The Effects of Barriers to Technology Adoption on the Japanese Prewar and Postwar Growth

Daisuke Ikeda and Yasuko Morita

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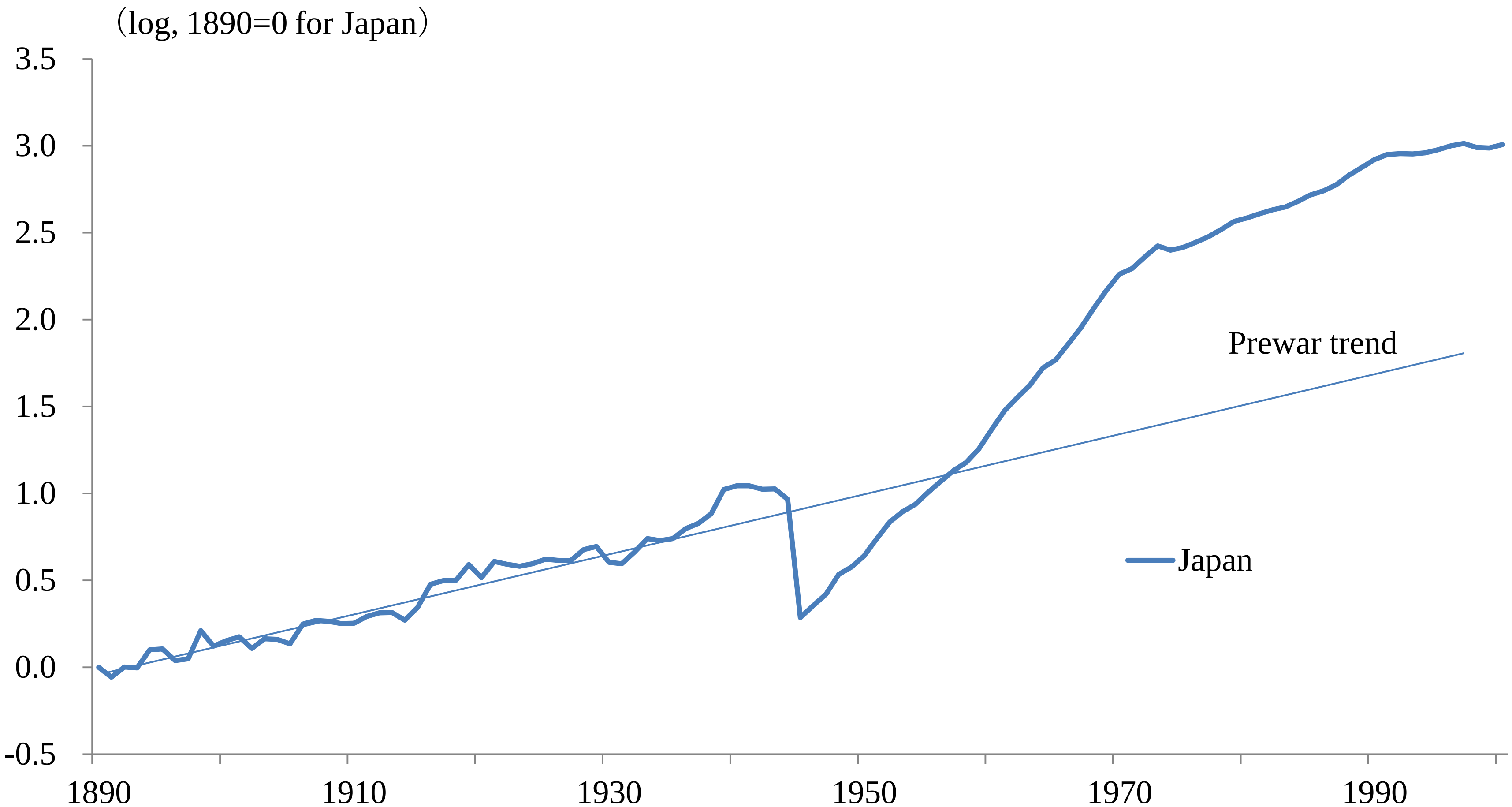
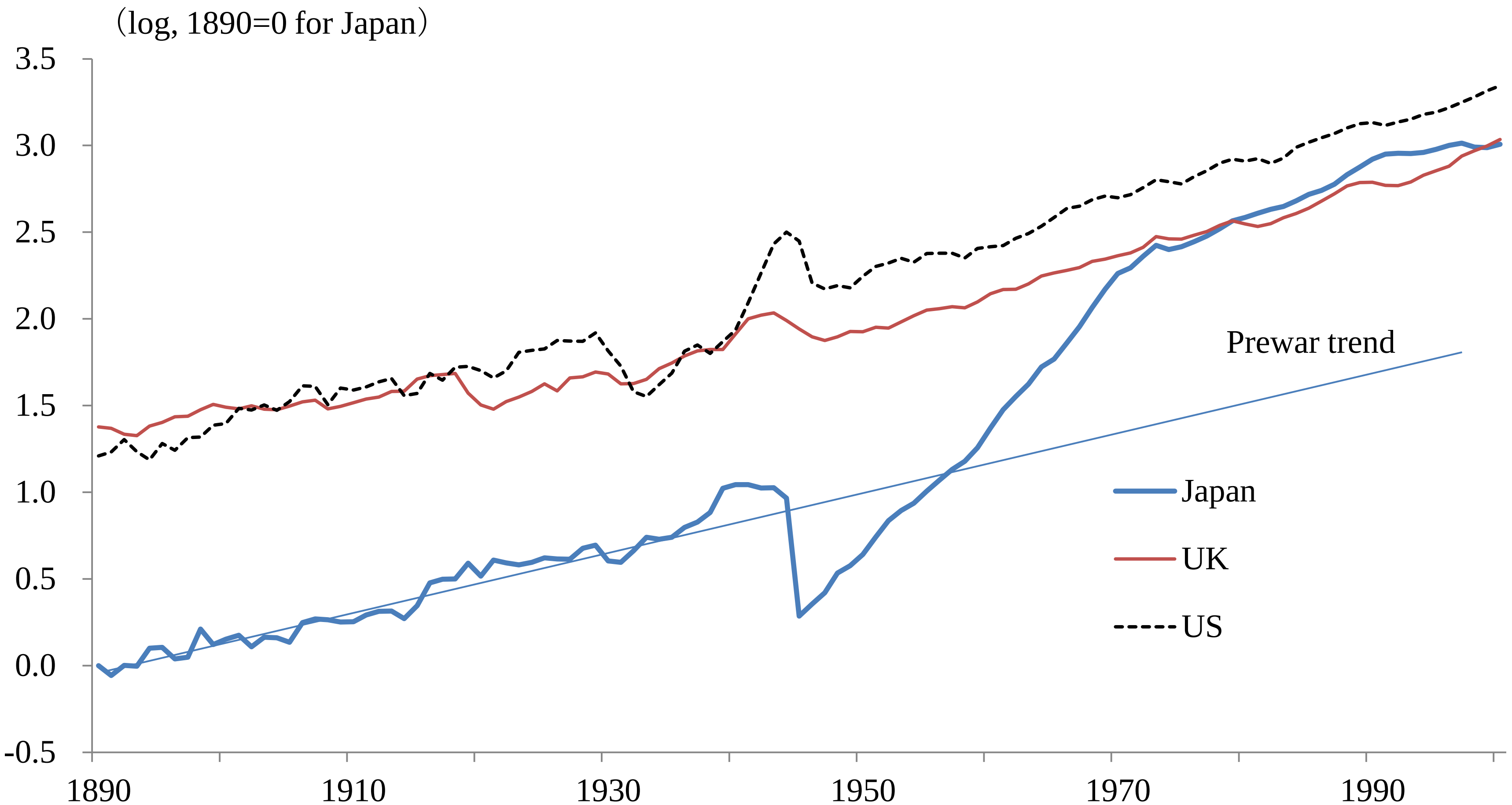
Per-capita GDP for Japan



Source: Professor Angus Maddison’s Database

Per-capita GDP for Japan, UK, and US



Source: Professor Angus Maddison’s Database

Three Puzzles about Japan's Economic Growth

1. Prewar-Stagnation

2. Postwar growth miracle

3. Lost Decade

This paper addresses 1 and 2.

Road Map

1. Hypothesis, main results, and related literature
2. Model
3. Quantitative analyses and results
4. Analyses from historical perspective
5. Some caveats

Hypothesis on Barriers to Technology Adoption

Three reasons why we focus on the barriers

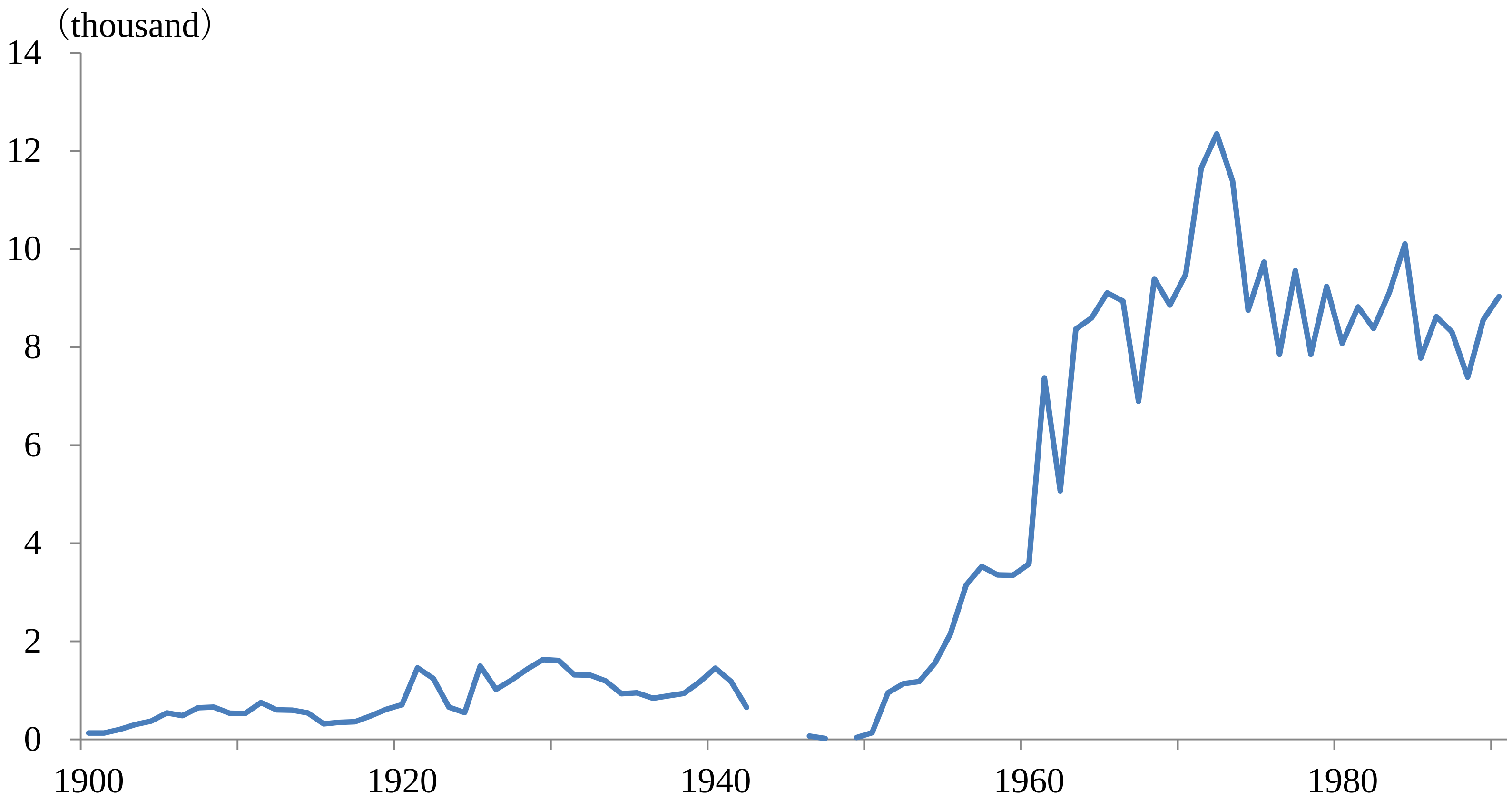
1. The source of postwar growth miracle is the high growth of TFP (Hayami and Ogasawara, 1999; Otsu, 2009)

2. Historical evidence on the role of technology adoption in the postwar growth miracle (Peck and Tamura, 1976)

3. Number of existing contracts of technology adoption from abroad: 231 in 1941 → 1,413 in 1960.

Hypothesis on Barriers to Technology Adoption (cont'd)

Number of patents registered in Japan by foreigners

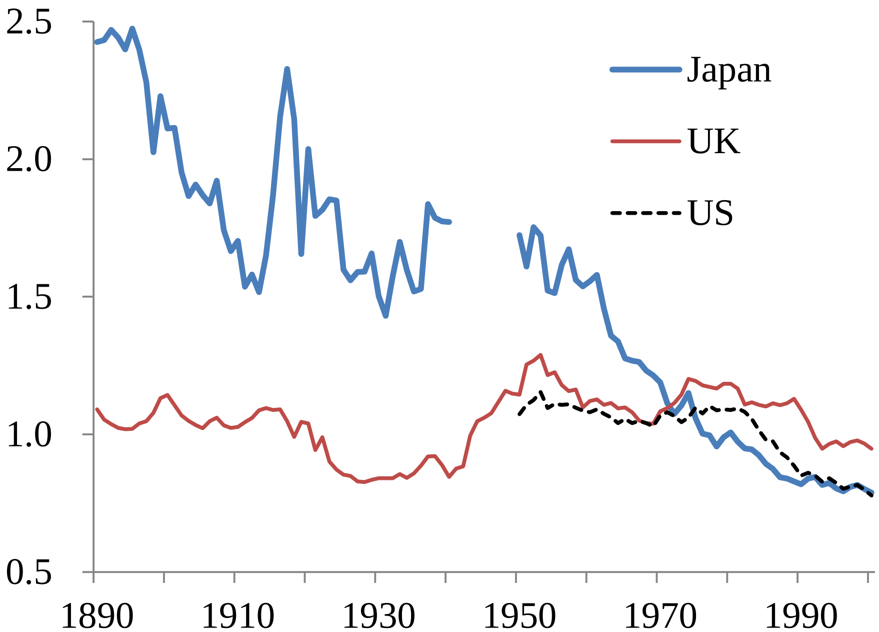


Source: Japan Patent Office

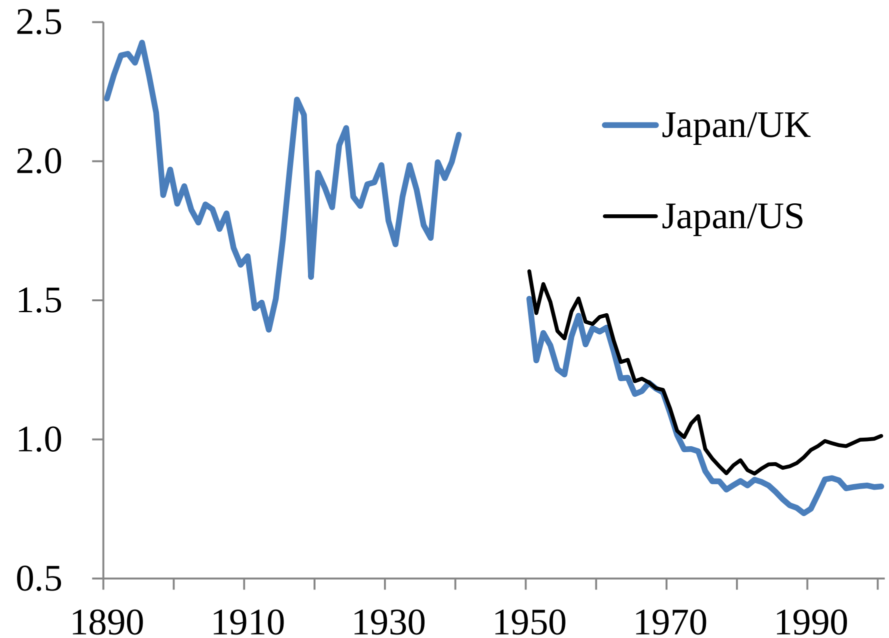
"Technology" adoption : Investment-Specific Technology (IST)

- Technology importation concentrated on capital goods.
- Data on the relative price of investment support the hypothesis.
- IST could explain the postwar growth of TFP

(a) Relative price of investment



(b) Ratio of relative price of investment



Sources: Appendix for the period before 1950 and Penn World Table 7.1. for 1950 and after.

What We Do

- Building a two-sector dynamic model that features endogenous technology adoption and its barriers
- Quantifying the barriers by applying data to the model
- Analyzing the effect of the barriers on the prewar stagnation
- Analyzing the effect of a reduction in the barriers on the postwar growth miracle
- Discussing the sources of the barriers from historical perspective

Main Results

- Barriers to technology adoption explains about 1/4 of a gap of per-capita GDP between Japan and the UK in the prewar period.
- Postwar reduction in the barriers explains about 1/4 of the growth miracle.
- Simultaneously, the model replicates the transitional dynamics of the relative price of investment in the postwar period.
- Three sources of barriers to technology adoption from historical perspective: (i) Low capability for absorbing technology; (ii)economic and political instability; (iii) less-competitive environment.

Related Literature

- Hayashi and Prescott (2008)
- Esteban-Pretel and Sawada (2014)
- Aoki, Esteban-Pretel, Okazaki, and Sawada (2010)
- Otsu (2009)
- Braun, Okada, and Sudo (2008)
- Ngai (2004)

Model

Overview of the Model

- Simplified version of Comin and Gertler (2006)

  -- Two-sector neoclassical growth model + endogenous technology adoption

- Five types of agents: (i) consumption-good firms; (ii) final-investment-good firms; (iii) intermediate-investment-good firms; (iv) technology-adoption firms; (v) households.

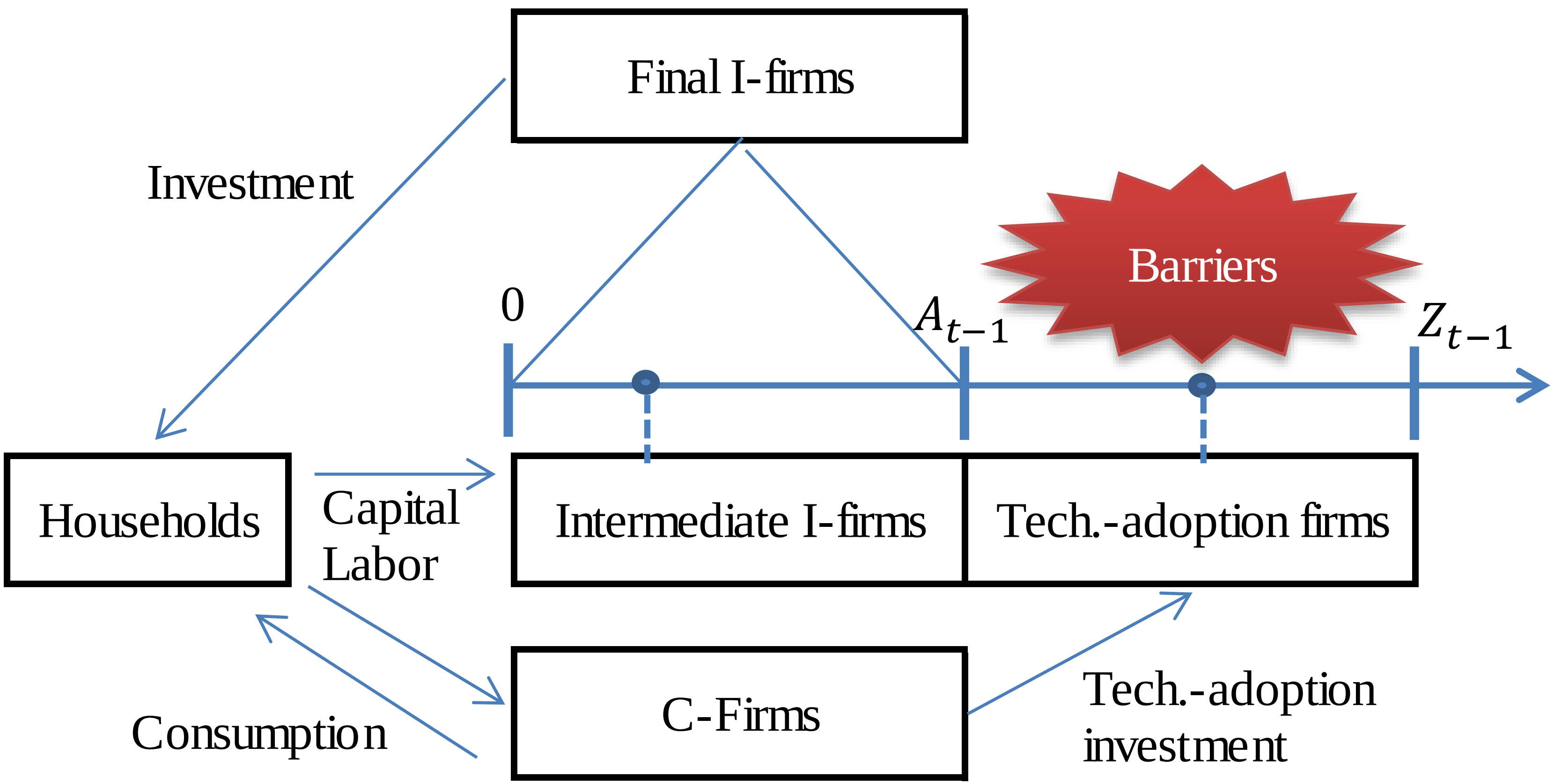
- Technology-adoption firms transform an idea into an idea in practical use (technology) that produces a new intermediate-investment good.

  -- Model of expanding varieties of intermediate goods as in Romer (1990）

  -- World frontier of ideas

  -- Barriers to technology adoption that make it costly to adopt technology

Overview of the Model (cont'd)



Consumption-good firms

Competitive consumption-good firms

Production function

$$y_{c,t} = z_t k_{c,t-1}^{\alpha} n_{c,t}^{1-\alpha}, \quad 0 < \alpha < 1,$$

$$z_t = z_0 \gamma^t.$$

The price of consumption good = Numeraire

Profit maximization → Factor prices

$$w_t = (1-\alpha) z_t (k_{c,t-1}/n_{c,t})^{\alpha},$$

$$r_t = \alpha z_t (k_{c,t-1}/n_{c,t})^{\alpha-1}.$$

Final-investment-good firms

Competitive final-investment-good firms

Production function

$$y_{I,t} = \left(\int_0^{A_{t-1}} y_{I,t}(i)^{\frac{1}{\theta}} di \right)^{\theta}, \quad \theta > 1,$$

Profit maximization

$$\max p_{I,t} y_{I,t} - \int_0^{A_{t-1}} p_{I,t}(i) y_{I,t}(i) di$$

Demand function and the (relative) price of investment

$$y_{I,t}(i) = \left(\frac{p_{I,t}(i)}{p_{I,t}} \right)^{\frac{\theta}{1-\theta}} y_{I,t}, \qquad p_{I,t} = \left(\int_0^{A_{t-1}} p_{I,t}(i)^{\frac{1}{1-\theta}} di \right)^{1-\theta}.$$

Intermediate-investment-good firms

Monopolistically competitive intermediate-investment-good firm $i \in [0, A_{t-1}]$

Production function

$$y_{I,t}(i) = z_t k_{I,t-1}(i)^{\alpha} n_{I,t}(i)^{1-\alpha}.$$

Cost minimization → Factor prices

$$w_t = mc_{I,t}(1-\alpha) z_t (k_{I,t-1}/n_{I,t})^{\alpha},$$

$$r_t = mc_{I,t} \alpha z_t (k_{I,t-1}/n_{I,t})^{\alpha-1},$$

Identical capital-labor ratio → $mc_{I,t} = 1$

Intermediate-investment-good firms (cont'd)

Profit maximization

$$\max p_{I,t}(i)\, y_{I,t}(i) - mc_{I,t} y_{I,t}(i)$$

Optimality conditions → Relative price of investment

$$p_{I,t}(i) = \theta mc_{I,t} = \theta, \qquad p_{I,t} = \frac{\theta}{A_{t-1}^{\theta-1}}.$$

Aggregated production function

$$y_{I,t} = A_{t-1}^{\theta-1} z_t k_{I,t-1}^{\alpha} n_{I,t}^{1-\alpha}.$$

Value of an intermediate-investment-good firm

$$V_t = (\theta - 1) A_{t-1}^{-1} z_t k_{I,t-1}^{\alpha} n_{I,t}^{1-\alpha} + m_{t,t+1} V_{t+1}$$

Technology-adoption firms

Competitive technology-adoption firms

Each adoption firm owns an not-yet-adopted idea in $(A_{t-1}, Z_{t-1}]$

Each adoption firm invests $i_{a,t}$ to adopt technology with the success probability of λ_t where

$$\lambda_t = \frac{\lambda_0}{\pi}\left(\frac{A_{t-1}}{A^*_{t-1}} i_{a,t}\right)^{\omega},\ 0 < \omega < 1,\ \lambda_0 > 0$$

Here $\pi > 0$ denotes the barriers to technology adoption and $A^*_{t-1} \equiv z_t^{\frac{1}{1-\alpha}} A_{t-1}^{\frac{(\theta-1)\alpha}{1-\alpha}}$

Profit maximization

$$J_t = \max_{\{i_{a,t}\}}\{-i_{a,t} + m_{t,t+1}[\lambda_t V_{t+1} + (1-\lambda_t)J_{t+1}]\}$$

Technology-adoption firms (cont'd)

Optimality condition

$$1 = \frac{\lambda_0 \omega}{\pi} \left(\frac{A_{t-1}}{A^*_{t-1}} i_{a,t} \right)^{\omega-1} \frac{A^*_{t-1}}{A_{t-1}} m_{t,t+1} (V_{t+1} - J_{t+1})$$

Technology adoption investment $i_{a,t}$ is

✓ Decreasing in the barriers to technology adoption

✓ Increasing in the value of the intermediate-investment-good firm

Law of motion for adopted ideas and the frontier of ideas

$$A_t = A_{t-1} + \lambda_t (Z_{t-1} - A_{t-1})$$

$$Z_t = \gamma_Z Z_{t-1}$$

Households

Households own capital stock and supply one unit of labor inelastically.

Utility maximization

$$\max \sum_{t=0}^{\infty} \beta^t \log(c_t),$$

s.t.

$$c_t + p_{I,t} y_{I,t} = w_t + r_t k_{t-1} + T_t,$$

$$k_t = (1-\delta) k_{t-1} + y_{I,t},$$

Euler equation

$$1 = \frac{\beta c_t}{c_{t+1}} \left[\frac{r_{t+1} + p_{I,t+1}(1-\delta)}{p_{I,t}} \right]$$

Market Clearing and Equilibrium

Market clearing conditions:

$$z_t k_{c,t-1}^{\alpha} n_{c,t}^{1-\alpha} = c_t + (Z_{t-1} - A_{t-1}) i_{a,t},$$

$$k_t = k_{c,t} + k_{I,t},$$

$$1 = n_{c,t} + n_{I,t}.$$

Output (per capita GDP)

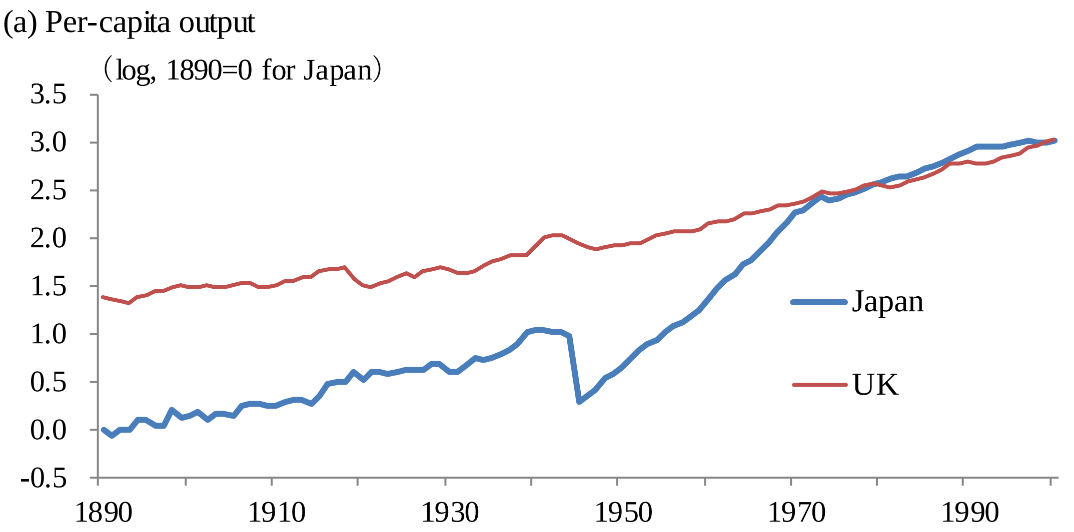
$$y_t = z_t k_{c,t-1}^{\alpha} n_{c,t}^{1-\alpha} + p_{I,t} A_{t-1}^{\theta-1} z_t k_{I,t-1}^{\alpha} n_{I,t}^{1-\alpha}.$$

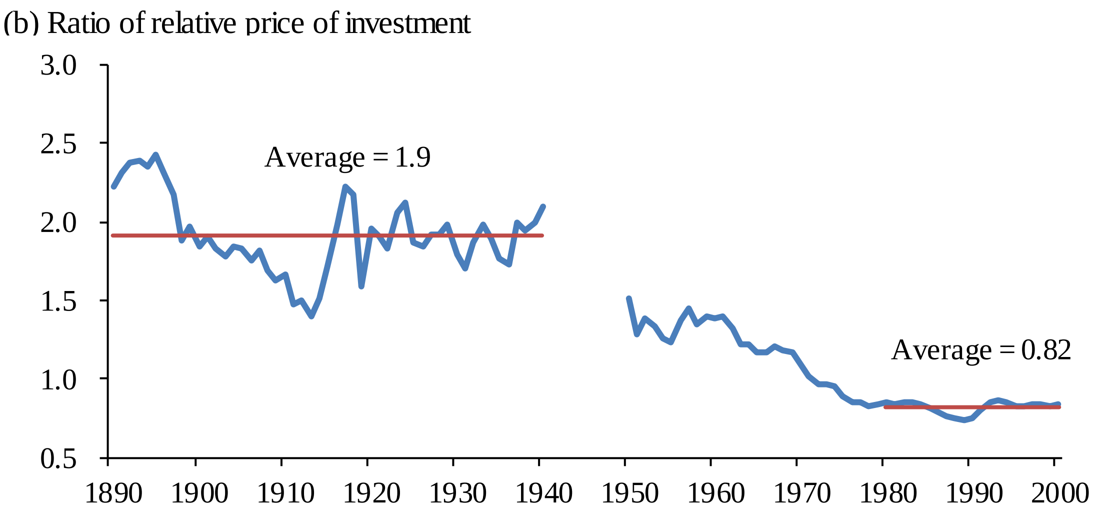
Equilibrium : standard concept of competitive equilibrium

Quantitative Analyses and Results

Approach of Quantitative Analyses

- Quantifying the degree of the barriers from the model and data





Quantifying the barriers

- Two model economies: Japan and the UK
- Two differences: (i)Barriers π; (ii) Initial TFP level z_0 $(z_{0,UK} = 1)$
- Three assumptions consistent with the data
  1. The UK economy is in steady state (π_{UK})
  2. The prewar Japan's economy is in steady state (π_{JP})
  3. Japan's barriers change after the war $\pi_{JP} \longrightarrow \pi'_{JP} = 1$
- Relationship between relative price of investment and distance to frontiers $(a = A/Z)$

$$\frac{p_{I,\mathrm{JP}}}{p_{I,\mathrm{UK}}} = 1.9 = \left(\frac{a_{\mathrm{UK}}}{a_{\mathrm{JP}}}\right)^{\theta-1}, \qquad \frac{p'_{I,\mathrm{JP}}}{p_{I,\mathrm{UK}}} = 0.82 = \left(\frac{a_{\mathrm{UK}}}{a'_{\mathrm{JP}}}\right)^{\theta-1}$$

- One-to-one relationship between π and the distance

$\rightarrow \pi_{JP} = 7.2$

Model Parameters

Parameter	Description	Value
β	Subjective discount factor	0.97
α	Capital share	0.36 or 0.5
δ	Capital depreciation rate	0.089
θ	Gross markup	1.2
γ	Gross growth rate of neutral technology	1.0061
γ_z	Gross growth rate of the frontier of ideas	1.0463
λ	Adoption probability in the steady state in Japan after the war	0.125
ω	Elasticity of technology adoption	0.6

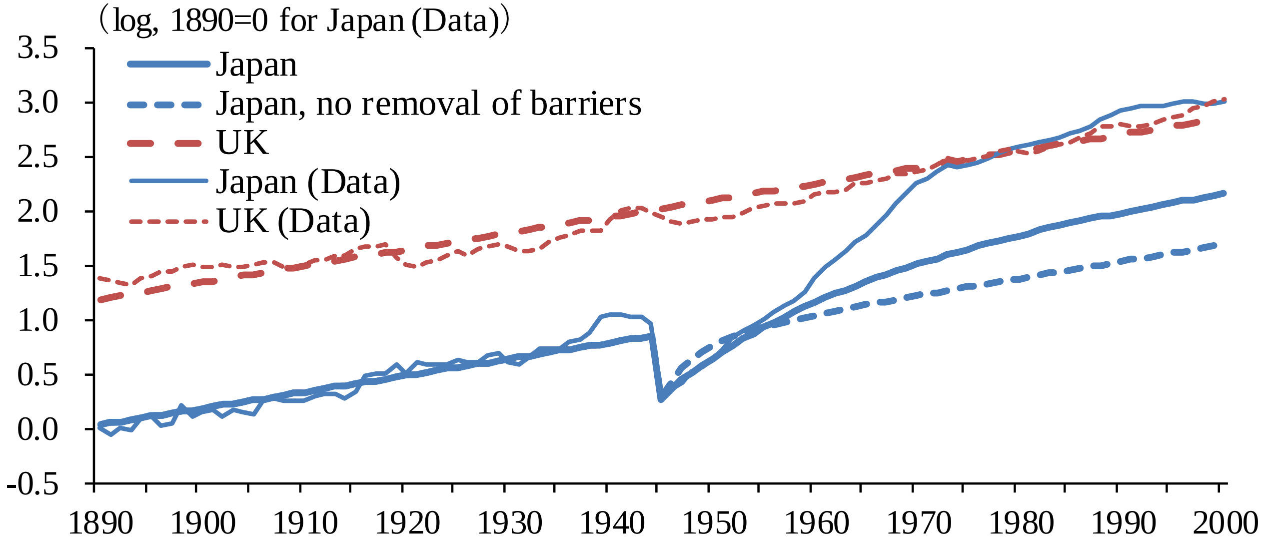
Simulation

- Model solution method：Function-iteration method

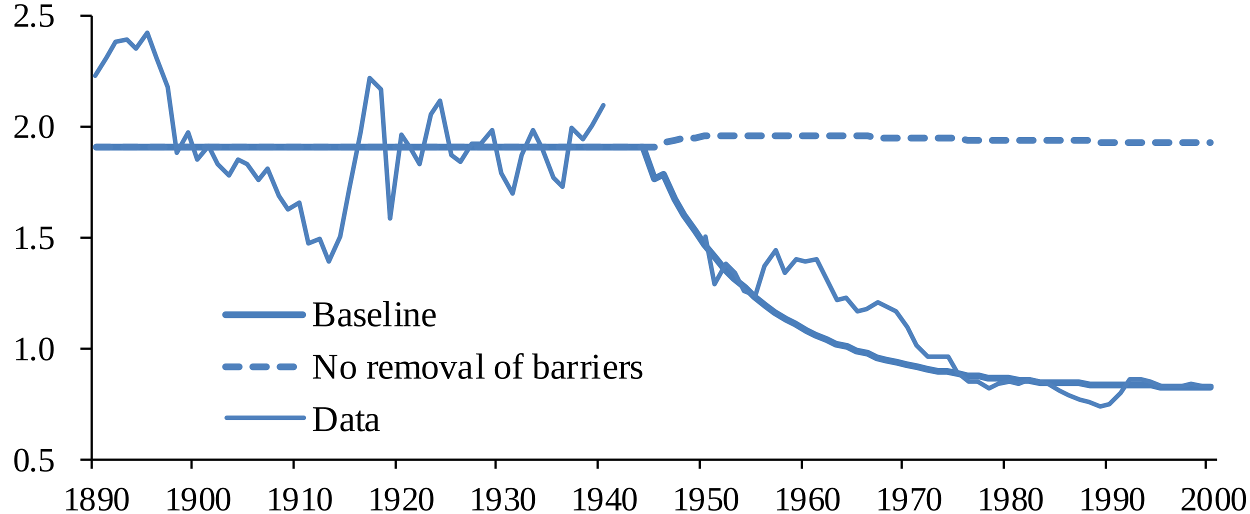
- Simulation
  1. UK economy is on the steady state from 1890 to 2000.
  2. Japan economy is on the steady state from 1890 to 1944.
  3. Unexpected mitigation of the barriers, $\pi_{\mathrm{JP}} \rightarrow \pi'_{\mathrm{JP}}$, in 1945
  4. Unexpected destruction of capital stock due to the war in 1945 (Christiano, 1989)

Simulation Results when α=0.36

(a) Per-capita output

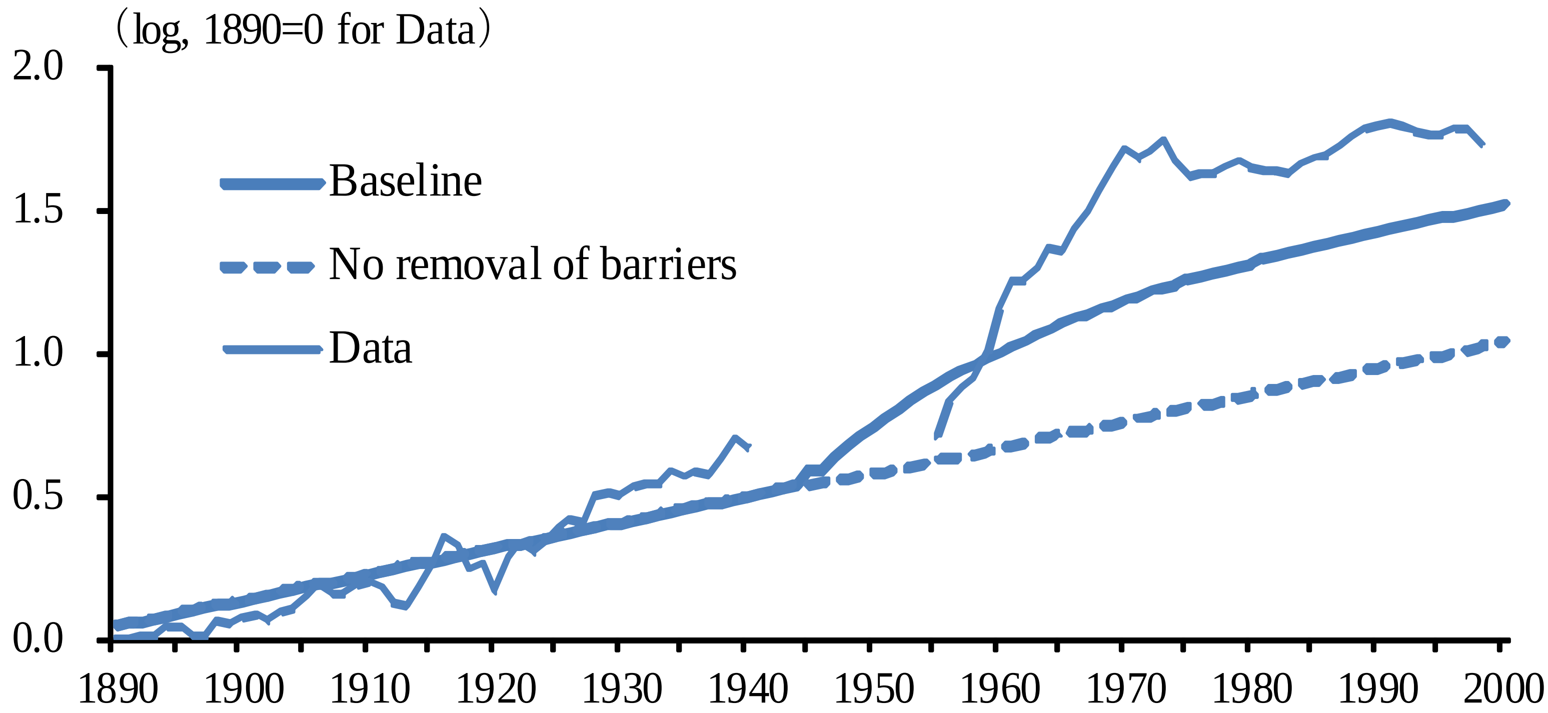


(b) Ratio of the relative price of investment: Japan/UK



Simulation Results when α=0.36 (cont’d)

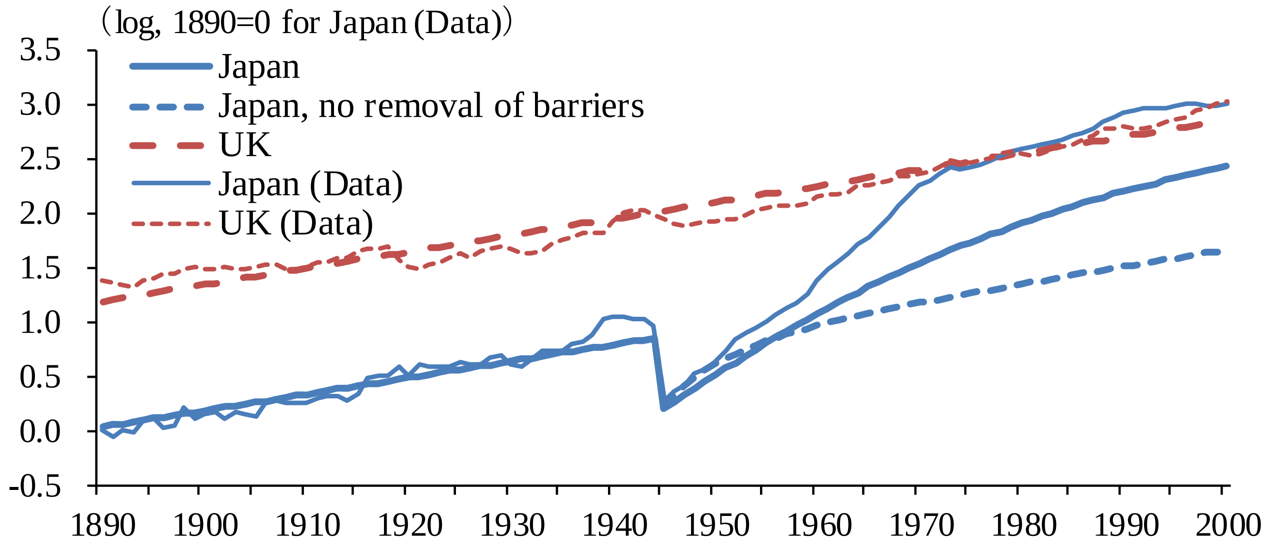
Measured TFP under the assumption of no IST



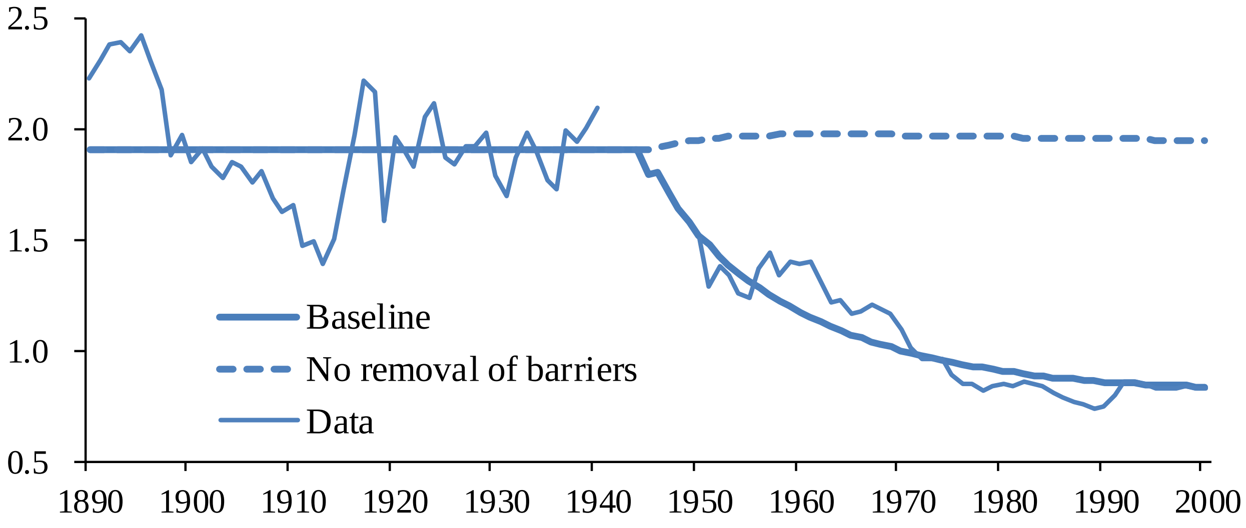
Notes: Data correspond to the TFP of non-primary sectors.
Source: Appendix

Simulation Results when α=0.5

(a) Per-capita output



(b) Ratio of the relative price of investment: Japan/UK



Analyses from Historical Perspective

Step Back… And Review the Literature

- In the postwar growth, technology adoption played a leading role (Peck and Tamura, 1976; Goto, 1993)
- In the prewar modernization, technology adoption played an important role (Minami, 1987; Minami, 2002)
- Almost no literature that compares technology adoption between the prewar and postwar periods.
- What are barriers to technology adoption from historical perspective?
  1. Low capability for absorbing technology
  2. World economic and political instability
  3. Less-competitive environment

Factor 1: Low Capability for Absorbing Technology

- Capability for absorbing technology

  The degree of skill and knowledge of workers that allow them to learn, manage, and put new technology to practical use in a given period of time.

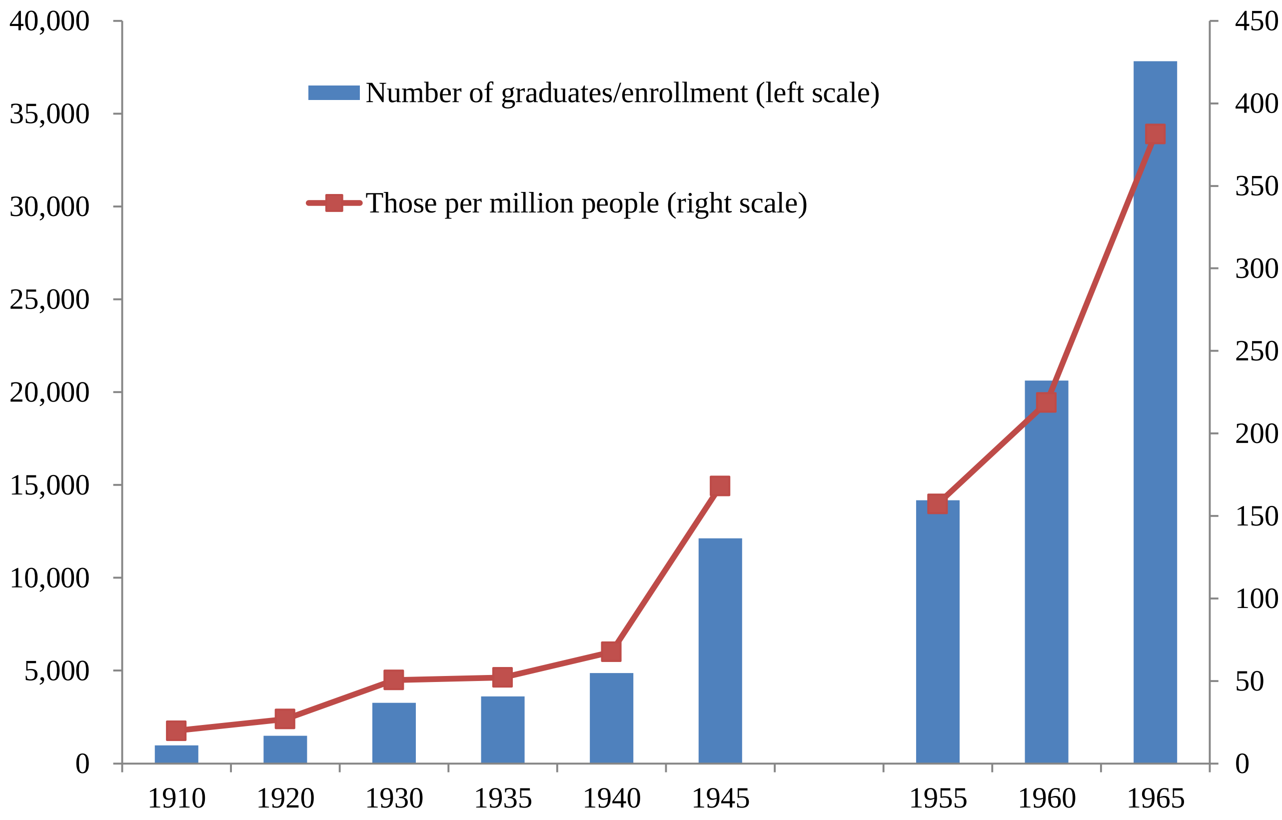
- Our argument: Capability had been low until the WWII but increased sharply in the WWII and the postwar period.

  Minami (2002): Slow spread of modern science → Difficulty in developing industries that require advanced technology → Industrialization was concentrated on light industries.

  Makino (1996): Technology adoption depended on the capability. The adopted technology mainly consisted of intermediate technology between old and advanced technology.

Factor 1 (cont'd): Low Capability for Absorbing Technology

The number of university graduates/enrollment with engineering majors



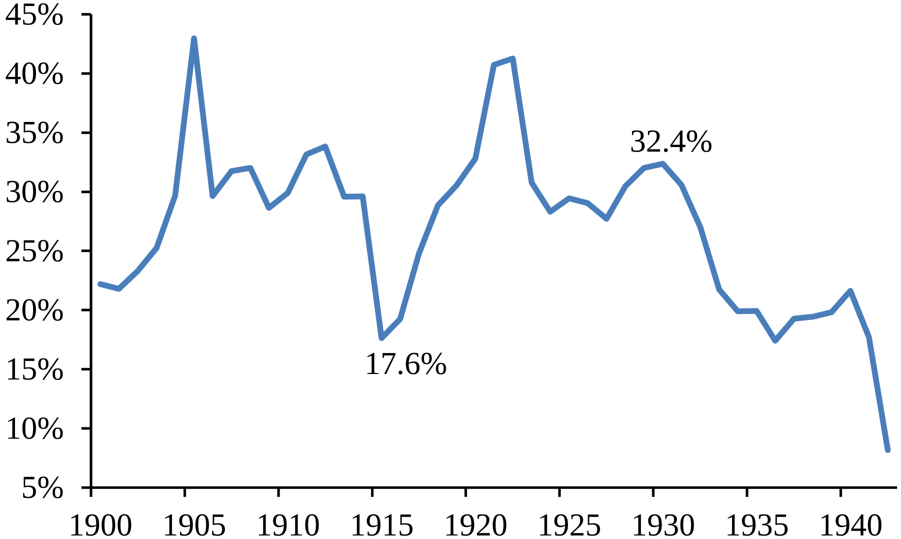
Sources: Sawai (2012a), p.172, Figure 10-2, etc.

Factor 2: Economic and Political Instability between Japan and Foreign Countries

- A series of wars must have negatively affected technology adoption.

-- World War I (1914--1918), Manchurian Incident (1931), Second Sino-Japanese War (1937--1945), and World War II (1939--1945)

The share of foreigners who registered patents in Japan



Factor 3: Less-Competitive Environment

- Main argument

  Due to less competition and a vested interest, Zaibatsu companies could have distorted the decision making of their subsidiaries, for example within the model's framework, by imposing restriction $i_{a,t} \leq \bar{i}_{a,t}$.

- High value of π is a reduced form of such a restriction.

- In the prewar period, technology adoption was mainly conducted by Zaibatsu and its subsidiary companies.

Factor 3 (cont'd): Less-Competitive Environment

- Conservative aspects of Zaibatsu (Morikawa, 1978)
  1. Slow decision making due to its large size
  2. Priority on protecting assets held by Zaibatsu family
  3. Difficulty in reconciling differences of opinion among subsidiaries

- In the postwar period, resolution of Zaibatsu and division of large companies contributed to change the less-competitive environment to a competitive one.

- Competition led to an increase in technology adoption.

Some Caveats on the Main Results

1. Quantitative results depend on data on the relative price of investment that could involve errors especially before 1950.

2. Barriers to technology adoption as a reduced form of (i) low capability, (ii) economic and political instability, and (iii) less-competitive environment.