What Do We Learn From Schumpeterian Growth Theory?

Reading Aghion, Akcigit, & Howitt (2014)

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Overview

1. The baseline model
2. The Schumpeterian model with Competition intensity
3. The Schumpeterian model with Institution quality

Core Schumpeterian Idea: Creative Destruction

The Engine of Growth

Growth is generated by **innovations** that...

- award innovators **monopoly rents**.
- **replace old technologies** (Creative Destruction).
- exert **positive knowledge spillovers** on future innovators.

What Makes It Distinct?

This framework can address questions other models cannot:

- The role of **competition** and **firm dynamics**.
- The notion of **appropriate institutions** for development.

1. Baseline Model

Production

- Final Good (FG): $Y_t = A_t y_t^{\alpha}$
- Intermediate Good (IG): $y_t = l_t$
- FG takes prices p_t from IG as given and find optimal y_t^*
- IG takes price of labor w_t as given and find optimal price $p_t^* = w_t/\alpha$.
- Innovation grants monopolistic profits

$$\pi_t = \left(\frac{1-\alpha}{\alpha}\right) w_t y_t \qquad (1.4)$$

- This profit drives innovation.

Innovation

- z: unit of labor spent on R&D
- Arrives at Poisson rate λz (λ: prob. of choosing to innovate)
- If success, quality change $A \to \gamma A$
- New innovator replaces the incumbent (Creative Destruction)
- Innovation decision

$$w_t = \lambda V_{k+1} \qquad (R)$$

Value of innovation

$$\rho V_{k+1} = \pi_{t+1} - \lambda z V_{k+1} \qquad (1.1)$$

The Basic Model: Solving for BGP

Two key equations define the Balanced Growth Path (BGP):

1. **Labor Market Clearing:** $L = y + z$
2. **Research Arbitrage:** A worker is indifferent between R&D and production. $w_t = \lambda V_{k+1}$

The value of innovation is the discounted profit stream, adjusted for destruction risk: $V_{k+1} = \frac{\pi_{k+1}}{\rho + \lambda z}$

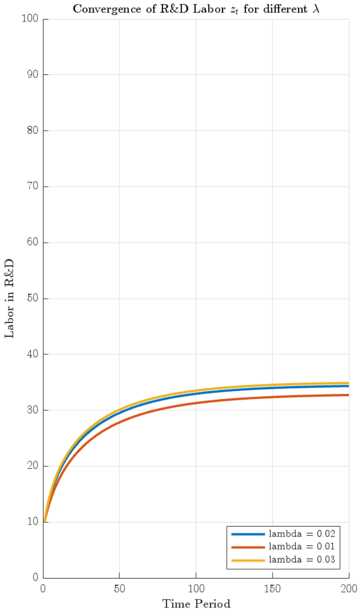
Combining these yields equilibrium R&D and growth:

$$z^* = \frac{\left(\frac{1-\alpha}{\alpha}\gamma\right) L - \rho/\lambda}{1 + \frac{1-\alpha}{\alpha}\gamma} \qquad g^* = \lambda z^* \ln \gamma$$

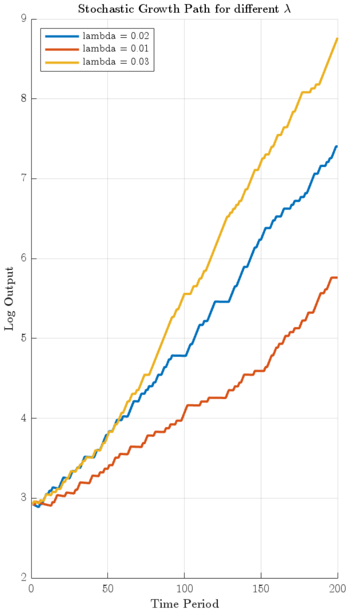
Prediction 0

Turnover correlates with growth: The rate of creative destruction λz^* is positively correlated with the growth rate g^*.

Simulation



Convergence of R&D Labor z_t for different λ
Labor in R&D
Time Period
lambda = 0.02
lambda = 0.01
lambda = 0.03



Stochastic Growth Path for different λ
Log Output
Time Period
lambda = 0.02
lambda = 0.01
lambda = 0.03

Empirical Evidence:

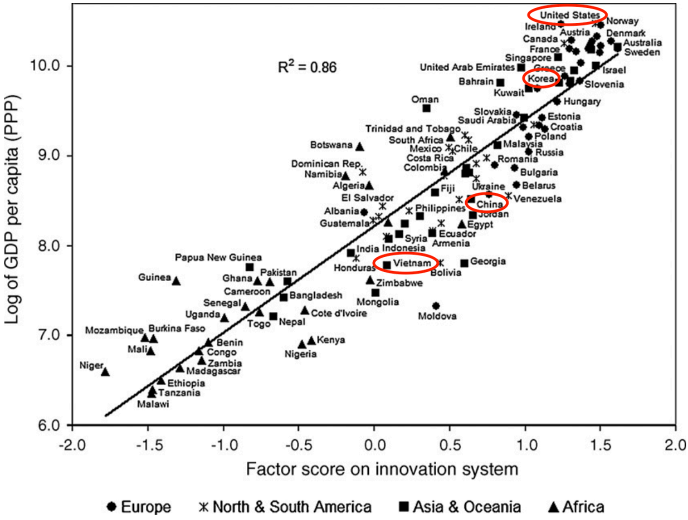


Figure: Innovation and Growth (Fagerberg and Srholec, 2008).

2. Competition: Step-by-Step Innovation

Production

- Final Good (FG): $Y_t = \int_0^1 \ln y_{jt} dj$
- Each sector j has 2 firms $i = A, B$
- Each firm takes the wage rate as given, using only labor to produce

$$y_{it} = A_{it} l_{it}$$

Technology:

$$A_i = \gamma^{-m} A_{leader}$$

- $m = 0$ (leveled): 2 firms are **neck-and-neck** (N&N)
- $m = 1$ (unleveled): The **laggard** is 1 step behind the **leader**.
  Tech level is k-step

$$A_i = \gamma^{k_i}$$

Unit cost

$$c_i = w\gamma^{-k_i}$$

Innovation

- z_0: R&D intensity of N&N firms
- z_{-1}: R&D intensity of laggard
- z_1: RD intensity of the leader maximum lag is 1, so $z_1 = 0$. Leader cannot be more than 1 step ahead.
- R&D cost is universal $\psi(z) = z^2/2$.
- Laggard can move one step ahead to catch up with prob. h just by copying the leader so their innovation rate is $z + h$ for the same cost.

Equilibrium

Unleveled sectors

- Leader's unit cost is c
- Monopolistic profit

$$p_1 y_1 - c y_1 = \left(1 - \frac{c}{p_1}\right) Y = \pi_1 Y$$

Higher p_1 leads to higher π_1 but $p_1 \leq \gamma c$ since leader cannot sell at a price higher than laggard's cost.

- Profit at $p_1 = \gamma c$

$$\pi_1 = 1 - 1/\gamma$$

Laggard will be priced out and earn zero profit

$$\pi_{-1} = 0$$

Leveled sectors

- If there is no collusion, the equilibrium price falls under competitiveness

$$p = c$$

which implies zero profit.

- If 2 firms collude, they act like a leader and set $p = \gamma c$ and share the profit $\pi_1/2$.
- The intensity of competition can be parameterized by $\Delta \in [1/2, 1]$

$$\pi_0 = (1 - \Delta)\pi_1$$

- Higher Δ, more comp., less collusion, lower profits for non-innovators.

Steady-state solutions

- Value of **N&N** firms $m = 0$

$$\rho V_0 = \max_{z_0}[\pi_0 + z_0(V_1 - V_0) + \overline{z}_0(V_{-1} - V_0) - \omega z_0^2/2]$$

LHS: ρV_0 (opportunity cost of the investment). Also impatience: $(\beta = e^{-\rho})$
RHS: profit flow π_0, plus the expected capital gain from innovating $z_0(V_1 - V_0)$, plus the expected capital loss if the rival innovates and becomes a leader, minus the R&D cost $\omega z_0^2/2$ (with $\omega = w/Y$ as normalized steady-state wage rate).

- Value of laggard $(m = -1)$

$$\rho V_{-1} = \max_{z_{-1}}[\pi_{-1} + (z_{-1} + h)(V_0 - V_{-1}) - \omega z_{-1}^2/2)]$$

RHS: profit flow $\pi_{-1} = 0$, plus the expected capital gain from catching up $(z_{-1} + h)(V_0 - V_{-1})$ minues the R&D cost $\omega z_{-1}^2/2)$.

- Value of leader $(m = 1)$

$$\rho V_1 = \pi_1 + (z_{-1} + h)(V_0 - V_1)$$

RHS: the profit flow π_1 plus the expected capital loss from being caught up. The leader does not invest in R&D so $z_1 = 0$.

The Escape-Competition vs. Schumpeterian Effect

FOC for neck-and-neck and laggard

$$\omega z_0 = V_1 - V_0$$
$$\omega z_{-1} = V_0 - V_{-1}$$

Simplification: $\omega = 1$. Plugging in, and solve for z_0 and z_{-1}

$$z_0 = -(\rho + h) + \sqrt{(\rho + h)^2 + 2\Delta\pi_1},$$
$$z_{t-1} = -(\rho + z_0 + h) + \sqrt{(\rho + z_0 + h)^2 + 2(1 - \Delta)\pi_1 + z_0^2}$$

- **Effects on neck-and-neck**: z_0 is increasing in Δ. Higher competition reduces π_0, increasing the incremental profit from innovating $(\pi_1 - \pi_0) = \Delta\pi_1$, which incentivizes neck-and-neck firms to innovate more to escape competition.
- **Effects on laggards**: z_1 is ambiguous on Δ. There is a Schumpeterian effect where higher competition intensity Δ reduces the profit π_0 , which the laggard will get if they catch up. This is an innovation discouraging effect. If laggards are impatient (high ρ), the Schumpeterian effect dominates.

Steady state

- μ_1: fraction of unleveled sectors
- μ_0: fraction of leveled sectors

On aggregate, each period

- outflow of unleveled: $(z_{-1} + h)\mu_1$ (catching up)
- inflow into unleveled: $2z_0\mu_0 = 2z_0(1 - \mu_1)$ (both firms innovate to escape)

In the steady state, μ_1 and μ_0 are constants

$$(z_{-1} + h)\mu_1 = 2z_0(1 - \mu_1)$$

Solving for μ_1 yields $\mu_1 = \frac{2z_0}{z_{-1}+h+2z_0}$. The agg. flow of innovations in all sectors is

$$x = \underbrace{(z_{-1} + h)\mu_1}_{laggard \;\; catching \;\; up} + \underbrace{2z_0(1 - \mu_1)}_{neck-and-neck \;\; firms \;\; innovate}$$

The Inverted-U Relationship

- **Low Competition:** Economy is mostly Leveled. Strong escape-competition effect $\Rightarrow x$ increases with Δ.
- **High Competition:** Economy is mostly Unleveled. Schumpeterian effect may dominate $\Rightarrow x$ decreases with Δ.

Prediction 1

The relationship between product market competition and innovation is **inverted-U-shaped**. The average technology gap within a sector increases with competition.

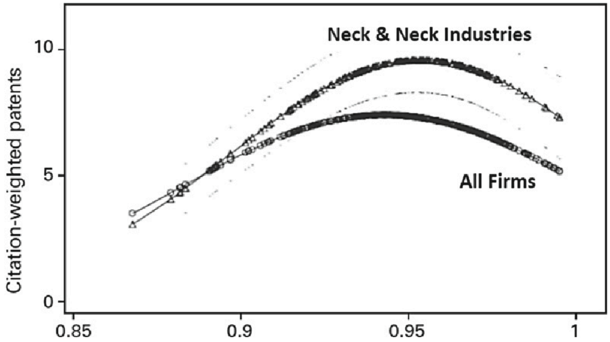


Figure: Aghion et al. (2005) use a panel dataset on UK firms spanning 17 two-digit SIC industries between 1973 and 1994 to test this.

Prediction 2

More intense competition enhances innovation in “frontier” firms but may discourage it in “non-frontier” firms.

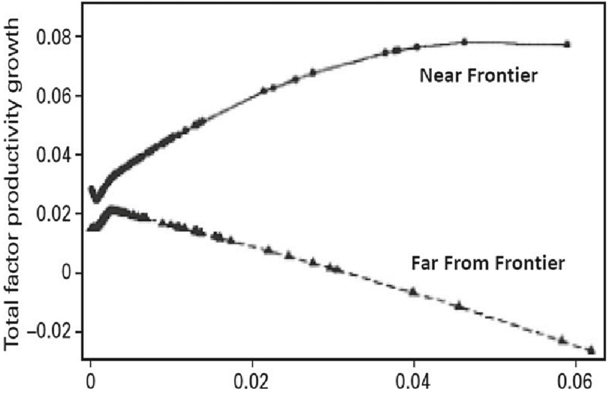


Figure: Aghion et al. (2009) use a panel of more than 5000 incumbent lines of businesses in UK firms in 180 four-digit SIC industries over the time period 1987–1993 to test this hypothesis.

Model 3: Institution

Growth-enhancing institutions depend on a country's proximity to the frontier

- World tech $\overline{A}$ grows exogenously

  $$\overline{A}_t = \gamma \overline{A}_{t-1}$$

  Home country's average productivity is A_t.

- Proximity to the frontier

  $$a_t = A_t / \overline{A}_t$$

  Denote:
  - μ_n fraction of innovating sectors
  - μ_m fraction of immitating sectors

  Then, growth in discrete time is

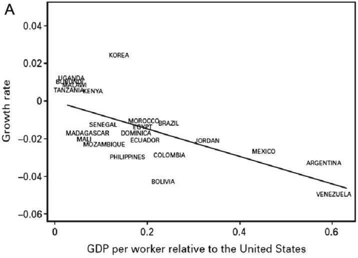
  $$A_{t+1} - A_t = \underbrace{\mu_n(\gamma - 1)A_t}_{innovation} + \underbrace{\mu_m(\overline{A}_t - A_t)}_{imitation}$$

  Dividing both sides by A_t

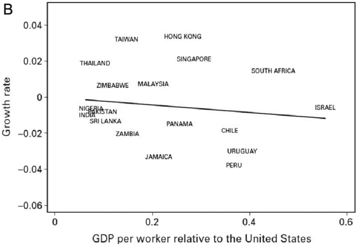
  $$g_t = \frac{A_{t+1} - A_t}{A_t} = \mu_n(\gamma - 1) + \mu_m\Big(\frac{1}{a_t} - 1\Big)$$

Prediction

The closer to the frontier an economy is, that is, the closer to one the proximity variable at is,the more is growth driven by innovation-enhancing rather than imitation-enhancing policies or institutions.



(a) High barriers to entry



(b) Low barriers to entry

Figure: Entry costs (barrier to entry) is measured by the number of days to create a new firm in the various countries, relative to the median.

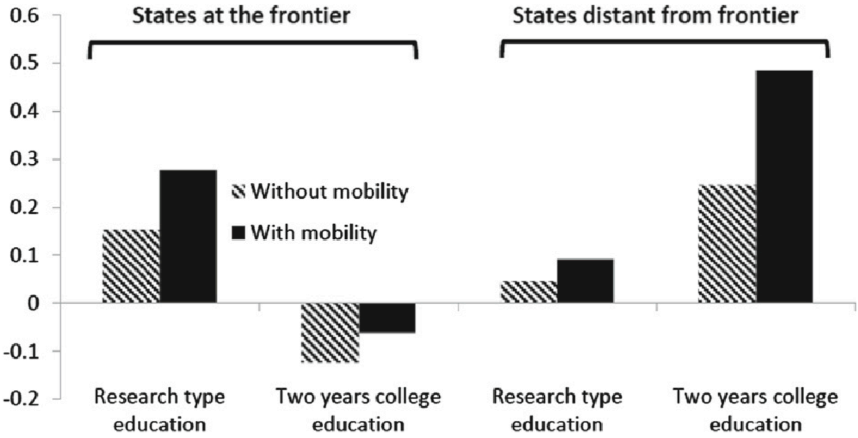


Figure: Cross-US-states panel data. Mobility indicates workers' mobility across US states.

The more frontier a country or region is, the more its growth relies on frontier innovation. Research-type education is always more growth-enhancing in states that are more frontier, whereas a bigger emphasis on 2-year colleges is more growth-enhancing in US states that are farther below the productivity frontier.

Basic Structure

- Discrete time model with periods $t = 0, 1, 2, \ldots$
- All agents and firms live for one period
- Final good produced using continuum of intermediate inputs
- Each intermediate sector has one incumbent and one potential entrant

Production Structure

Final Good Production:

$$\ln Y_t = \int_0^1 \ln y_{jt} dj$$

Intermediate Good Production:

$$y_{jt} = A_{jt} l_{jt}$$

Competitive Fringe: Can produce with technology A_{jt}/γ
Resulting Profit Flow:

$$\pi_{jt} = \pi Y_t \quad \text{where} \quad \pi \equiv \frac{\gamma - 1}{\gamma}$$

Labor Market Equilibrium

- Labor demand per intermediate firm: $l_{jt} = \frac{Y_t}{\gamma w_t} \equiv l$
- Total labor supply $= 1$ (used only for production)
- Labor market clearing: $l = 1 \Rightarrow w_t = \frac{Y_t}{\gamma}$
- Final output: $Y_t = A_t$ where $\ln A_t \equiv \int_0^1 \ln A_{jt} dj$

Technology and Frontier

- World technology frontier: $\overline{A_t} = \gamma \overline{A}_{t-1}$
- Sector types at beginning of period t:
  - Advanced: $A_{jt}^b = \overline{A}_{t-1}$
  - Backward: $A_{jt}^b = \overline{A}_{t-2}$
- Spillovers come from Imitation: Backward sectors automatically jump to $\overline{A}_{t-1}$ when frontier advances.

Innovation Process

- Only potential entrants innovate
- Innovation increases productivity: $A_{jt} = \gamma A_{jt}^{b}$
- Innovation technology: Spending $A_t \lambda z_{jt}^2/2$ yields success probability z_{jt}
- Timing:
  1. Period starts with productivity A_{jt}^{b}
  2. Entrant invests in R&D
  3. If successful, produces with $A_{jt} = \gamma A_{jt}^{b}$
  4. Otherwise, incumbent produces with $A_{jt} = A_{jt}^{b}$

Democracy and Entry

- Democracy level: $\beta \in [0, 1]$ as **freedom to enter**.
- Probability that successful innovation leads to actual entry with probability β and is blocked with prob. $1 - \beta$ [1]
- Probability of unblocked entry: βz_j

Measurement of democracy

- Captures freedom from expropriation, lobbying, and entry barriers
- Democracy is measured using the Polity 4 indicator, which itself is constructed from combining constraints on the executive; the openness and competitiveness of executive recruitment; and the competitiveness of political participation.

[1] a bit ad-hoc

Entrant's Optimization Problem

The potential entrant in sector j chooses z_{jt} to maximize:

$$\max_{z_{jt}} \left\{ z_{jt}\beta\pi Y_t - A_t\lambda\frac{z_{jt}^2}{2} \right\}$$

- Expected benefit: $z_{jt}\beta\pi Y_t$
- R&D cost: $A_t\lambda\frac{z_{jt}^2}{2}$
- Note: $Y_t = A_t$ in equilibrium

FOC:

$$z_{jt} = \frac{\beta\pi}{\lambda} \equiv \bar{z}$$

- innovation intensity increases with democracy β and profit potential π

Growth Rate Derivation

Let μ be the fraction of advanced sectors at beginning of period t.

- Beginning-of-period average productivity:

$$A_{t-1} = \mu \overline{A}_{t-1} + (1-\mu)\overline{A}_{t-2}$$

- End-of-period average productivity:

$$A_t = \mu \left[\beta \bar{z} \gamma \overline{A}_{t-1} + (1-\beta\bar{z})\overline{A}_{t-1}\right] + (1-\mu)\overline{A}_{t-1}$$

The growth rate is:

$$g_t = \frac{A_t - A_{t-1}}{A_{t-1}}$$

After substitution and simplification:

$$g_t = \gamma \frac{\mu\beta\bar{z}(\gamma-1)+1}{\mu(\gamma-1)+1} - 1 > 0$$

Effect of Democracy on Growth

$$\frac{\partial g_t}{\partial \beta} = \left(\bar{z} + \frac{\partial \bar{z}}{\partial \beta}\beta\right) \frac{\gamma\mu(\gamma - 1)}{\mu(\gamma - 1) + 1} > 0$$

- Democracy always enhances growth ($\frac{\partial g_t}{\partial \beta} > 0$)
- Effect is stronger when μ is larger (more frontier sectors):

$$\frac{\partial^2 g_t}{\partial \beta \partial \mu} = \left(\bar{z} + \frac{\partial \bar{z}}{\partial \beta}\beta\right) \frac{(\gamma - 1)\gamma}{[\mu(\gamma - 1) + 1]^2} > 0$$

Democratization allows for more turnover which in turn encourages outsiders to innovate and replace the incumbents.

Empirical Evidence

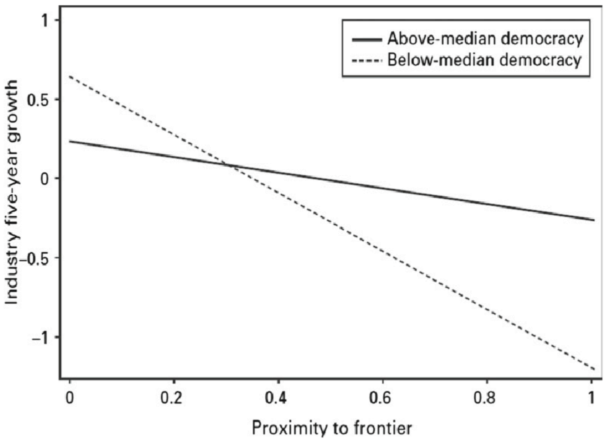


Figure: Data from Aghion et al. (2007)

Growth is higher in more democratic countries when they are close to the technological frontier, but not when they are far below the frontier.

Simulation

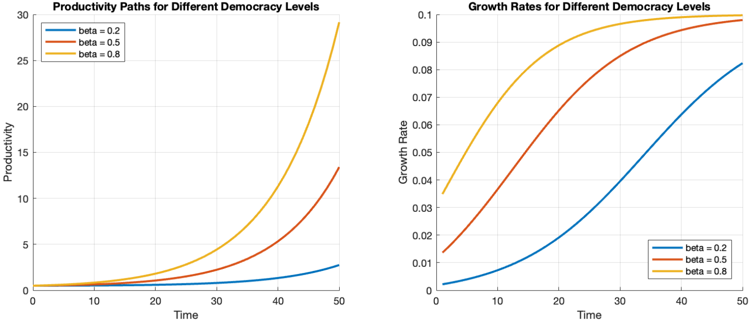


Figure: Simulations for different values of β

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