

CHAPTER 8

ECONOMIC GROWTH II: TECHNOLOGY, EMPIRICS, AND POLICY

Objectives:

- To understand the contribution of technological progress to growth;
- To learn what empirical studies of growth tell us;
- To analyse policies to promote growth and increases in per capita income.

I. Technological Progress.

1. Growth in the efficiency of labour and the aggregate production function.

- We assume that there is technological progress which is “**labour-augmenting**” in the sense that it increases the productivity, or efficiency, of labour over time.
- Labour input is measured as the “**effective**” number of workers equal to the number of actual workers (L) multiplied by an index number (E) measuring the average ***efficiency of labour***:

$$\text{Labour input} = L \cdot E = \text{effective number of workers}$$

- Assume that the value of E increases at a constant annual rate, denoted as g .
- Example: Suppose that, due to improvements in knowledge and ability, each worker becomes 2 percent more productive each year (i.e $g = 0.02$). Then, from a base value of 1.00 in 2006, E will grow to 1.02 in 2007 and 1.0404 in 2008.
- 100 actual workers employed in 2007 are able to produce what would have taken 102 actual workers to produce in 2006 and 100 actual workers employed in 2008 are able to produce what (slightly more than) 104 actual workers would have produced in 2006.

- The aggregate production function is re-written as:

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

- Labour input, or the effective number of workers ($L \cdot E$), grows at rate $n + g$.

2. The new per capita production function.

- We will analyse the model in terms of output (capital, consumption etc) *per effective worker*, not per actual worker.

- We redefine k and y as the levels of capital per **effective** worker and output per **effective** worker:

$$k = K / (L \cdot E); \quad y = Y / (L \cdot E)$$

- As before: $y = f(k)$ or $Y / (L \cdot E) = f(K / (L \cdot E))$

3. The steady state with technological progress.

- To keep the level of capital **per effective worker** (k) constant, investment as a proportion of capital stock needs to equal the rate of depreciation (δ) plus the rate of growth of the **effective** number of workers ($n+g$):

Break-even investment per effective worker = $(\delta+n+g)k$.

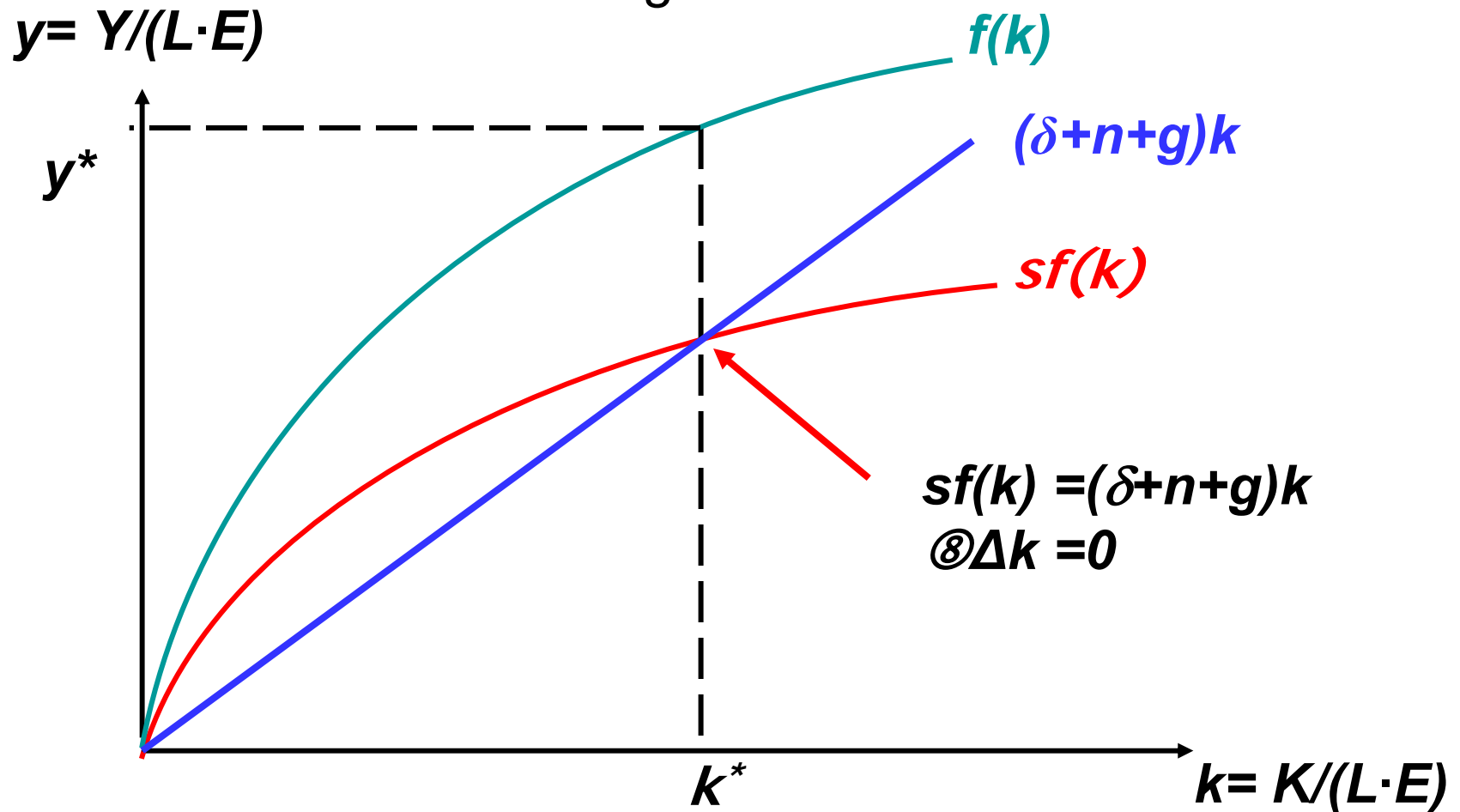
- Intuition:
 - need δk of investment per effective worker to compensate for **depreciation**;
 - need nk of investment per effective worker to equip new **actual** workers due to **population growth**;
 - need gk of investment per effective worker to equip new **effective workers**, created by **technological progress**.

- The steady state occurs when:

$$\Delta k = sf(k) - (\delta + n + g)k = 0$$

- The graphical determination of the steady-state growth equilibrium *with population growth and tech. change*:

Fig. 8-1



□ In the steady state with technological progress:

➤ output and capital **per effective worker** are **constant**:

$$\Delta y/y = \frac{\Delta(Y/L \cdot E)}{Y/L \cdot E} = 0$$

$$\Delta k/k = \frac{\Delta(K/L \cdot E)}{K/L \cdot E} = 0$$

➤ output and capital **per actual worker** ($Y/L = y \cdot E$; and $K/L = k \cdot E$) **grow** at rate g :

$$\frac{\Delta(Y/L)}{Y/L} = \frac{\Delta(K/L)}{K/L} = g$$

- **total** output and capital ($Y = y \cdot E \cdot L$; $K = k \cdot E \cdot L$)
grow at rate $n+g$.

$$\frac{\Delta Y}{Y} = \frac{\Delta K}{K} = n+g$$

- For example, in an economy in which population grows by 1 percent per year ($n = 0.01$) and labour productivity grows by 2 percent per year ($g = 0.02$) total output (Y) will grow by 3 percent per year in the steady state, and output/income per actual worker (or per capita) will grow by 2 percent per year in the steady state.

TABLE 8-1

Steady-State Growth Rates in the Solow Model with Technological Progress

Variable	Symbol	Steady-State Growth Rate
Capital per effective worker	$k = K/(E \times L)$	0
Output per effective worker	$y = Y/(E \times L) = f(k)$	0
Output per worker	$Y/L = y \times E$	g
Total output	$Y = y \times (E \times L)$	$n + g$

Table 8.1

Mankiw and Scarth: Macroeconomics, Canadian Third Edition
 Copyright © 2008 by Worth Publishers

II. Empirical Studies of Growth

1. The prediction of “*balanced growth*”.

- The Solow growth model predicts that in steady-state equilibrium, total output (Y) will grow at the **same rate** as the total capital stock (K) and output per (actual) worker or Y/L will grow at the **same rate** as capital per (actual) worker or K/L .

- The facts are consistent with this prediction:
 - In Canada, over the course of the 20th century Y and K both grew at an average annual rate of 3% while output per capita (Y/L) and capital per capita (K/L) grew at an average annual rate of 1%;
 - Over the past 50 years in the US Y/L and K/L both grew at approximately 2 percent per year.

2. The prediction of “convergence”.

- The Solow model predicts that two economies which for historical reasons start off with different levels of capital accumulation but which have the same steady state (i.e. same $y = f(k)$ and same values for s , δ , n and g) will in the long run **converge** - the initially poorer will catch-up with the initially richer economy.
- Evidence shows that similar economies **do** tend to converge to one another at a rate of 2 percent a year; dissimilar economies (ones with different steady-states) exhibit **conditional convergence** - converging to their own steady-states.

3. The causes of the “income gap” between rich and poor countries.

- Is the income gap between rich and poor countries the result of cross-country differences in the stocks of physical and human capital or differences in the efficiency with which these inputs are used?
- Both factors appear to be important and they appear to be correlated: countries with high levels of physical and human capital also tend to use those factors efficiently.

4. Is free trade good for growth?

- ❑ Economists Andrew Warner and Jeffrey Sachs found that over the period 1970 -1989, among developed economies, those which were “open” grew at 2.3 percent per year while those that were closed grew at 0.7 percent per year; among developing economies those that were open grew at 4.5% per year while those that were closed grew at 0.7% per year.
- ❑ Increases in the rate of economic growth appear to follow removal of trade restrictions: Japan in 1850s, South Korea in the 1960s, Vietnam in the 1990s.

- Economists Jeffrey Frankel and David Romer found that a one percentage point rise in the ratio of trade to GDP increased income per capita by at least half a percentage point. Trade appeared to increase income by spurring the accumulation of physical and human capital and increasing the productivity of capital.

5. Institutions matter.

- ❑ Studies show that economic growth is encouraged when countries have strong legal systems (particularly those based on English-style common law) which protect property rights, contracts, and the rights of creditors and shareholders.
- ❑ Some studies show that countries grow faster as they become more democratic and as the level of government corruption is reduced.

III. Policies to Promote Growth

1. Increasing the Canadian Savings Rate

- The Solow growth model predicts that, if an economy's capital stock is below its Golden Rule level ($k^* < k^*_{\text{gold}}$) an increase in the savings rate ($\uparrow s$) will increase the steady-state level of consumption per capita.
- Evidence shows Canada's capital stock is **well below** its Golden Rule level.

- ❑ Policies to **increase the Canadian saving rate** include:
 - run budget surplus = increase **public** saving;
 - raise **private** savings through
 - reducing investment taxes: taxation of dividend income, capital gains, interest;
 - promoting tax-free forms of savings: RRSP's;
 - use of sales taxes (GST) versus income taxes.

- ❑ No agreement on whether policies designed to increase private saving work or not.

- Note: an increase in after-tax rate of return on savings has two effects:
 - makes future consumption cheaper → savings **more** attractive;
 - need less savings to achieve a given level of future consumption → savings **less** attractive.

2. Promoting Investment.

- Policies to promote investment by making it more profitable include:
 - accelerated depreciation allowance;
 - investment tax credits;
 - R&D tax credits.

3. Policies on allocating investment.

- ❑ In actual economy there are different types of capital and capital investment.
- ❑ For some forms of capital the **social return** to investment exceeds the **private return**, resulting in positive **externalities** to investment.
- ❑ Examples include:
 - investment in public capital or **infrastructure** (roads, transit systems, electricity);
 - investment in **human capital** (knowledge and skills acquired through education and training);
 - investment with positive **knowledge spillovers** which increases an economy's pool of knowledge.

- Governments can use their spending and taxing powers to increase investment in areas where private sector investment would not occur or would be less than socially optimal.

4. Policies to encourage technological progress.

- ❑ Many studies suggest that there are sizeable positive externalities to research and development activities and, hence, private profit-maximizing firms may undertake too little research.
- ❑ Government can encourage technological research through:
 - patents (temporary monopolies to innovating firms);
 - basic research support (grants to universities);
 - picking and subsidizing promising industries (e.g aerospace).

IV. Explaining the Worldwide Slowdown in Economic Growth: 1972-1995.



The facts:

- A worldwide slowdown in the pace of economic growth began in the early 1970s and continued to the mid-1990s;
- In Canada the average annual rate of growth of output per person fell from 2.9% in the period 1948-1972 to 1.8% in the period 1972 -1995;
- Other countries experienced similar or worse declines;
- Real income per person today is 35% lower than it would have been in the absence of the growth slowdown.

TABLE 8-2

Growth Around the World

Country	GROWTH IN OUTPUT PER PERSON (PERCENT PER YEAR)		
	1948-1972	1972-1995	1995-2004
Canada	2.9	1.8	2.4
France	4.3	1.6	1.7
West Germany	5.7	2.0	
Germany			1.2
Italy	4.9	2.3	1.5
Japan	8.2	2.6	1.2
United Kingdom	2.4	1.8	2.5
United States	2.2	1.5	2.2

Source: Angus Maddison, *Phases of Capitalist Development* (Oxford: Oxford University Press, 1982); *OECD National Accounts*; and *World Bank: World Development Indicators*.

Table 8.2

Mankiw and Scarth: Macroeconomics, Canadian Third Edition

Copyright © 2008 by Worth Publishers

- ❑ Studies have shown that the growth slowdown is attributable to a reduction in the rate of productivity improvement or the rate of growth of **total factor productivity**.

- ❑ Several hypotheses have been proposed to explain this reduction in productivity growth including the following.

- ❑ **Measurement errors:** output growth may be underestimated because of difficulties in measuring: (i) quality improvements in goods; and (ii) increases in output of the service industries; [not likely to be the full story]

- ❑ **Oil price increases:** Large increases in the price of energy in the 1970s which made energy-intensive and capital-intensive methods of production more costly; [But, drop in productivity too large to be caused by oil price hike; and when oil prices fell after 1986 productivity did not increase.]

- ❑ **Worker quality:** The entrance of the baby-boom generation to the labour force in the 1970s lowered the average experience and productivity of the work force. Also, educational attainments not increasing as rapidly as in past and some possibility of decline in the quality of education.

- ❑ **Depletion of ideas:** After World War II there was a gradual exhaustion of the stock of new ideas and a slowing pace of innovation.

- ❑ All of the above hypotheses are plausible but none has been established as the cause of the slowdown. The exact origins of the slowdown remain a puzzle.

V. Explaining the Acceleration in Economic Growth: 1995 - ????

- ❑ In the period after 1995 growth in per capita output rebounded in a number of countries, including Canada.
- ❑ In Canada, from 1995-2004 per capita output grew at an annual rate of 2.4%, up from 1.8% for 1972-1995. In the US and UK growth rates of per capita output regained their pre-1972 levels.
- ❑ As with the slowdown in growth in the 1970s and 1980s, the acceleration of growth in the 1990s is hard to definitively explain.

- ❑ The “computer revolution” - advances in information technology - are likely a large part of the explanation.

- ❑ But why didn't the effects of the computer revolution show up earlier? Evidence from economic history suggests that new technologies influence growth with a **long lag**.