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Economia regionale e dell'innovazione,
Scienze Economiche
Lezione 2

- Stefano Usai
- email: stefanousai@unica.it
- tel.: 070-6753766

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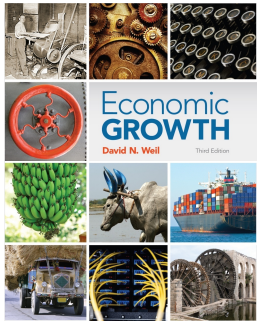
PHYSICAL CAPITAL



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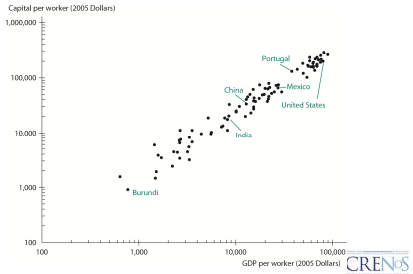
An interesting stylised fact: GDP and Capital per Worker, 2009



Source: Calculations based on Heston et al. (2010).

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Nature of capital

- Capital is productive
- But it is has been produced itself…through investments. In other words capital is accumulated. Distinction between flows and stocks
- Capital depreciates
- Capital stock is made of machinery, tools, buildings, roads….
- It can be private or public (mainly infrastructures)

Early models of economic growth

- Harrod-Domar model
- Solow model

Capital's role in production

- Production function:
  - Y=F(K,L)
  - Y/L=F(K/L, 1)
  - y= f(k)

NOTE: in a competitive environment alpha is the capital factor share, in a Cobb-Douglas model this is constant

SOLOW model: Cobb-Douglas PF

- $Y=F(K,L) = AK^{\alpha}L^{\beta}$
- Usually $\alpha+\beta=1$ (assumption of no economies of scale), in this case we can rewrite the function above as follows:
- $Y=F(K,L) = AK^{\alpha}L^{1-\alpha}$, which is also in per capita terms
- $y = A\,k^{\alpha}$

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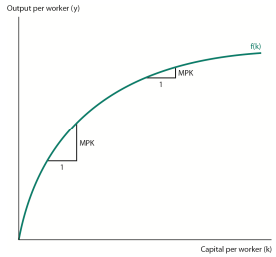
Solow model: A Production Function with Diminishing Marginal Product of Capital



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Capital's role in production

In a competitive environment, where factors are paid according to marginal productivity,

alpha is the capital factor share, and in a Cobb-Douglas model this is constant:

$$MPK = \alpha A K^{\alpha-1} L^{1-\alpha}$$

– Quota of income to capital:

– $(MPK*K)/Y = (\alpha A K^{\alpha-1} L^{1-\alpha} * K)/A K^{\alpha} L^{1-\alpha} = \alpha$

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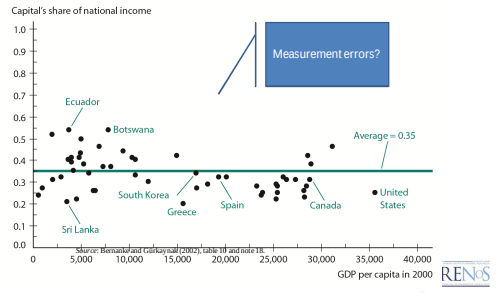
Capital's Share of Income **(which is equal to α)** in a Cross-Section of Countries



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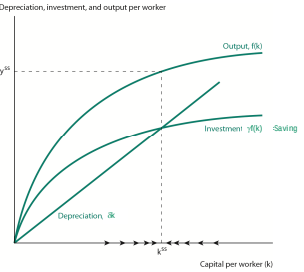
The Steady State of the Solow Model (with no population dynamics)

γ= saving rate

δ=depreciation rate



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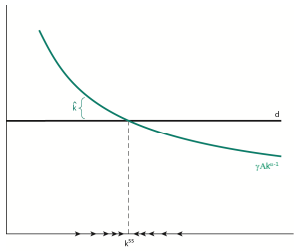
Speed of Convergence to the Steady State



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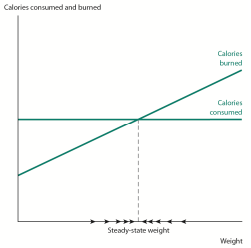
A non economic example: Determination of Steady-State Weight

Think also about changes in the position of the two lines



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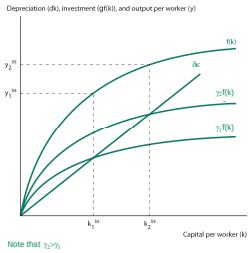
Effect of Increasing the Investment Rate on the Steady State



Note that $\gamma_2 > \gamma_1$

Solow model calibration

Using $y = A k^{\alpha}$

- $\Delta k = \gamma A k^{\alpha} - \delta k$

In steady state Δk is equal to zero, that is

- $0 = \gamma A k_{ss}^{\alpha} - \delta k_{ss}$

Which implies that

- $\gamma A k_{ss}^{\alpha} = \delta k_{ss} \Rightarrow \gamma A k_{ss}^{\alpha} / k_{ss} \delta = 1 \Rightarrow \gamma A / \delta k_{ss}^{\alpha-1} = 1$
- $k_{ss} = (\gamma A / \delta)^{1/(1-\alpha)}$

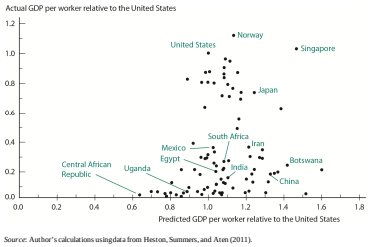
Solow model calibration

- $y_{ss} = A k_{ss}^{\alpha} = A^{1/(1-\alpha)} (\gamma/\delta)^{\alpha/(1-\alpha)}$
- If we take the value of y of steady state for country *i* and country *j*, we can compare them in the following way
- $y^i_{ss} / y^j_{ss} = (\gamma^i/\gamma^j)^{\alpha/(1-\alpha)}$
- Now let us assume that country *i* has an investment rate of 20% and country *j* of 5%

Solow model calibration

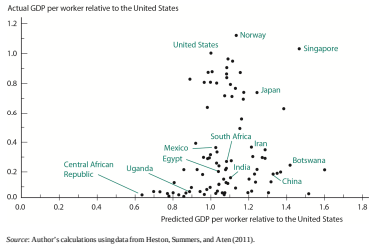
- With alpha equal to 0.3 the previous formula gives a value of 2….
- … do you remember the example of Silvania and Freedonia?

Predicted versus Actual GDP per Worker



Source: Author's calculations using data from Heston, Summers, and Aten (2011).

Predicted versus Actual GDP per Worker based a calibration of the Solow model



Source: Author's calculations using data from Heston, Summers, and Aten (2011).

The Solow model as a theory of relative growth rates (difference btwn s.r. and l.r.)

The Solow model does not provide a complete explanaton of growth rates since once a country reaches its steady state there is no longer growth!

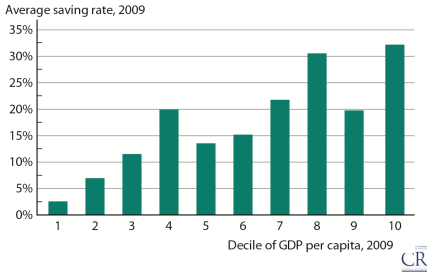
Despite this failing we may still ask whether the model has something to say about relative growth rates - that is why some countries grow faster than others...

The Solow model as a theory of relative growth rates (difference btwn s.r. and l.r.)

The key is to think about countries which are not in s.s.

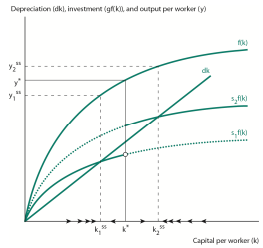
- *If two countries have the same rate of investment but different levels of income, the country with lower income will have higher growth*
- *If two countries have the same level of income but different rates of investment, then the country with a higher rate of investment will have higher growth*
- *A country that raises its level of investment will experience an increase in its rate of income growth*

Saving rate: is it really exogenous?
Saving by Decile of Income per Capita



Solow Model with Saving Dependent on Income Level

Multiple equilibria = Poverty traps



The rise and fall of capital revisited

- The belief that capital accumulation is the key ingredient for economic growth reached its peak after WWII (see Arthur Lewis and Soviet Union's success)
- Policies were designed accordingly
- Now economist have discarded the idea that development depends mainly on capital accumulation

Chapter 4

POPULATION AND ECONOMIC GROWTH

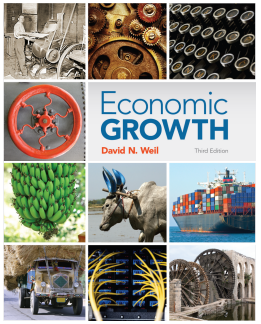


Figure 4.1 Relationship Between Income per Capita and Population Growth

See Gapminder

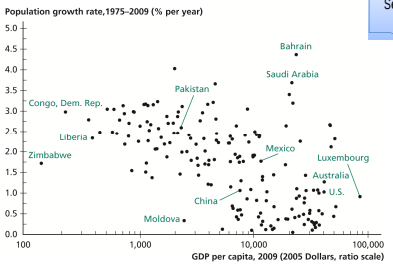
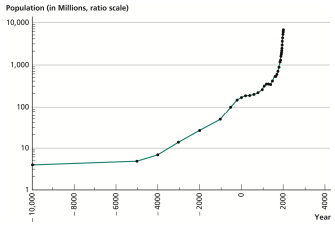
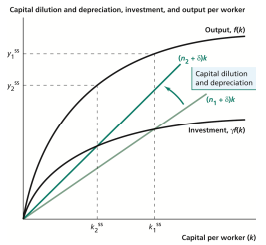


Figure 4.2 World Population, 10,000 B.C. to A.D. 2010



Source: Kremer (1993).

Figure 4.7 The Solow Model Incorporating Population Growth: Capital dilution



The figure shows how raising the population growth rate from n_1 to n_2 affects the steady-state level of capital per worker (k) and the steady-state level of output per worker (y).

Population growth and capital dilution

- The solow model extended to incorporate population growth explains how higher population growth can lower income per capita through the channel of capital dilution
- The solow model can therefore partially account for the negative correlation between income per capita and population growth

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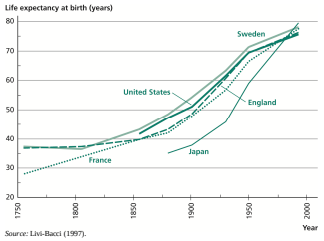
Figure 4.8 Life Expectancy in Developed Countries



Source: Livi-Bacci (1997).

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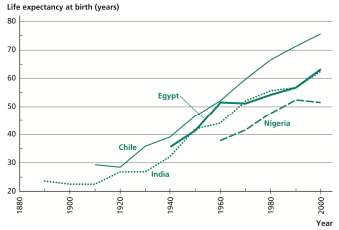
Figure 4.9 Life Expectancy in Developing Countries



Source: Kalemli-Ozcan (2002).

Demographic transition: a tale of two traps...

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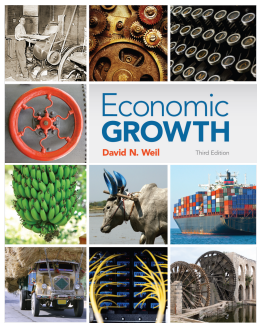
Chapter 6

HUMAN CAPITAL



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Human capital as an input

- We focus on qualities of people who are productive
- We concentrate on qualities which are produced, as with phisical capital also human capital is itself produced
- Human capital earns returns (even though workers have to work to get it whilst capital owners acan relax on a beach)

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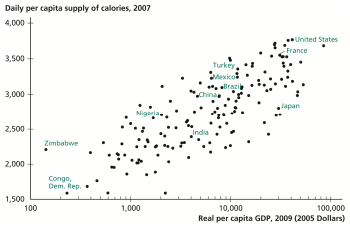
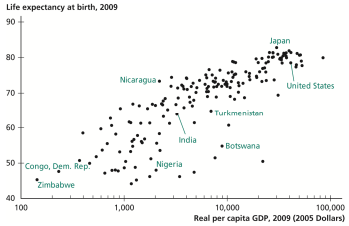
Human capital as a form of health

Figure 6.1 Nutrition versus GDP per Capita



Sources: FAOSTAT database, Heston, Summers, and Aten (2011).

Figure 6.2 Life Expectancy versus GDP per Capita



Sources: Heston, Summers, and Aten (2011), *World Development Indicators* database.

Figure 6.3 How Health Interacts with Income

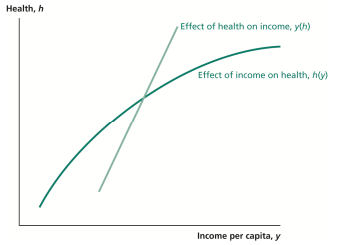


Figure 6.4 Health and Income per Capita: Two Views

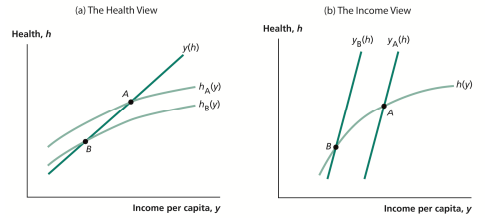
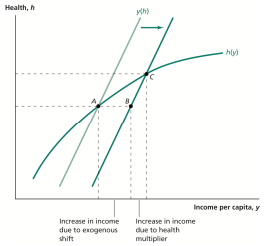


Figure 6.5 Effect of an Exogenous Shift in Income



Human capital in the form of education

Table 6.1 Changes in the Level of Education, 1975-2010

		Average Years of Schooling	Percentage of the Adult Population with: No Schooling	Complete Primary Education	Complete Secondary Education	Complete Higher Education
Developing Countries	1975	3.2	47.4	32.9	8.1	1.6
	2010	6.7	20.8	68.8	31.5	5.3
Advanced Countries	1975	8.0	6.2	78.8	34.9	8.0
	2010	11.0	2.5	94.0	63.9	16.6
United States	1975	11.4	1.3	94.1	71.1	16.1
	2010	12.4	0.4	98.8	85.4	20.0

Source: Barro and Lee (2010). Data for population 25+.

Education as an investment

- It is costly (6% of GDP in US, 4.5% in Italy)
- Not only in terms of money but especially in terms of opportunity costs (this is true mostly for developing countries)
- The return to education is wage…a wage premium

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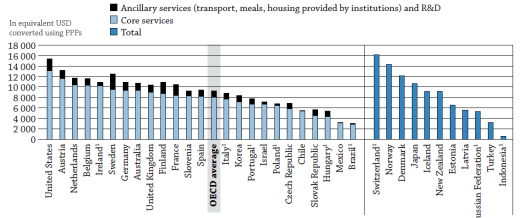
Chart B1.1. Annual expenditure per student by educational institutions, by type of service (2011)

In equivalent USD converted using PPPs, based on full-time equivalents, for primary through tertiary education



1. Public institutions only.

Countries are ranked in descending order of expenditure per student by educational institutions for core services.

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Change in per student expenditure total, constant prices(1995 = 100)

Table B1.5a

Indice di variazione (1995 = 100)

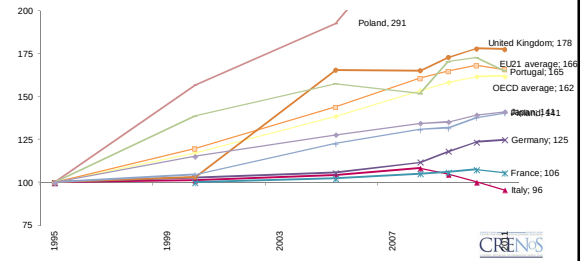


Figure 6.6 Effect of Education on Wages

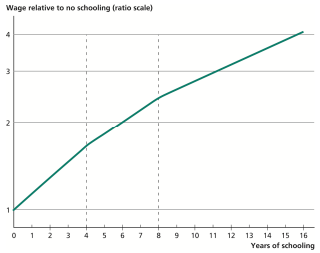
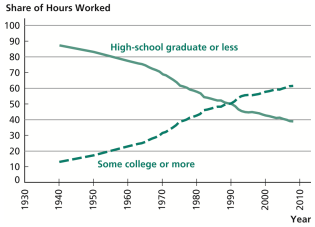


Figure 6.7 Share of Hours Worked by Education Level, 1940–2008



Sources: Autor, Katz, and Krueger (1998), Autor, Katz, and Kearney (2008), Acemoglu and Autor (forthcoming).

Figure 6.8 Ratio of College Wages to High-School Wages

Sources: Autor, Katz, and Krueger (1998), Autor, Katz, and Kearney (2008), Acemoglu and Autor (2010).

Table 6.2 Breakdown of the Population by Schooling and Wages

Highest Level of Education	Years of schooling	Wage Relative to No Schooling	Percentage of the Population: Developing Countries	Percentage of the Population: Advanced Countries
No Schooling	0	1.00	20.8	2.5
Incomplete Primary	4	1.65	10.4	3.4
Complete Primary	8	2.43	18.6	12.3
Incomplete Secondary	10	2.77	19.3	17.6
Complete Secondary	12	3.16	23.2	37.4
Incomplete Higher	14	3.61	2.9	9.9
Complete Higher	16	4.11	5.3	16.8

Source: Barro and Lee (2010).

Figure 6.9 Share of Human Capital in Wages in Developing Countries

Remember alpha in the Solow model

Figure 6.10 Share of Human Capital in Wages in Advanced Countries

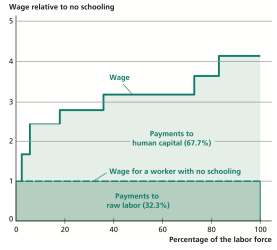
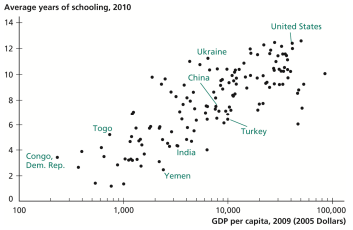


Figure 6.11 Average Years of Schooling versus GDP per Capita



Sources: Barro and Lee (2010), Heston, Summers, and Aten (2011).

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Table A7.3a. Private costs and benefits for a man attaining tertiary education (2010)

As compared with a man attaining upper secondary or post-secondary non-tertiary education, in equivalent USD converted using PPPs for GDP

		Year	Direct costs (1)	Foregone earnings (2)	Total costs (3)	Gross earnings benefits (4)	Income tax effect (5)	Social contribution effect (6)	Transfers effect (7)	Unemployment effect (8)	Grants effect (9)	Total benefits (10)	Net present value (11)	Internal rate of return (12)
OECD	Netherlands	2010	- 14 646	- 95 834	**- 110 480**	442 661	- 197 999	- 26 901	0	10 736	13 770	**242 267**	**131 787**	7.2%
	New Zealand	2010	- 9 384	- 43 347	**- 52 731**	193 910	- 62 325	- 3 875	- 86	358	3 039	**131 021**	**78 290**	7.3%
	Norway	2010	- 1 086	- 47 946	**- 49 032**	274 357	- 107 528	- 23 197	0	23 000	4 690	**171 321**	**122 289**	8.2%
	Poland	2010	- 7 343	- 16 928	**- 24 270**	376 155	- 30 873	- 75 986	0	38 492	2 228	**310 015**	**285 745**	24.6%
	Portugal	2010	- 4 627	- 16 181	**- 20 808**	324 887	- 89 461	- 36 243	0	17 564	m	**216 746**	**195 937**	18.3%
	Slovak Republic	2010	- 6 183	- 15 019	**- 21 202**	290 121	- 51 866	- 40 961	0	38 465	1 226	**236 985**	**215 783**	21.4%
	Slovenia	2010	- 3 564	- 26 242	**- 29 806**	447 946	- 110 866	- 96 037	0	19 992	259	**261 294**	**231 488**	17.1%
	Spain	2010	- 8 864	- 28 219	**- 37 083**	178 900	- 52 903	- 14 033	0	41 874	3 791	**157 629**	**120 546**	11.2%
	Sweden	2010	- 3 560	- 50 291	**- 53 851**	209 467	- 84 430	- 9 281	0	8 454	7 735	**131 945**	**78 094**	7.4%
	Switzerland		m	m	**m**	m	m	m	m	m	m	**m**	**m**	m
	Turkey	2005	- 1 061	- 9 402	**- 10 463**	106 985	- 18 682	- 16 424	0	2 761	m	**74 640**	**64 177**	19.3%
	United Kingdom	2010	- 20 162	- 47 655	**- 67 817**	413 163	- 89 124	- 49 107	- 4 303	40 284	5 225	**316 138**	**248 322**	14.3%
	United States	2010	- 61 135	- 44 678	**- 105 813**	628 922	- 210 898	- 55 768	0	100 046	27 162	**489 463**	**383 649**	15.4%
	OECD average		- 10 563	- 40 755	**- 51 318**	347 075	- 105 528	- 38 085	- 777	29 016	6 181	**236 602**	**185 284**	13.9%
	EU21 average		- 6 258	- 41 078	**- 47 335**	361 801	- 112 936	- 45 075	- 1 123	31 620	6 135	**239 503**	**192 167**	15.1%
	Italy	2008	- 7 285	- 50 608	**- 57 893**	408 011	- 159 562	- 41 835	0	3 295	3 330	**213 239**	**155 346**	8.1%
	Japan	2007	- 37 215	- 66 750	**- 103 965**	326 614	- 64 523	- 36 039	0	20 931	m	**246 983**	**143 018**	7.4%
	Korea	2010	- 19 211	- 34 019	**- 53 231**	379 884	- 47 160	- 25 602	0	12 407	m	**319 528**	**266 298**	12.8%

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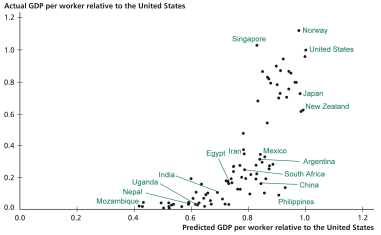
Figure 6.12 Predicted versus Actual GDP per Worker



Important factors to explain figure 6.12

- Quality of schooling
- Externalities

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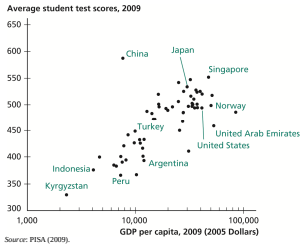
Figure 6.13 Student Test Scores versus GDP per Capita



Source: PISA (2009).

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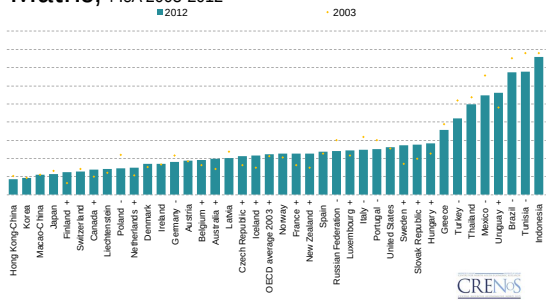
Percentage of low performers in Maths, PISA 2003-2012



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Chapter 7

MEASURING PRODUCTIVITY

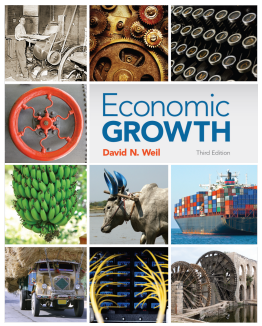


Figure 7.1 Possible Sources of Differences in Output per Worker

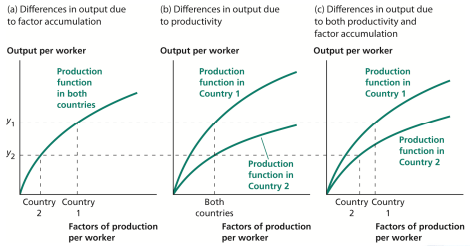
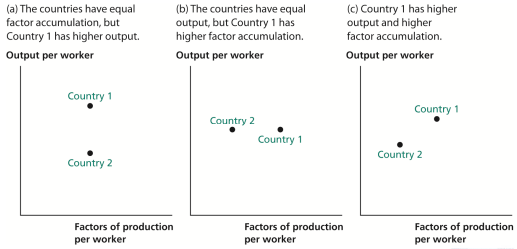


Figure 7.2 Inferring Productivity from Data on Output and Factor Accumulation



productivity accounting

- Ratio of output=
- Ratio of productivity * Ratio of factors of production
- Ratio of productivity=
- Ratio of income/Ratio of factors of production

Table 7.1 Data Used to Analyze Productivity in Country 1 and Country 2

	Output per Worker, y	Physical Capital per Worker, k	Human Capital per Worker, h
Country 1	24	27	8
Country 2	1	1	1

Table 7.2 Development Accounting

Country	Output per Worker, y	Physical Capital per Worker, k	Human Capital per Worker, h	Factors of Production, $k^{1/3}h^{2/3}$	Productivity, A
United States	1.00	1.00	1.00	1.00	1.00
Norway	1.12	1.32	0.98	1.08	1.04
United Kingdom	0.82	0.88	0.97	0.93	1.03
Canada	0.80	0.81	0.96	0.91	0.88
Japan	0.73	1.16	0.98	1.04	0.70
South Korea	0.62	0.92	0.95	0.95	0.64
Turkey	0.37	0.26	0.75	0.55	0.68
Mexico	0.35	0.33	0.84	0.61	0.58
Brazil	0.20	0.19	0.78	0.48	0.42
India	0.10	0.089	0.65	0.34	0.31
Kenya	0.032	0.022	0.73	0.23	0.14
Malawi	0.018	0.029	0.57	0.21	0.087

Sources: Output per worker: Heston, Summers, and Aten (2011); physical capital and human capital: Barro and Lee (2010). The data set used here and in Section 7.3 is composed of data for 90 countries for which consistent data are available for 1975 and 2000.

Problems with measuring capital and implications

- Waste of investment
- Quality of investment

- There are estimate according to which the actual level of the capital stock is in between 60% to 75% of the official statistics...

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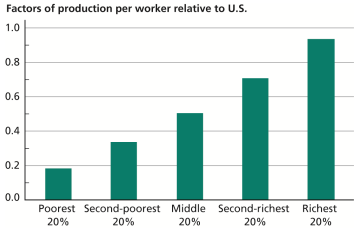
Figure 7.3 Role of Factors of Production in Determining Output per Worker, 2009



For sources, see Table 7.2.

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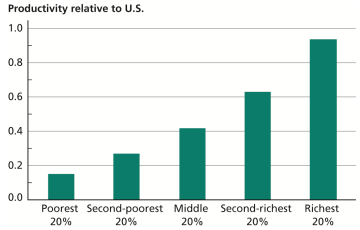
Figure 7.4 Role of Productivity in Determining Output per Worker, 2009



For sources, see Table 7.2.

Growth accounting

Output =productivity*factors of production

Output growth rate =
Productivity growth rate + growth rate of factors of production

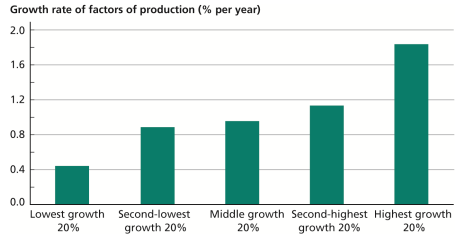
The growth rate of factors of productions has to be weighted with respect to their share on output

Productivity growth rate=
Output growth rate – growth rate of factors of production

Table 7.3 Data for Calculating Productivity Growth in Erewhon

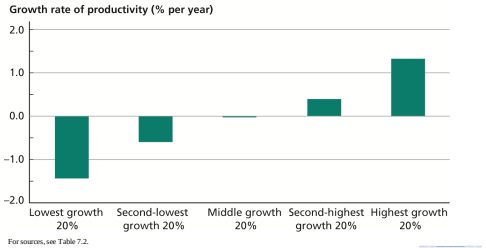
	Output per Worker, *y*	Physical Capital per Worker, *k*	Human Capital per Worker, *h*
Erewhon in 1975	1	20	5
Erewhon in 2010	4	40	10
Annual Growth Rate	4%	2%	2%

Figure 7.5 Role of Factors of Production in Determining Growth, 1975–2009



For sources, see Table 7.2.

Figure 7.6 Role of Productivity in Determining Growth, 1975–2009



For sources, see Table 7.2.

Chapter 8

THE ROLE OF TECHNOLOGY IN GROWTH

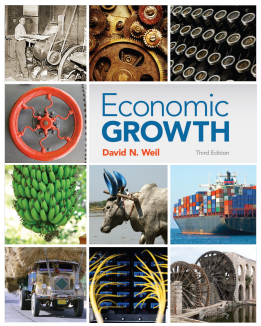


Table 8.1 Researchers and Research Spending, 2009

And Italy?

Country	Number of Researchers	Researchers as a Percentage of the Labor Force	Research Spending ($ billions)	Research Spending as a Percentage of GDP
United States	1,412,639	0.89%	398.2	2.8%
Japan	655,530	1.00%	137.9	3.4%
Germany	311,519	0.74%	82.7	2.8%
France	229,130	0.80%	48	2.2%
Korea	236,137	0.96%	43.9	3.3%
OECD Total	4,199,512	0.70%	965.6	2.4%

Source: OECD Main Science and Technology Indicators database.

The nature of technological progress

- Technology creation
- Technology transfer or diffusion
  - Non rivarly
  - Non excludability

Determinants of R&D spending

- Profit considerations
  - How much advantage with respect to followers
  - Size of the market
  - How long does the advantage last
  - Uncertainty

Concept of creative distruction

One country model

- Labour is the only factor
- Which can be used either in production or in the R&D
- γ_A is the quota of labour used in R&D…
- Its function is similar to the saving rate in the Solow model

Process of productivity growth

- Growth of A = L_A/μ
- where μ represents the price/cost of the new invention
- The growth rate of A represents the growth rate of y

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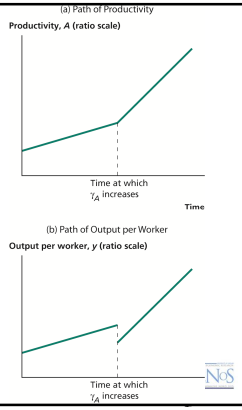
Figure 8.1 Effect of Shifting Labor into R&D



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Two country model

- μ is now different among countries
- One country invests more in R&D and it is the leadear the other one is the follower

Figure 8.2 Cost of Copying for the Follower Country

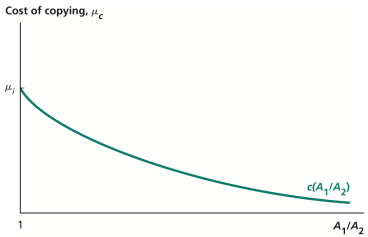


Figure 8.3 Steady State in the Two-Country Model

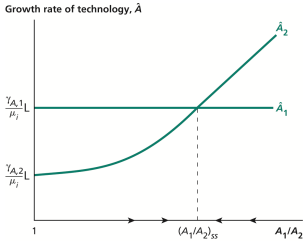


Figure 8.4 Effect of an Increase in R&D in the Follower Country on the Steady State

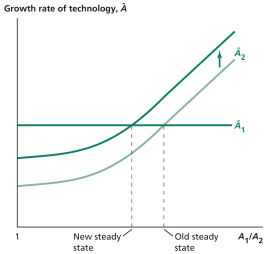
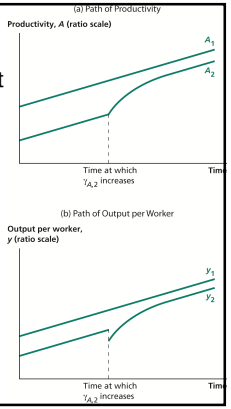


Figure 8.5 Effect of an Increase in $\gamma_{A,2}$ on Productivity and Output



Barriers to international technology transfer

- Appropriate technology
- Tacit knowledge
- Patents and other tools to appropriate R&D returns

Figure 8.6 Neutral Technological Change

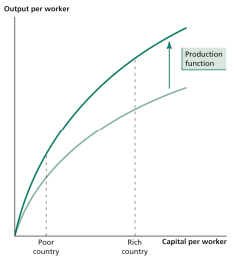


Figure 8.7 Capital-Biased Technological Change

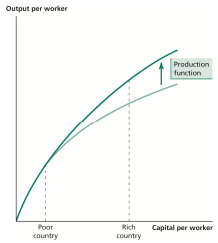


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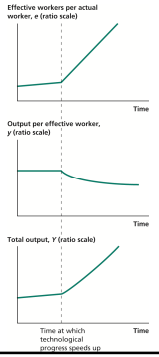
Figure 8.8 Effect of an Increase in Technological Progress

Incorporating Technological Progress into the Solow Model



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Chapter 9

THE CUTTING EDGE OF TECHNOLOGY

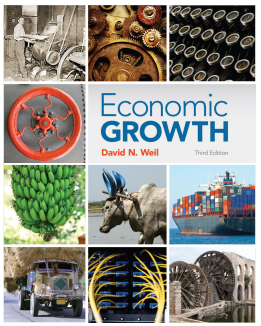
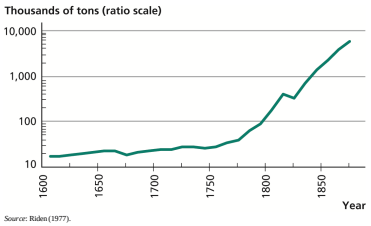


Table 9.1 Growth Accounting for Europe, A.D. 500–1700

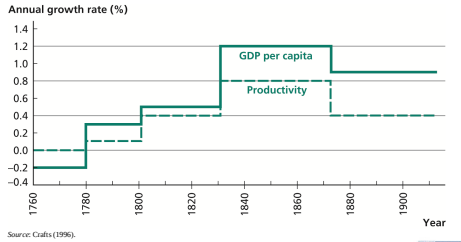
Period	Annual Growth Rate of come per Capita, $\dot{Y}$	Annual Growth Rate of Population, $\dot{L}$	Annual Growth Rate of Productivity, $\dot{A}$
500–1600	0.0%	0.1%	0.033%
1600–1700	0.1%	0.2%	0.166%

Figure 9.1 British Iron Production, 1600–1870



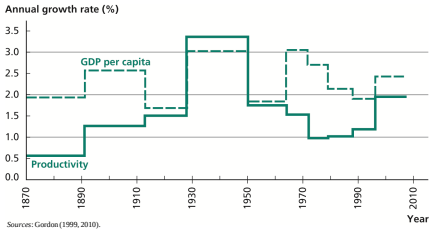
Source: Riden (1977).

Figure 9.2 British Output and Productivity Growth, 1760–1913



Source: Crafts (1996).

Figure 9.3 U.S. Output and Productivity Growth, 1870–2007



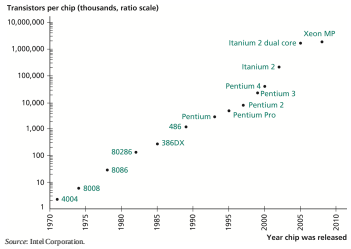
Sources: Gordon (1999, 2010).

Table 9.2 U.S. Patents and Patents per Million Residents, 2010

Country	Patents	Patents per Million Residents
Taiwan	9,633	418.3
Japan	46,978	368.2
Israel	1,917	268.7
Finland	1,252	234.4
Switzerland	1,889	247.8
Sweden	1,596	174.7
South Korea	12,598	257.2
Germany	13,663	167.0
Canada	5,515	163.3
Hong Kong	716	101.9
Singapore	633	123.2
Luxembourg	44	88.4
Denmark	766	138.9
Netherlands	1,919	115.8
Iceland	25	80.9
Austria	905	110.2
Australia	2,079	95.6
Belgium	896	86.0
France	5,044	77.8
Norway	398	85.8
United Kingdom	5,048	80.8
Ireland	375	86.5
New Zealand	252	54.6
Italy	2,254	37.1

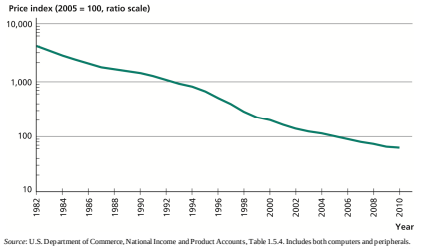
Source: U.S. Patent and Trademark Office, http://www.uspto.gov/web/offices/ac/ido/oeip/taf/cst_all.htm

Figure 9.4 Moore's Law as Seen in Intel Microprocessors



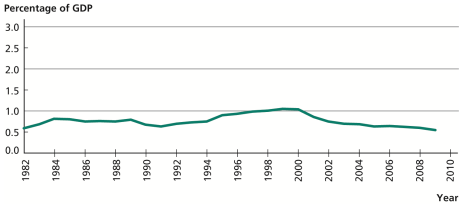
Source: Intel Corporation.

Figure 9.5 Price of Computers, 1982–2010



Source: U.S. Department of Commerce, National Income and Product Accounts, Table 1.5.4. Includes both computers and peripherals.

Figure 9.6 Investment in Computers as a Percentage of GDP, 1982–2009



Source: U.S. Department of Commerce, National Income and Product Accounts, Table 5.5.5. Includes both computers and peripherals.

Chapter 10

EFFICIENCY

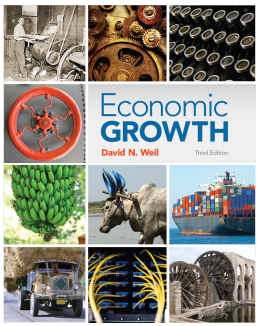
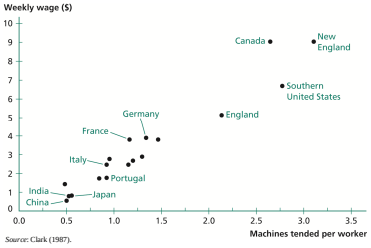


Table 10.1 Decomposition of Productivity Gap Between India and the United States

Years India Lags United States in Technology (*G*)	Level of Technology in India Relative to United States (*T*)	Level of Efficiency in India Relative to United States (*E*)
10	0.95	0.33
20	0.90	0.35
30	0.85	0.36
40	0.81	0.38
50	0.76	0.41
75	0.67	0.46
100	0.58	0.53
125	0.51	0.61

Figure 10.1 Wages and Machines in the Textile Industry, 1910



Source: Clark (1987).

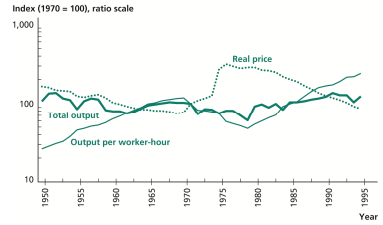
Table 10.2 Productivity in Selected Industries in the Early 1990s

	United States	Japan	Germany
Automobiles	100	127	84
Steel	100	110	100
Food Processing	100	42	84
Telecommunications	100	51	42
Aggregate Productivity	100	67	89

Types of inefficiencies

- Unproductive activities
  - Rent seeking phenomena
- Idle resources
- Misallocation of factors among sectors
  - Barriers to mobility
  - Wages not equal to marginal product

Figure 10.2 U.S. Subsurface Coal Mining: Output, Price, and Output per Worker-Hour, 1949–1994



Source: Parente and Prescott (2000).

Figure 10.3 Efficient Allocation of Labor between Sectors

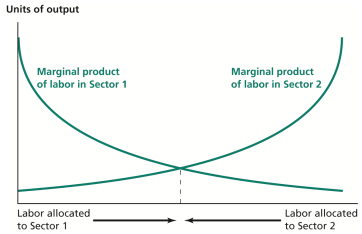


Figure 10.4 Overallocation of Labor to Sector 1

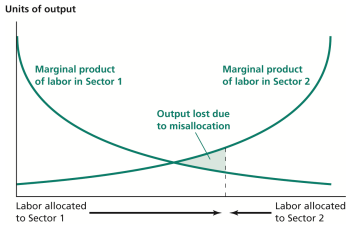
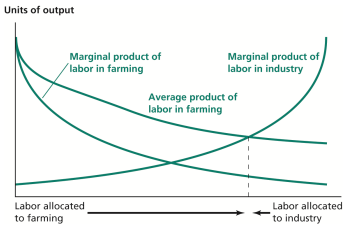


Figure 10.5 Overallocation of Labor to Farming When Farmworkers Are Paid Their Average Product



Chapter 11

GROWTH IN THE OPEN ECONOMY

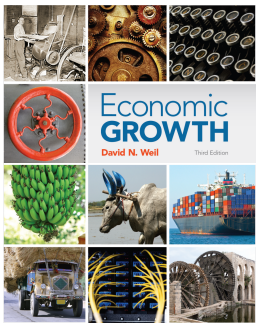
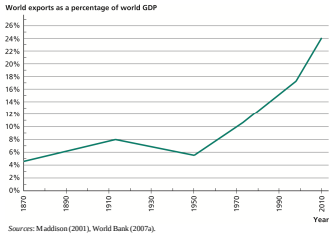
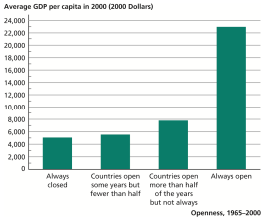


Figure 11.1 Growth of World Trade, 1870–2010



Sources: Maddison (2001), World Bank (2007a).

Figure 11.2 Relationship between Economic Openness and GDP per Capita

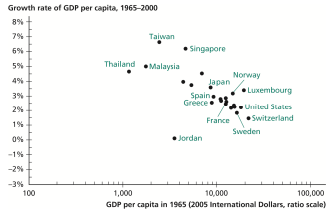


Sources: Sachs and Warner (1995), Wacziarg and Welch (2008).

Figure 11.3 Growth in Closed Economies

Sources: Sachs and Warner (1995), Wacziarg and Welch (2008), Heston et al. (2011).

Figure 11.4 Growth in Open Economies



Sources: Sachs and Warner (1995), Wacziarg and Welch (2008), Heston et al. (2011).

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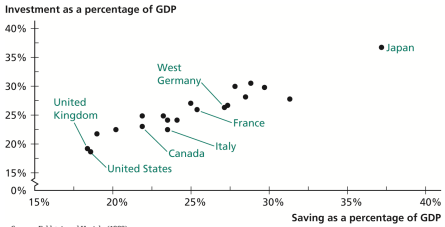
Figure 11.5 Saving and Investment Rates of Industrialized Countries, 1960–1974



Sources: Feldstein and Horioka (1980).

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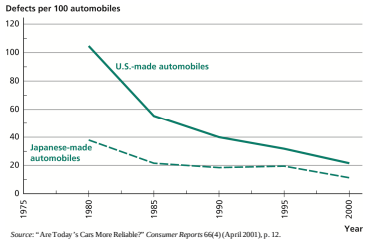
Table 11.1 Prices in Japan before and after Opening to Trade

	Price Before Opening (U.S. cents per pound)	Price After Opening (U.S. cents per pound)
Tea	19.7	28.2
Sugar	22.7	11.2

Source: Huber (1971).

Figure 11.6 Quality of U.S.- and Japanese-made Automobiles



Source: "Are Today's Cars More Reliable?" *Consumer Reports* 66(4) (April 2001), p. 12.

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