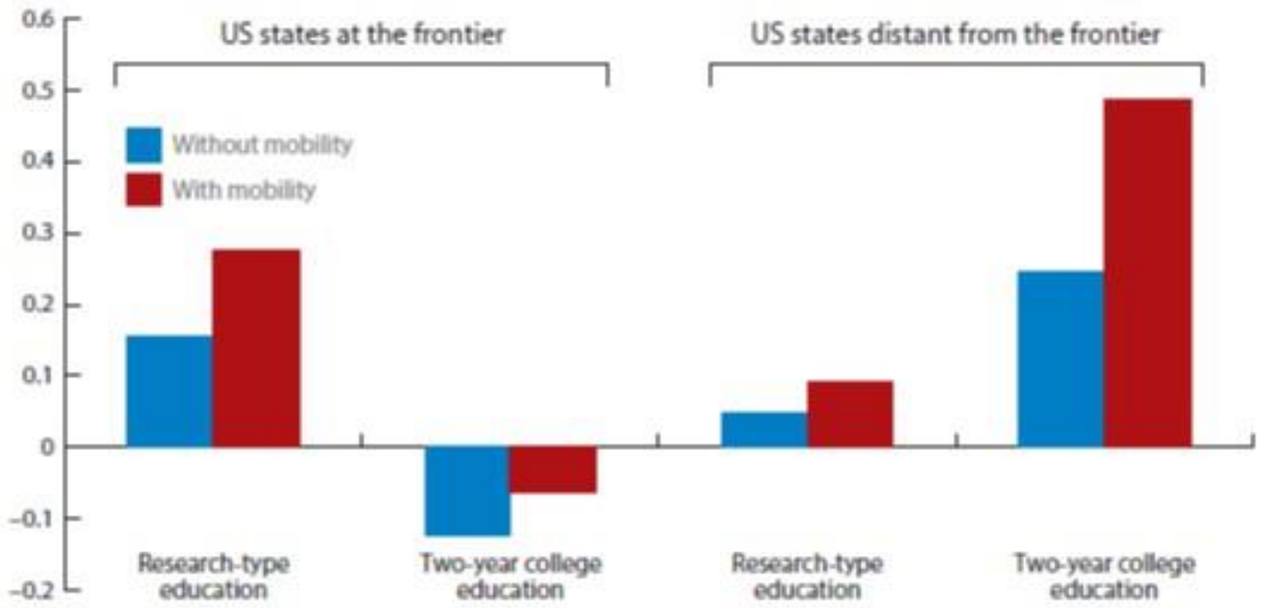


– The more frontier an economy is, the more growth in this economy relies on research education



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