Introduction to Economic Growth

World Distribution of Real GDP

1. 先看几个图
2. 然后总结几个特点：
   - 整体来说，全球经济在增长（最低值和最高值都在提升）
   - 全球处于贫困区间的人口在减少
   - 一些穷国永远穷
   - 发展中国家占大多数，发达国家依旧少数（长尾）
   - 发展中国家的追赶效应明显

Figure 3.2 World distribution of real GDP per person in 1960

The graph shows the distribution of real gross domestic product (GDP) per person for 107 countries in 1960. The horizontal axis is in 2005 international dollars and uses a proportionate scale. Representative countries are indicated for the ranges of real GDP per person.

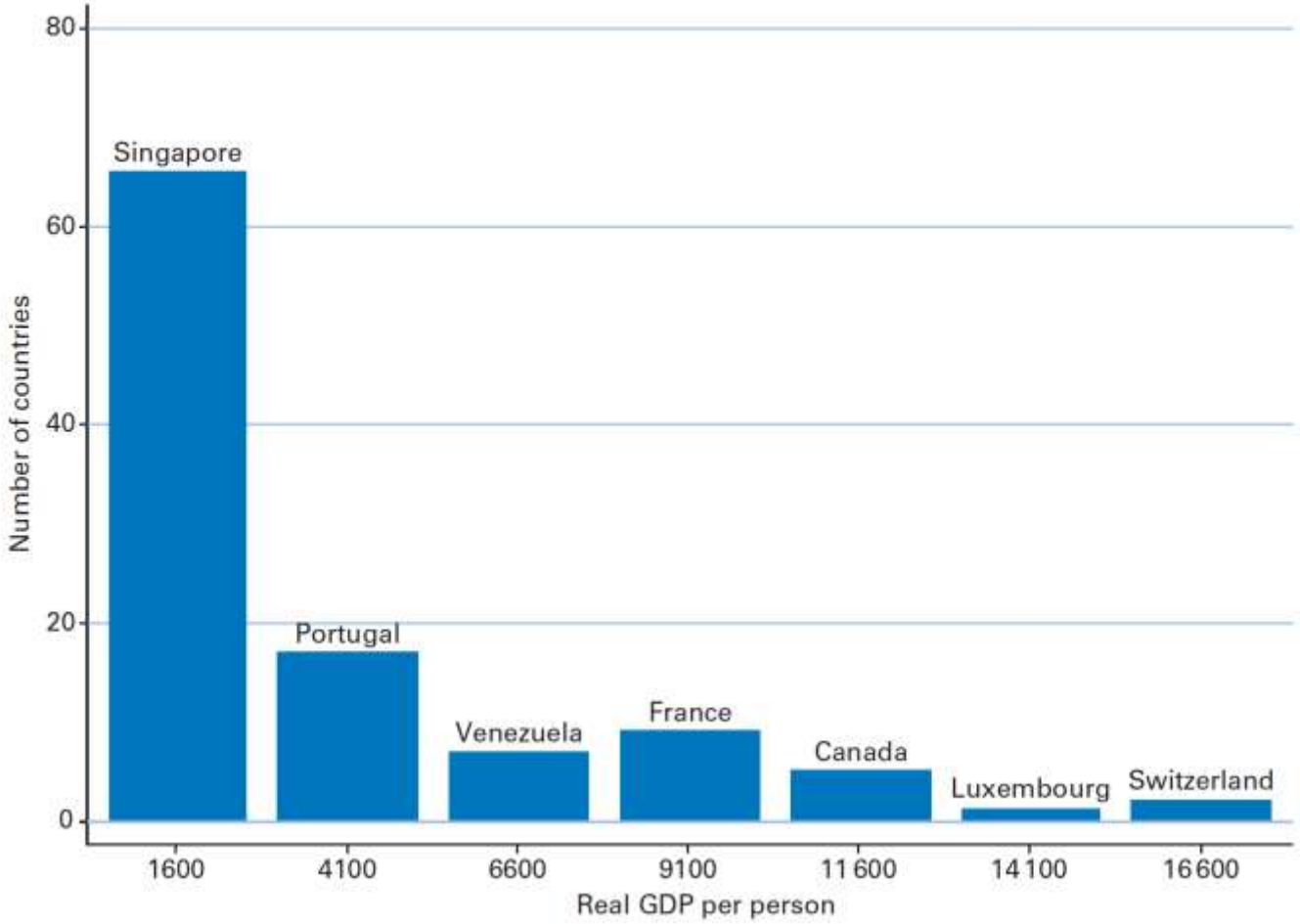


Figure 3.1 World distribution of real GDP per person in 2011

The graph shows the distribution of real gross domestic product (GDP) per person for 160 countries (or economies) in 2011. The horizontal axis is in 2005 US dollars and uses a proportionate scale. Representative countries (or economies) are indicated for the ranges of real GDP per person.

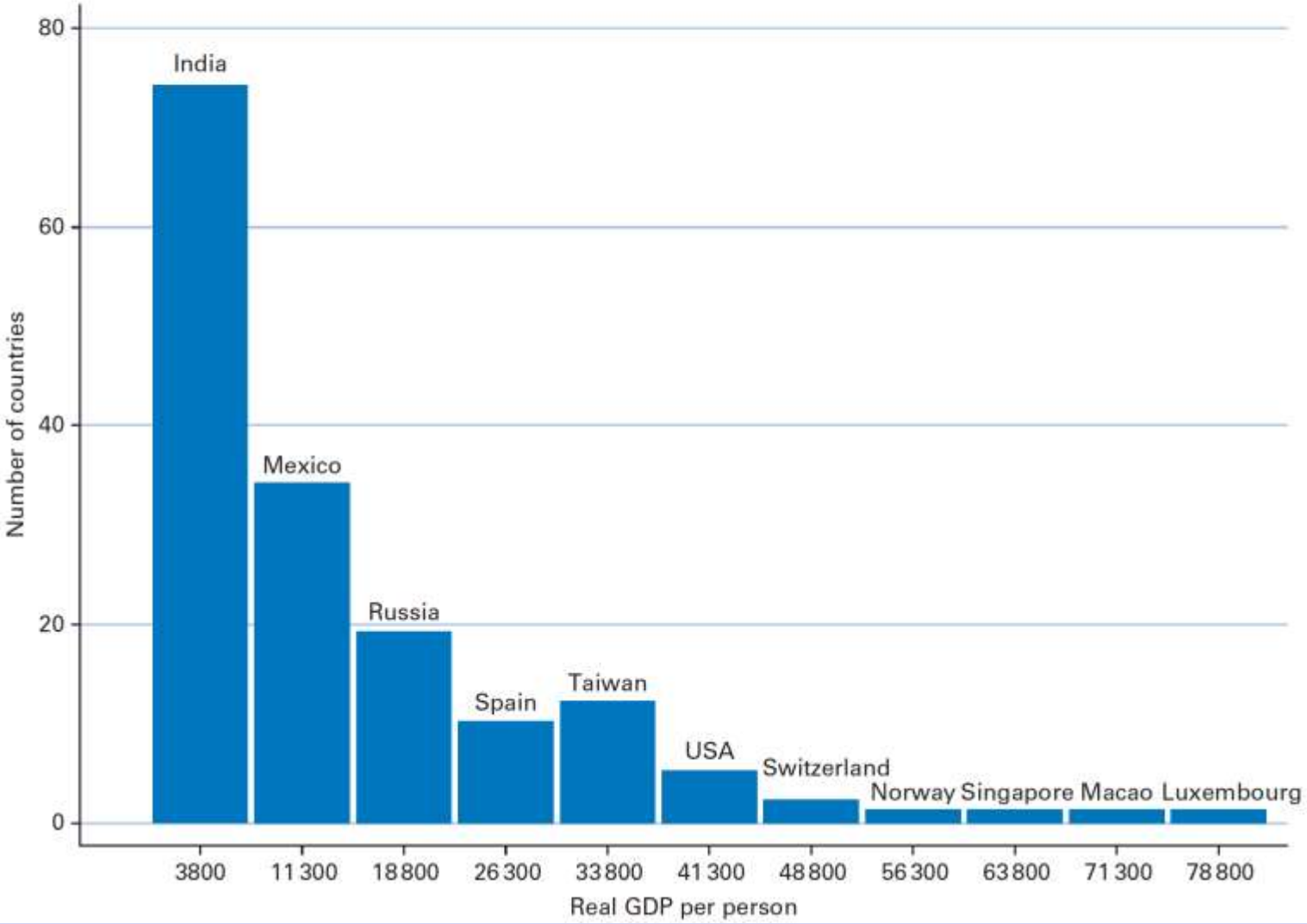


Figure 3.3 World distribution of growth rates of real GDP per person, 1960–2011

The graph shows the distribution of the growth rate of real GDP per person for 107 countries from 1960 to 2011. Representative countries are indicated for the ranges of growth rates. The unweighted average growth rate was 2.2% per year.

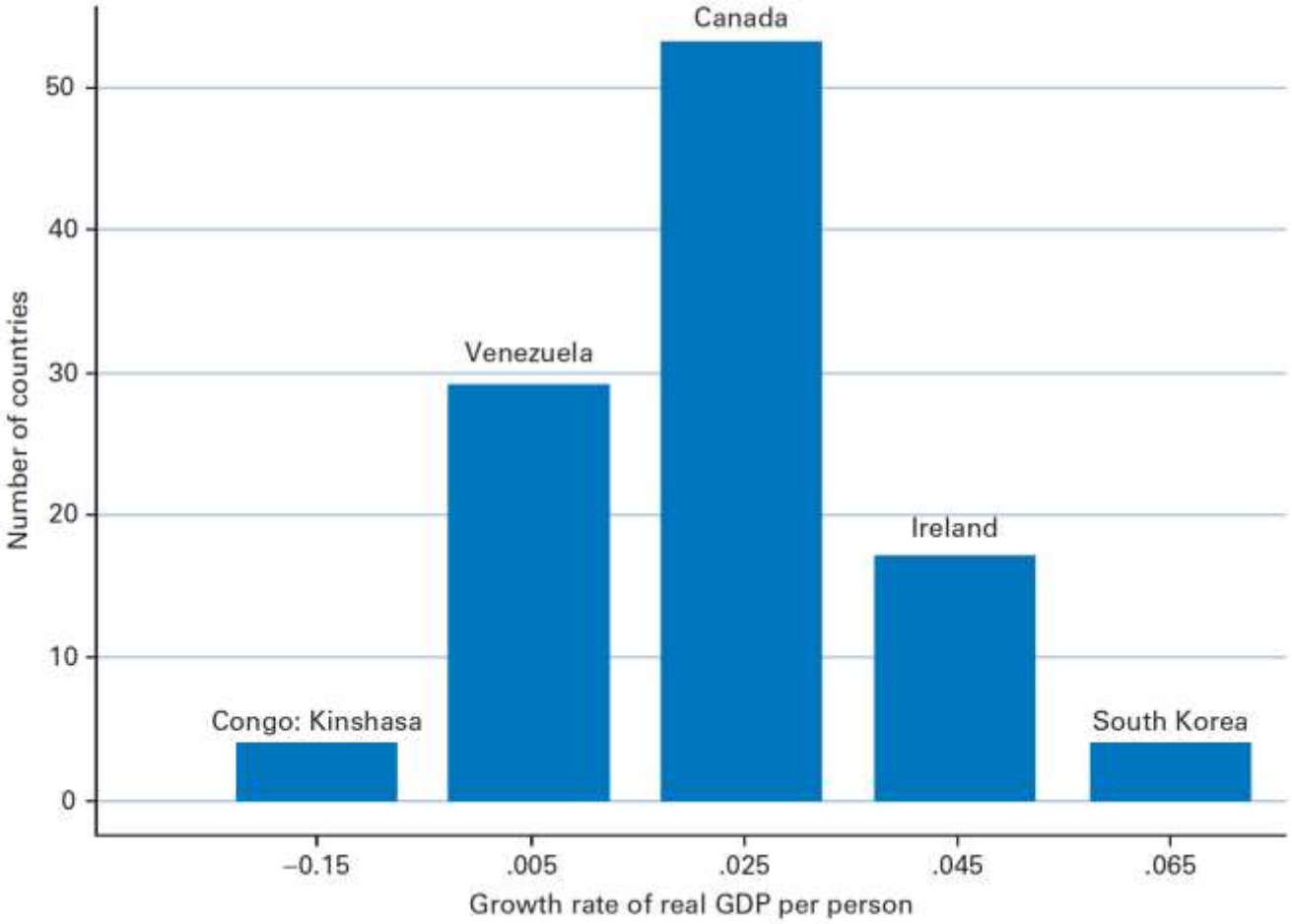
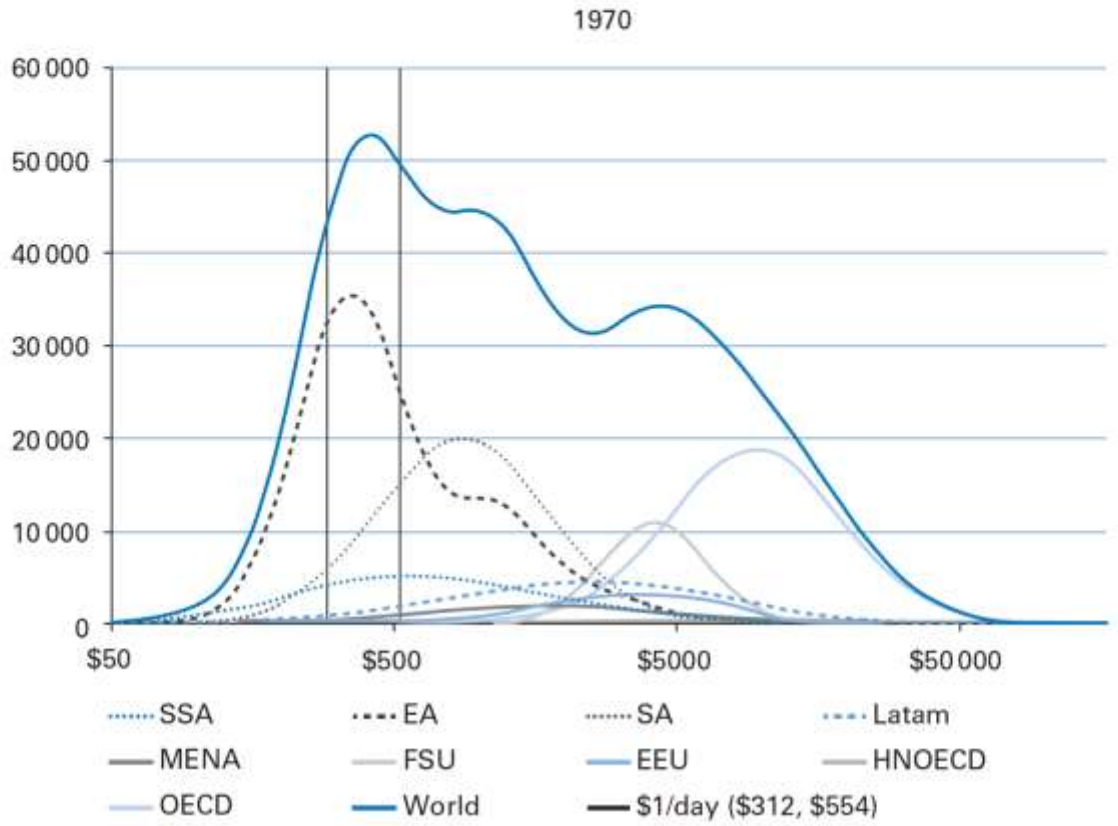


Figure 3.4 (a) At the head of the figure for 1970; (b) At the head of the figure for 2006

Figure 3.4(a) is for 1970 and Figure 3.4(b) is for 2006. In each case, the horizontal axis plots real income in 2006 international dollars on a proportionate scale. For the upper curves in the two figures, the vertical axis shows the number of people in the world with each level of income. The vertical lines marked $1 show the annual real incomes that correspond to the standard poverty line of $1 per day ($312 per year in 2006 prices). The income distributions for countries are grouped into regions: East Asia (labelled EA), Eastern Europe (EEU), Former Soviet Union (FSU), High Income Non-OECD countries (HNOECD), Latin America (Latam), Middle East and North Africa (MENA), South Asia (SA) and sub-Saharan Africa (SSA). The values shown on the upper curves for numbers of people in the world are the vertical sums of the numbers of people in all of the individual countries.



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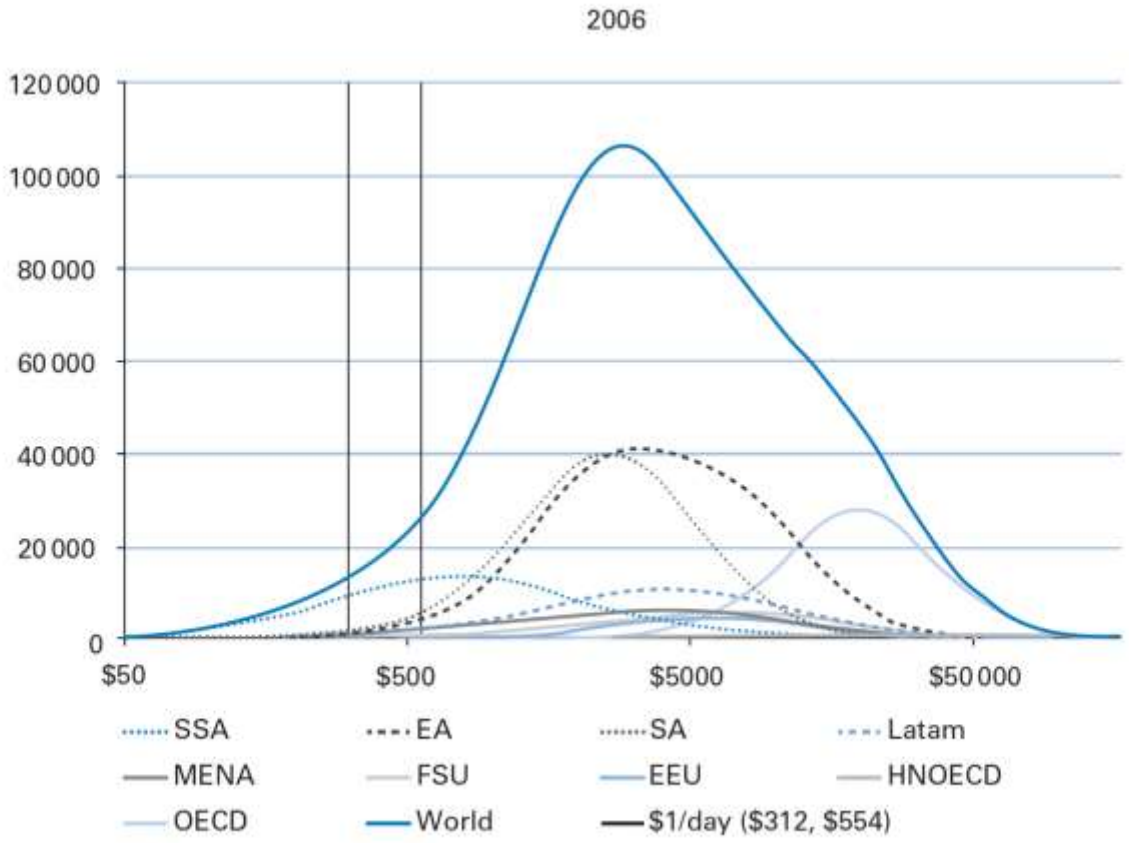


Source: These graphs come from Pinkovskiy and Sala-i-Martin (2009). Reproduced with permission.

Long Term Economic Growth in OECD Countries

Table 3.2 Long-term economic growth in OECD countries

Period	Growth rate of real GDP per person (per cent per year)	Number of countries
1800–1830	0.1	5
1820–1850	1.0	13
1850–1880	1.2	20
1860–1890	1.2	18
1890–1920	1.0	20
1920–1950	1.5	20
1950–1980	3.4	21
1980–2010	1.7	21

Note: The data are from the Angus Maddison Project described in Bolt and van Zanden (2014). The 21 countries included are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Italy, Ireland, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom and the United States. The growth rates are unweighted averages for the countries with available data. Fewer countries have data for the earlier periods.

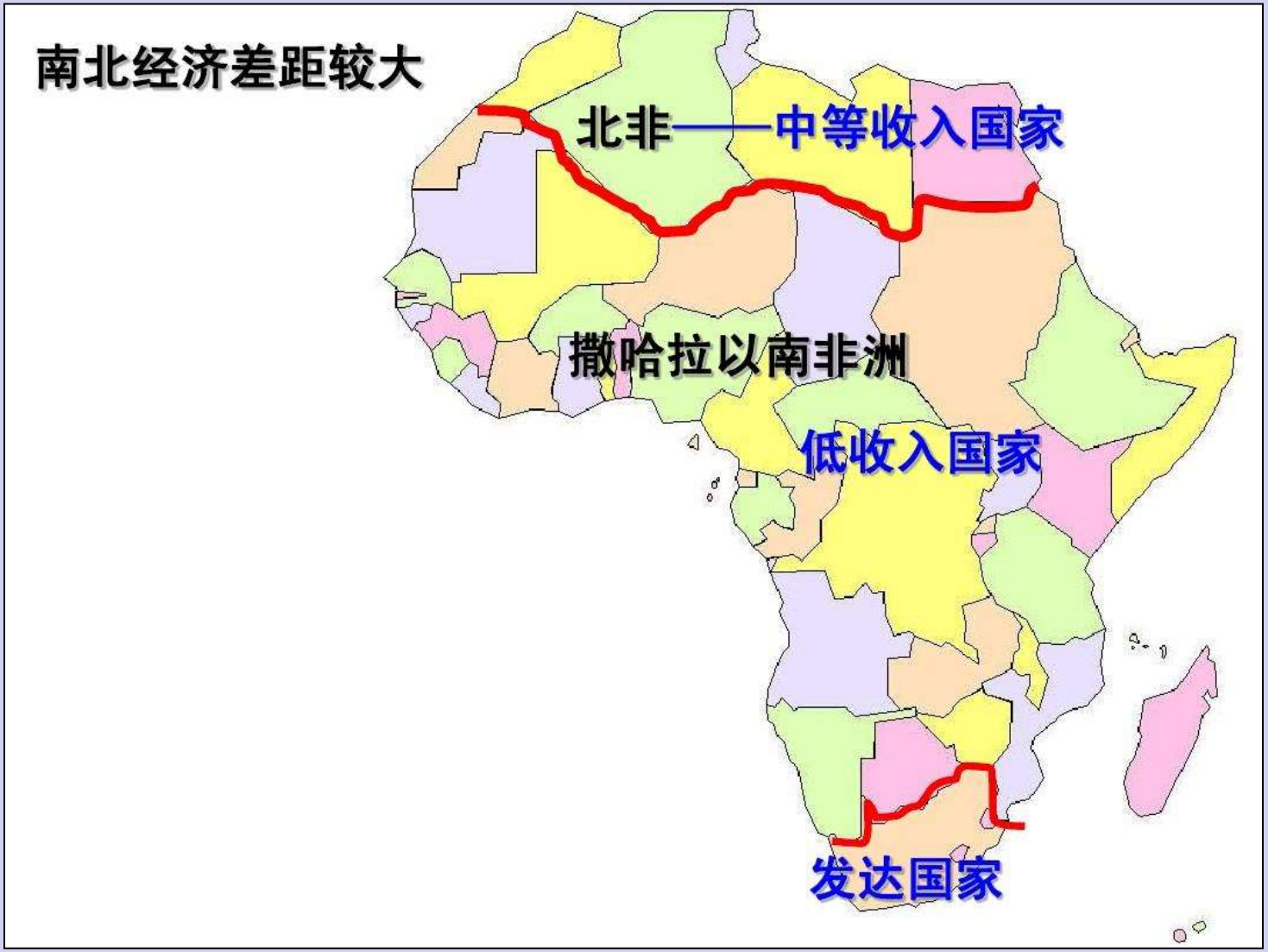
Productivity Slowdown

- **OECD国家**: The decline in the growth rate of real GDP per person from 3.4% per year for 1950–1980 to 1.7% per year for 1980–2010 is sometimes called the **Productivity Slowdown （生产力下降)**

Growth Questions

- What factors caused some countries to grow fast and others to grow slow over periods, such as 1960 to 2011?
- In particular, why did the East Asian countries do so much better than the sub-Saharan African countries（SSA：撒哈拉以南非洲）?
- How did countries such as the United States and other OECD members **sustain** growth rates of real GDP per person of around 2% per year for a century or more?
- What can policymakers do to increase growth rates of real GDP per person?

非洲地图



非洲地图


突尼斯
地中海
叙利亚
摩洛哥
伊拉克
伊朗
阿尔及利亚
利比亚
埃及
西撒哈拉
沙特阿拉伯
阿曼
毛利塔尼亚
马里
尼日尔
乍得
苏丹
也门
布基纳法索
亚丁湾
阿拉伯
几内亚
尼日利亚
南苏丹
埃塞俄比亚
加纳
几内亚湾
索马里
加蓬
肯尼亚
坦桑尼亚
安哥拉
赞比亚
莫桑比克
纳米比亚
津巴布韦
马达加斯加岛
博茨瓦纳
南大西洋
南非

Production Function

$$Y = A \cdot F(K, L)$$

- A ➔ Technology Level
- K ➔ Capital Stock – machines and buildings used by business and factories
- L ➔ Labor Force – number of workers

Production Function

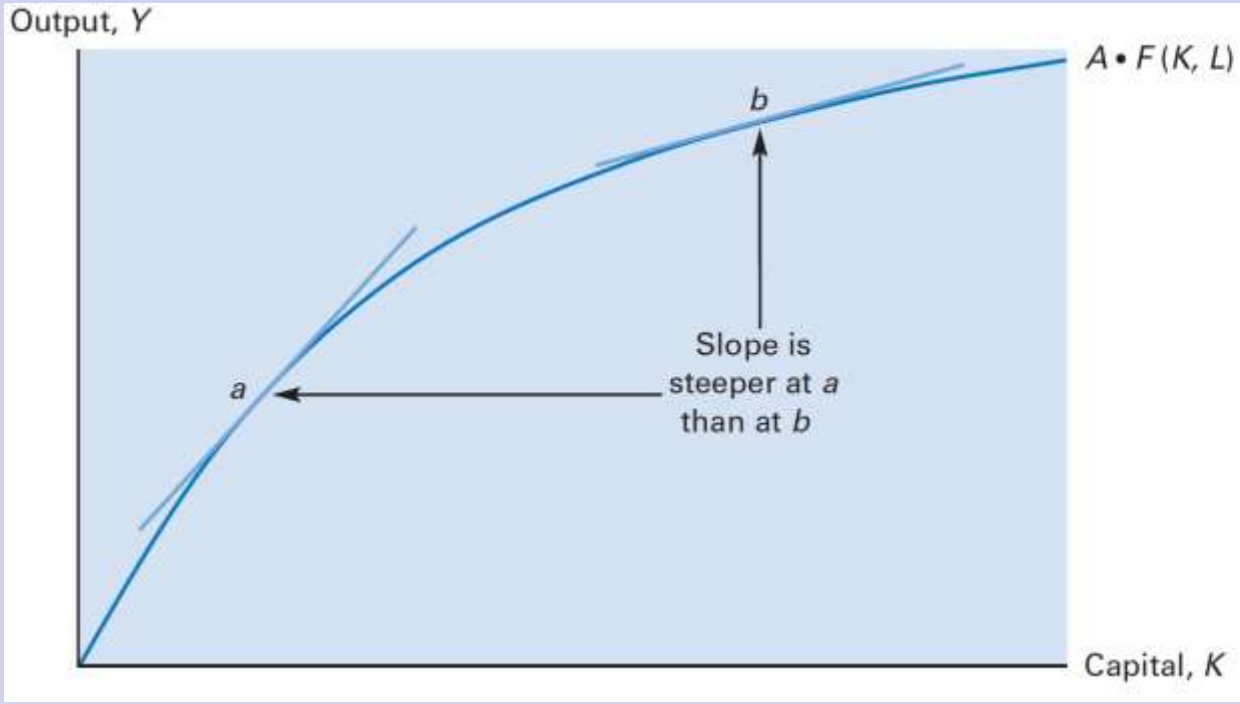


Figure 3.5 The production function in terms of capital input

The curve shows the effect of capital input, *K*, on output, *Y*. We hold fixed the technology level, *A*, and the quantity of labour input, *L*. Therefore, the slope of the curve at any point is the marginal product of capital, MPK. This slope gets less steep as *K* rises because of diminishing marginal product of capital. Therefore, the slope at point *a* is greater than that at point *b*.

Production Function

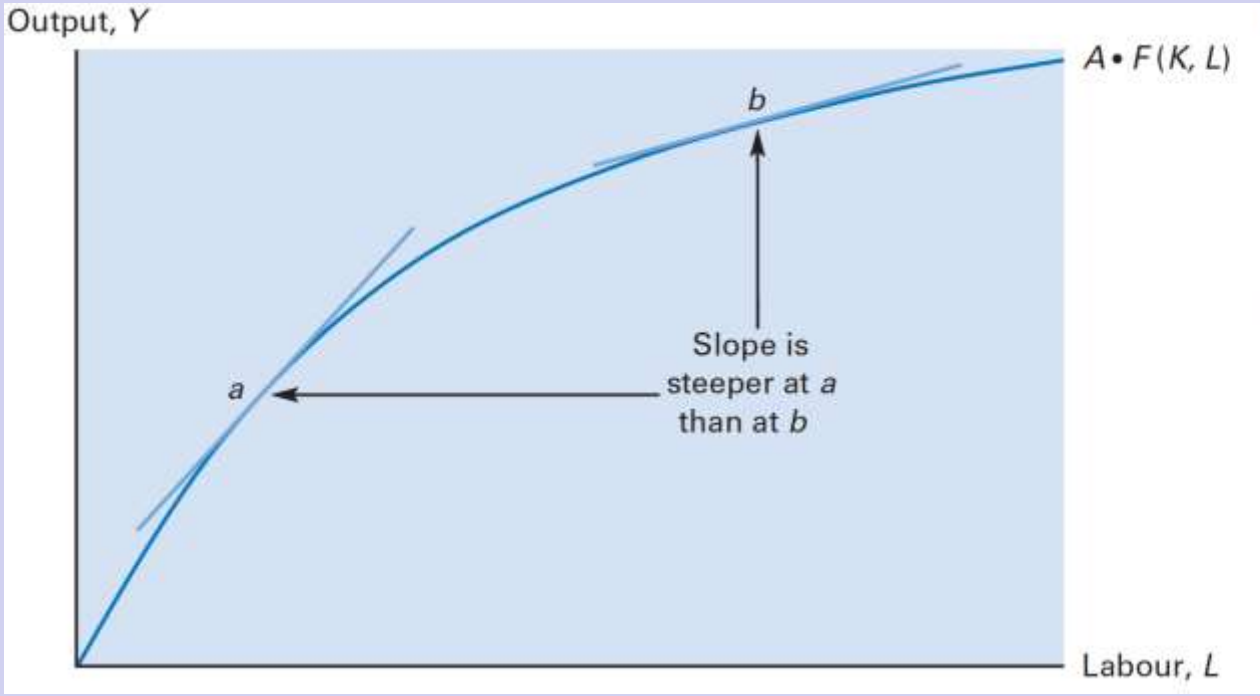


Figure 3.6 The production function in terms of labour input

The curve shows the effect of labour input, *L*, on output, *Y*. We hold fixed the technology level, *A*, and the quantity of capital input, *K*. Therefore, the slope of the curve at any point is the marginal product of labour, MPL. This slope gets less steep as *L* rises because of diminishing marginal product of labour. Therefore, the slope at point *a* is greater than that at point *b*.

Production Function

- *MPL* – Marginal Product of Labour
  - **Diminishing** Marginal Product of labour
- *MPK* – Marginal Product of Capital
  - **Diminishing** Marginal Product of Capital

Constant Returns to Scale

- Constant Returns to Scale
  - Double K and L, THEN, Y will also double
- Therefore, if we multiply *K* and *L* by the quantity 1*/L, THEN, Y* should also multiply by 1*/L* to get
- $Y / L = A \cdot F(K / L, L / L)$
- Let Y/L=y, K/L=k, THEN,
- $y=A \cdot f(k)$

Per Worker Production Function

- $y = A \cdot f(k)$

  y ➔ output per worker: Y/L

  k ➔ capital per worker: K/L

- 人均产出是人均资本的函数
- 人均产出：我们在《经济学原理B》中，也叫劳动生产力。

Per Worker Production Function

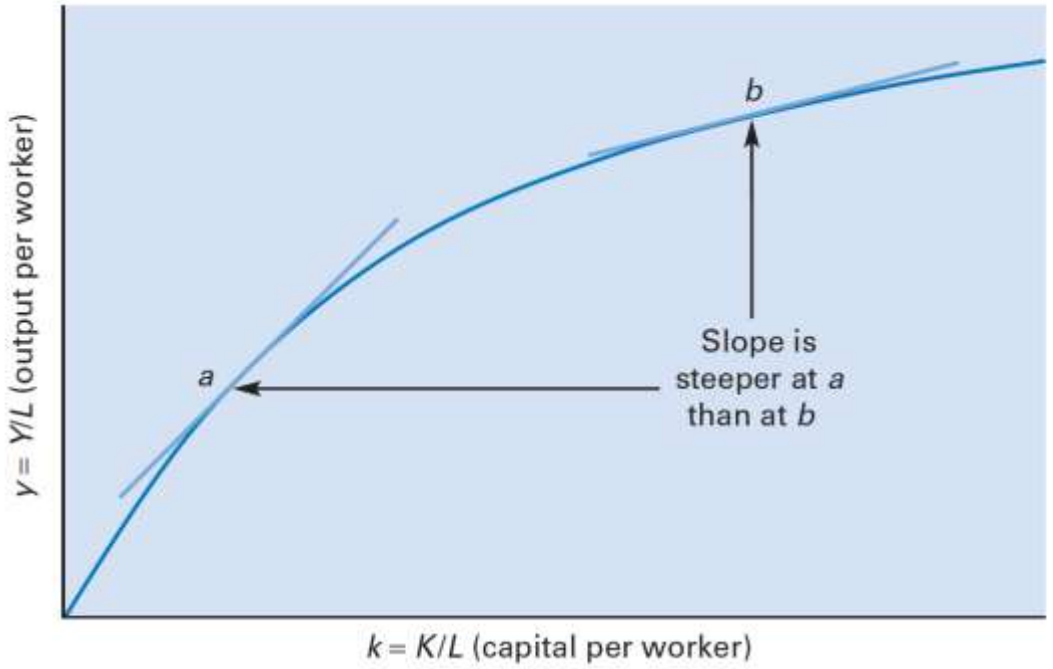


Figure 3.7 Output per worker versus capital per worker

This method for showing the production function plots output per worker, $y = Y/L$, against capital per worker, $k = K/L$. We hold fixed the technology level, A. The slope of the curve at any point is the marginal product of capital, MPK. This slope gets less steep as k rises because of diminishing marginal product of capital. Therefore, the slope at point a is greater than that at point b.

Contributions to GDP Growth

- $Y = AK^{\alpha}L^{\beta}$:柯布道格拉斯生产函数
- $LnY = LnA + \alpha LnK + \beta LnL$
- $\Delta Y/Y = \Delta A/A + \alpha\cdot(\Delta K/K) + \beta\cdot(\Delta L/L)$
- The growth rate of real GDP, $\Delta Y/Y$, equals the growth rate of technology, $\Delta A/A$, plus the contributions from the growth of capital, $\alpha\cdot(\Delta K/K)$, and labor, $\beta\cdot(\Delta L/L)$.
- 比如 α=0.3, β=0.7

Contributions to GDP Growth

- $\Delta Y/Y = \Delta A/A + \alpha\cdot(\Delta K/K) + \beta\cdot(\Delta L/L)$

  $0 < \alpha < 1$，$0 < \beta < 1$

  •可以推算技术进步的速度：$g=\Delta A/A$

- $\alpha + \beta = 1$，即 *share of capital income (α) + share of labor income (β)* = 1，比如 α=0.3，β=0.7

  ➢α + β = 1, 规模报酬不变，就是产量增加的比例等于生产要素的投入增加的比例。比如生产要素均增加10%，则产量增加10%。

  ➢α + β>1, 规模报酬递增，就是产量增加的比例大于生产要素的投入增加的比例

  ➢α + β<1, 规模报酬递减,就是产量增加的比例小于生产要素的投入增加的比例

Solow Growth Model

- 索罗经济增长模型（Solow growth model):
- 提出人：罗伯特·索罗（Robert Solow）1956年提出，所提出的发展经济学中著名的模型，又称作新古典经济增长模型、外生经济增长模型，是在新古典经济学框架内的经济增长模型。

Solow Growth Model

- Labor force, L
- L= labor force participation rate · population
  = (labor force/ population) · population
- Assume labor force participation rate is constant.
- 因此, Labor force growth rate is the population growth rate, *n*.

Solow Growth Model

- Model ignores:
  - Government/ Central Bank
    - No taxes, public expenditures, debt, or money issue, that is, no government, no central bank
  - International Trade
    - No trade in goods or financial assets
    - Thus, close economy assumed, no NX, no NCO

Solow Growth Model

- Assume $\Delta A/A = 0$
- 非常关键的假设，切记!
- Thus, $\Delta Y/Y = \alpha \cdot (\Delta K/K) + (1-\alpha) \cdot (\Delta L/L)$
- The growth rate of real GDP is a weighted average of the growth rates of capital and labor.

Solow Growth Model

- From the conversion of per worker production function

$$\Delta y/y = \Delta Y/Y - \Delta L/L$$

$$\Delta k/k = \Delta K/K - \Delta L/L$$

- ???，自己换算一下。

Solow Growth Model

- $\Delta Y/Y = \alpha \cdot (\Delta K/K) + (1-\alpha) \cdot (\Delta L/L)$
- $\Delta Y/Y = \alpha \cdot (\Delta K/K) - \alpha \cdot (\Delta L/L) + \Delta L/L$
- $\Delta Y/Y - \Delta L/L = \alpha \cdot (\Delta K/K - \Delta L/L)$
- $\Longrightarrow \Delta y/y = \alpha \cdot (\Delta k/k)$

Solow Growth Model

- Each household divides up its real income in a fixed proportion s to saving and $1 - s$ to consumption (C).
- Capital depreciate at the same constant rate δ
- δK is the amount of capital depreciation each year
- Y- δK*: real net income*

Solow Growth Model

- *Real saving* = $s \cdot (Y - \delta K)$
- *Real saving* = (*saving rate*) · (*real net income*)

Solow Growth Model

- $Y - \delta K = C + S$
- $Y - \delta K = (1-s) \cdot (Y - \delta K) + s \cdot (Y - \delta K)$
- *Real net income = consumption + real saving*

Solow Growth Model

- $Y = C + I$: 假设封闭经济+没有政府
- *Real GDP = consumption + gross investment*
- $Y - \delta K = C + (I - \delta K)$
- *Real net income = consumption + net investment*

Solow Growth Model

- $C + s \cdot (Y - \delta K) = C + I - \delta K$

or

- $s \cdot (Y - \delta K) = I - \delta K$
- *Real saving = net investment*

Solow Growth Model

- $\Delta K = I - \delta K$
- *Change in capital stock = net investment*
- $\Delta K = s \cdot (Y - \delta K)$
- *Change in capital stock = real saving*

Solow Growth Model

- Divide both sides by K
- $\Delta K/K = s \cdot Y/K - s\delta$

  其中，ΔK/K: 资本增长率； Y/K：资本生产力

Solow Growth Model

- Growth rate in population
  - We assume that population grows at a constant rate, denoted by n, where n is a positive number ($n > 0$).
- $\Delta L/L = n$

Solow Growth Model

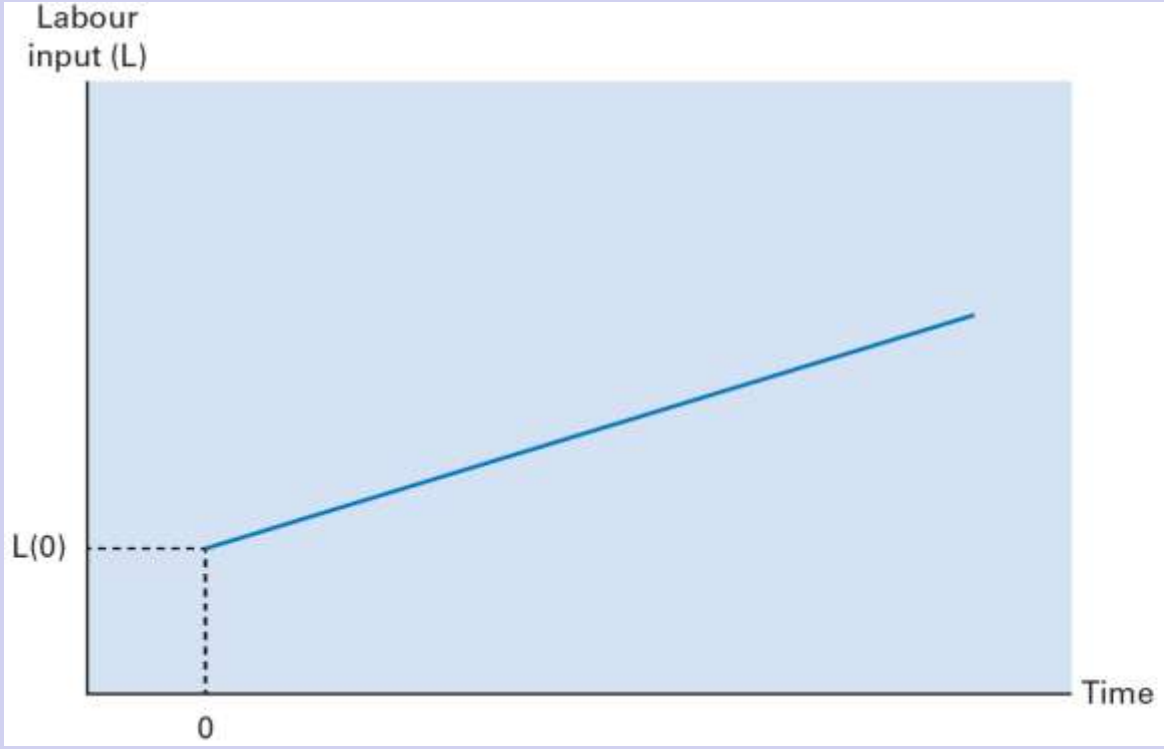


Figure 3.8 Time path of labour input

Labour input, L, starts at time 0 at $L(0)$. Labour input then grows with population at the constant rate n. On a proportionate scale, L follows a straight line, as shown in the figure.

Solow Growth Model

- $\Delta k/k = \Delta K/K - \Delta L/L$
- $\Delta k/k = s\cdot (Y/K) - s\delta - n$
- $Y/K = (Y/L) / (K/L) = y/k$
- $\Delta k/k = s\cdot(y/k) - s\delta - n$

  人均资本的增长率是资本生产力的函数
- $\Delta y/y = \alpha\cdot(\Delta k/k)$
- $\Longrightarrow$ $\Delta y/y = \alpha\cdot[\, s\cdot(y/k) - s\delta - n]$

人均GDP的增长率是资本生产力的函数

Solow Growth Model

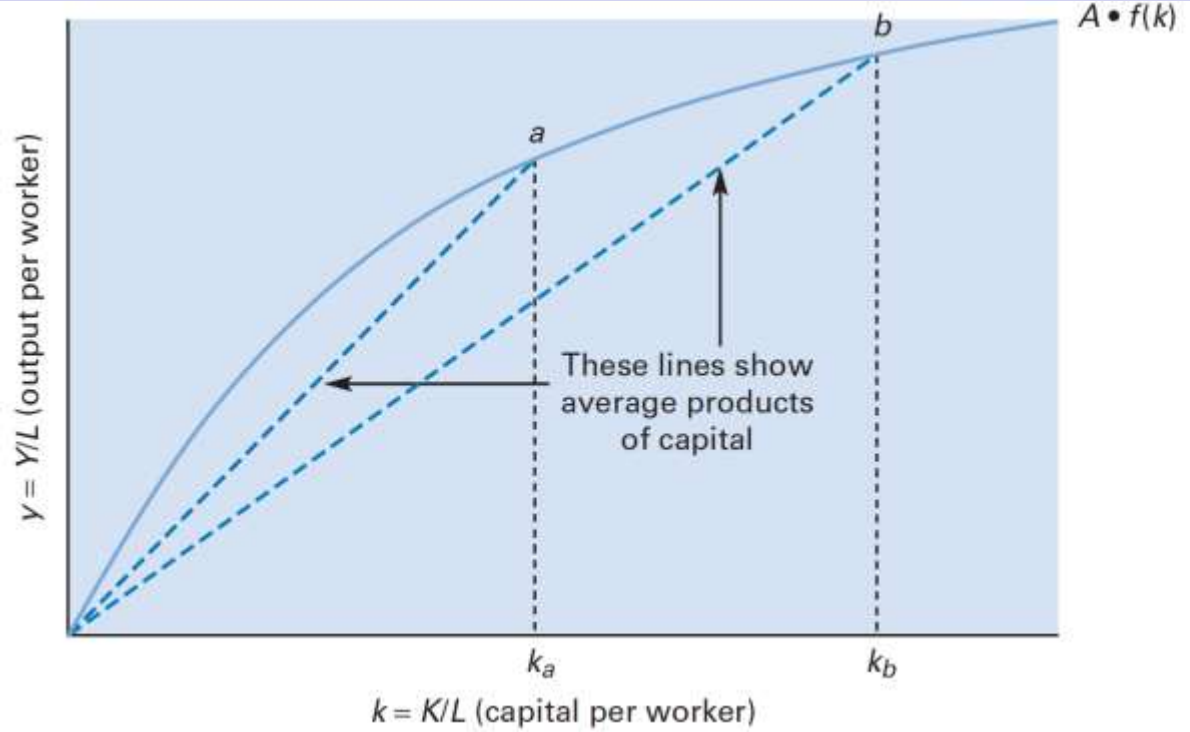


Figure 3.9 The average product of capital

The graph shows the production function for output per worker, $y = Y/L$, versus capital per worker, $k = K/L$, as in Figure 3.7. The slope of a straight line from the origin to the production function gives the average product of capital, y/k, at the associated value of k. As k rises, for a given technology level, A, the average product of capital falls. For example, the slope of the dashed blue line, from the origin to point a, is greater than that of the dashed blue line, from the origin to point b. Therefore, the production function exhibits diminishing average product of capital.

边际收益递减：随着k的增加， y的增量 越来越小

- $k(0) = K(0)/ L(0)$
- $y(0) = Y(0)/L(0)$
- $y = A \cdot f(k)$
- $y(0) = A \cdot f[k(0)]$

Solow Growth Model

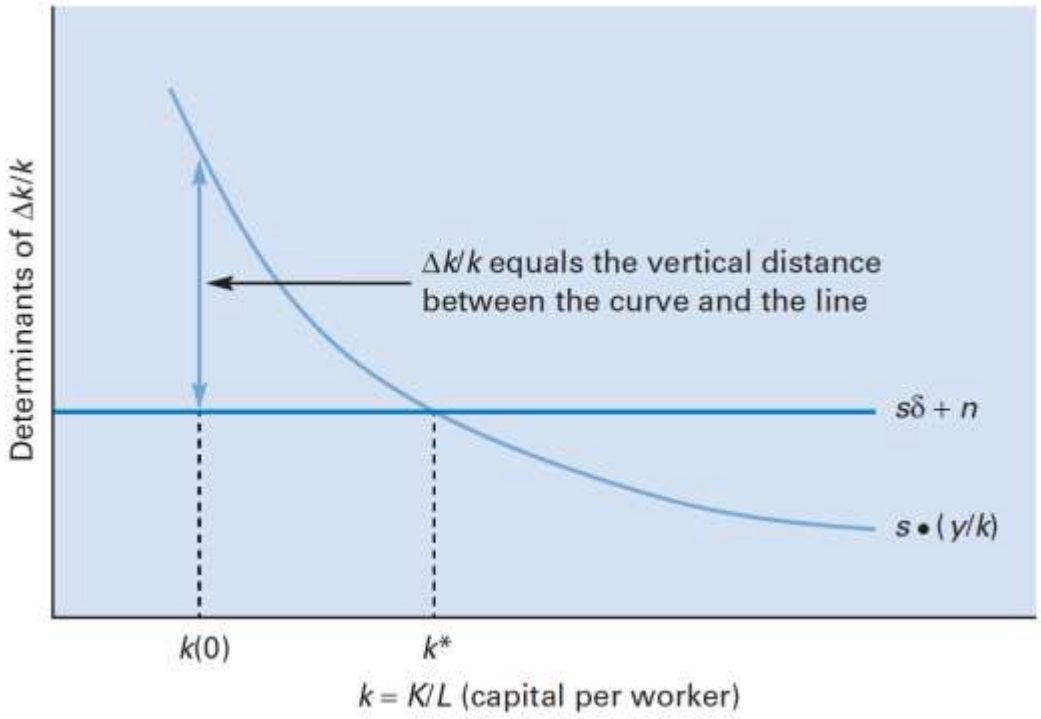


Figure 3.10 Determination of the growth rate of capital per worker in the Solow model

The technology level, A, is fixed. The vertical axis plots the two determinants of the growth rate of capital per worker, $\Delta k/k$, from the right-hand side of equation (3.16). $\Delta k/k$ equals the vertical distance between the negatively sloped $s \cdot (y/k)$ curve and the horizontal line at $s\delta + n$. At the steady state, where $k = k^*$, the curve and line intersect, and $\Delta k/k = 0$. The initial capital per worker, $k(0)$, is assumed to be less than k^*. Therefore, when $k = k(0)$, $\Delta k/k$ is greater than zero and equal to the vertical distance shown by the blue arrows.

$$\Delta k/k = s \cdot (y/k) - s\delta - n$$

Solow Growth Model

- Steady State.
  - ✓When $k = k*$, $\Delta k/k = 0$, k stays fixed at the value $k*$.
  - ✓Then, $\Delta y/y = \alpha \cdot (\Delta k/k) = 0$
  - ✓$y^* = f(k^*)$

Solow Growth Model

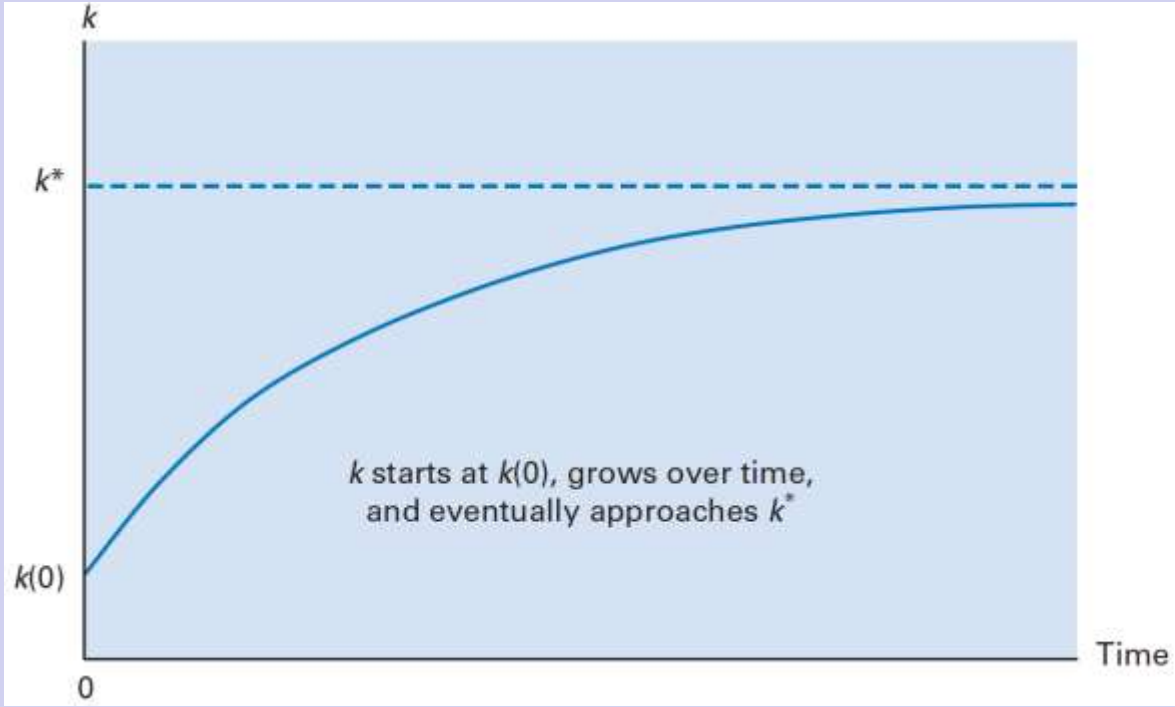


Figure 3.11 The transition path for capital per worker

In the Solow model, described by Figure 3.10, capital per worker, k, starts at $k(0)$ and then rises over time. The growth rate of k slows down over time, and k gradually approaches its steady-state value, k^*. The transition path from $k(0)$ to k^* is shown by the solid blue curve. The dashed blue line shows the steady-state value, k^*.

Solow Growth Model

- In the steady state,
- $\Delta k/k = 0 \rightarrow s \cdot (y^*/k^*) - s\delta - n = 0$
- $s \cdot (y^* - \delta k^*) = nk^*$
- *Steady-state saving per worker = steady-state capital provided for each* ***new*** *worker*
- $s \cdot (y^* - \delta k^*) = nk^*$
- $\rightarrow s \cdot (f(k^*) - \delta k^*) = nk^* \rightarrow$ *solve out* k^*