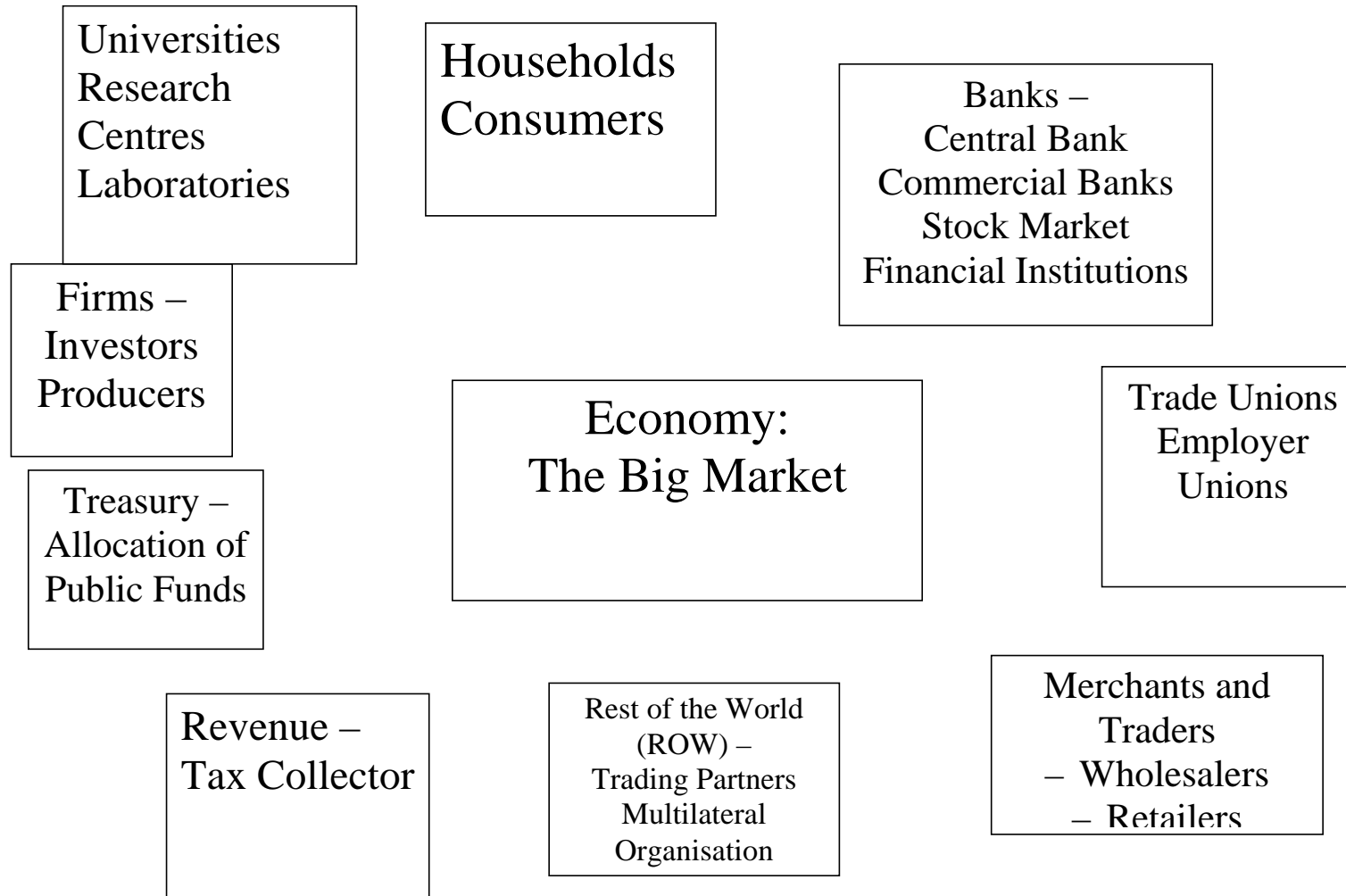


Macroeconomic Analysis 2003

Complementarity Between Human and Physical Capital and Economic Growth

Importance of Human Capital in Different Parts of the Economy



Capital Stock , Labour, GDP and Work Hours in UK in 2000

Capital Stock (2000, billion)		3132.5
	Road Vhcl	101.2
	PlantMch	792.9
	Buildings	1072.7
	Dwellings	1102.7
	Railway	24
Labor Force (Million)		29.8
Unemployed (million)		1.5
Stock of Knowledge	?	
GDP (VA)		831053
Work Hours	1600?	

Growth Experience is Outcome of Interaction between Human and Physical Capital Accumulation

(www.HM-Treasury.co.uk)

<i>Average annual % real changes, unless otherwise stated</i>	Decades¹			Gomvernments			Economic cycles²	
	1970s	1980s	1990s	1979- 1997	1992- 1997	1997- 2001	1975- 1981	1981- 1992

OUTPUT

GDP	2.4%	2.4%	2.0%	2.2%	2.9%	2.7%	1.3%	2.4%
Industrial production	1.8%	1.4%	0.9%	1.4%	2.3%	0.6%	0.7%	1.9%
Manufacturing output	0.6%	1.0%	0.4%	0.9%	1.9%	0.6%	-2.0%	1.9%
Services output	2.5%	2.6%	2.7%	2.6%	3.5%	3.6%	1.6%	2.5%
Household consumption	2.6%	3.3%	2.2%	2.6%	2.8%	4.0%	1.6%	2.9%

General Indicators of human capital

- Education: literacy, numeracy and problem solving ability
- Sound health and long life expectancy
- Productive skills
- Proportion of Independent Thinkers in the population
- Opportunities for on the job training

Specific Elements of Human Capital

A. General Human capital Index:

1. Literacy
2. Innumeracy
3. Health
4. Income
5. HDI (total of 1-4)

B. Information processing aspect of human capital:

6. Gathering information
7. Summarising the information
8. Analysing links among variables.
9. Constructing an analytical model
10. testing the model

C. Application of human capital for production:

entrepreneurship:

11. planning
12. programming
13. organising
14. implementing
15. monitoring

D. Generating new ideas: Research and Innovations

16. Generating new ideas
17. Creating a new product
18. innovation
19. Generalising the idea.

Investment and Productivity in UK

(www.HM-Treasury.co.uk)

<u>INVESTMENT</u>	1970 s	1980 s	1990 s	1979- 9 7	1992- 9 7	1997- 2 1	1975- 8 1	1981- 9 2
Whole economy	1.3%	4.0%	2.2%	2.5%	2.8%	5.9%	-2.0%	3.9%
Business	2.7%	4.8%	3.5%	3.1%	3.7%	7.2%	-0.1%	4.3%
Manufacturing	1.5%	0.5%	-0.3%	0.5%	5.4%	-1.1%	-0.9%	1.1%
General govt.	-	-	-1.4%	-	-5.3%	4.3%	-	-
Whole economy (% GDP)	16.9 %	16.1 %	17.2 %	16.3 %	16.6 %	17.7 %	16.5 %	16.3 %
Business (% GDP)	9.7%	10.2 %	11.9 %	10.3 %	10.7 %	12.7 %	9.8%	10.2 %
Manufacturing (% GDP)	3.0%	2.5%	2.4%	2.5%	2.3%	2.4%	2.9%	2.5%
General govt. (% GDP)	-	-	1.8%	-	2.0%	1.3%	-	-
<u>PRODUCTIVITY</u>								
Whole economy	2.0%	1.8%	2.0%	2.0%	2.6%	1.6%	1.4%	2.1%
Manufacturing	-	4.0%	2.5%	3.5%	2.2%	3.1%	-	5.0%

Average annual % real changes, unless otherwise stated

Human Capital and Types of Technical Advancement

Advancement in knowledge (new products, processes and innovation and management such as e-capital) is the source to technological growth. It comes from R&D; applied research. It may take one of three forms:

- Labour augmenting technology $Y = F(K, AL)$

- Capital augmenting technology $Y = F(AK, L)$

- Neutral technology $Y = AF(K, L)$

	Y	K	L
Base0	20	10	10
Lab Ag.	20	10	5
Cap Ag.	20	5	10
Neutral	20	5	5

Labour Augmenting Technology and Growth: A Simple Model

$$Y = K^\alpha (AL)^{1-\alpha} \Rightarrow \frac{Y}{AL} = \left(\frac{K}{AL}\right)^\alpha \Rightarrow g_y = g_k = g_A + g_L$$

Per capita output grows at the rate of technology:

$$g_y - g_L = g_A$$

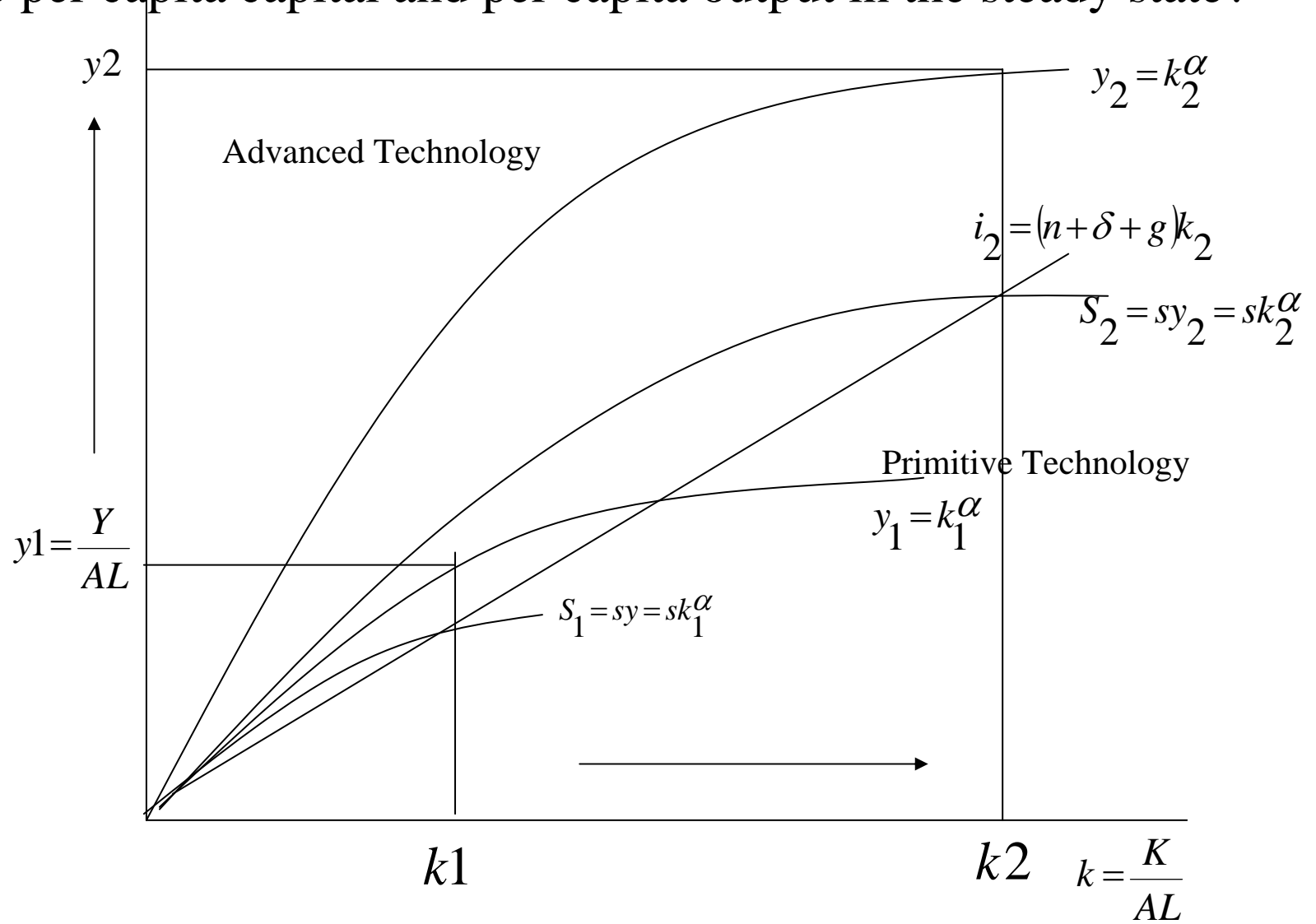
$$\dot{K} = sY - \delta K = sK^\alpha (AL)^{1-\alpha} - \delta K$$

Steady state investment requirement per worker

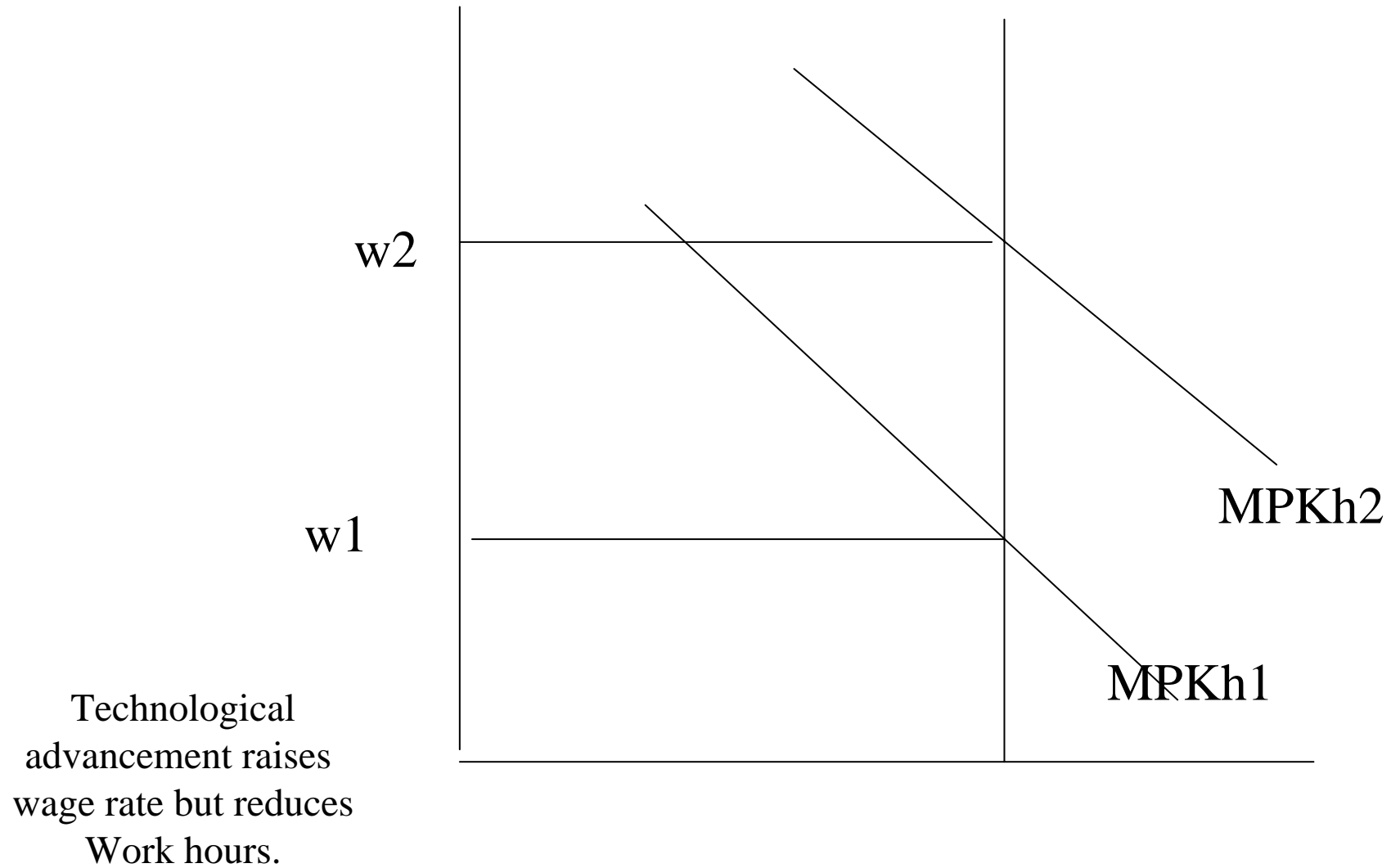
$$I = (\delta + g_A + g_L) \frac{K}{AN}$$

Assume that technology grows at $A_t = A_0 e^{g_A t}$

How does the labour augmenting technological advancement affect the per capita capital and per capita output in the steady state?

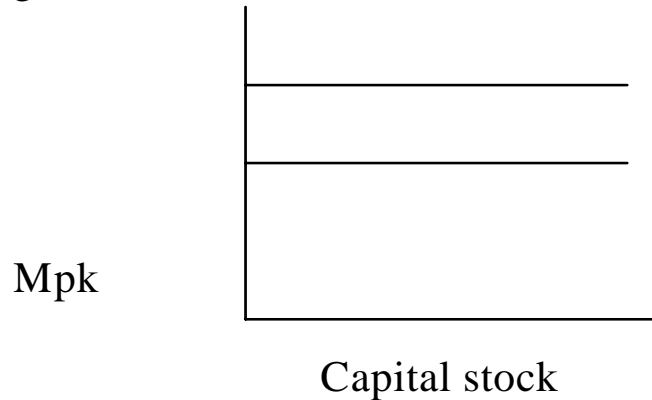


Increase in Real Wage Rate with Human Capital

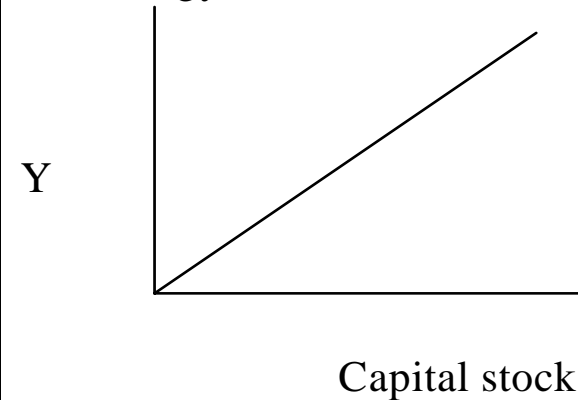


Complimentarity of Human and Physical Capital and Output

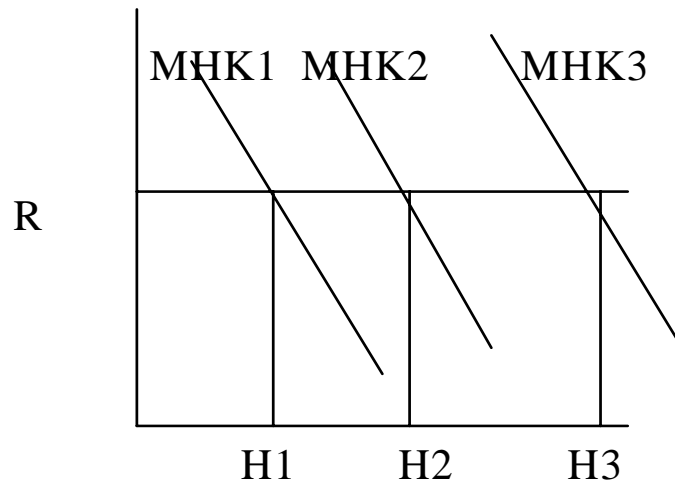
Higher saving rate generates higher growth rate



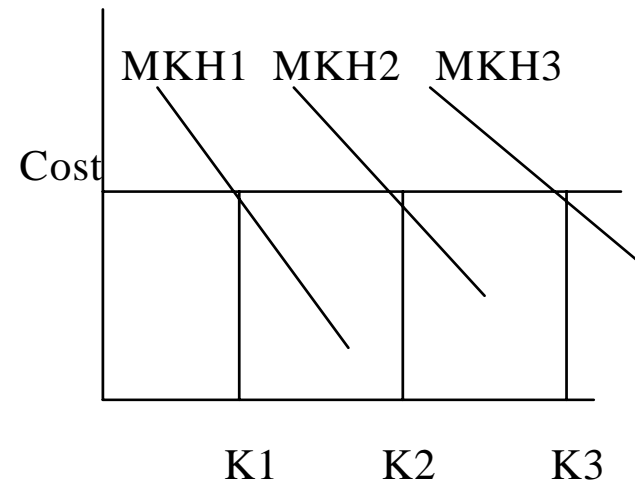
Graphical illustration of AK production technology



Marginal product of human capital



Marginal product of physical capital



Human Capital Augmented Solow Growth Model

Production: $Y = AK^\alpha L^\beta H^\gamma$

Income share: $\alpha + \beta + \gamma = 1$.

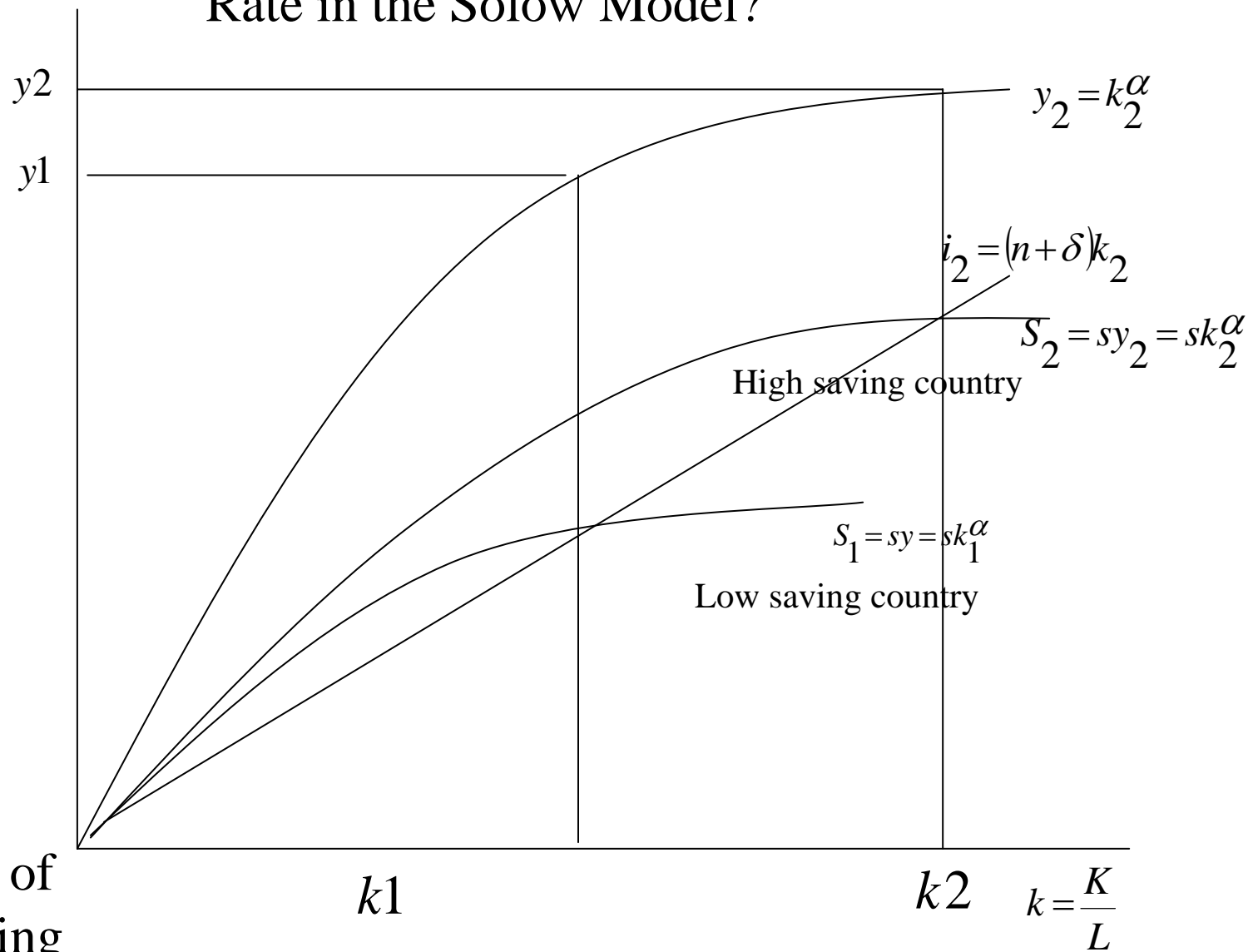
By log differentiation with respect to time:

$$\frac{\Delta y}{y} = g_y = g_a + \alpha g_k + \beta g_n + \gamma g_h$$

Recall the fact that in steady state output and capital grow at the rate of population growth rate :

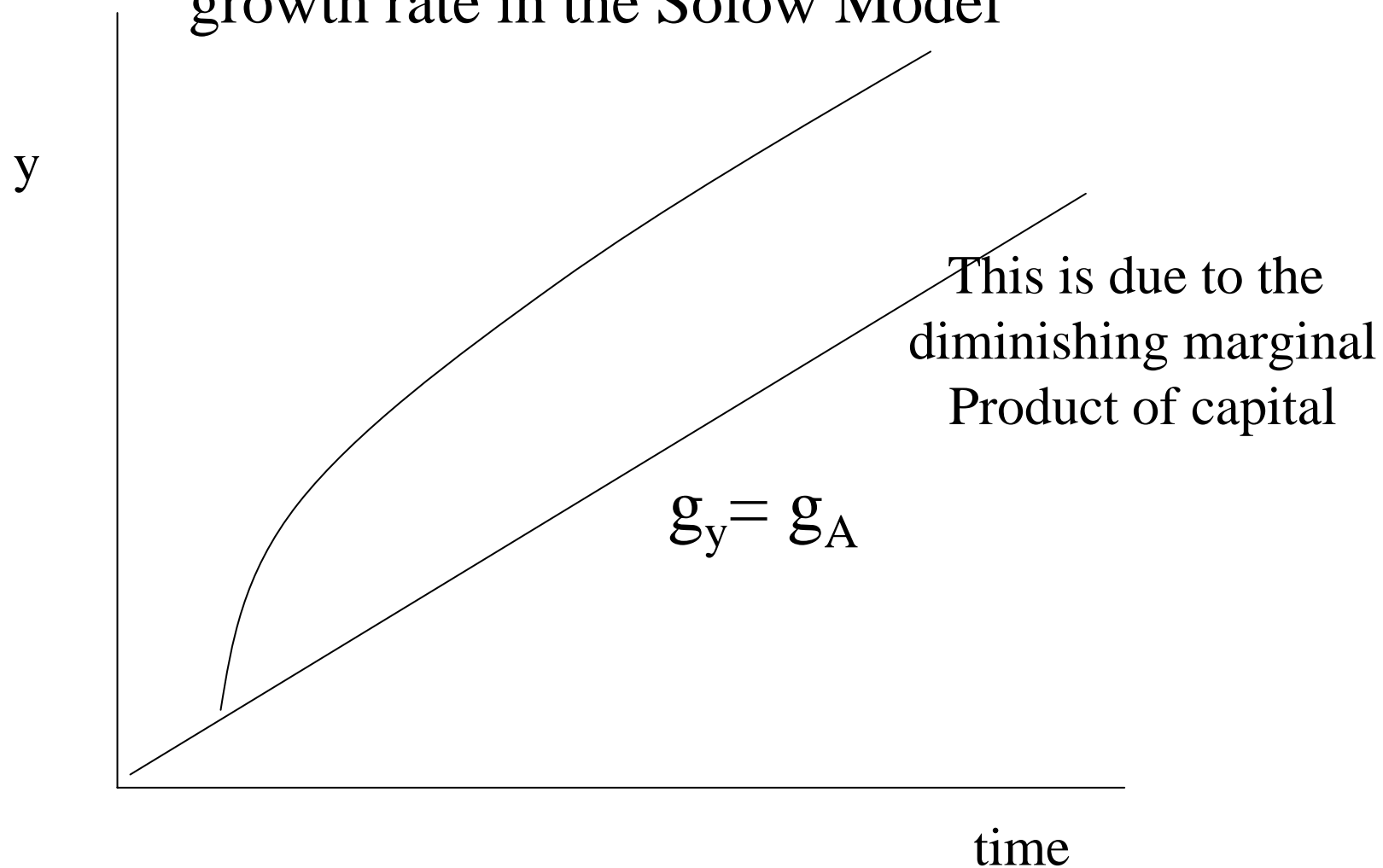
$$y = \frac{Y}{L}, \text{ or } \frac{dy}{y} = \frac{dY}{Y} - \frac{dL}{L} = 0$$

Why a Higher Saving Rate Does not Lead to a Higher Growth Rate in the Solow Model?



Because of
diminishing
returns to capital

Economy grows only at the rate of technology and
the Saving Rate does not affect the steady State
growth rate in the Solow Model



- **Human Capital, Savings and Economic Growth**
- $g_y - g_n = 0 \quad g_y = g_n$;

- or $k = \frac{K}{L} \rightarrow \frac{dk}{k} = \frac{dK}{K} - \frac{dL}{L} = 0 \quad g_k - g_n = 0 \quad g_k = g_n$.

Recall that $\alpha + \beta + \gamma = 1$

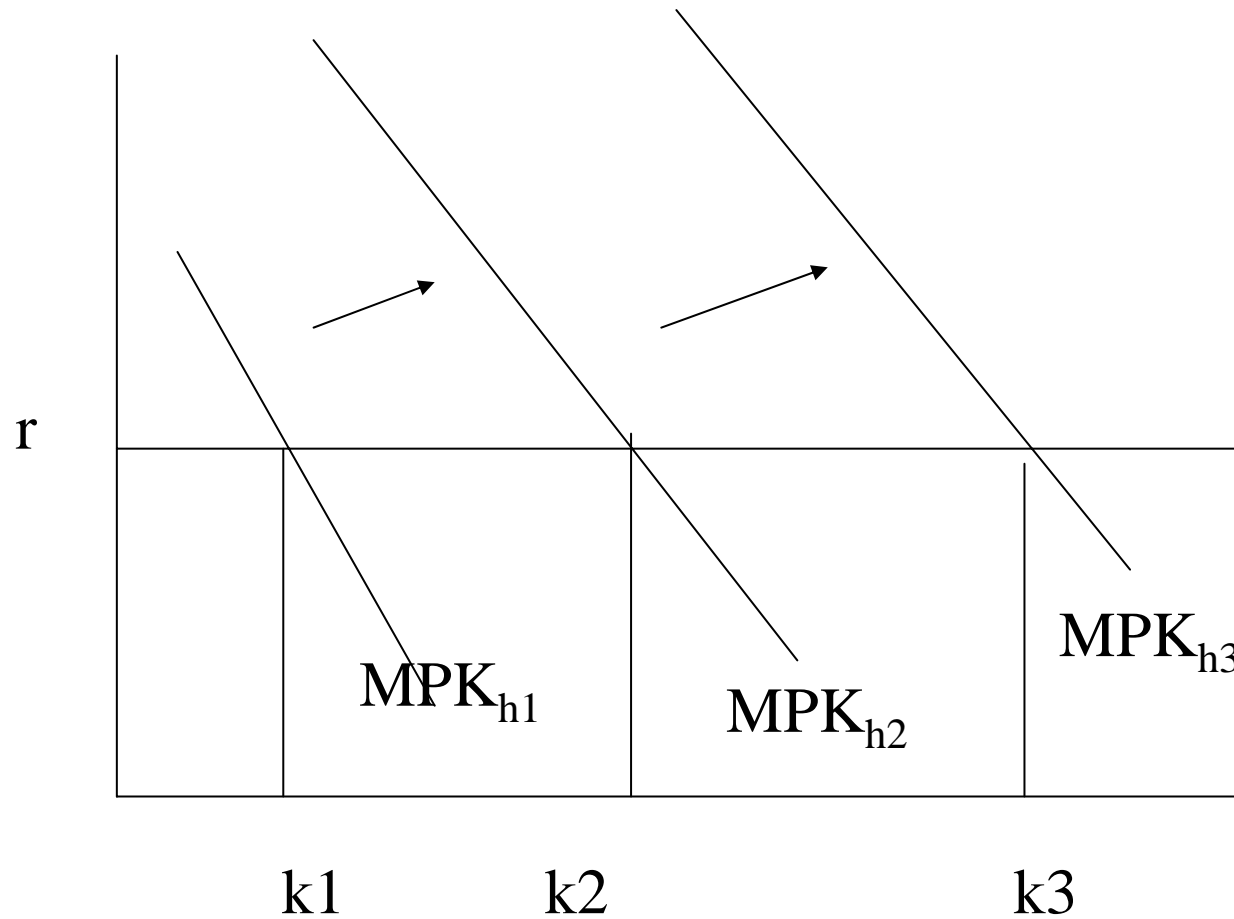
$$\frac{\Delta y}{y} = g_y = g_a + \alpha g_k + (1 - \alpha - \gamma) g_n + \gamma g_h$$

$$g_y - g_n = g_a + \alpha (g_k - g_n) + \gamma (g_h - g_n)$$

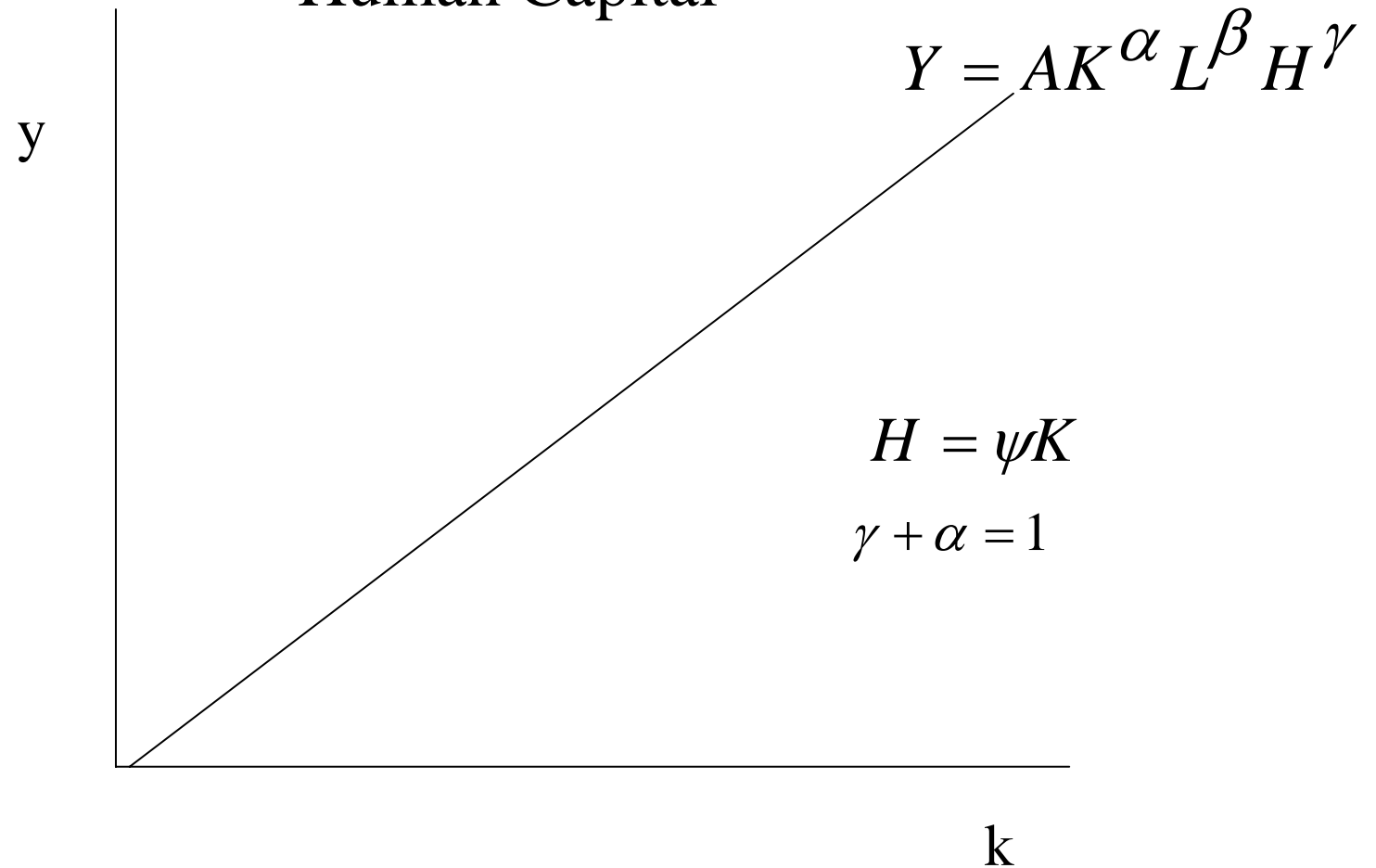
$$(g_y - g_n) - \gamma (g_h - g_n) = g_a + \alpha (g_k - g_n)$$

Per capita growth rate adjusted for human capital this depends on technological growth rate as well as per capita growth rate of capital stock.

Constant Marginal Product of Capital with Human Capital



Saving, Capital Accumulation and Output with Human Capital



Complimentarily Between Physical and Human Capital

Solow model with human capital (H):

$$Y = AK^\alpha L^\beta H^\gamma$$

Marginal product of human capital:

$$MPH = \gamma AK^\alpha L^\beta H^{\gamma-1} = \gamma Y / H$$

Marginal product of physical capital:

$$MPK = \alpha AK^{\alpha-1} L^\beta H^\gamma = \alpha Y / K$$

If the Human capital is proportion of physical capital:

$$H = \psi K \quad \text{and} \quad \gamma + \alpha = 1$$

$$Y = AK^\alpha L^\beta = A(\psi)^\gamma K^{\alpha+\gamma} L^\beta \quad \text{.or} \quad Y = A(\psi)^\gamma KL^\beta .$$

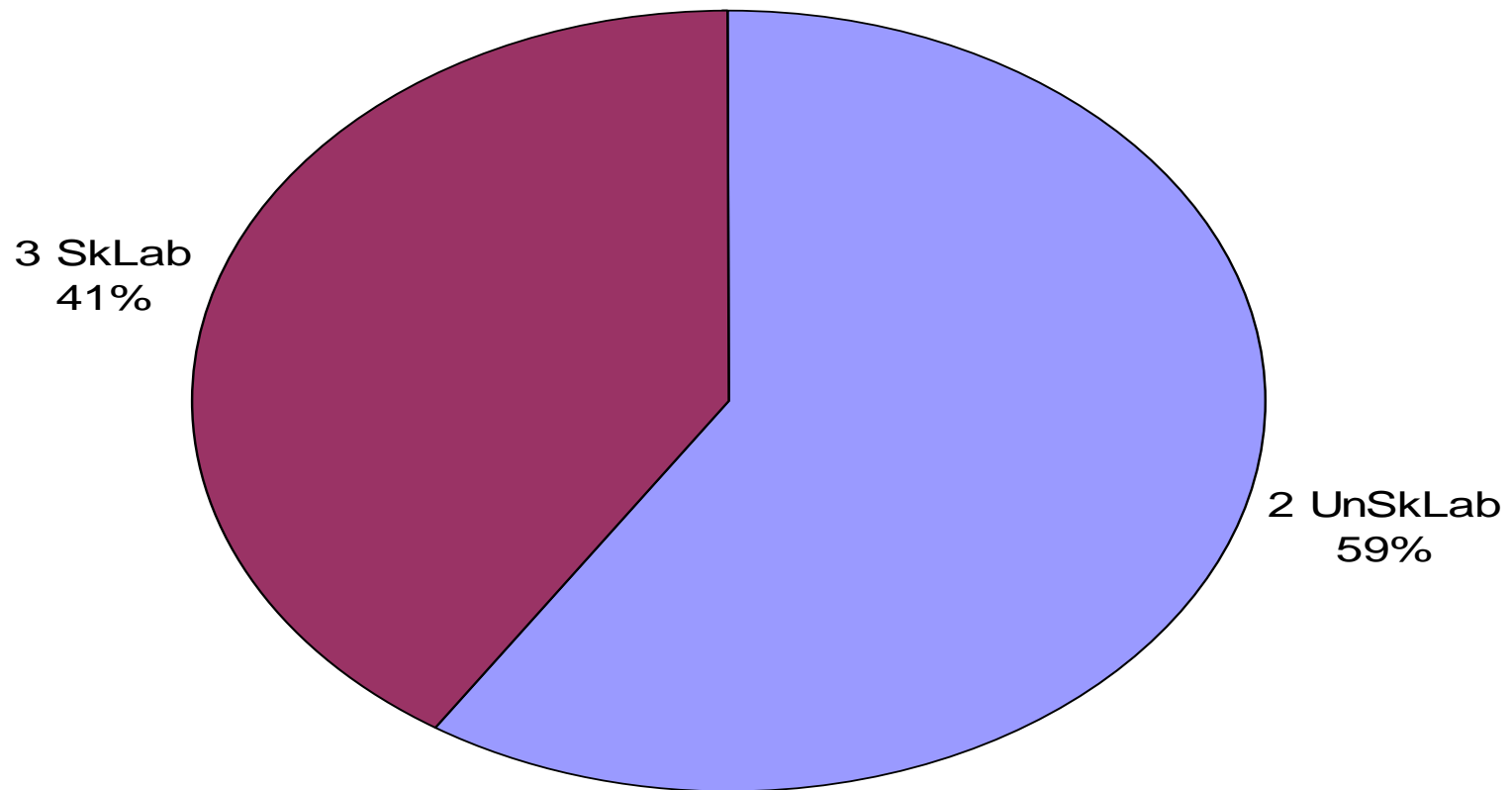
Constant Marginal product of capital:

$$MPK = \frac{\partial Y}{\partial K} = A(\psi)^\gamma L^\beta$$

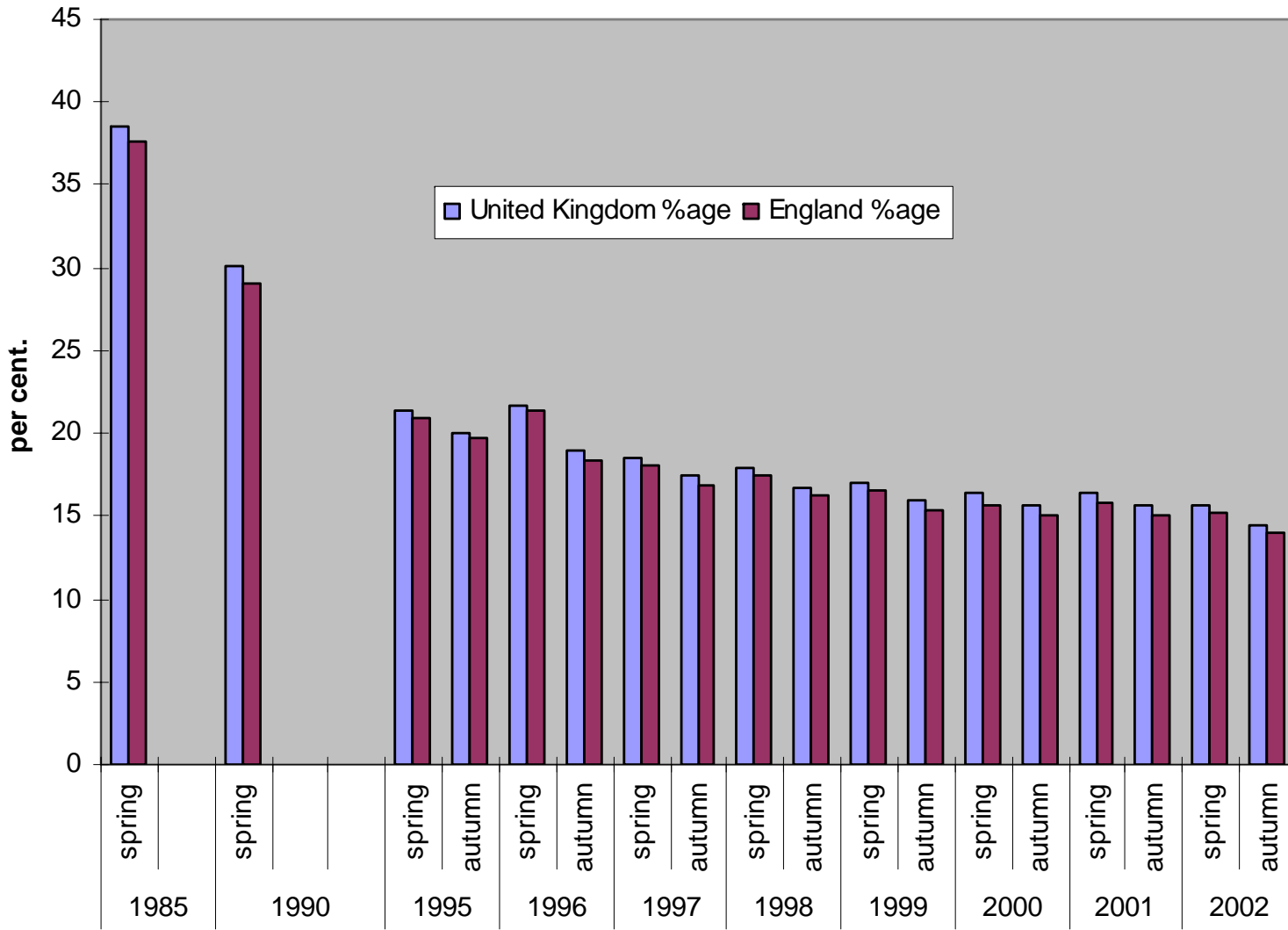
More saving \rightarrow More Capital \rightarrow Steadily Rising Output 20

What Can Policy Do to Improve the Human Capital and Technology?

Skilled and Unskilled Labour In Production, UK 2000



The proportion of all adults of working age in the UK and England with no formal qualifications: 1985 - 2002 (www.defs.gov.uk)



Human Capital Formation: Students and Teachers in Higher Education in the UK

www.dfes.gov.uk, www.hesa.co.uk

	Total	Undegraduate		Post Graduate		
		Full time	Part Time	Total	Male	Females
Total UK	2094110	0.496	0.241	0.161	0.086	0.075
Total England	0.837	0.401	0.210	0.135	0.072	0.063
Total Wales	0.054	0.028	0.014	0.008	0.004	0.003
Total Scotland	0.086	0.055	0.012	0.015	0.008	0.007
Total Northern Ireland	0.022	0.012	0.005	0.004	0.002	0.002

	Proportion of Overseas Students						
	Total	Undergraduate			Postgraduate		
		Total	Male	Female	Total	Male	Female
Total UK	0.110	0.057	0.029	0.029	0.053	0.023	0.030

	Staff Student Ratio				
	England	Wales	Scotland	Northern Ir	Total
Female	31590	1830	4615	955	38990
Male	62085	3960	9430	1940	77415
Total number of Teachers	93670	5790	14045	2900	116405
Student	1753325	114025	180440	46320	2094110
Student staff ratio	18.71811	19.69344	12.84728	15.97241	17.98986

Students in Higher Education in the UK by Subject Categories

	Number	Proportion		Number	Proportion
Medicine & dentistry	46145	0.023	Social, economic & po	141665	0.071
Subjects allied to medi	233320	0.117	Economics	23010	0.012
Biological sciences	93730	0.047	Law	60160	0.030
Veterinary science	3815	0.002	Business & administra	237615	0.119
Agriculture & related s	15625	0.008	Librarianship & inform	28795	0.014
Physical sciences	69285	0.035	Languages	96335	0.048
Mathematical sciences	20520	0.010	Humanities	64590	0.032
Computer science	110400	0.055	Creative arts & design	107895	0.054
Engineering & technol	129925	0.065	Education	149275	0.075
Architecture, building &	44000	0.022	Combined	337540	0.170
			Total - All subject area	1990625	1

Simple version of the Lucas Model with Human Capital

Production function

$$Y = K^{\alpha} (\theta h L)^{1-\alpha}$$

h = is human capital per worker

θ = fraction of time spent on working

L = labour supply –(assume this as given)

Example :

If $K=100$, $L=100$ $h=3$ $\theta=0.8$, $\alpha =0.3$

$$Y = 100^{0.3} (0.8 * 3 * 100)^{0.7} = 100(2.4)^{0.7}$$

$$= 185 \text{ where with } Y = K^{\alpha} L^{1-\alpha} = 100.$$

Production Function with Study Time and Capital

Define output and capital stock per effective labour as:

$$k = \frac{K}{hL} \quad y = \frac{Y}{hL}$$

Here hL total amount of effective work hours adjusted for human capital.

Output per effective worker y depends on capital per effective worker k and time spent on studying which can be derived as

$$\frac{Y}{hL} = \frac{K^\alpha (\theta hL)^{1-\alpha}}{hL}$$
$$y = \theta^{1-\alpha} k^\alpha$$

Study Time and Growth of Human Capital

Human capital grows faster when people spend more time in studying

$$\dot{h} = \phi(1-\theta)h \text{ or } g_h = \frac{\dot{h}}{h} = \phi(1-\theta)$$

where ϕ is the rate of creation of human capital per unit of time spent on studying and $(1-\theta)$ is the fraction of time spent on studying.

Stock of human capital for a given time

$$h_t = h_0 e^{\phi(1-\theta)t}$$

if $h_0 = 1$, $\phi = 0.4$, $(1-\theta) = 0.2$, time $(t) = 20$

$$h_t = 1 \cdot e^{0.4(0.2)20} = 4.95$$

Unbounded Growth Prospect with More Study and Growth of Human Capital (UK Example)

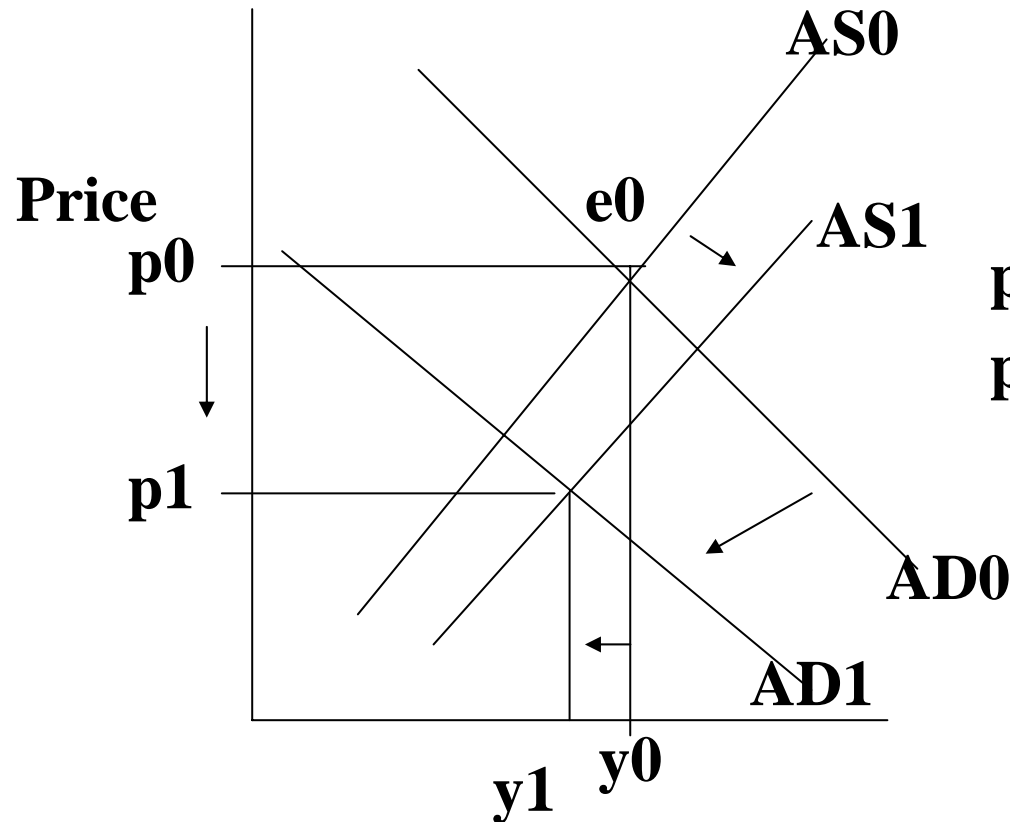
	phi	Theta	alpha	s	delta	n	
	1.3	0.2	0.3	0.17	0.03	0.005	
	k-per cap	h	y-per cap	Savin g	Depreciati on	Net Inv	C per cap
Time	k	1	y	s	D	I	C
1	1.000	1.040	0.324	0.055	0.030	-0.005	0.269
2	0.995	1.082	0.333	0.057	0.030	-0.003	0.276
3	0.992	1.125	0.342	0.058	0.030	-0.001	0.284
4	0.991	1.170	0.351	0.060	0.030	0.000	0.291
273	18336	44679	10786	1834	550	733	8952
274	19070	46466	11217	1907	572	763	9311
275	19833	48325	11666	1983	595	793	9683
276	20626	50258	12133	2063	619	825	10070

Does an Advancement in the Technology Increase the Real Wage Rate of Every one Equally?

- With mobility of labour across regions and sectors introduction of new technology should increase wages of all types of workers
 - But
- Wage rates in the high tech and manufacturing sectors have grown at higher rate than in the service sectors
- New technology replaces old technology and people with obsolete technology may become redundant and may spend a long time before finding a new job.

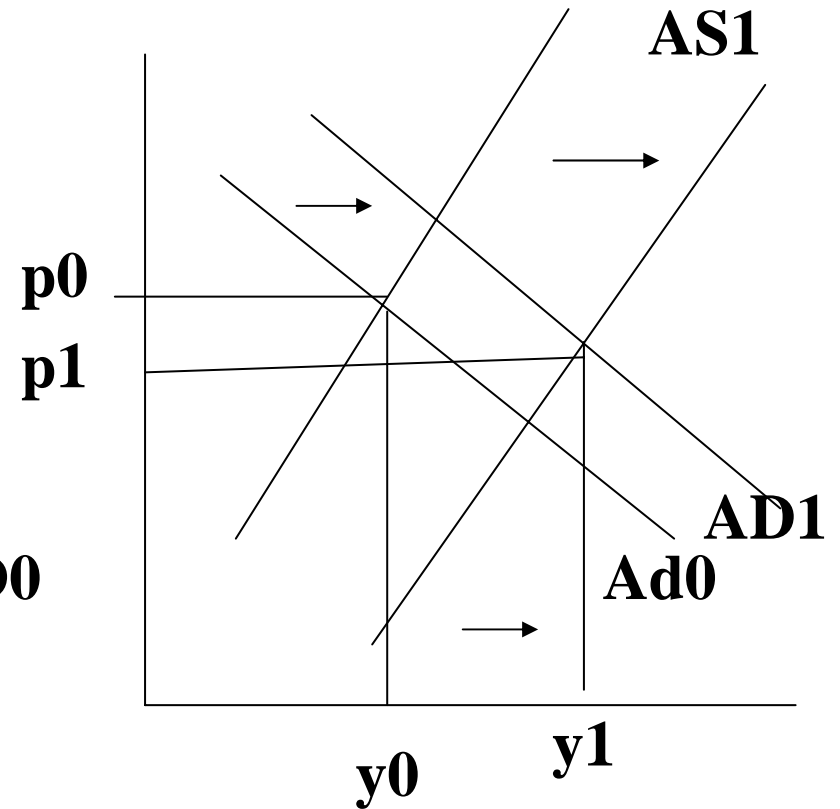
Pessimistic and Optimistic View of Impact of Technology on Output and Employment

Pessimistic view



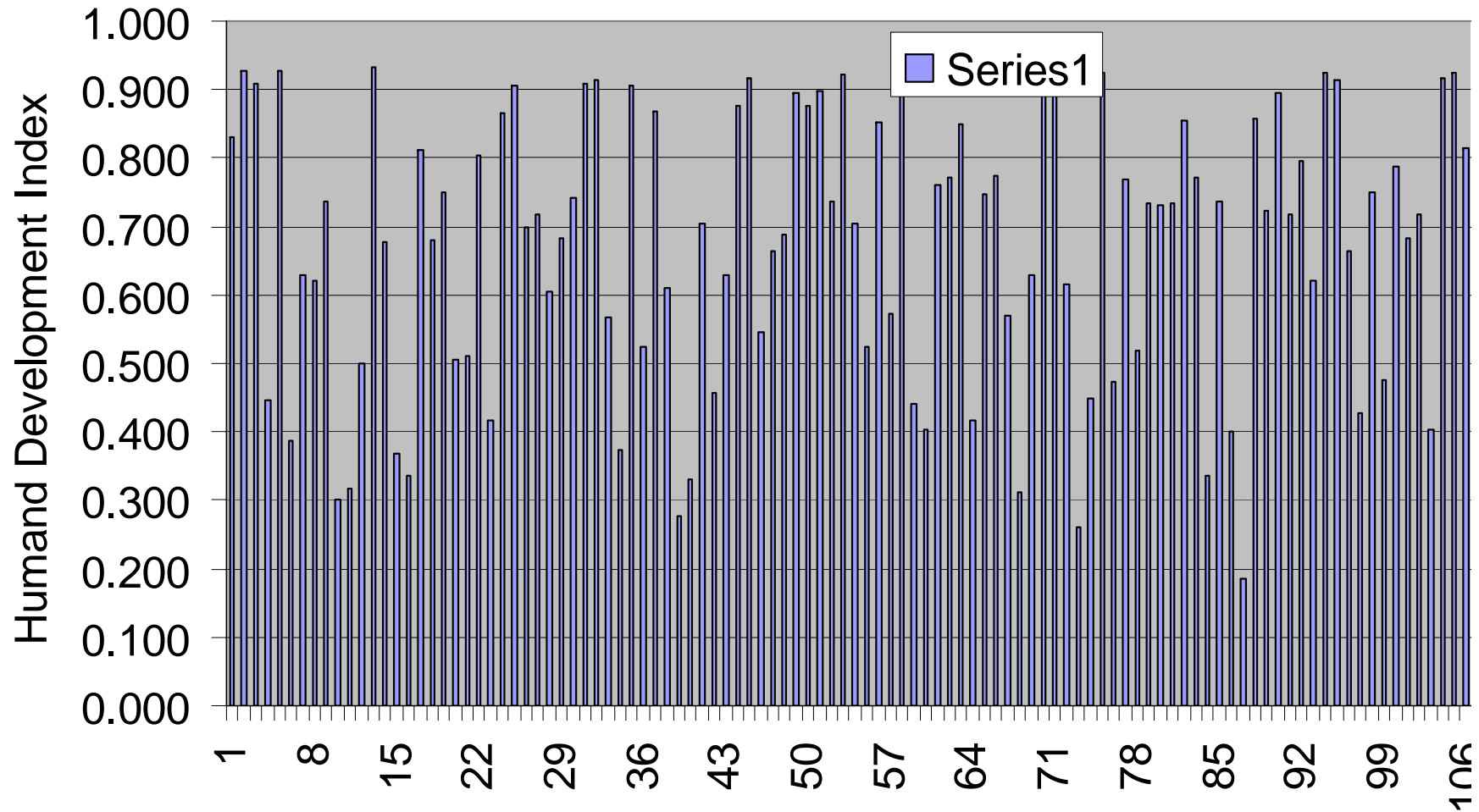
Reason for Trade Disputes

Optimistic view



Reasons for Technology Adoption

Variation in Human Development Index across the World
(Source: UNDP HDI report 2002)



Growth Rate of Per Capita Income and Human Development Index Among the slowest and Fastest Growers

	Growth Disasters		Growth Miracles		
Slow Growing Country	Average growth	HDI	Fast Growing Country	Average Growth	HDI
CAFR	-1.22	0.375	China	8.15	0.726
Chad	0.92	0.365	Hong Kong, China	4.22	0.888
Ghana	0.21	0.548	Ireland	4.71	0.925
Haiti	-2.01	0.471	Korea, Rep.	5.81	0.882
Madagascar	-1.61	0.469	Japan	2.33	0.933
Nicaragua	-1.58	0.635	Malta	4.11	0.875
Niger	-2.34	0.277	Portugal	2.85	0.88
Senegal	0.25	0.431	Singapore	5.02	0.88
Sierra Leone	-2.85	0.275	Thailand	4.74	0.75
Venezuela, RB	-1.15	0.77			
Zambia	-1.82	0.433			

European Countries Have Better Human Capital to Grow

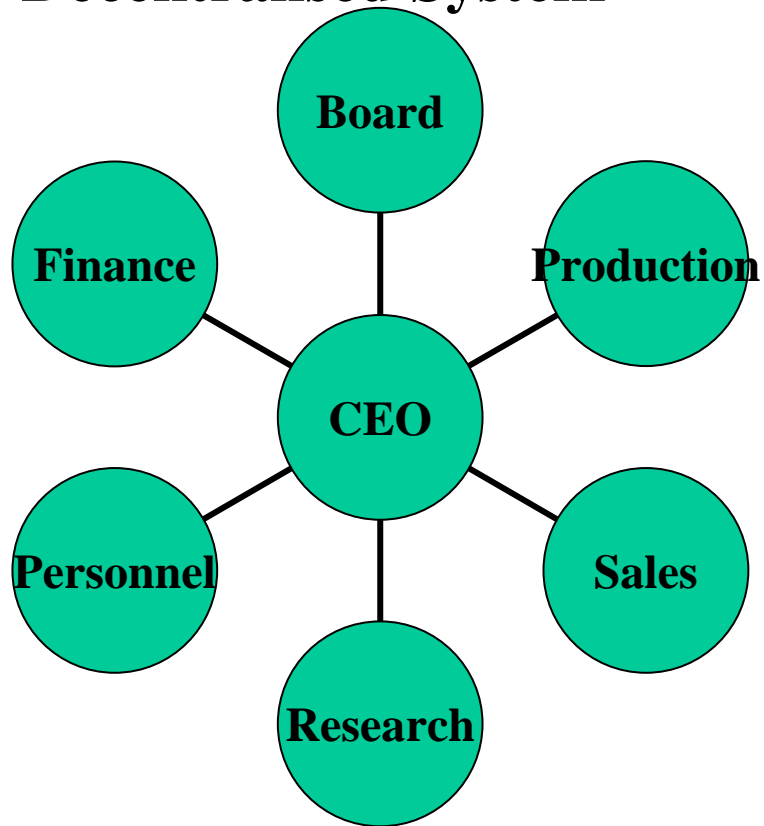
	Average Growth rate		HDI		Average Growth rate		HDI
	80-2000	95-2000			80-2000	95-2000	
Austria	1.95	2.16	0.926	Lithuania	-0.83	3.52	0.808
Belgium	2.00	2.50	0.939	Luxembourg	4.04	4.40	0.925
Bulgaria	0.77	0.10	0.779	Malta	4.11	3.80	0.875
Cyprus	4.16	3.41	0.883	Netherlands	1.83	2.71	0.935
Czech Republic	0.18	1.91	0.849	Norway	2.52	2.60	0.942
Denmark	1.63	2.25	0.926	Poland	3.59	5.40	0.833
Estonia	0.73	6.41	0.826	Portugal	2.85	3.29	0.880
Finland	2.40	4.59	0.930	Romania	-0.71	0.14	0.775
France	1.65	1.99	0.928	Slovak Republic	0.83	4.38	0.835
Germany	1.65	1.61	0.925	Slovenia	2.01	4.31	0.879
Greece	0.98	2.90	0.885	Spain	2.42	3.44	0.913
Hungary	1.28	4.01	0.835	Sweden	1.63	2.85	0.941
Ireland	4.71	8.57	0.925	Turkey	2.20	2.91	0.742
Italy	1.88	1.90	0.913	United Kingdom	1.95	2.42	0.928

Economically Important Innovations: Product of Genius, Active and Risk-loving People (Forbes Dec 2002)

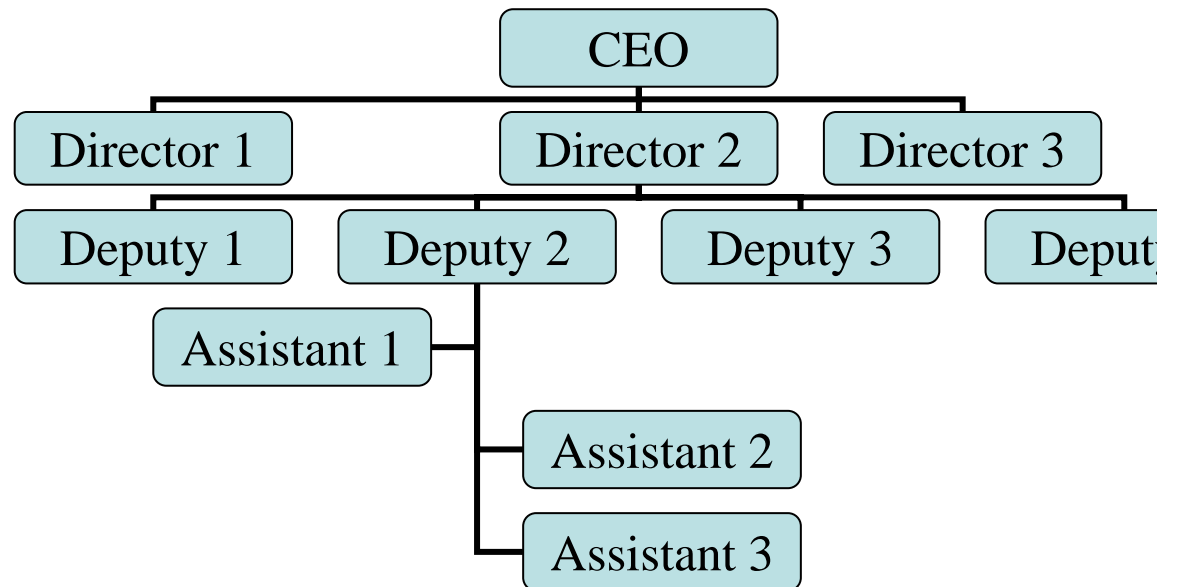
year	Innovation	year	Innovation	year	Innovation
1917	Sneakers	1940	Radar		
1918	Spectrometer, Uranium 235	1942	Electronic digital computer	1964	Mainframe
1921	Tetrathyle lead	1945	Nuclear power		Mouse
1923	Business Management	1948	LP	1971	Microprocessor
1923	Multiple camera	1949	Magnetic core memory		Answering machine
1924	Mutual funds	1947	Cellular phone	1972	3-D images of body (MRI)
1924	Frozen food		Microwave		Ethernet -LAN
1925	Transistor, digital signal processor		Instant Photos		Unix/C programming
1926	Rocket science		Transistors		E-entertainment
1927	TV		Tupperware	1976	DNA
1928	Penicillin	1951	Pill		Personal computer chips
1929	Synthetic rubber	1955	Fast food	1979	Spreadsheets
1930	Jet engine	1956	Containerised Shipping	1984	Dell PC
1933	Radio frequency modulation		Disk drives	1991	WWW
1937	Pulse code modulation		Fiber optics	1995	Internet business
	Blood bank	1958	Laser	1998	Viagra
1938	Xerography	1959	Integrated circuit	2000	Automated sequencing r
1939	Automatic transmission	1961	diapers		
	Helicopter	1962	Modem		

Human Capital in a Production Firm

Decentralised System

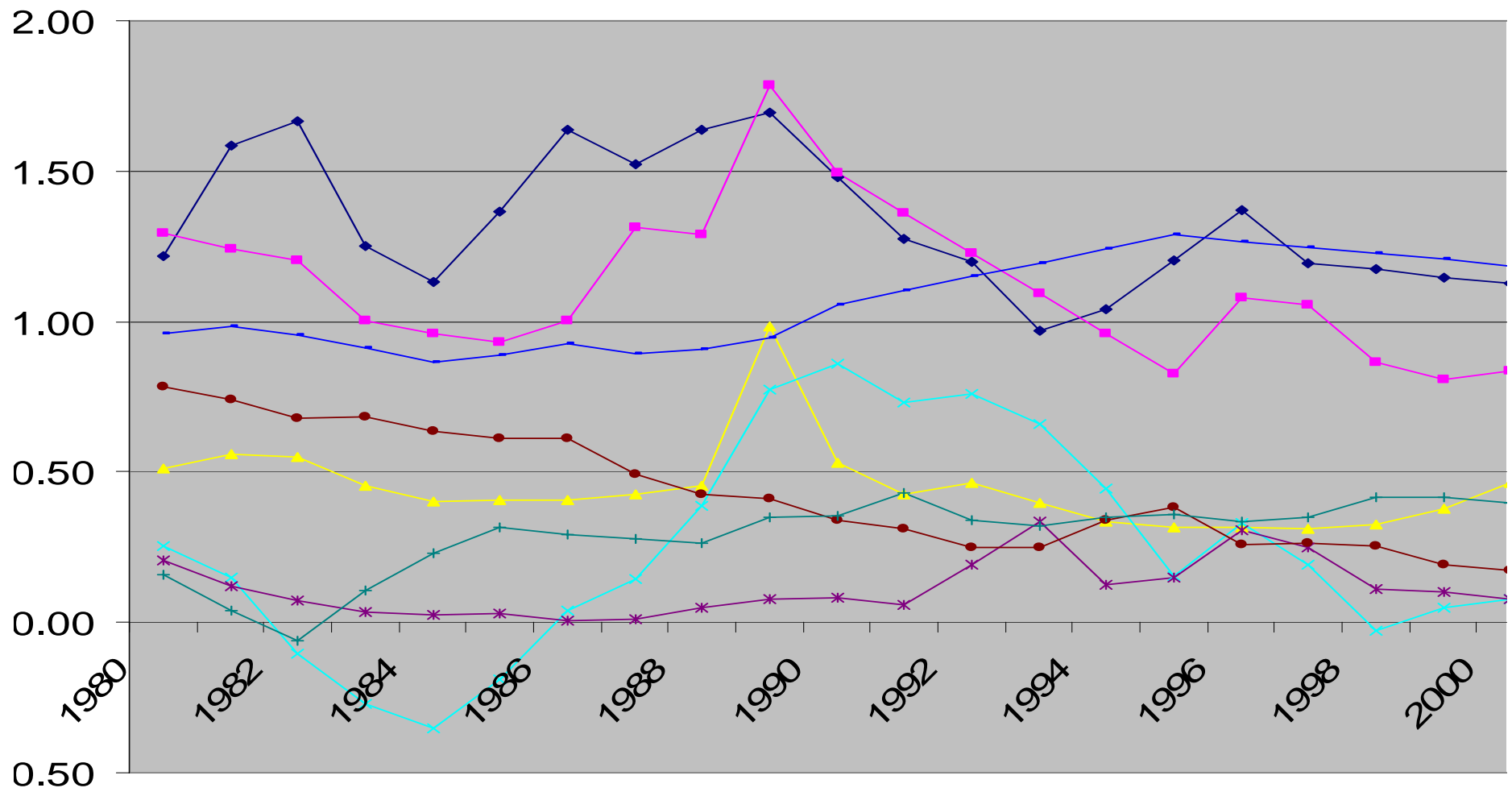


Centralised System



Demand for Schools Depends on Population Growth Rate

Population Growth Rates in Advanced Countries



Exercises

- Prove why saving rate does not affect the growth rate of output in the Solow model.
- Analyse complementarity between human and physical capital with human capital augmented Solow model.
- Find the steady state per capita output and capital stock with labour augmenting technological change.
- A few economically important innovations
- Real wage effect of the technology: two speed economy?