ECO 4933 Topics in Theory

Introduction to Economic Growth

Fall 2015

Neoclassical Growth Models

Chapter 3

Empirical Applications of Neoclassical Growth Models

Neoclassical Growth Models

The Solow Growth Model with Human Capital

1. Empirical applications of SM show that it performs very well
2. "Fit" of the model can be improved by including human capital (levels of education and skills are different across countries)

$$Y = K^{\alpha}(AH)^{1-\alpha}$$

$$H = e^{\psi u}L$$

u = fraction of time spent learning new skills
L = total amount of raw labor
ψ (Psi), positive constant

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If $u = 0$ the $H = L$

By how much does u increases H?

$$\frac{d \ln H}{du} = \psi \Rightarrow \frac{dH}{du} = \psi H$$

If u increases by 1 unit and $\psi = .10$, then H increases by 10%

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Physical capital accumulates following

$$\dot{K} = s_K Y - \delta K$$

s_K = investment rate; δ = depreciation rate

We can rewrite de PF in terms of L as

$$y = k^{\alpha}(Ah)^{1-\alpha} \quad \text{where} \quad h = e^{\psi u} \quad (3.5)$$

We assume u to be constant and exogenous

Neoclassical Growth Models

h is constant ➔ PF (3.5) is similar to the one used in Ch. 2. Along a b.g.p. y and k will grow at the constant rate g

Dividing (3.5) by Ah we have

$$\tilde{y} = \tilde{k}^{\alpha} \text{ where } \tilde{y} = \frac{y}{Ah}$$ (Same as equation 2.11)

The capital accumulation equation is

$$\dot{\tilde{k}} = s_K \tilde{k} - (n + g + \delta)\tilde{k}$$ (Same as equation 2.12)

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The steady state values of $\tilde{k}$ and $\tilde{y}$ are found by setting $\dot{\tilde{k}} = 0$

$$\frac{\tilde{k}}{\tilde{y}} = \frac{s_K}{n+g+\delta}$$

Substituting in equation (3.6)

$$\tilde{y}^* = \left(\frac{s_K}{n+g+\delta} \right)^{\alpha/1-\alpha}$$

Rewriting in terms of output per worker we get

$$y^*(t) = \left(\frac{s_K}{n+g+\delta} \right)^{\alpha/1-\alpha} hA(t) \quad (3.8)$$

Neoclassical Growth Models

Equation (3.8) summarizes the explanation provided by the extended SM for why some countries are rich and others are poor

Countries are rich because:

1. Have high investment rates (s)
2. Spend a large fraction of time acc. skills (h)
3. Have low pop. growth rates (n)
4. And have high levels of technology (g)

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How well does this model perform empirically explaining why some countries are richer than other?

It's useful to analyze in terms of relative incomes

$$\hat{y}^* = \frac{y^*}{y^*_{US}} \quad \text{from (3.8)}$$

$$\hat{y}^* = \left(\frac{\hat{s}_K}{\hat{x}} \right)^{\alpha/1-\alpha} \hat{h}\hat{A} \quad (3.9)$$

The "hat" (^) is used to denote a variable relative to its U.S. value and $x \equiv n + g + \delta$

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Unless countries are growing at the same rate, relative income will not be constant. In order for relative incomes to be constant in the SS, we need to assume that g is the same for all countries. This seems at odd with Fact #2.

Notice that if g varies across countries , then the income "gap" becomes infinite. This does not seem plausible is growth is driven by tech.

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Tech. may flow through international trade, journals, migration of scientists, etc.

Tech. transfer may keep poor countries from falling behind.

Tech. *levels* need not be the same, only rates of growth (g)

Differences in tech. explain why some countries are richer.

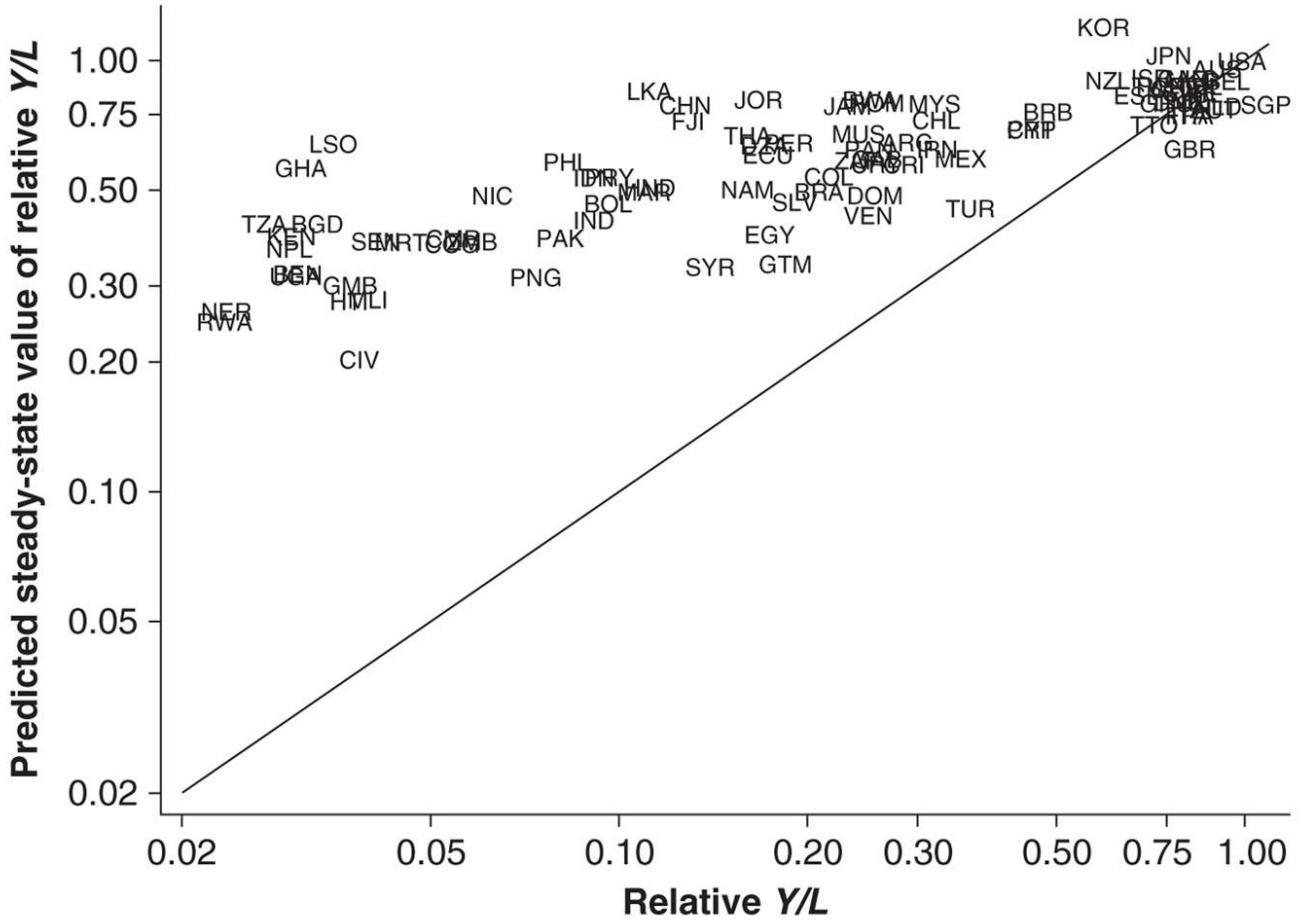
Neoclassical Growth Models

How does the extended SM fit the data?

- Start with eq. (3.9) and obtain estimates of the variables and parameters to see how the model "fits" the data
- Figure 3.1: actual levels of y in '08 vs values predicted by the model
- We assume: $\alpha = 1/3$; u = level of education in years; $\psi = .10$; $g + \delta = .075$; A = same across countries.

Neoclassical Growth Models

FIGURE 3.1 THE "FIT" OF THE NEOCLASSICAL GROWTH MODEL, 2008



Neoclassical Growth Models

- The main failure of the model (ignoring differences in A) can be seen by the departure from the 45^o line in Figure 3.1.
- The model predicts that poor countries should be richer
- How to incorporate actual technology levels in the analysis? Difficult.
- Solution: a “cheat”

Neoclassical Growth Models

Use PF itself to calculate A consistent with each country's output and capital and see if the values are plausible

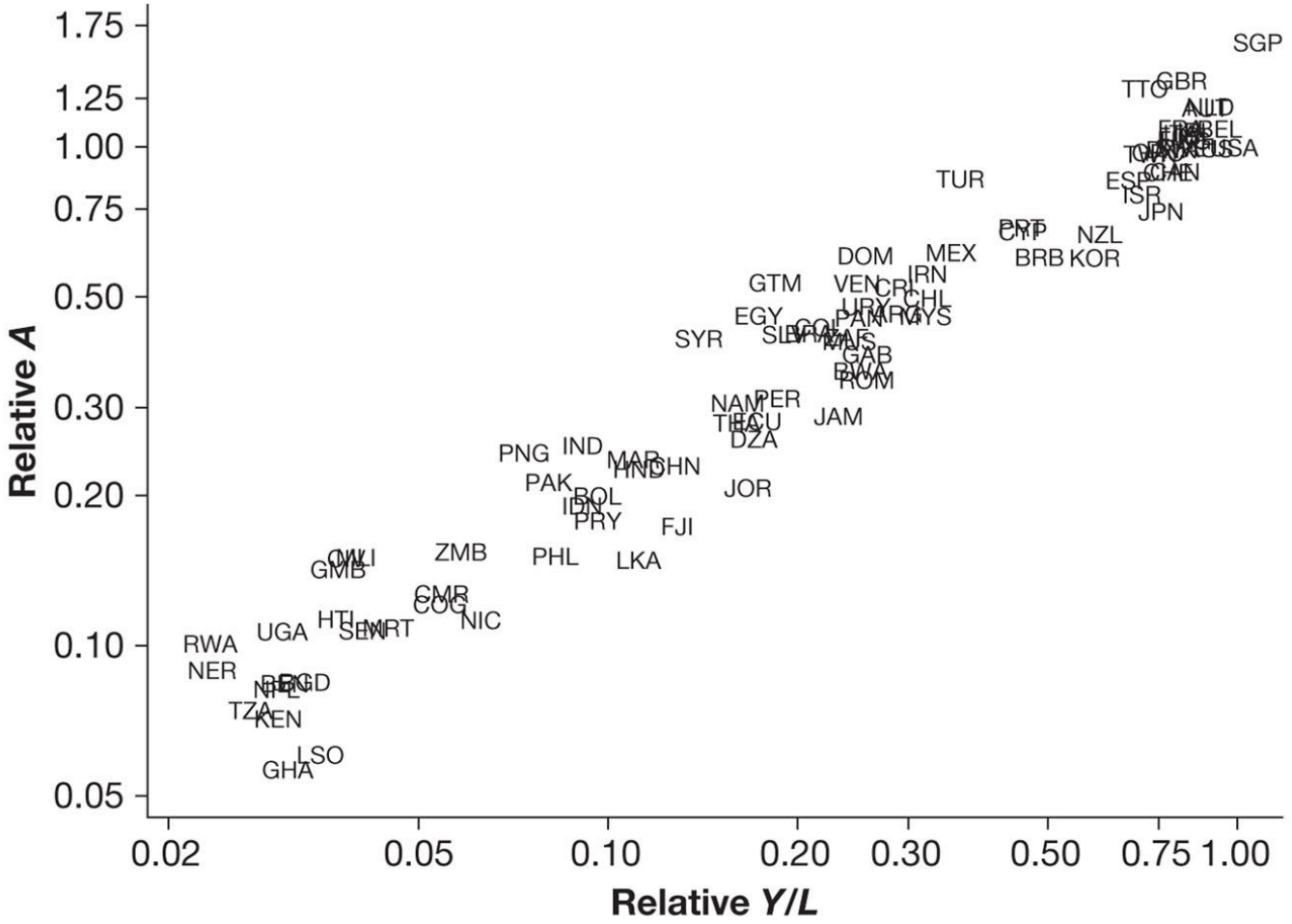
$$A = \left(\frac{y}{k}\right)^{\alpha/1-\alpha} \frac{y}{h}$$

With data on y, k, & h, A can be estimated.

Figure 3.2

Neoclassical Growth Models

FIGURE 3.2 **PRODUCTIVITY LEVELS, 2008**



Neoclassical Growth Models

Discoveries:

- The levels of A calculated are strongly correlated with the levels of y across countries. Rich countries have high levels of A and use resources better.
- Although A is highly correlated with Y, the correlation is far from perfect . A may contain "any" differences in production not included in inputs (quality of ed., training, health, etc.)

Neoclassical Growth Models

Discoveries:

- The differences in TFP across countries are large. For poorest countries A is only 10-15% of those in rich countries.
- $y_{RICH} \approx 4.y_{POOR}$
- Differences can be broken into: Investment rates in K; investment rates in H; differences in productivity (Appendix C)

Neoclassical Growth Models

Convergence

- The neoclassical GM can explain diff. in income levels across economies.
- Can it explain diff. in growth rates?
- Early hypothesis: under certain conditions "backward" countries grow faster than rich one = *convergence*
- An important cause of convergence might be tech. transfer

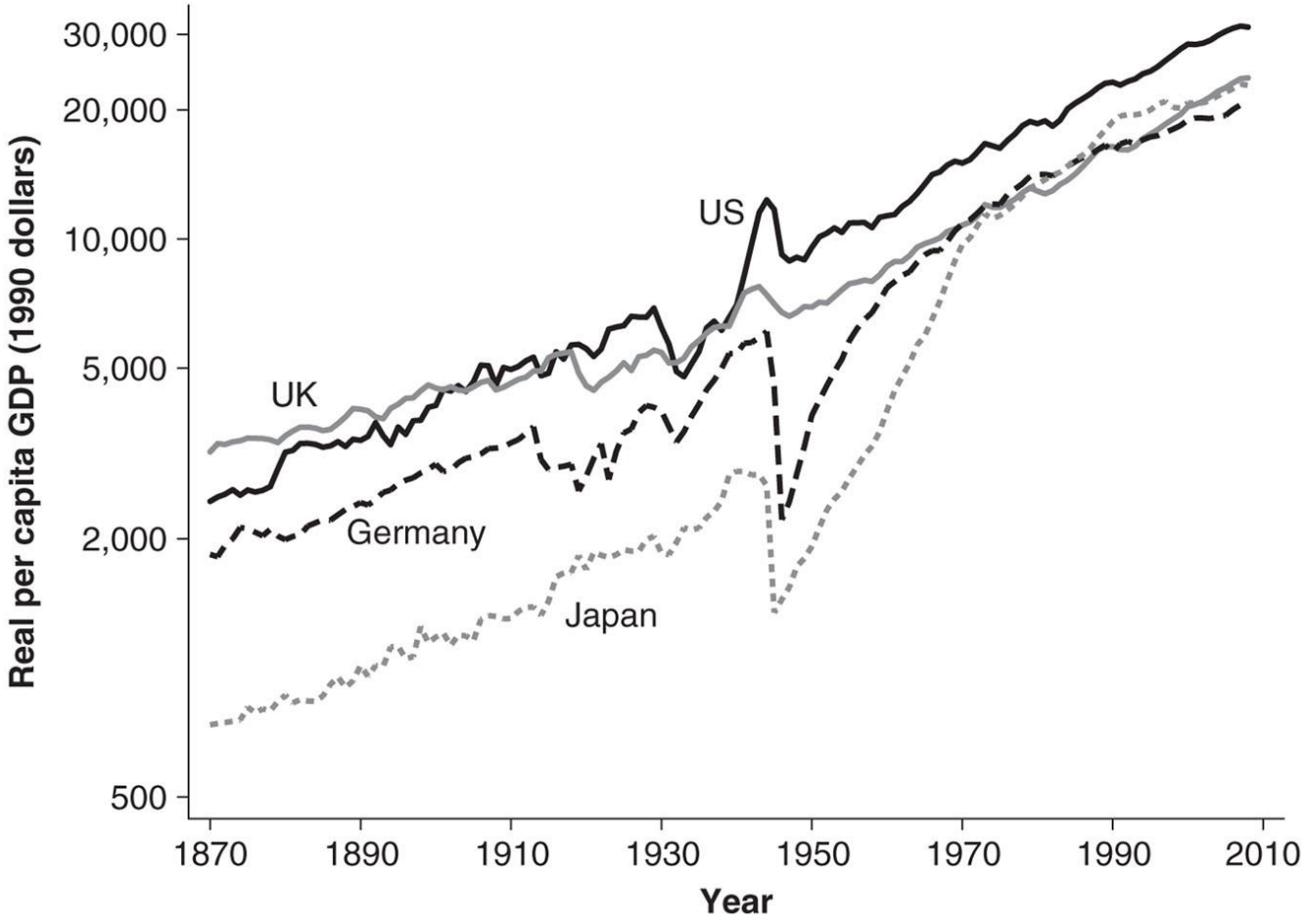
Neoclassical Growth Models

Baumol provides statistical evidence of convergence among some countries and absence of convergence among others.

First evidence: Figure 3.3

Neoclassical Growth Models

FIGURE 3.3 **PER CAPITA GDP, 1870–2008**



Neoclassical Growth Models

Notice:

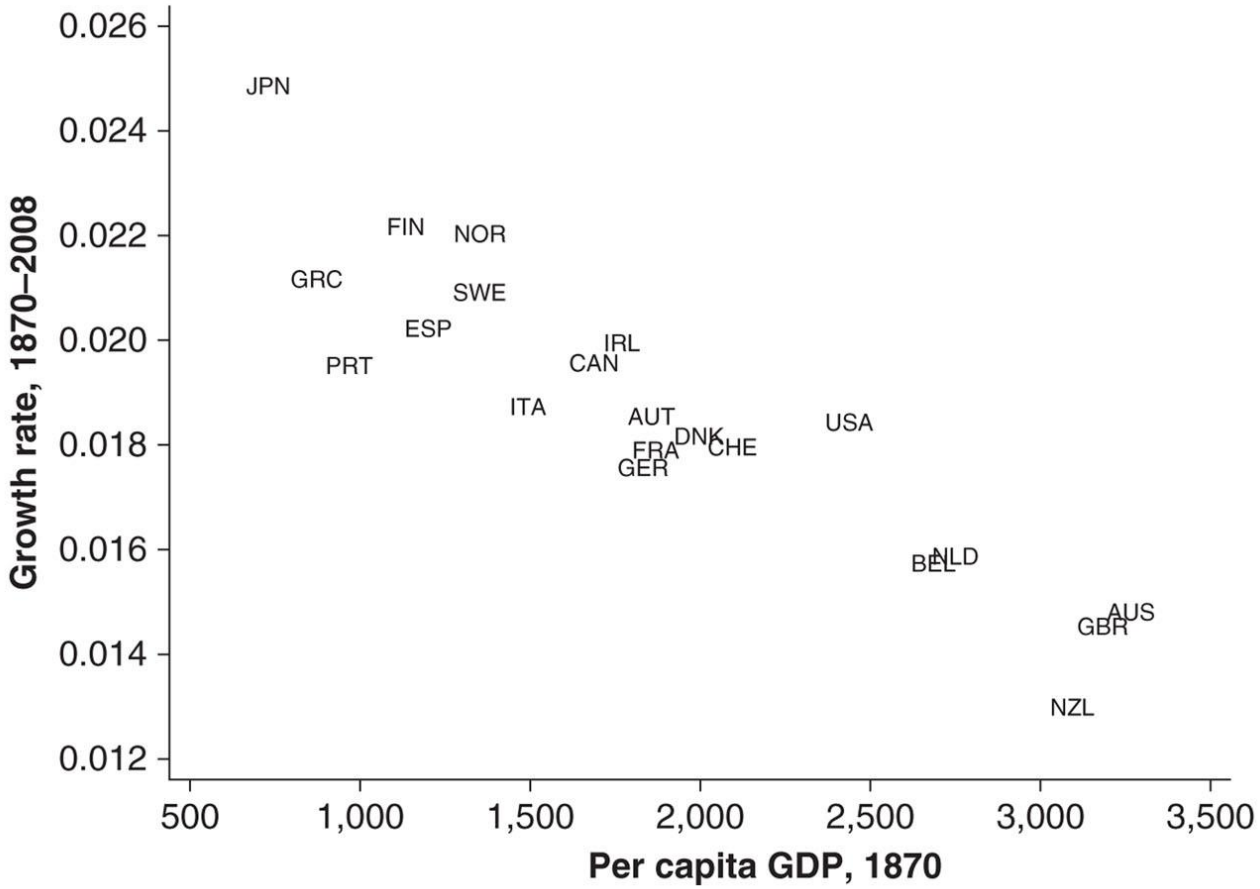
1. US surpassed UK at the beginning of 20th century
2. Sharp negative shock to Germany and Japan after WWII
3. Both countries grew faster in the 1950s and 1960s

Neoclassical Growth Models

- Figure 3.4 shows how the convergence hypothesis can explain why some countries grew fast and others grew slowly over the course of the 20th century.
- The negative correlation is strong.
- The simple convergence hypothesis seems to do a good job of explaining diff. in growth rates among a sample of industrialized countries

Neoclassical Growth Models

FIGURE 3.4 **GROWTH RATE VERSUS INITIAL PER CAPITA GDP, 1870–2008**

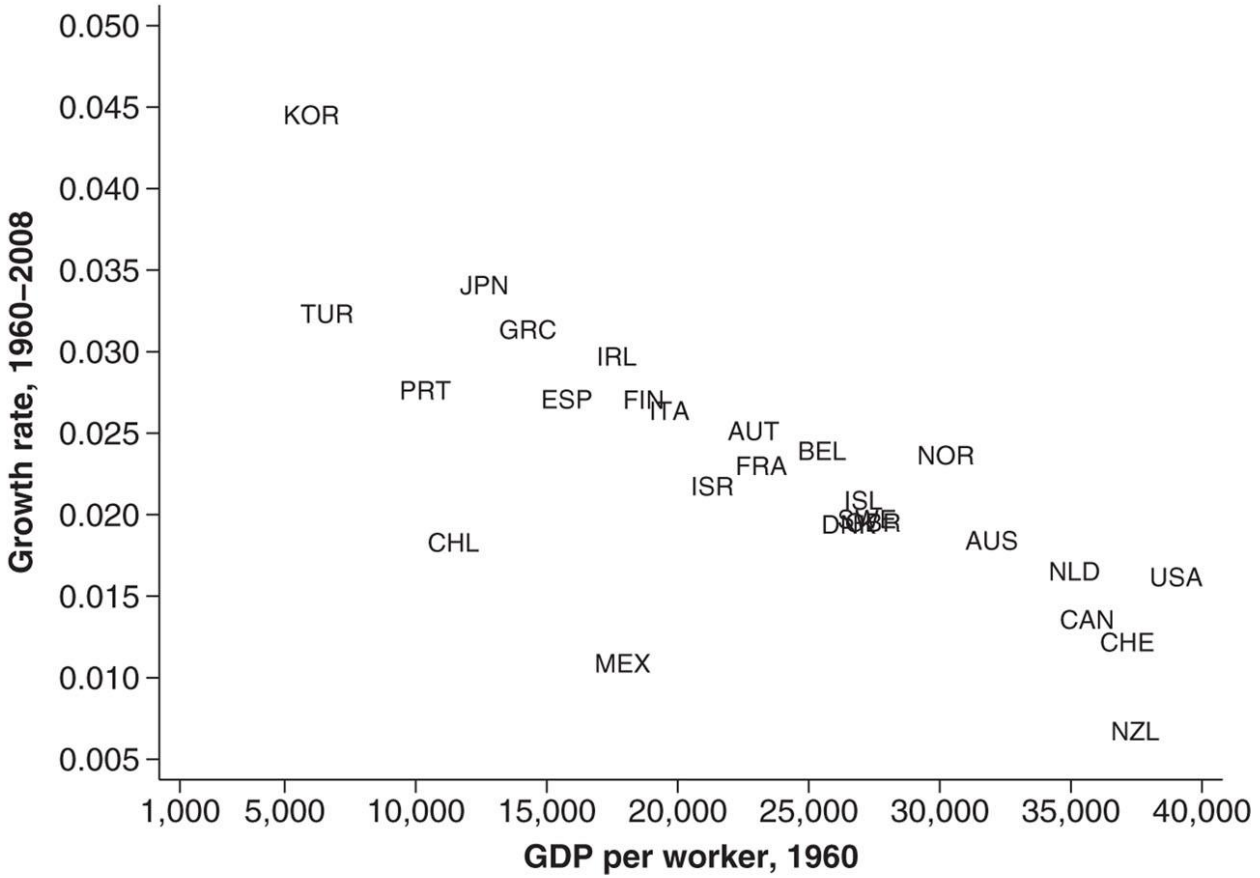


Neoclassical Growth Models

- Figures 3.5 shows data for OECD countries
- Convergence hypothesis works extremely well for explaining growth across members, except for Mexico and Chile (new members)
- Figure 3.6 show data for the world as a whole. Convergence hypothesis fails to explain differences in growth across countries.
- Poor countries are not closing the gap

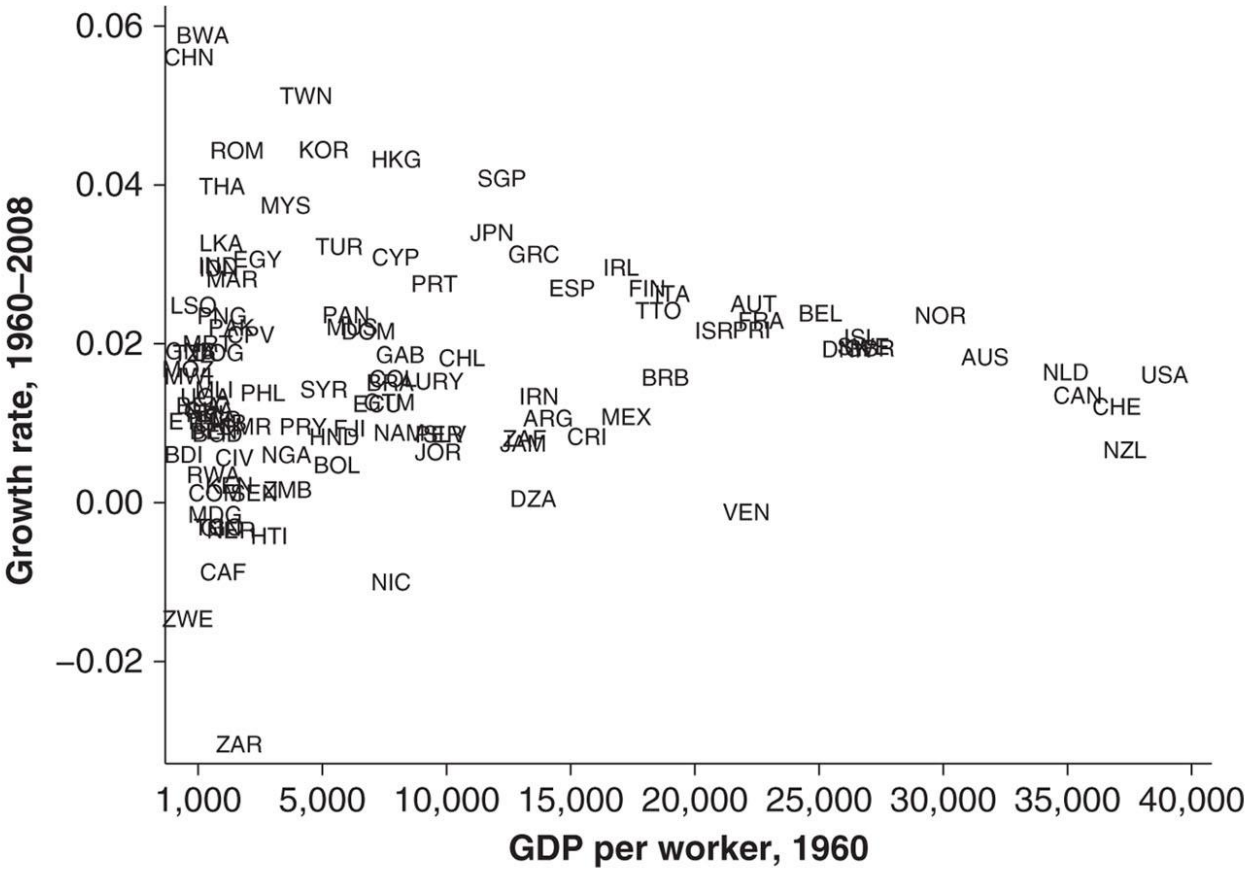
Neoclassical Growth Models

FIGURE 3.5 **CONVERGENCE IN THE OECD, 1960–2008**



Neoclassical Growth Models

FIGURE 3.6 **THE LACK OF CONVERGENCE FOR THE WORLD, 1960–2008**



Neoclassical Growth Models

Why is there convergence among certain countries but not in the world as a whole?

The neoclassical GM suggests an explanation

Recall eq. (3.7). We can rewrite it as:

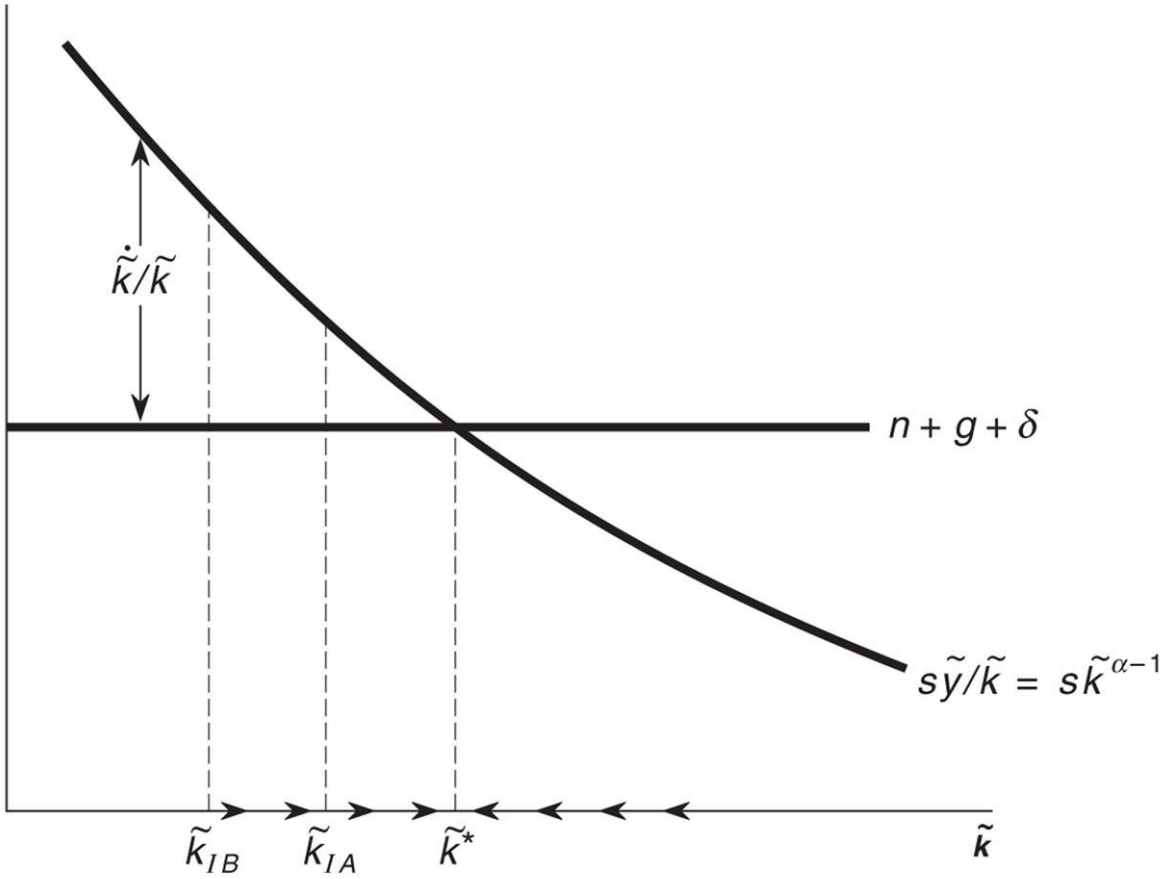
$$\frac{\dot{\tilde{k}}}{\tilde{k}} = s_K \frac{\tilde{y}}{\tilde{k}} - (n + g + \delta) \quad (3.10); \text{ remember that } \tilde{y} = \tilde{k}^{\alpha}$$

$$\Rightarrow \frac{\tilde{y}}{\tilde{k}} = \tilde{k}^{\alpha - 1}$$

This equation can be analyzed in the diagram in Figure 3.7

Neoclassical Growth Models

FIGURE 3.7 TRANSITION DYNAMICS IN THE NEOCLASSICAL MODEL



Neoclassical Growth Models

Two economies: InitiallyBehind and InitiallyAhead; $\tilde{k}_{IB} < \tilde{k}_{IA}$; same tech., s, & n

IB will growth temporarily faster than IA but both economies will approach the same SS.

Among countries that have the same SS, the convergence hypothesis should hold: poor countries grow faster than rich ones.

Neoclassical Growth Models

But… not all countries have the same SS

Diff. in income levels suggest diff. in SS

Because all countries do not have the same s, n, growth rates and tech levels, they are not generally expected to grow toward the same SS target

Another prediction of the Neoclassical GM is…

Neoclassical Growth Models

Principle of Transition Dynamics

The further an economy is "below" its steady state, the faster the economy should grow. The further an economy is "above" its steady state, the slower the economy should grow.

(Equation 3.10 and Figure 3.7)

Neoclassical Growth Models

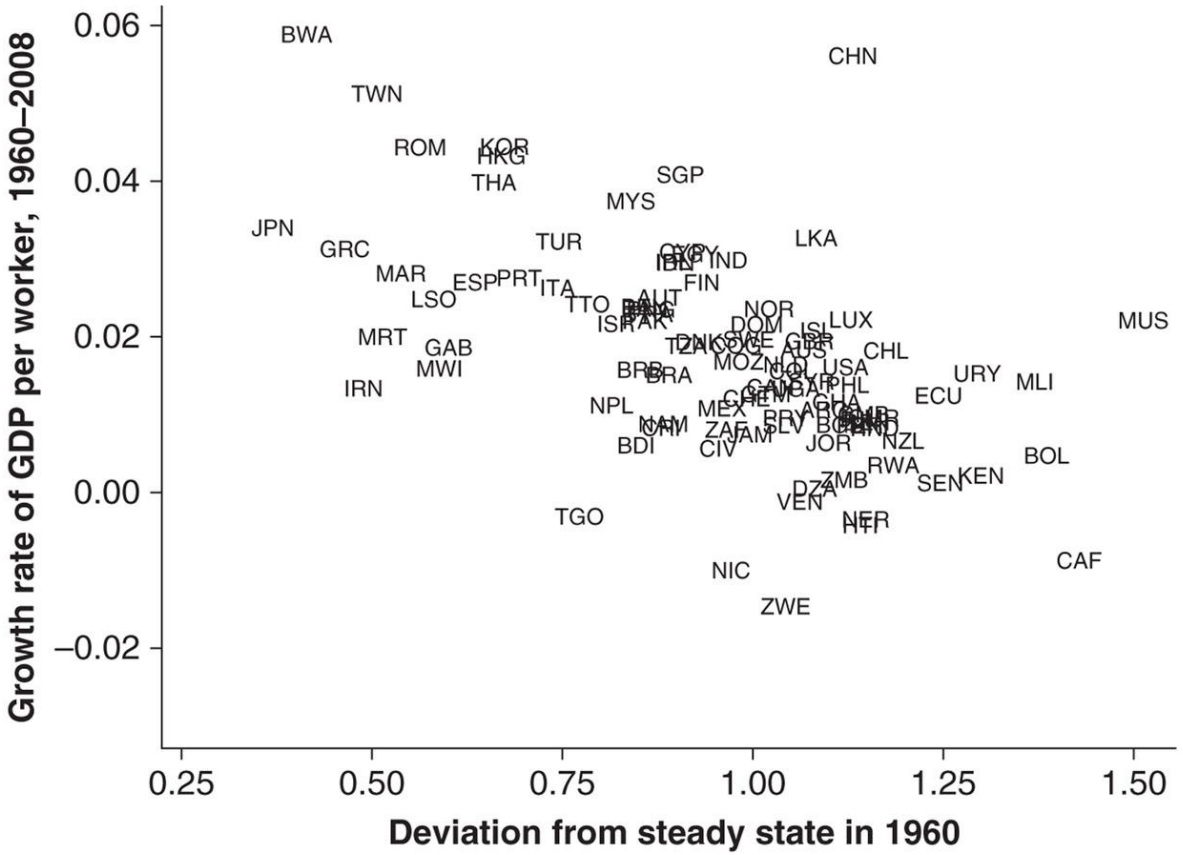
Several authors have shown that this prediction of the neoclassical model can explain differences in growth rates across countries. Figure 3.8

(Growth rate of y (1960-2008) vs deviation of y relative to US from its SS value)

Fig 3.6 vs Fig 3.8: Poorer countries do not necessarily grow faster, but countries that are "poor" relative to their own SS do tend to go more rapidly

Neoclassical Growth Models

FIGURE 3.8 "CONDITIONAL" CONVERGENCE FOR THE WORLD, 1960–2008



Neoclassical Growth Models

States or regions within the same country exhibit “unconditional” convergence.

What about wide differences in growth rate across countries?

Apply principle of transition dynamics: countries that have not reached their SS are not expected to grow at the same rate.

Those “below” SS will grow faster; those “above” SS will grow slowly

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There are many reason why countries may not be in SS: increase in s, a change in n or a war that destroys K will generate a gap between current Y and Yss. The gap will change growth rates until the economy returns to its SS.

Other shocks: large changes in oil prices, macro mismanagement, hyperinflation. These can be interpreted as changes in TFP

Neoclassical Growth Models

Most important shocks:

Positive: higher rates of primary schooling and higher life expectancy in 1960

Negative: higher prices for investment goods and the prevalence of malaria in the 1960s

In general: anything that shifts the SS path of an economy upward can increase growth rates along a transition path

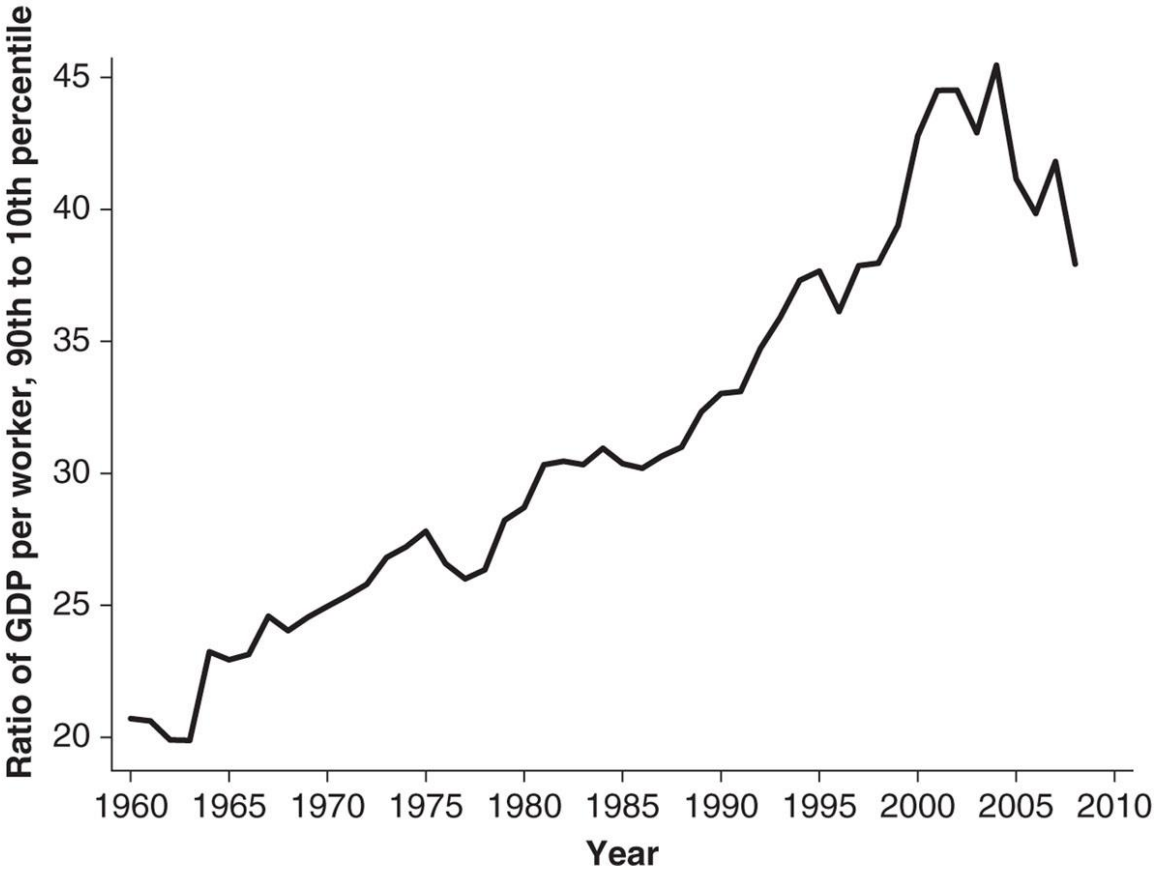
Neoclassical Growth Models

The Evolution of Income Distribution

1. Convergence is one of many possible outcomes
2. Perhaps the poorest countries are falling behind while countries with “intermediate” incomes are converging
3. Or, rich countries are getting richer and poor countries poorer
4. This is about world distribution of income.

Neoclassical Growth Models

FIGURE 3.9 INCOME RATIOS, 90TH PERCENTILE COUNTRY TO 10TH PERCENTILE COUNTRY, 1960–2008



Neoclassical Growth Models

Fig. 3.9 shows a key fact: the gap in income across countries have not narrowed over time

Fig. plots ration of y for a country in the 90th percentile to a country in the 10th percentile

1960: 90th to 10th was 20 times

2000: 90th to 10th was 40 times

Jumped to 45 times for a few years

Around 2008 it was 40 times again

Neoclassical Growth Models

The widening of the world income distribution is fact that characterizes the world economy over its entire history

Lower incomes bound is about $250 per year. Poorest countries are close

On the other hand, incomes of rich countries have been growing over time; ratio rich to poor too.

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Ratio of y between rich and poor countries:

Only 8.7 in 1870

Rose to 45.2 in 1990

Will the widening continue? = Open question

Possible explanation:

Escalator analogy

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Fig. 3.10 shows GDP relative to US in 1960 and 2008

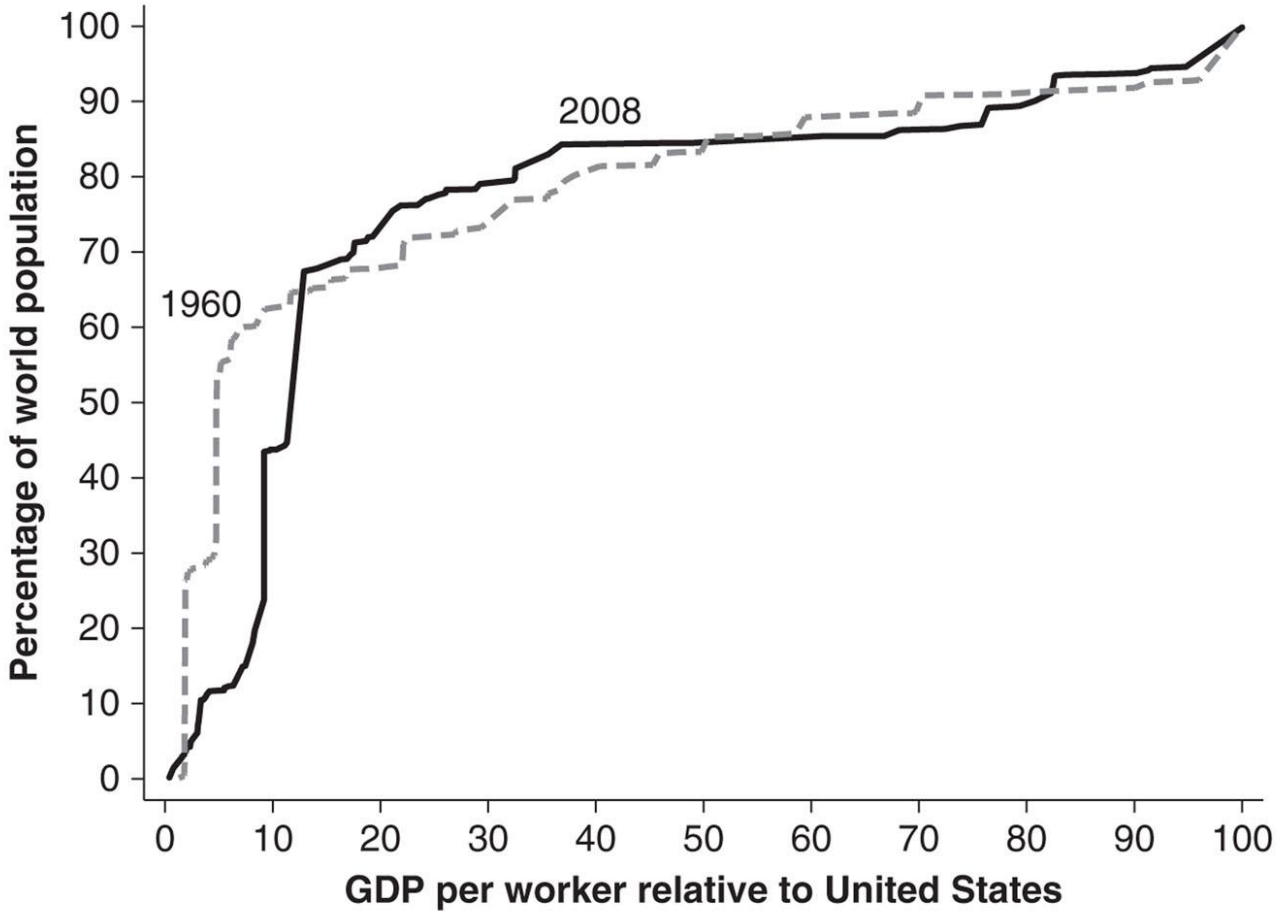
1960: about 60% of world pop. had GDP per capita of less that 10% of US level

2008: fraction was only 20% (China & India)

In both years about 80% of world pop. had GDP per worker of less than 50% of US level

Neoclassical Growth Models

FIGURE 3.10 THE EVOLUTION OF THE WORLD INCOME DISTRIBUTION



Neoclassical Growth Models

Sala-i-Martin

1970: 534 m. (15%) living on less than $1/day

2000: 321m. (6%) living on less than $1/day

Absolute poverty has been decreasing over time for the world as a whole

Neoclassical Growth Models

On the other hand:

1960: poorest 33 countries had an average GDP per worker relative to US of 3.8%

2008: 3%

In relative terms countries are poorer. This suggest divergence ➔ “Twin Peaks”

Pop. based measures show convergence; country based measures show divergence.