

macro

Topic 4:
Economic Growth I
 (chapter 7)

macroeconomics
 fifth edition

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PowerPoint® Slides
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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

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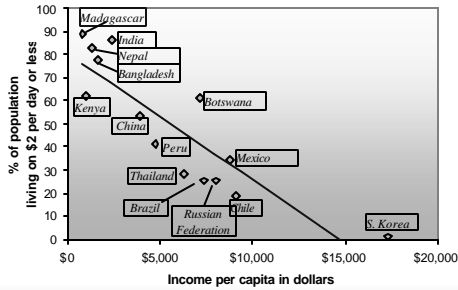
selected poverty statistics

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.
- ...

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Income and poverty in the world
selected countries, 2000



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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...

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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%

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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
- 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. _____ investment causes it to grow, depreciation causes it to shrink.
2. _____ population growth causes it to grow.
3. The consumption function is simpler.

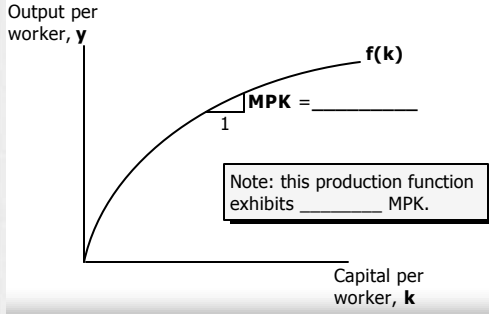
How Solow model is different from Chapter 3's model

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

The production function

- In aggregate terms: $Y = F(K, L)$
- Define: $y =$ _____
 $k =$ _____
- Assume _____:
 $zY = F(zK, zL)$ 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



The national income identity

▪ $Y = C + I$ (remember, no G)

▪ In "per worker" terms:

_____ where $c = \underline{\quad}$ and $i = \underline{\quad}$

The consumption function

▪ s = the saving rate,
_____ (s is an exogenous parameter)

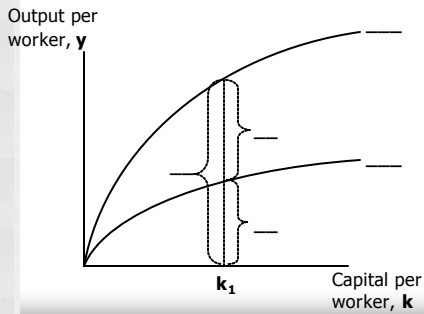
Note: s is the only lowercase variable that is not equal to its uppercase version divided by L

▪ Consumption function: _____ (per worker)

Saving and investment

- saving (per worker) = $y - c$
 = _____
 = _____
- National income identity is $y = c + i$
 Rearrange to get: _____
 (investment = saving, like in chap. 3!)
- Using the results above,

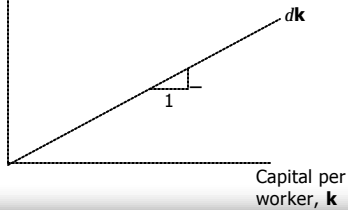
Output, consumption, and investment



Depreciation

Depreciation per worker, dk

$d =$ the rate of depreciation
 = _____



Capital accumulation

The basic idea:
Investment makes
the capital stock bigger,
depreciation makes it smaller.

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Capital accumulation

Change in capital stock = investment – depreciation
 $\Delta k = \quad - \quad k$

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

$$\Delta k = \underline{\hspace{2cm}}$$

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The equation of motion for k

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

- 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: $y = \underline{\hspace{2cm}}$
consump. per person: $c = \underline{\hspace{2cm}}$

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The steady state

$$Dk = sf(k) - dk$$

If investment is just enough to cover depreciation [$sf(k) = dk$], then capital per worker will remain constant:

_____.

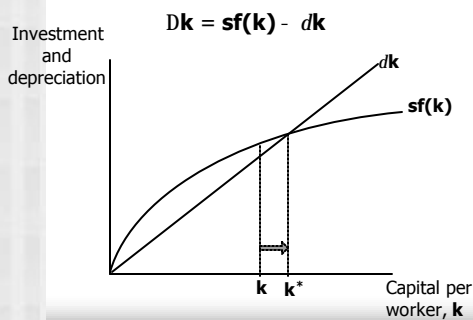
This constant value, denoted k^* , is called the

_____.

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Moving toward the steady state



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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 :

$$\frac{Y}{L} = \text{_____}$$

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

$$y = f(k) = \text{_____}$$

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A numerical example, cont.

Assume:

- $s = 0.3$
- $d = 0.1$
- initial value of $k = 4.0$

Approaching the Steady State: A Numerical Example

Assumptions: $y = \sqrt{k}$; $s = 0.3$; $d = 0.1$; 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

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

Use the equation of motion

$$Dk = sf(k) - dk$$

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

Solution to exercise:

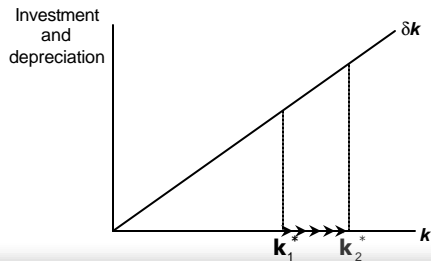
$Dk = 0$ def. of steady state
 $sf(k^*) = dk^*$ eq'n of motion with $Dk = 0$

Solve to get: $k^* = 9$ and $y^* =$ _____

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

An increase in the saving rate

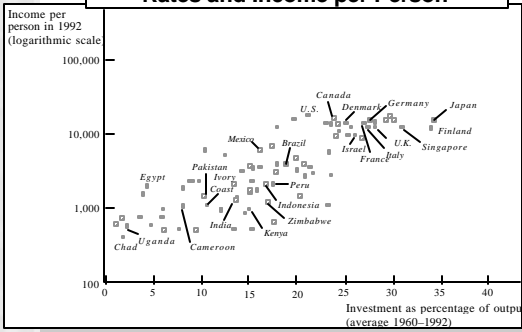
An increase in the saving rate raises investment...
...causing the capital stock to grow toward a new steady state:



Prediction:

- Higher $s \Rightarrow$ _____.
- And since $y = f(k)$,
higher $k^* \Rightarrow$ _____.
- 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



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 :
 - _____
 - _____
- So, how do we find the s and k^* that maximize c^* ?

The Golden Rule Capital Stock

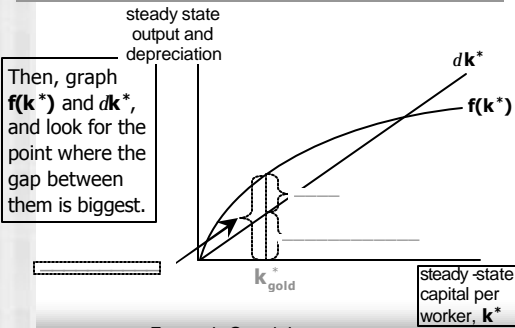
k_{gold}^* = the Golden Rule level of capital,

 _____.

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

$$\left. \begin{aligned} c^* &= y^* - i^* \\ &= f(k^*) - i^* \\ &= f(k^*) - dk^* \end{aligned} \right\}$$

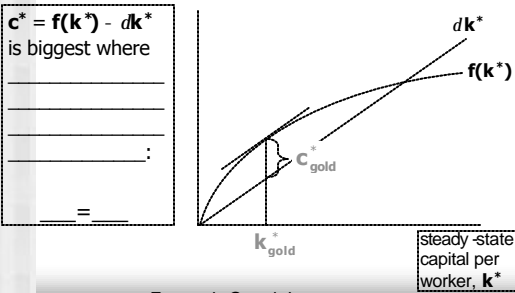
The Golden Rule Capital Stock



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The Golden Rule Capital Stock



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Use calculus to find golden rule

We want to maximize: $c^* = f(k^*) - dk^*$

From calculus, at the maximum we know the derivative equals zero.

Find derivative: $dc^*/dk^* = MPK - d$

Set equal to zero: $MPK - d = 0$ or $MPK = d$

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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?

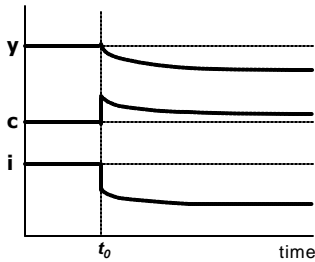
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Starting with too much capital

If $k^* > k_{gold}^*$ then increasing c^* requires a _____.

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



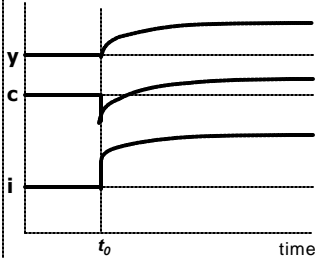
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Starting with too little capital

If $k^* < k_{gold}^*$ then increasing c^* requires an _____.

Future generations enjoy higher consumption, but the current one experiences _____.



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

Break-even investment

$(d + n)k = \text{break-even investment}$

_____.

Break-even investment includes:

- _____ to replace capital as it wears out
- _____ 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

$$\Delta k = \underbrace{\hspace{2cm}}_{\text{actual investment}} - \underbrace{\hspace{2cm}}_{\text{break-even investment}}$$

The impact of population growth

Investment,
break-even
investment

An increase in n
causes an _____
in break-even
investment.
_____.

Capital per
worker, k

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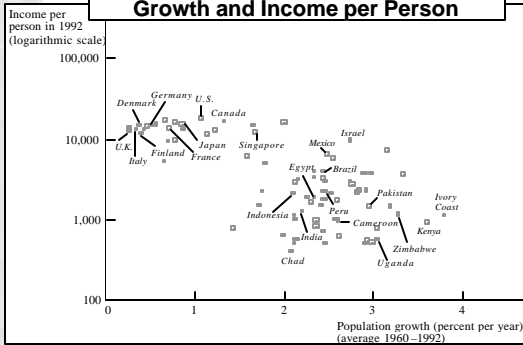
Prediction:

- Higher $n \Rightarrow$ _____.
- And since $y = f(k)$,
lower $k^* \Rightarrow$ _____.
- 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.

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International Evidence on Population Growth and Income per Person



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The Golden Rule with Population Growth

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

$$c^* = y^* - i^* \\ = f(k^*) - \underline{\hspace{2cm}}$$

c^* is maximized when

$$MPK = d + n$$

or equivalently,

In the Golden Rule Steady State, the marginal product of capital

 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.
