

# Trade and the Diffusion of the Industrial Revolution

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# Growth and the Industrial Revolution

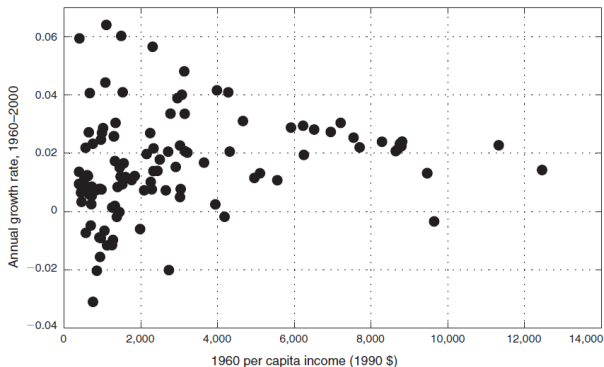
- ▶ Before industrial revolution
  - ▶ Annual real per-capita incomes were stagnant and low for centuries
- ▶ After industrial revolution
  - ▶ Leading economies annual growth rates  $\approx 2\%$  and stable
  - ▶ Other economies still stagnant at “Malthusian” income levels
- ▶ There exists huge cross-country income inequality

## Growth and Idea Diffusion

- ▶ Global economic growth is a phenomenon of cross-country flows of production related knowledge from successful economies to unsuccessful ones
- ▶ Flow of ideas more important than flow of labor and capital as a force for convergence

Thesis: These idea flows can be described by simple laws with few parameters that are stable over time

# Income and Growth Rates



- ▶ Rich countries grow at  $\approx 2\%$
- ▶ Poor countries have highly variable growth rates



## Model Setup

- ▶ Let GDP/capita be proportional to stock of human capital
- ▶ Let there exist a leader economy that grows at constant rate
- ▶ Let other economies be followers who grow at rate that depends on distance to leader

# A Mechanical Model of Catch-Up Growth

- ▶ Leader:  $H(t) = H_0 e^{\mu t}$
- ▶ Follower:  $\frac{dh}{dt} = \mu h^{1-\theta} H^\theta$
- ▶ Follower Growth Rate:  $\mu \left(\frac{H}{h}\right)^\theta$

Note:

- ▶  $H > h$  means follower grows faster than leader
- ▶ Follower grows faster:
  1. the further behind the leader
  2. the bigger the spillover

# Solving and Calibrating the Model

## 1. Solve the differential equation

$$\blacktriangleright h(t, h_0) = H_0 e^{\mu t} \left[ 1 - \left( 1 - \left( \frac{h_0}{H_0} \right)^\theta \right) e^{-\mu \theta t} \right]^{\frac{1}{\theta}}$$

## 2. Define growth rate between $t = 0$ and $t = T$

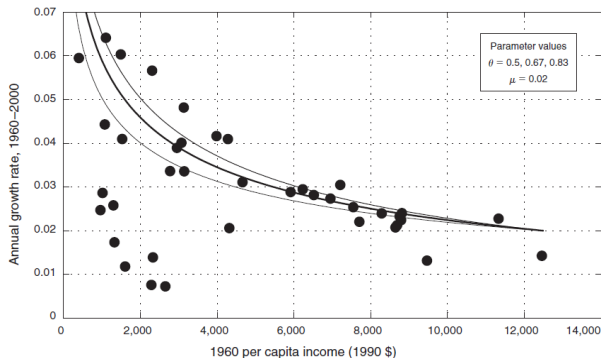
$$\blacktriangleright g := \frac{1}{T} [\ln h(T, h_0) - \ln h_0]$$

## 3. Choose $h_0$ proportional to $t = 0$ GDP/capita

## 4. Set $\mu = 0.02$ , $T = 40$ , $H_0 = 12,000$

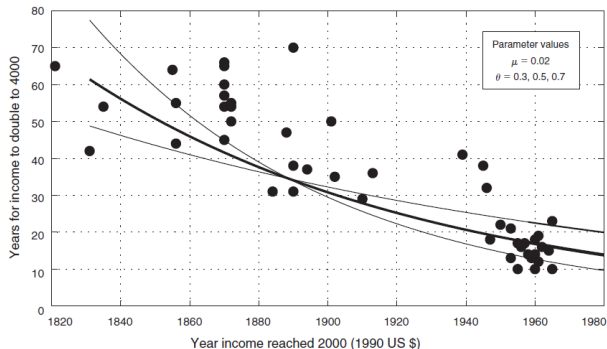


# Model Fit



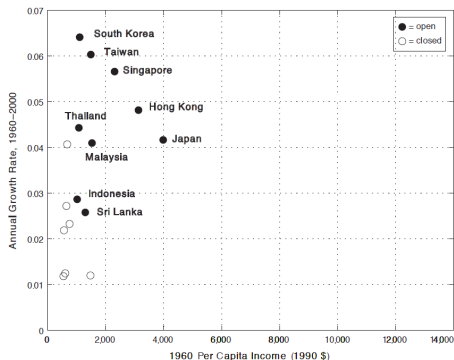
- ▶ US, Canada, Australia, New Zealand, Europe, fast growing Asian countries fall on same curve
- ▶ Some poor open Asian countries are below curve

# Post 1820 Evidence



- ▶ Use same solution to ODE to calculate doubling time
- ▶ Long term data well described by post-war calibration of simple model

## Model Fails for Poor Asian Countries



- ▶ Model needs modification
- ▶ Focus on ability to absorb ideas and behavior as  $h \rightarrow 0$

## A Static 2 Sector Model

Let  $(1 - x)$  be fraction of labor in the city sector:

- ▶  $y_c = h(1 - x)$

Let  $x$  be fraction of labor in the farming sector:

- ▶  $y_f = Ah^\xi x^\alpha$

$\xi$  controls the spillover effect of city knowledge on farm productivity

## Solving the Static Model

$$y(h) = \max_x Ah^\xi x^\alpha + h(1-x)$$

Trivially,

$$x = \begin{cases} 1 & \text{if } \alpha Ah^\xi x^{\alpha-1} > h \\ \left(\frac{\alpha A}{h^{1-\xi}}\right)^{\frac{1}{1-\alpha}} & \text{o/w} \end{cases}$$

Note: As  $h \rightarrow \infty$ ,  $x(h) \rightarrow 0$

## Calibrating 2 Sector Model: Cross-Section

$x(h)$  and  $y(h)$  imply a relationship between population share in agriculture as a function of GDP/capita

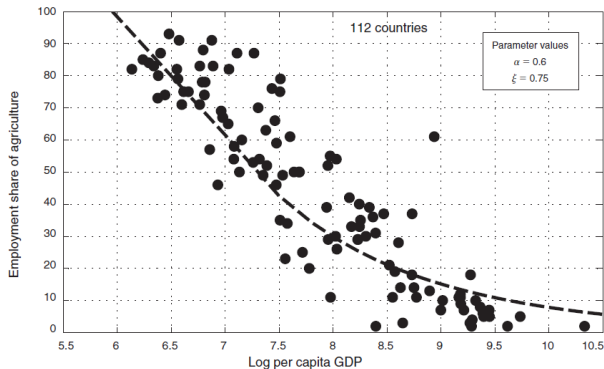
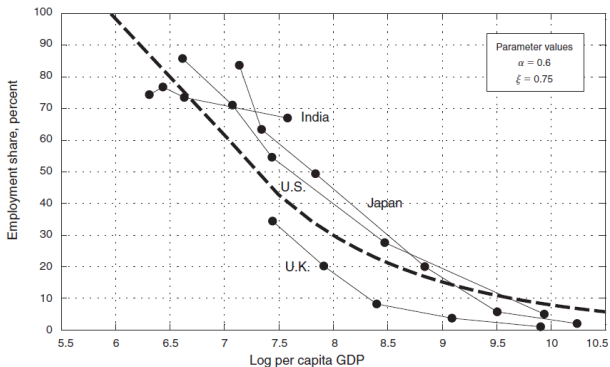


FIGURE 14. AGRICULTURAL EMPLOYMENT SHARES, 1980

## Calibrating 2 Sector Model: Time-Series

$x(h)$  and  $y(h)$  imply a relationship between population share in agriculture as a function of GDP/capita



## Dynamic 2 Sector Model: Agglomeration

Modify the follower diffusion to include an agglomeration effect:

$$\frac{dh}{dt} = \mu [1 - x(h)]^\zeta h^{1-\theta} H^\theta$$

Using optimal  $x(h)$  from static problem:

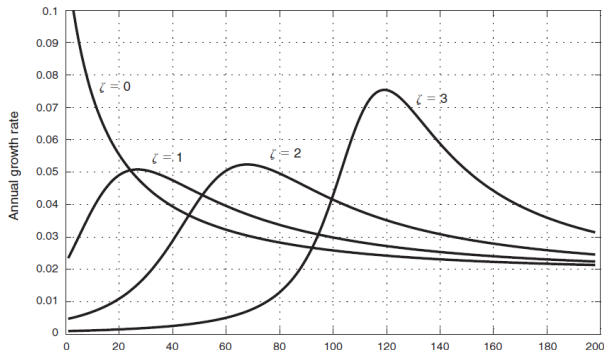
$$\frac{dh}{dt} = \mu \left[ 1 - \left( \frac{\alpha A}{h^{1-\xi}} \right)^{\frac{1}{1-\alpha}} \right]^\zeta h^{1-\theta} H^\theta$$

Differential equation can be solved numerically. Given  $H(0)$  and  $h(0)$  can recover  $H(t)$  and  $h(t)$ , thus  $x(h)$  and  $y(h)$ .



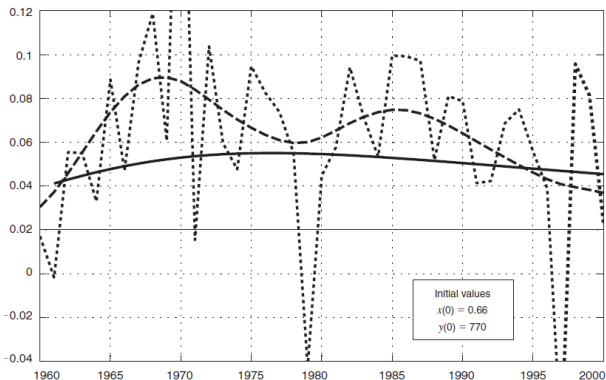
## 2 Sector Model: Dynamic Behavior

Agglomeration effects do successfully limit initial growth

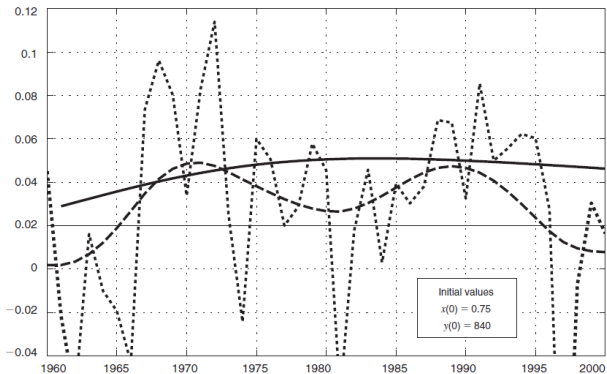


## 2 Sector Model Case Study: South Korea

How well does 2 sector model perform?



# 2 Sector Model Case Study: Indonesia



# Conclusion

- ▶ Idea flows are the essential mechanism for growth
- ▶ Idea flows follow simple laws for non-rural open economies
- ▶ Simple laws are parsimoniously parameterized
- ▶ Parameters are stable

## Openness: Trade vs. Ideas

Some very related open questions

- ▶ How large are the gains from idea openness compared to the gains from trade
  - ▶ Very Large - Alvarez and Lucas (2007), Rodriguez-Clare (2007)
- ▶ How does openness to trade interact with openness to ideas
  - ▶ Alvarez, Buera, Lucas (2011)

## Future of Literature: Microfoundations

Many papers have mechanical technology diffusion

- ▶ This paper, Benhabib and Spiegel (2002), many others

What about agents with preferences taking actions in a specified economic environment

- ▶ Lucas and Moll (2011)