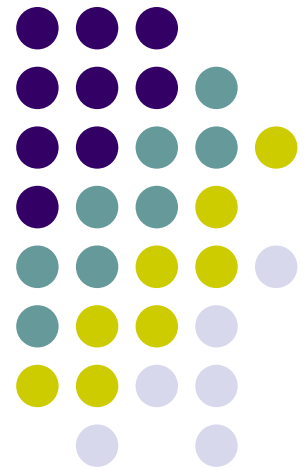
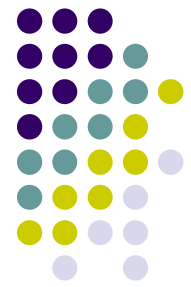


Introduction to Economics of Development

Basic Growth Models:
Solow Model



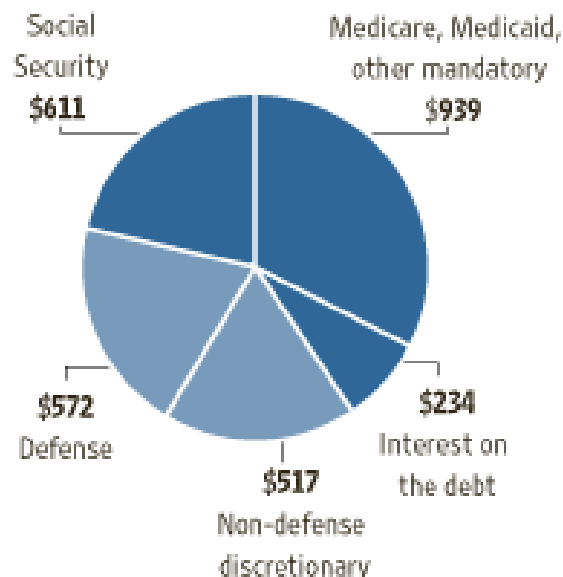


What's Happening 02/05/08

Bush's \$3 trillion budget for 2009

Spending This Year ...

Projected federal budget outlays for fiscal 2008, in billions of dollars.

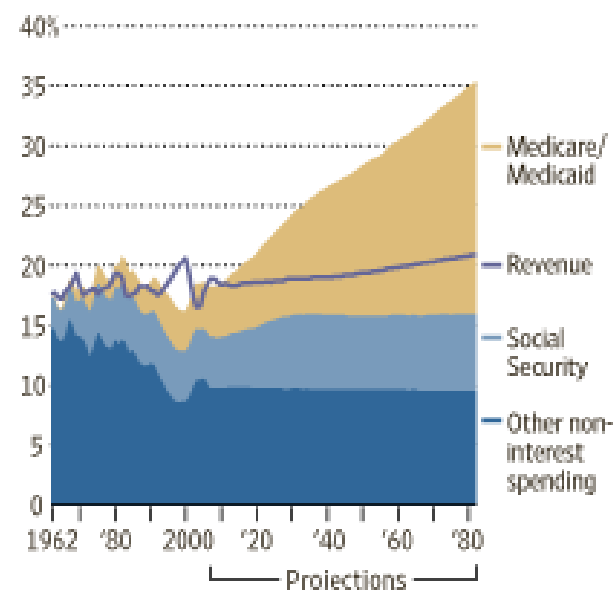


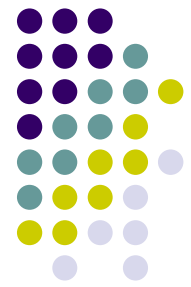
Source: Congressional Budget Office

Note: Projections are based on CBO's 'alternative fiscal scenario,' which incorporates expected policy changes

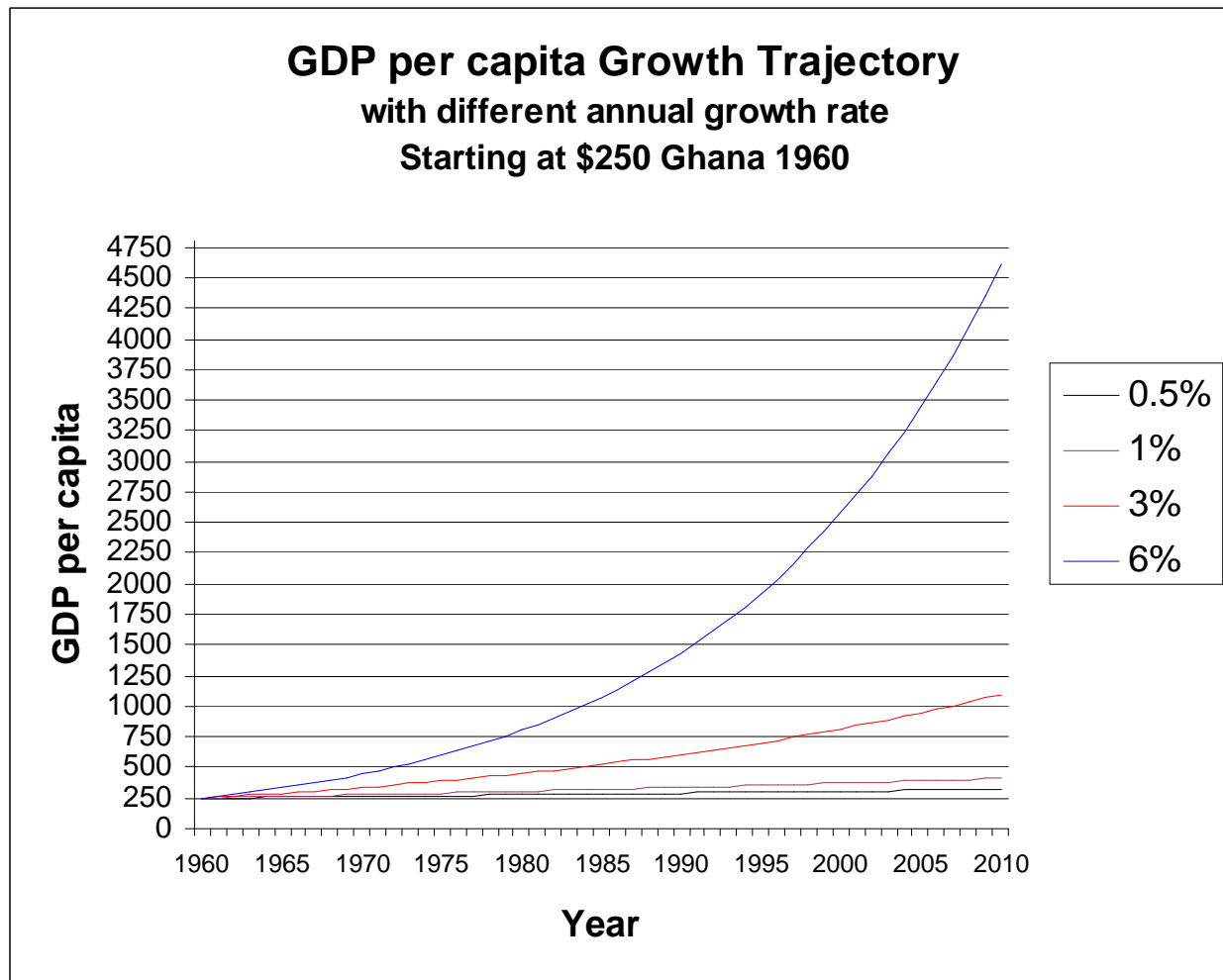
And a Look Ahead

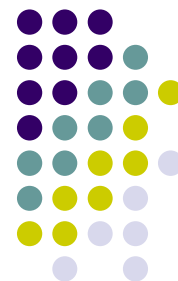
Federal revenue and spending excluding interest as a percentage of GDP





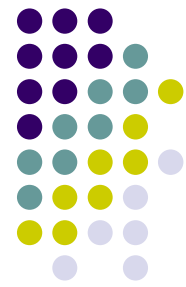
The Magic of Compounding





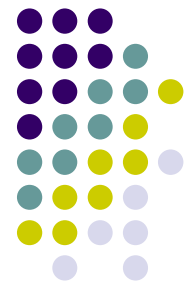
Solow Growth Model

- Key assumptions
- Model derivations
- Analysis and implications
- Convergence debate



Solow Model: Diminishing Returns

- The pancake story (Easterly)
 - Pancake recipe (production function) calls for 1 cup of milk and 2 cups of flour, with milk-flour ratio being 1:2
 - Out of flour, he adds in more and more milk to accommodate a surging demand, resulting in the thinnest pancakes ever made and an outright rejection
 - Diminishing returns in action: increasing one ingredient (milk) while the other ingredient (flour) is unchanged does not achieve sustained growth in pancake production
 - Now think of milk as capital investment (or machine), flour as workers (or labor) in generating GDP growth: as machines per work increases, the marginal product increases less and less.



Solow Model: Production Function

$$Y=F(K,L) \Rightarrow Y/L=F(K/L) \Rightarrow y=f(k), (y=Y/L, k=K/L)$$

To capture diminishing return, $f(k)=k^{\alpha} (\alpha < 1)$

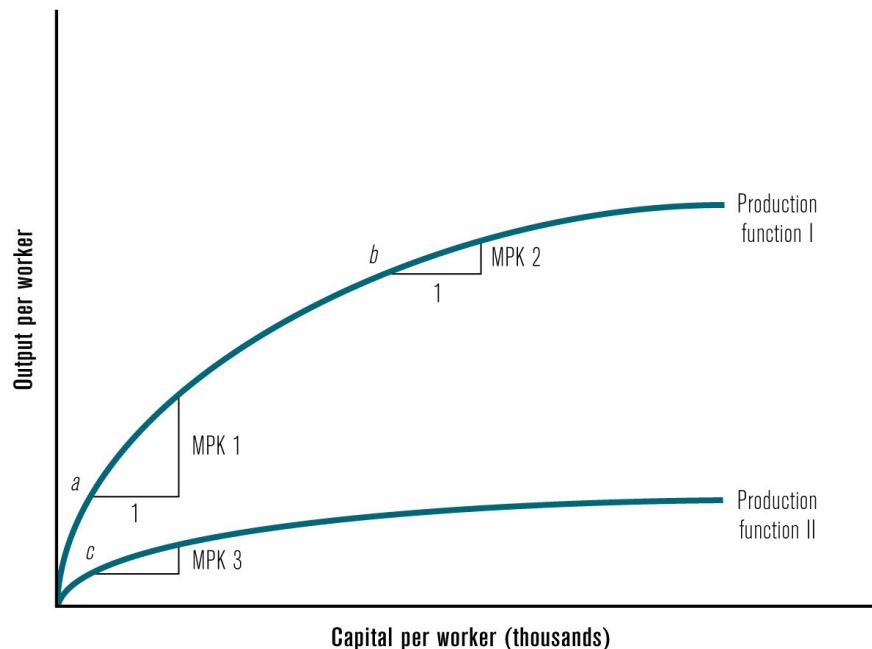


FIGURE 3.9 Diminishing Marginal Product of Capital

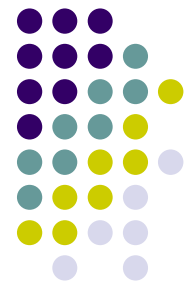
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Capital deepening:

The process in which capital per worker (k) increases. The capital could be machines, computers, equipment, etc.

Capital widening:

An increase in capital stock just keeps pace with the expanding labor force.



Solow Model: No More Fixed Ratios

- In HD model, we assumed fixed capital-output ratio (labor-capital ratio):
- In Solow model, we allow substitution between labor and capital, so for the same output, we could have many different combinations between capital and labor. Also, the capital-output ratio follows *the law of diminishing returns*.

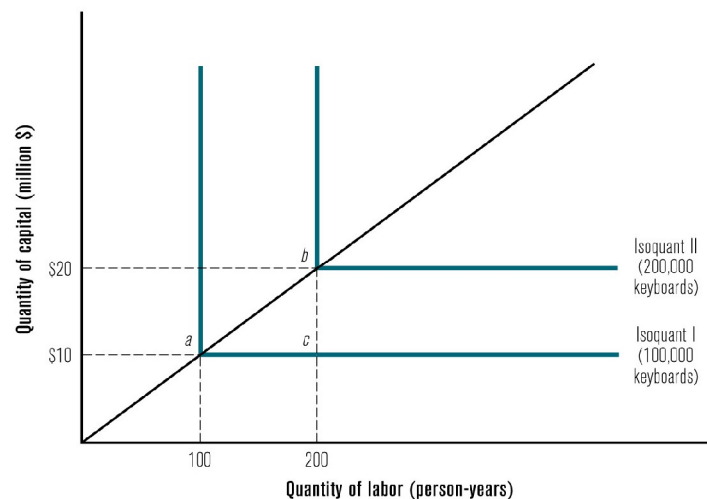


FIGURE 4.1 Production Function with Fixed Coefficients

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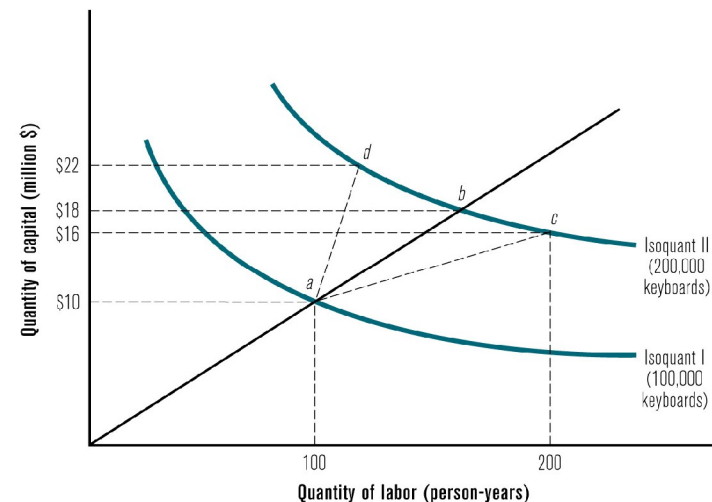


FIGURE 4.2 Neoclassical (variable proportions) Production Function

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Solow Model: Derivations

By definition, net change of capital input (ΔK) equals investment (I) minus capital depreciation $d \cdot K$ (d : depreciation rate), thus we have

$$\Delta K = I - d \cdot K \quad \textcircled{1}$$

Since all savings eventually finds its way to investment, we have $S = I$, and assume savings is a fixed proportion of income, we have $S = s \cdot Y$ (s is savings rate, or saving propensity).

Plug these two equations into equation $\textcircled{1}$, we get:

$$\Delta K = I - d \cdot K = s \cdot Y - d \cdot K \quad \textcircled{2}$$

Now is difficult part:

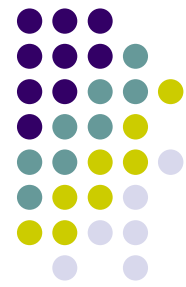
$k = K / L$, after total differentiation we have:

$$\Delta k = \Delta K / L - \Delta L \cdot K / L^2 = \frac{\Delta K}{L} - \frac{K}{L} \cdot \frac{\Delta L}{L} = \frac{\Delta K}{L} - k \cdot n \quad \textcircled{3}$$

(n : is the population growth rate, assume it equals labor growth rate)

Plug $\textcircled{2}$ into $\textcircled{3}$, we have:

$$\Delta k = \frac{s \cdot Y - d \cdot K}{L} - k \cdot n = s \cdot y - d \cdot k - n \cdot k = \boxed{sy - (n + d)k}$$



Solow Model: Analysis

$$\Delta k = sy - (n + d)k$$

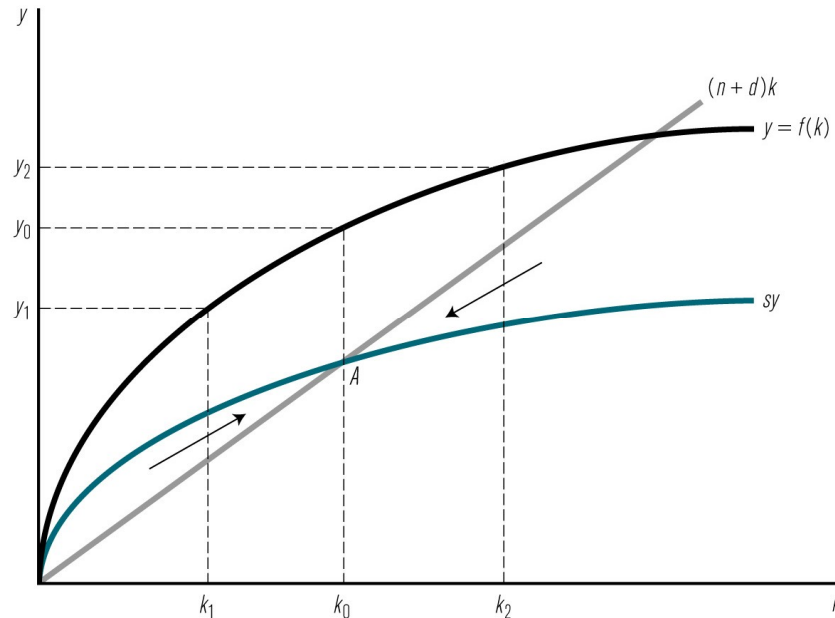


FIGURE 4.4 The Basic Solow Growth Model Diagram

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- Equilibrium point A is called break-even point, or steady state, where savings-investment equals investment required by population growth and depreciation.
 - Remember $k = K/L$, when population is growing at n , K needs to grow faster than n to enable k grow
- Any point before reaching A is when actual investment exceeds investment required by population growth (the process of capital deepening); The opposite is true for any point beyond A.
- At steady state A, economy is still growing in total terms (Y), but not in per capita terms (y) → capital widening.



Solow Model: Scenario 1 Analysis

$$\Delta k = sy - (n + d)k$$

1. When savings rate (s) changes:

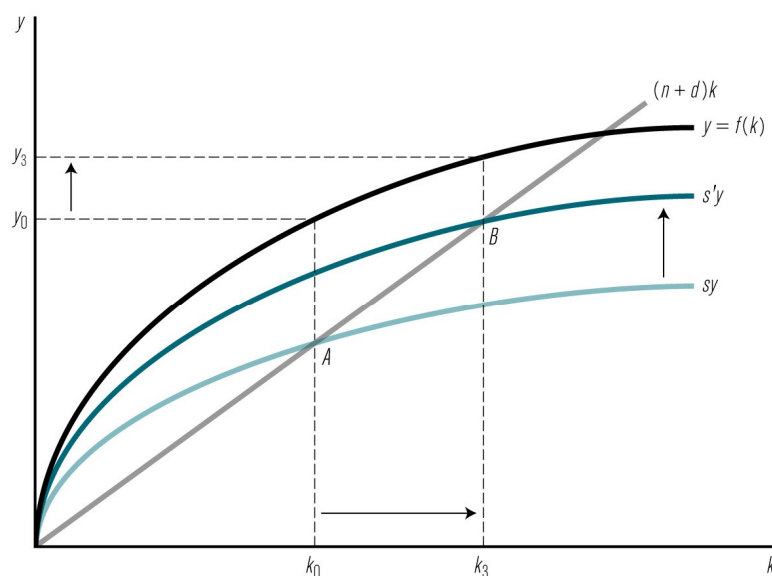
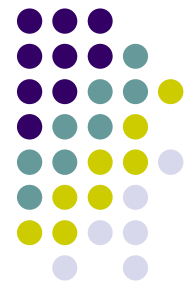


FIGURE 4.5 An Increase in the Saving Rate in the Solow Model

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- When savings rate, $s \rightarrow s'$ ($s' > s$), curve sy shifts upward to $s'y$.
- Equilibrium point shifts from A to B
- Compared two steady states (B vs. A), we have a higher investment per worker ($k=K/L$) and a higher output (or income) per worker ($y=Y/L$)



Solow Model: Scenario 2 Analysis

$$\Delta k = sy - (n + d)k$$

2. When population growth rate (n) changes:

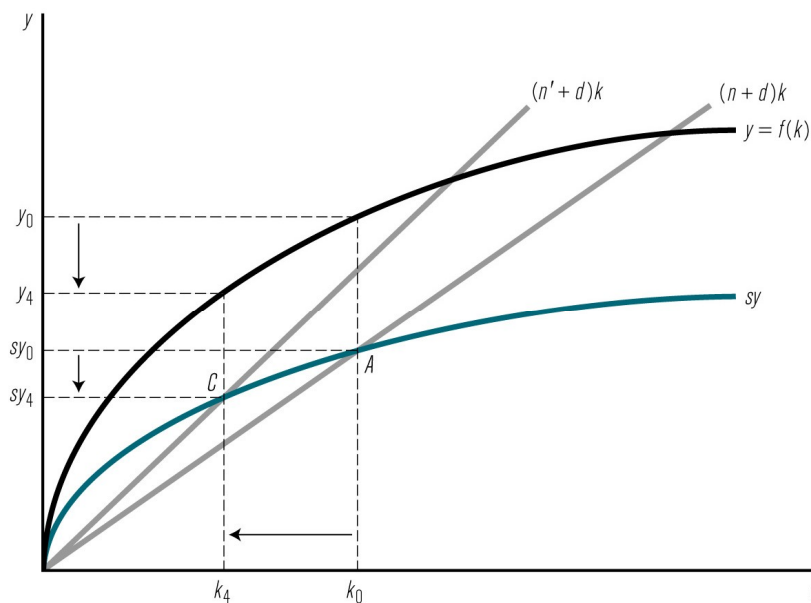
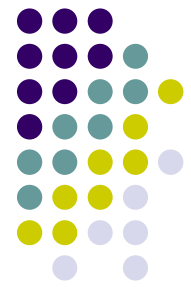


FIGURE 4.6 Changes in the Population Growth Rate in the Solow Model

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- In the situation we have a higher population growth (n increases to n'), line $(n+d)k$ shifts upward to $(n'+d)k$
- The equilibrium point A shifts back to point C.
- At steady state C, we have a lower investment per worker, and lower output per worker, and a lower savings per worker



What's Happening 02/07/08

BOE Cuts Rates; ECB Keeps Steady



European interest rates could head lower this year, as the ECB gave greater weight to slow growth than inflation worries, and the Bank of England cut its key rate and indicated more cuts may be on

the way. (BOE Statement) 1:21 p.m.

Fed Chief Met With Diverse Group



Alan Greenspan tops a list of academics, executives and economists who met with Bernanke during a turbulent period for the economy.

Economists gave Fed chief Bernanke the lowest grade of

his two-year tenure, in the latest Wall Street Journal forecasting survey, and said a recession is becoming more likely. 11:33 a.m.

Romney Suspends Campaign



Romney suspended his presidential campaign for the Republican nomination, effectively ceding the nomination to John McCain. "I must now stand aside, for our party and our country," he said during an appearance at the Conservative Political Action Conference. (Text of speech) 2:27 p.m.



Solow Model: Scenario 3

$$\Delta k = sy - (n + d)k$$

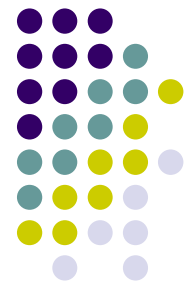
3. Robert Solow introduces technology into the growth model by changing absolute count of labor into effective unit of labor, or $L(e)$. We call this particular way of incorporating technology “labor augmenting”.

- Imagine we can divide labor into separate units measured by their *efficiency*.
- Workers in developing countries are less productive, so 100 (absolute) count of labor maybe just equals 200 *effective units of labor*.
- In contrast, workers in developed countries are more productive, so 100 (absolute) count of labor equals, say, 500 *effective units of labor*.

$$Y = F(K, L) = F(K, TL_e) \Rightarrow y_e = f(K / TL_e) = f(k_e)$$

$$\Rightarrow \Delta k_e = sy_e - (n + d + \theta)k_e, (\theta = \Delta T / T)$$

θ : measures technology growth rate



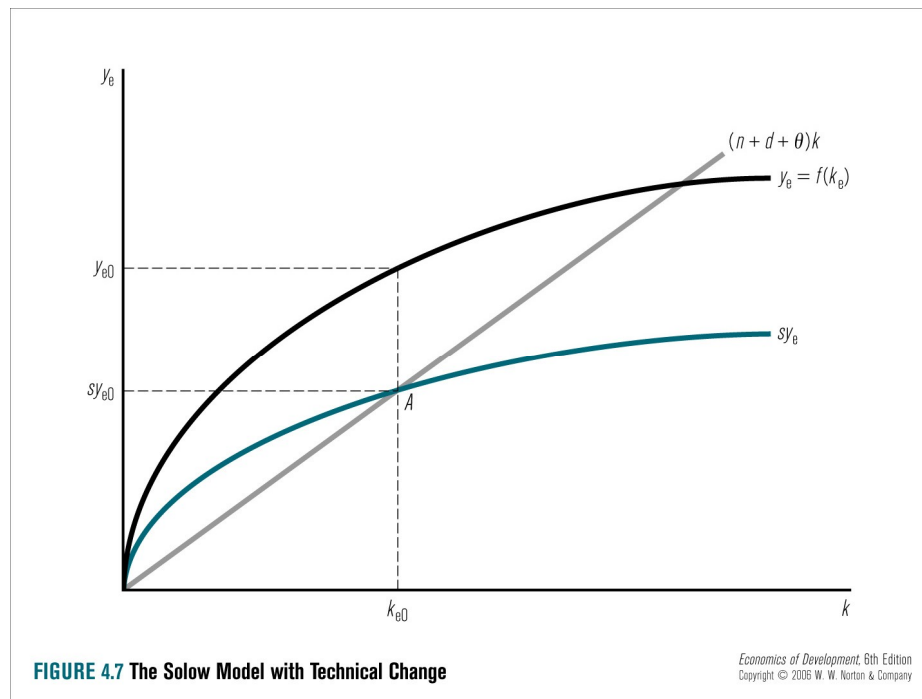
Solow Model: Scenario 3 Analysis

3. When labor is measured by effective unit of labor (Le):

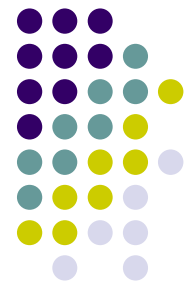
$$\Delta k = sy - (n + d)k$$

$$\Rightarrow \Delta k_e = sy_e - (n + d + \theta)k_e.$$

$$n + d + \theta \geq n + d$$



- At steady state A, now we have investment growth equal to the population growth plus rate of technology advancement.
- Compared with previous scenarios, at steady state, we have a faster growth rate.
- The introduction of effective unit of labor and its implications could possibly explain why developed countries did not suffer slower growth rate as implied by diminishing returns.

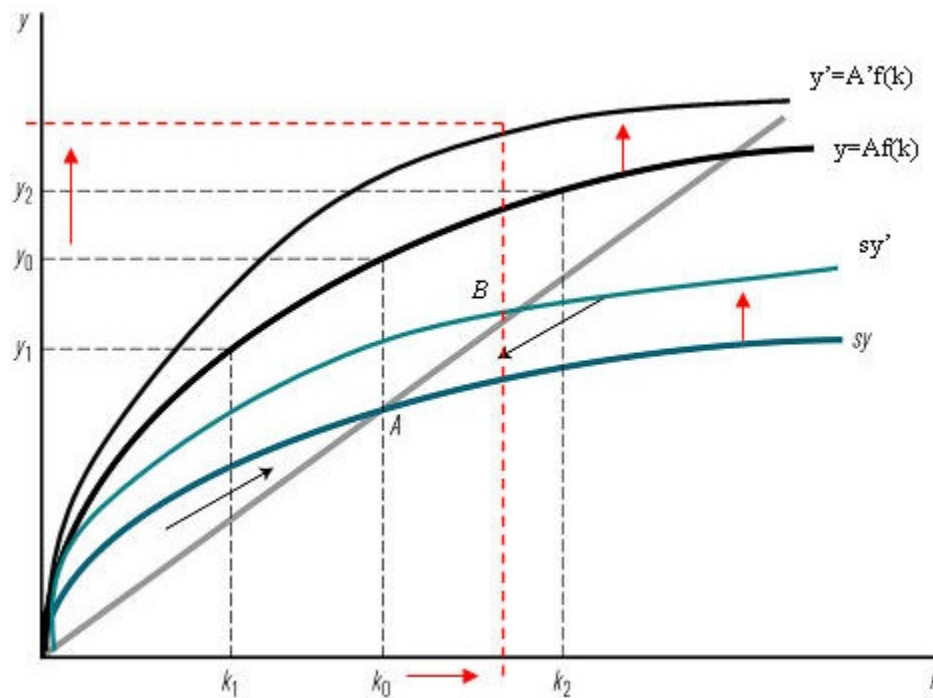


Solow Model: Scenario 4 Analysis

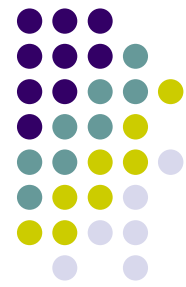
4. Now let's make technology exogenous to production function:

$$y_e = f(k_e) = f(K / TL_e) \text{ vs. } y = A \cdot f(k) \quad A: \text{Solow residual}$$

And when we have a positive technology shock:



- When the economy is hit by an exogenous technology shock, when $A \rightarrow A'$, both production function and savings curves (sy) shift upward.
- New steady state is at B ($A \rightarrow B$), where we have both a higher capital per worker and income per capita.
- Compare scenario 4 to 1, the difference is that increase of income per capita is a result of two changes: not only the upward-shifted sy curve, but also the upward-shifted y curve.



Solow's Shocker

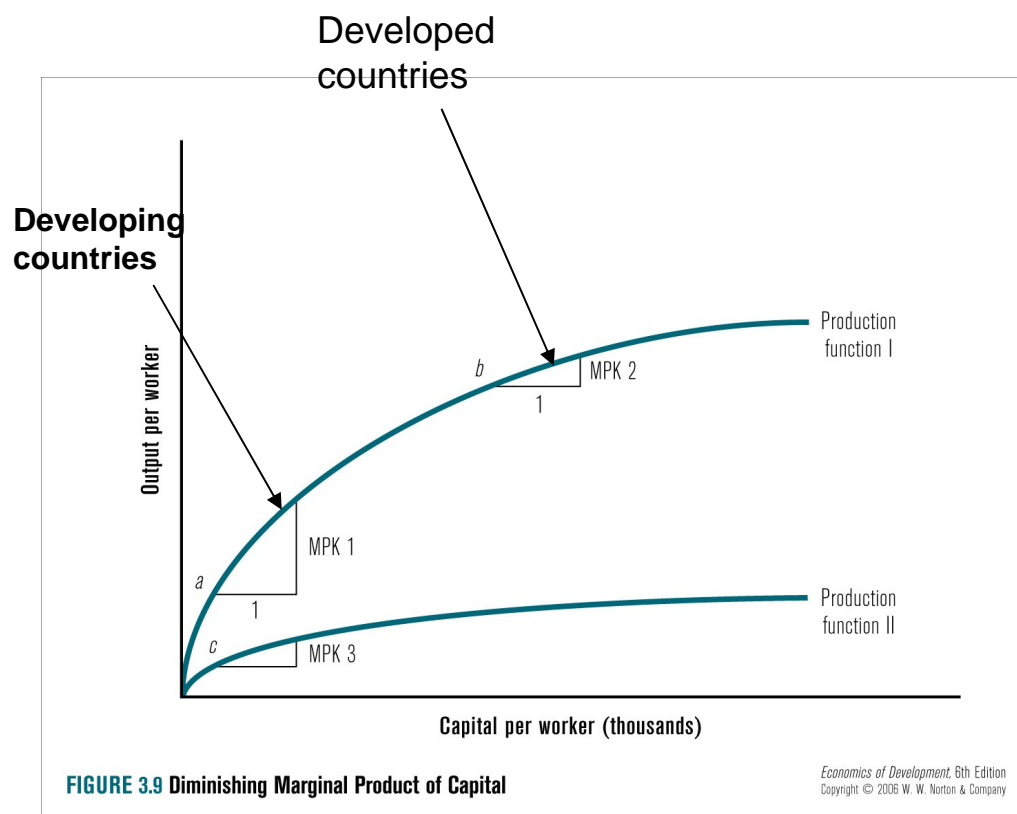
- Increasing machines (or capital investment) was not a feasible way to sustain growth (if growth is defined in increases in GDP per capita).
- Saving will not sustain long-run growth as saved money buys more machines and these machines eventually run into the same unavoidable problem of diminishing returns.
- It's the technology, Stupid
 - The simple logic outlined above would suggest long-run growth of output per worker could not be sustained, so capital could not be the ultimate source of growth.
 - However, many industrial economies had sustained growth of 2% per worker for the last two centuries. How is this possible?
 - In Solow's calculation that technology change accounted for 7/8 of the US growth per worker over the first half of the 20th century.

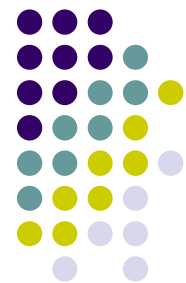


Solow Model & Convergence Debate

Diminishing returns and its implications on growth rate

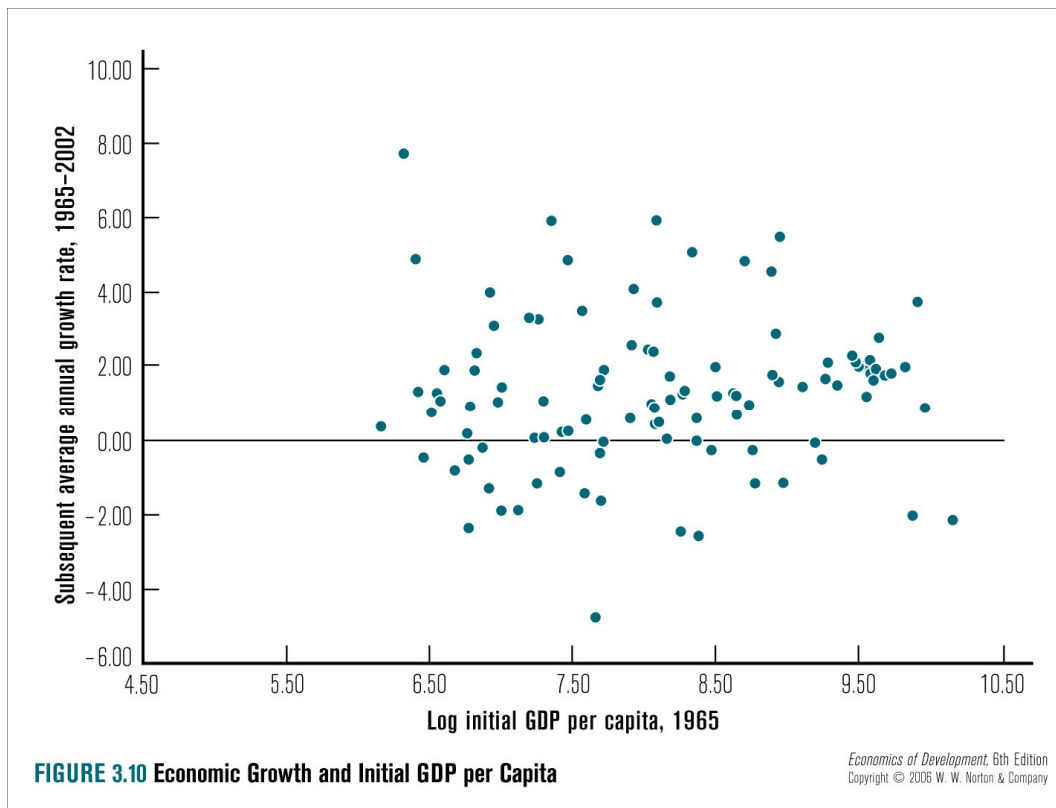
- Developing countries that are way below steady state should grow a lot faster than developed countries that are close or at steady state.
- In other words, we expect to witness a “catch-up effect” of developing countries (*once they start to grow*), or convergence between poor and rich countries.
- This faster growth will continue until developing countries reach the steady state.

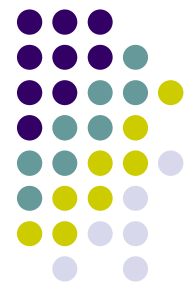




Solow Model & Convergence Debate

Convergence theory states that the higher income level a country has, the slower the country will grow in later periods. If this is true, we should expect to see a negative relationship between initial income level and subsequent growth rate.





Solow Model & Convergence Debate

The success of conditional convergence.

In conditional convergence test, a lot of control variables that might influence the hypothesized relationship were introduced, such as savings rate, education, technology, quality of institutions, etc. After controlling these variables, we do observe the expected negative relationship between initial income level and subsequent growth rate.

