macro

CHAPTER SEVEN

Economic Growth I

macroeconomics
fifth edition

N. Gregory Mankiw

PowerPoint® Slides
by Ron Cronovich

Chapter 7 learning objectives

- Learn the closed economy Solow model
- See how a country's standard of living depends on its saving and population growth rates
- Learn how to use the "Golden Rule" to find the optimal savings rate and capital stock

The importance of economic growth

…for poor countries

What are benefits of economic growth?

- *Increase in the standard of living*
- *Help reducing poverty incidence*

selected poverty statistics

In the poorest one-fifth of all countries,

- daily caloric intake is 1/3 lower than in the richest fifth
- the infant mortality rate is 200 per 1000 births, compared to 4 per 1000 births in the richest fifth.

selected poverty statistics

- In Pakistan, 85% of people live on less than $2/day
- One-fourth of the poorest countries have had famines during the past 3 decades. (none of the richest countries had famines)
- Poverty is associated with the oppression of women and minorities

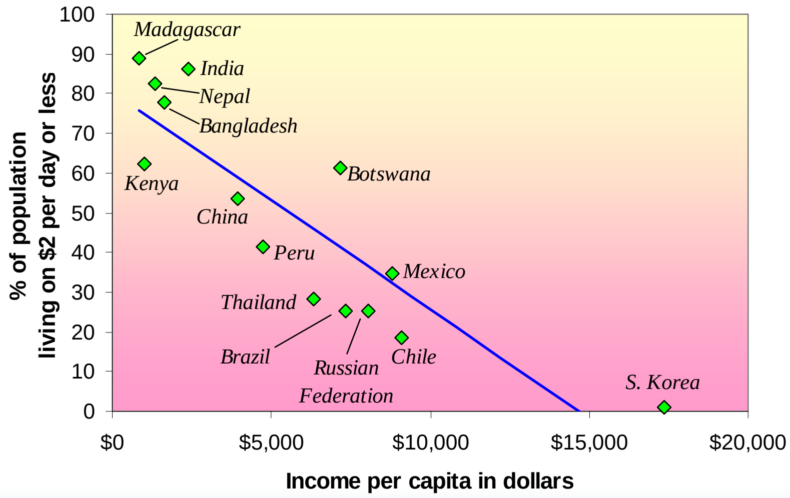
Estimated effects of economic growth

- A 10% increase in income is associated with a 6% decrease in infant mortality
- Income growth also reduces poverty. Example:

Growth and Poverty in Indonesia

	change in income per capita	change in # of persons living below poverty line
1984-96	+76%	-25%
1997-99	-12%	+65%

Income and poverty in the world
selected countries, 2000



The importance of economic growth

…for poor countries

…for rich countries

Huge effects from tiny differences

In rich countries like the U.S.,
if government policies or "shocks"
have even a small impact on the
long-run growth rate,
they will have a huge impact
on our standard of living
in the long run…

Huge effects from tiny differences

annual growth rate of income per capita	percentage increase in standard of living after…		
	...25 years	...50 years	...100 years
2.0%	64.0%	169.2%	624.5%
2.5%	85.4%	243.7%	1,081.4%

Huge effects from tiny differences

If the annual growth rate of
U.S. real GDP per capita
had been just
one-tenth of one percent higher
during the 1990s,
the U.S. would have generated
an additional $449 billion of income
during that decade

The lessons of growth theory

…can make a positive difference in the lives of hundreds of millions of people.

These lessons help us

- understand why poor countries are poor
- design policies that can help them grow
- learn how our own growth rate is affected by shocks and our government's policies

The Solow Model

- due to Robert Solow,
  won Nobel Prize for contributions to the study of economic growth

  www.nobel.se
- a major paradigm:
  - widely used in policy making
  - benchmark against which most recent growth theories are compared
- looks at the determinants of economic growth and the standard of living in the long run

How Solow model is different from Chapter 3's model

1. ***K*** is no longer fixed:
   investment causes it to grow,
   depreciation causes it to shrink.
2. ***L*** is no longer fixed:
   population growth causes it to grow.
3. The consumption function is simpler.

How Solow model is different from Chapter 3's model

4. No ***G*** or ***T***
   (only to simplify presentation;
   we can still do fiscal policy experiments)

5. Cosmetic differences.

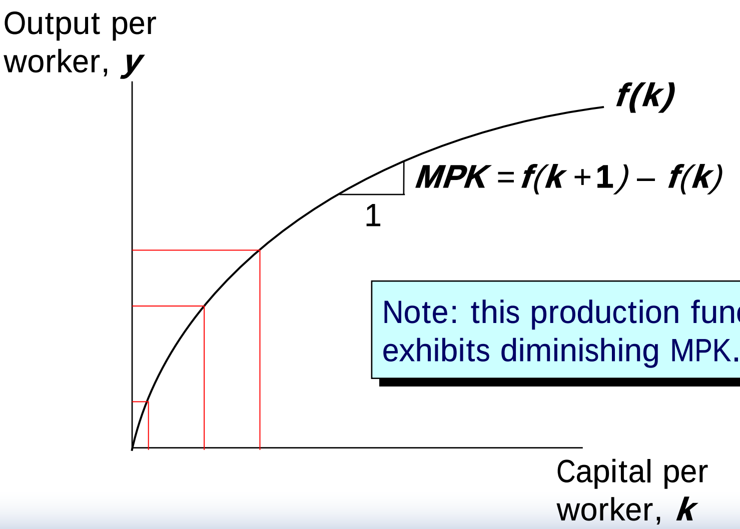
Mathematics is a language

- Why do economists prefer to use mathematics to express human relationship?
- Mathematics' rules = grammar
- Symbol and operator = vocab and verb
- We simply learn to speak in math.

A Look from Supply Side
The production function

- In aggregate terms: $Y = F(K, L)$
- Define: $y = Y/L$ = output per worker
  $k = K/L$ = capital per worker
- Assume constant returns to scale:
  $zY = F(zK, zL)$ for any $z > 0$
- Pick $z = 1/L$. Then
  $Y/L = F(K/L, 1)$
  $y = F(k, 1)$
  $y = f(k)$ where $f(k) = F(k, 1)$

The production function



Note: this production function exhibits diminishing MPK.

A Look from Demand Side
The national income identity

- $Y = C + I$ (*remember, no G*)
- In "per worker" terms:

$$y = c + i$$

where $c = C/L$ and $i = I/L$

First, look at "c"
The consumption function

- s = the saving rate,
  the fraction of income that is saved
  (s is an exogenous parameter)

  Note: s is the only lowercase variable that is not equal to its uppercase version divided by L
- In words, what is the relationship between income, savings, and consumption?
- Consumption function: $c = (1-s)y$
  (per worker)

Now, look at "*i*" Saving and investment

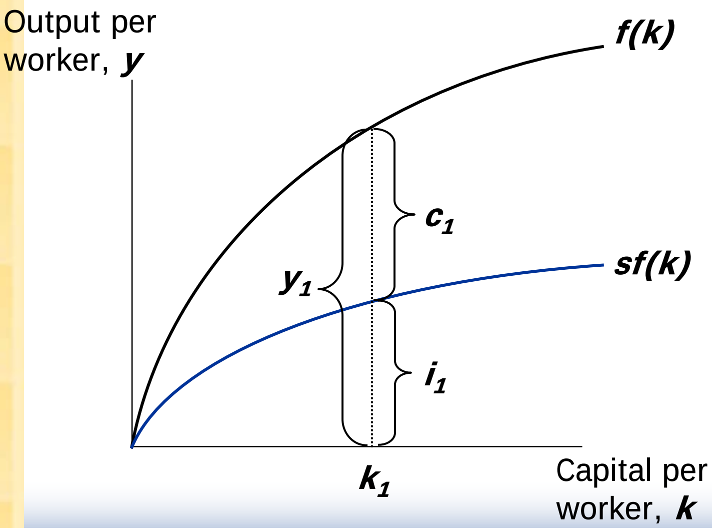
- saving (per worker) $= y - c$
  $= y - (1-s)y$
  $= sy$
- National income identity is $y = c + i$

  Rearrange to get: $i = y - c = sy$

  (investment = saving, like in chap. 3!)
- Using the results above,

  $$i = sy = sf(k)$$

Relationship between Output, consumption, and investment



Relationship between capital and investment

- How can we relate investment flows to capital stock?
  - New machines each year vs. total machines in the factory.
- Total machines =

  Unbroken old machines + New machines

Relationship between capital and investment

- Let δ = the rate of depreciation
  = the fraction of the capital stock that wears out each period
- Thus,

$$k_t = (1-\delta)k_{t-1} + i_t$$

Capital accumulation

The basic idea:

Investment makes the capital stock bigger, depreciation makes it smaller.

Capital accumulation

Change in capital stock = investment – depreciation

$\Delta k = i - \delta k$

What does the above equation say?

Since $i = sf(k)$, this becomes:

$$\Delta k = s f(k) - \delta k$$

The equation of motion for *k*

$$\Delta k = s f(k) - \delta k$$

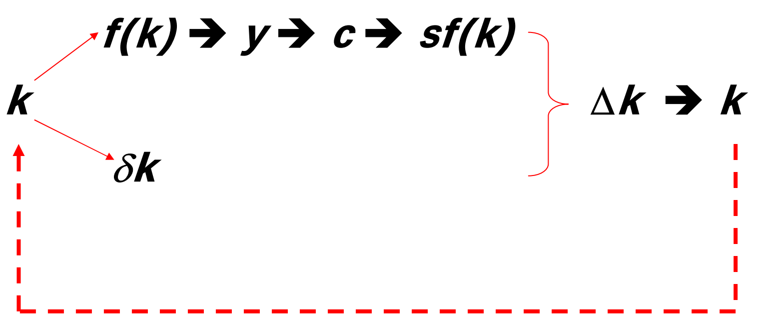
- the Solow model's central equation
- Determines behavior of capital over time…
- …which, in turn, determines behavior of all of the other endogenous variables because they all depend on ***k***. E.g.,

  income per person: $y = f(k)$

  consump. per person: $c = (1 - s) f(k)$

CHAPTER 7 Economic Growth I slide 26

Recap: Relationship between variables



- What would happen if top > below, if top < below, and if top = below?

CHAPTER 7 Economic Growth I slide 27

The Steady State: Property # 1

$$\Delta k = s f(k) - \delta k$$

If investment is just enough to cover depreciation, then capital per worker will remain constant:

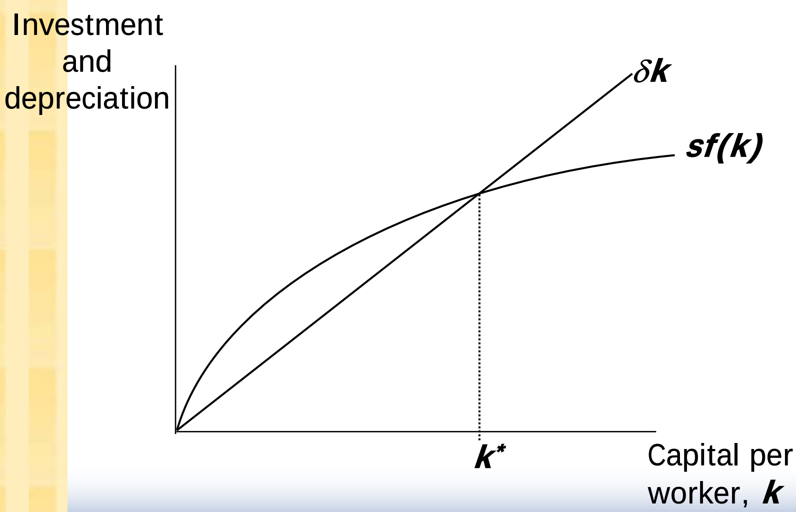
$$\Delta k = 0.$$

This constant value, denoted k^*, is called the ***steady state capital stock***.

What would happen once the economy is at the steady state?

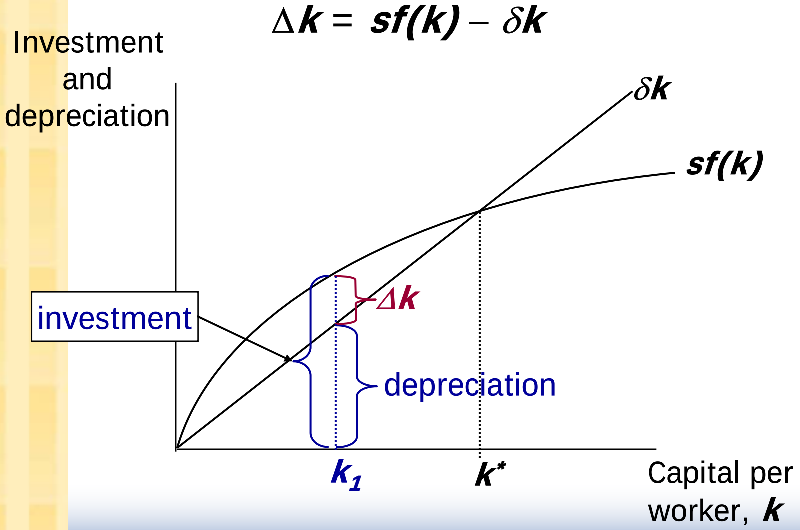
"An economy at the steady state will stay there."

The Steady State



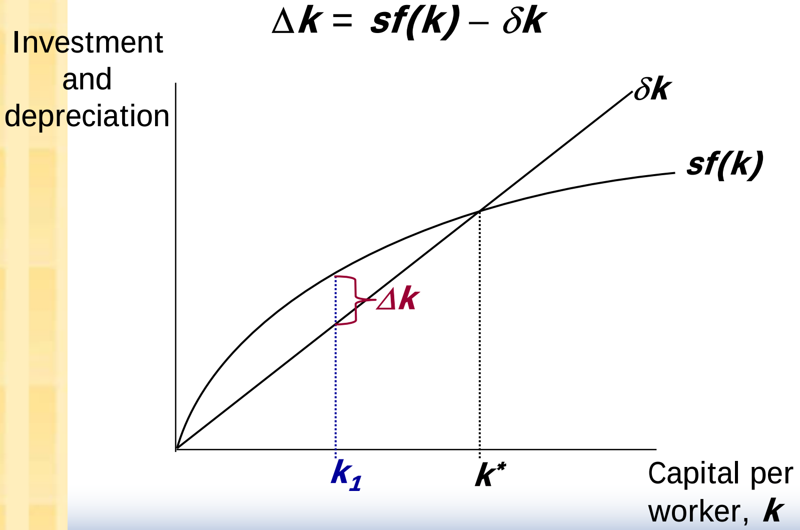
Moving toward the steady state: Property # 2

$$\Delta k = sf(k) - \delta k$$



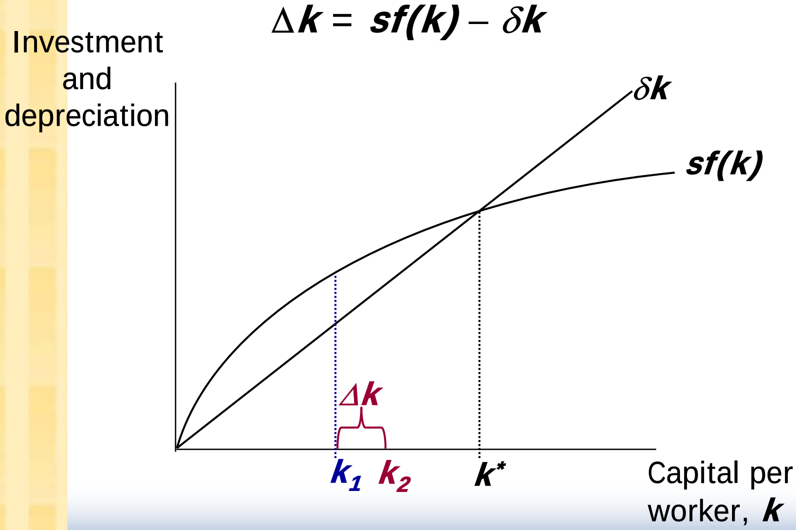
Moving toward the steady state

$$\Delta k = sf(k) - \delta k$$



Moving toward the steady state

$$\Delta k = sf(k) - \delta k$$

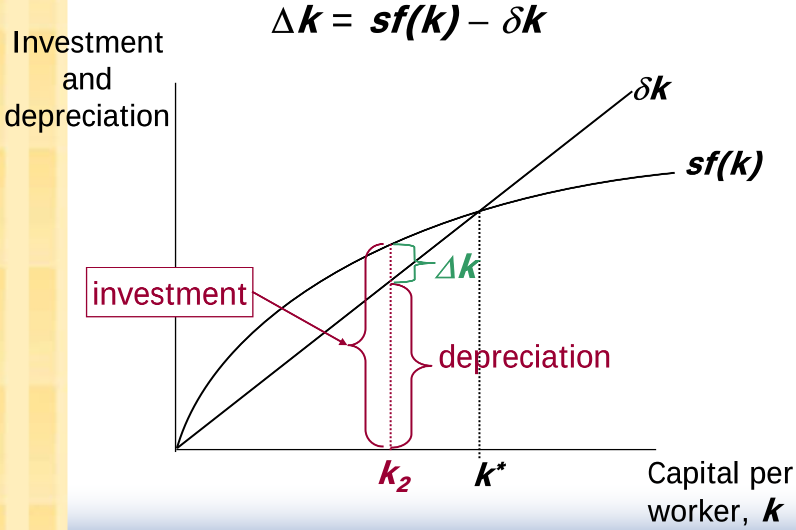


CHAPTER 7 Economic Growth I

slide 32

Moving toward the steady state

$$\Delta k = sf(k) - \delta k$$

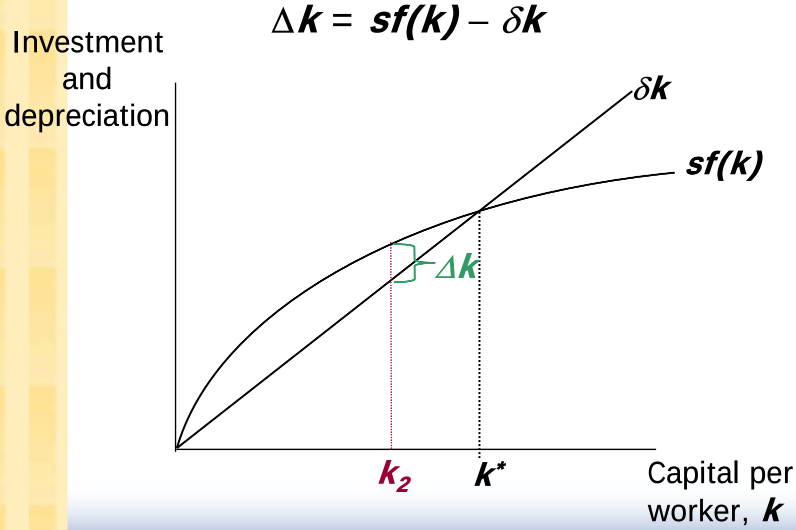


CHAPTER 7 Economic Growth I

slide 33

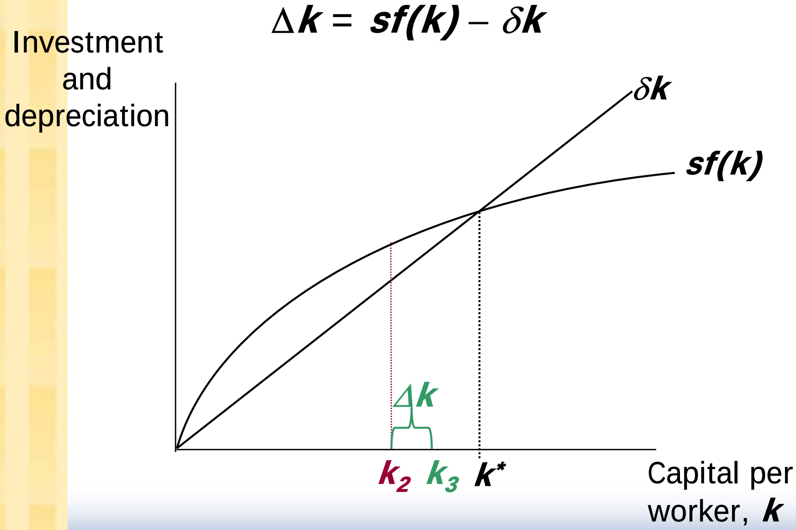
Moving toward the steady state

$$\Delta k = sf(k) - \delta k$$



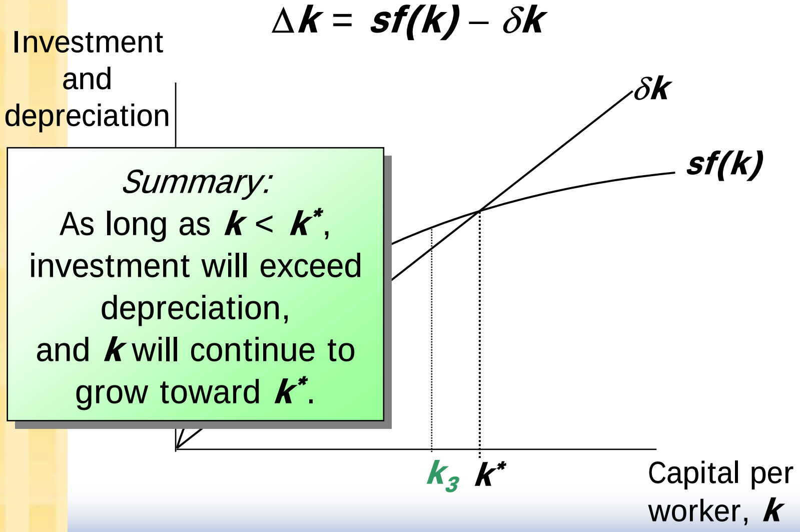
Moving toward the steady state

$$\Delta k = sf(k) - \delta k$$



Moving toward the steady state

$$\Delta k = sf(k) - \delta k$$



Two important properties of the steady state

1. An economy at the steady state will stay there.

2. An economy not at the steady state will go there. Regardless of the level of capitalwith which the economy begins, it ends up with the steady-state level of capital.

- *The "Steady State" represents the "long-run equilibrium" of the economy.*

Now you try:

Draw the Solow model diagram, labeling the steady state k^*.

On the horizontal axis, pick a value greater than k^* for the economy's initial capital stock. Label it k_1.

Show what happens to k over time. Does k move toward the steady state or away from it?

A numerical example

Production function (aggregate):

$$Y = F(K, L) = \sqrt{K \times L} = K^{1/2}L^{1/2}$$

To derive the per-worker production function, divide through by L:

$$\frac{Y}{L} = \frac{K^{1/2}L^{1/2}}{L} = \left(\frac{K}{L}\right)^{1/2}$$

Then substitute $y = Y/L$ and $k = K/L$ to get

$$y = f(k) = k^{1/2}$$

➔ Decreasing MPK?

A numerical example, *cont.*

Assume:

- ***s*** = 0.3 ➔ meaning...
- δ = 0.1 ➔ meaning...
- initial value of ***k*** = 4.0

Approaching the Steady State: A Numerical Example

Assumptions: $y = \sqrt{k}$; $s = 0.3$; $\delta = 0.1$; initial $k = 4.0$

Year	***k***	***y***	***c***	***i***	δk	Δk
1	4.000	2.000	1.400	0.600	0.400	0.200
2	4.200	2.049	1.435	0.615	0.420	0.195
3	4.395	2.096	1.467	0.629	0.440	0.189
4	4.584	2.141	1.499	0.642	0.458	0.184
…						
10	5.602	2.367	1.657	0.710	0.560	0.150
…						
25	7.351	2.706	1.894	0.812	0.732	0.080
…						
100	8.962	2.994	2.096	0.898	0.896	0.002
…						
∞	9.000	3.000	2.100	0.900	0.900	0.000

Exercise: solve for the steady state

Continue to assume

$s = 0.3, \quad \delta = 0.1, \quad \text{and} \quad y = k^{1/2}$

Use the equation of motion

$$\Delta k = s f(k) - \delta k$$

to solve for the steady-state values of k, y, and c.

Solution to exercise:

$\Delta k = 0$ def. of steady state

$s f(k^*) = \delta k^*$ eq'n of motion with $\Delta k = 0$

$0.3\sqrt{k^*} = 0.1 k^*$ using assumed values

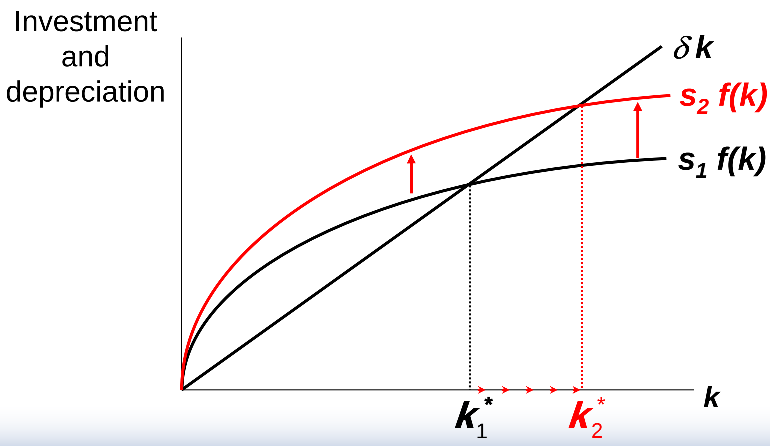
$$3 = \frac{k^*}{\sqrt{k^*}} = \sqrt{k^*}$$

Solve to get: $k^* = 9$ and $y^* = \sqrt{k^*} = 3$

Finally, $c^* = (1 - s)y^* = 0.7 \times 3 = 2.1$

An increase in the saving rate

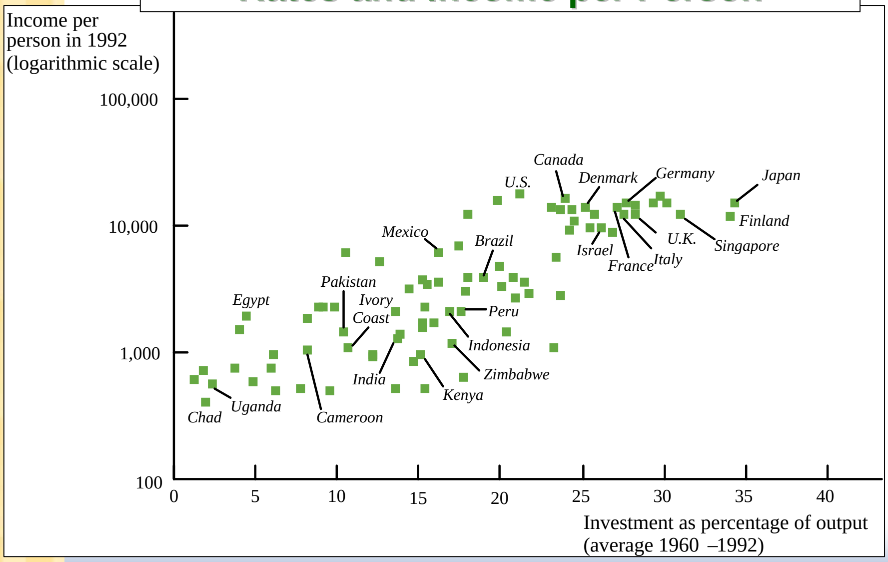
At the old *k*, an increase in the saving rate raises investment…
…causing the capital stock to grow toward a new steady state:



Prediction:

- Higher s ⇒ higher k^*.
- And since $y = f(k)$,
  higher k^* ⇒ higher y^* .
- Thus, the Solow model predicts that countries with higher rates of saving and investment will have higher levels of capital and income per worker in the long run.

International Evidence on Investment Rates and Income per Person



Implications to Thailand

- Recently, the Thai government proposed the national savings law.
  - What is the implication from the Solow growth model to the long-run equilibrium of Thai economy?

The Golden Rule: introduction

- Different values of s lead to different steady states. How do we know which is the "best" steady state?
- Economic well-being depends on consumption, so the "best" steady state has the highest possible value of consumption per person: $c^* = (1–s)\ f(k^*)$
- An increase in s
  - leads to higher k^* and y^*, which may raise c^*
  - reduces consumption's share of income $(1–s)$, which may lower c^*
- So, how do we find the s and k^* that maximize c^*?

The Golden Rule Capital Stock

k^*_{gold} = the **Golden Rule level of capital,** the steady state value of k that maximizes consumption.

To find it, first express c^* in terms of k^*:

$$
\begin{aligned}
c^* &= y^* - i^* \\
&= f(k^*) - i^* \\
&= f(k^*) - \delta k^*
\end{aligned}
$$

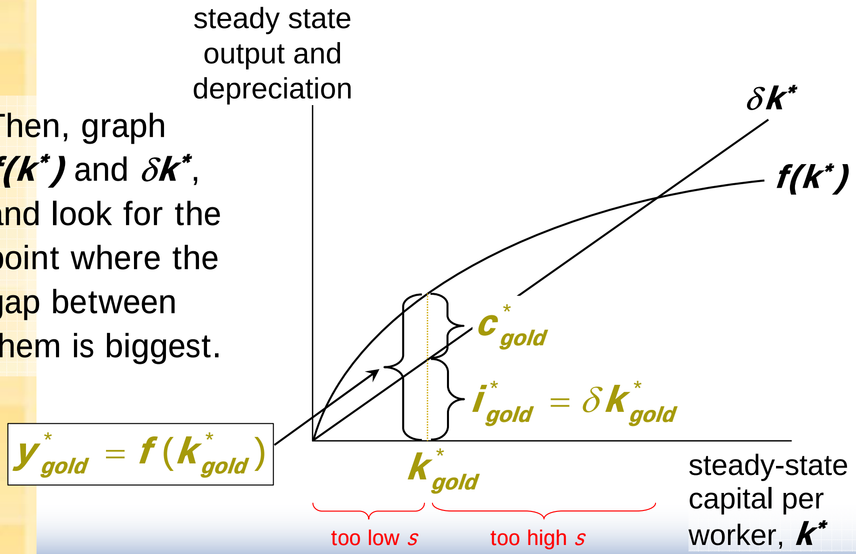
In general:
$i = \Delta k + \delta k$

In the steady state:
$i^* = \delta k^*$

because $\Delta k = 0$.

The Golden Rule Capital Stock

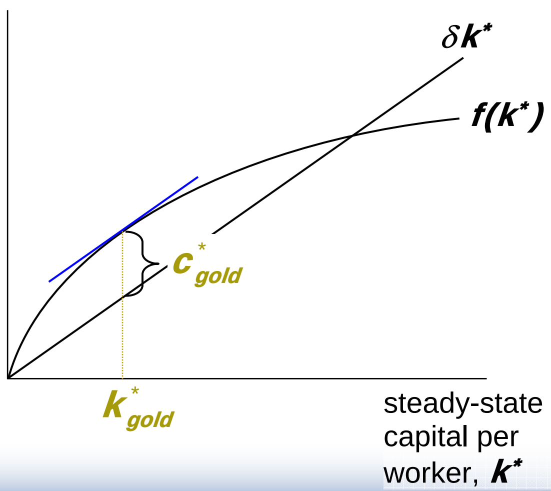
Then, graph $f(k^*)$ and δk^*, and look for the point where the gap between them is biggest.



The Golden Rule Capital Stock

$c^* = f(k^*) - \delta k^*$
is biggest where the slope of the production func.
equals
the slope of the depreciation line:

$MPK = \delta$



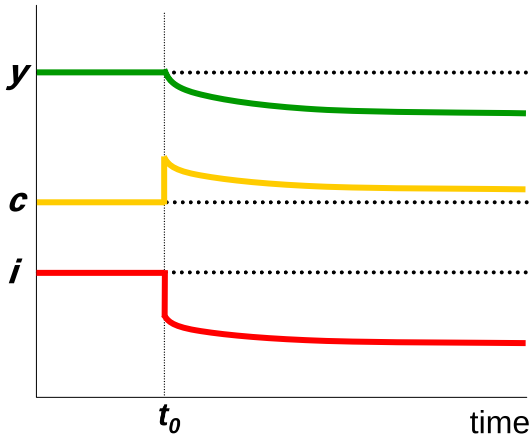
The transition to the Golden Rule Steady State

- The economy does NOT have a tendency to move toward the Golden Rule steady state.
- Achieving the Golden Rule requires that policymakers adjust ***s***.
- This adjustment leads to a new steady state with higher consumption.
- But what happens to consumption during the transition to the Golden Rule?

Starting with too much capital

If $k^* > k^*_{gold}$ then increasing c^* requires a fall in ***s***.

In the transition to the Golden Rule, consumption is higher at all points in time.

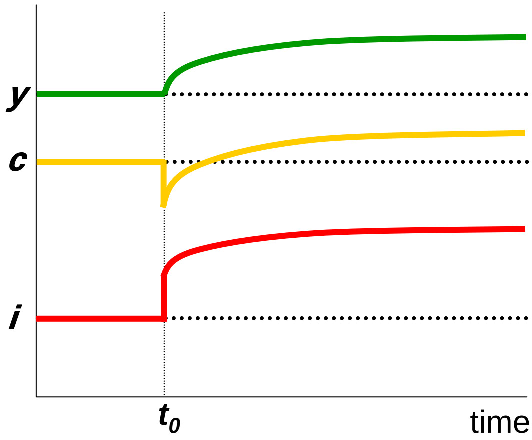


Starting with too little capital

If $k^* < k^*_{gold}$

then increasing c^* requires an increase in s.

Future generations enjoy higher consumption, but the current one experiences an initial drop in consumption.



Differences in consumption pattern between two cases

- When the economy begins above the Golden Rule, reaching the Golden Rule produces higher consumption at all points in time.
- When the economy begins below the Golden Rule, reaching the Golden Rule requires initially *reducing* consumption to increase consumption in the future.
- What is the implication to Thailand's consumption pattern in the short-run?

Population Growth

- Assume that the population--and labor force--grow at rate ***n***. (***n*** is exogenous)

$$\frac{\Delta L}{L} = n$$

- EX: Suppose ***L*** = 1000 in year 1 and the population is growing at 2%/year (***n*** = 0.02).

  Then $\Delta L = n\,L = 0.02 \times 1000 = 20$,
  so ***L*** = 1020 in year 2.

Break-even investment

$(\delta + n)k$ = **break-even investment**,
the amount of investment necessary to keep ***k*** constant.

Break-even investment includes:

- δk to replace capital as it wears out
- nk to equip new workers with capital
  (*otherwise, **k** would fall as the existing capital stock would be spread more thinly over a larger population of workers*)

The equation of motion for *k*

- With population growth, the equation of motion for ***k*** is

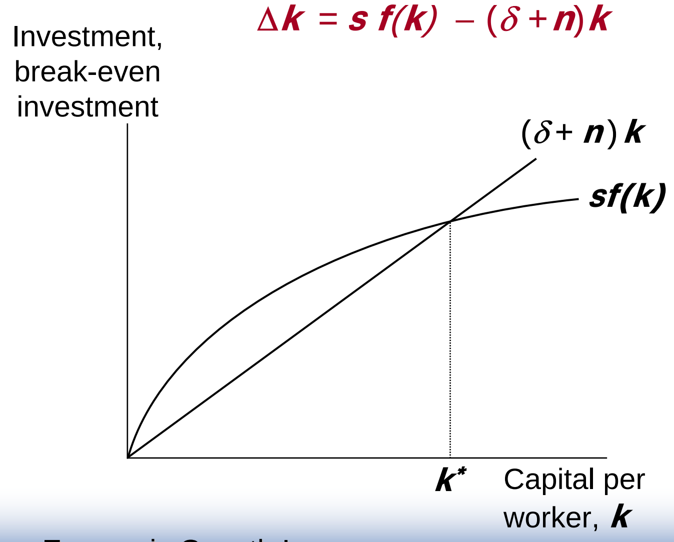
$$\Delta k = s f(k) - (\delta + n) k$$

$s f(k)$: actual investment

$(\delta + n) k$: break-even investment

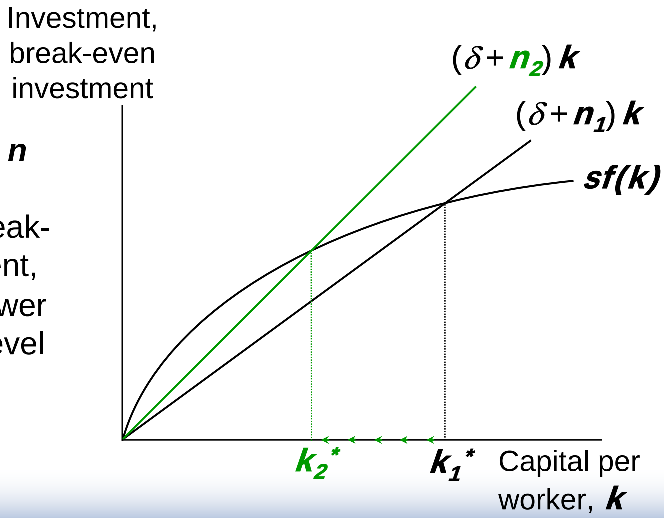
The Solow Model diagram

$$\Delta k = s f(k) - (\delta + n) k$$



The impact of population growth

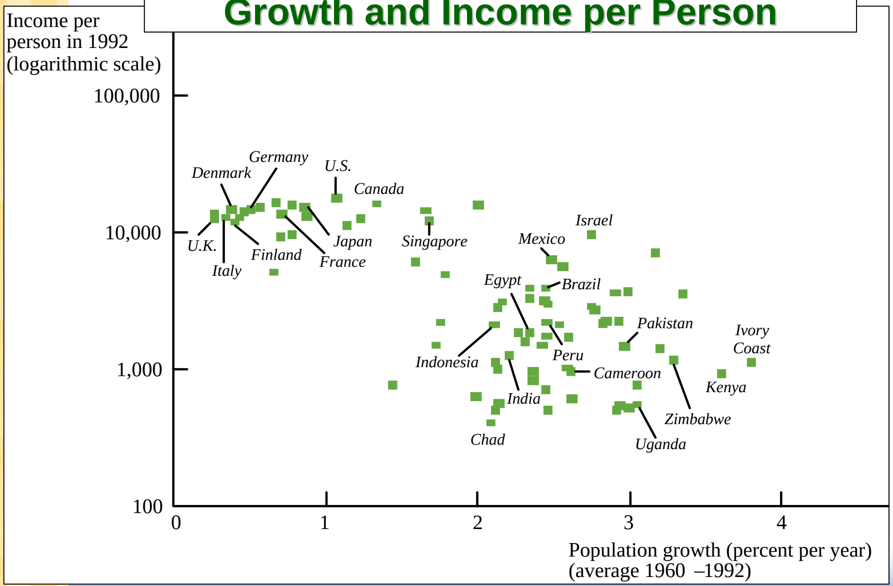
An increase in n causes an increase in break-even investment, leading to a lower steady-state level of k.



Prediction:

- Higher n $\Rightarrow$ lower k^*.
- And since $y = f(k)$, lower k^* $\Rightarrow$ lower y^* .
- Thus, the Solow model predicts that countries with higher population growth rates will have lower levels of capital and income per worker in the long run.

International Evidence on Population Growth and Income per Person



The Golden Rule with Population Growth

To find the Golden Rule capital stock, we again express c^* in terms of k^*:

$$c^* = y^* - i^*$$
$$= f(k^*) - (\delta + n)\,k^*$$

c^* is maximized when

$$\text{MPK} = \delta + n$$

or equivalently,

$$\boxed{\text{MPK} - \delta = n}$$

In the Golden Rule Steady State, the marginal product of capital net of depreciation equals the population growth rate.

Chapter Summary

1. The Solow growth model shows that, in the long run, a country's standard of living depends
   - positively on its saving rate.
   - negatively on its population growth rate.
2. An increase in the saving rate leads to
   - higher output in the long run
   - faster growth temporarily
   - but not faster steady state growth.

Chapter Summary

3. If the economy has more capital than the Golden Rule level, then reducing saving will increase consumption at all points in time, making all generations better off.

   If the economy has less capital than the Golden Rule level, then increasing saving will increase consumption for future generations, but reduce consumption for the present generation.