Economic Growth

Mankiw, Romer and Weil (1992): Augmenting the Solow model with Human Capital

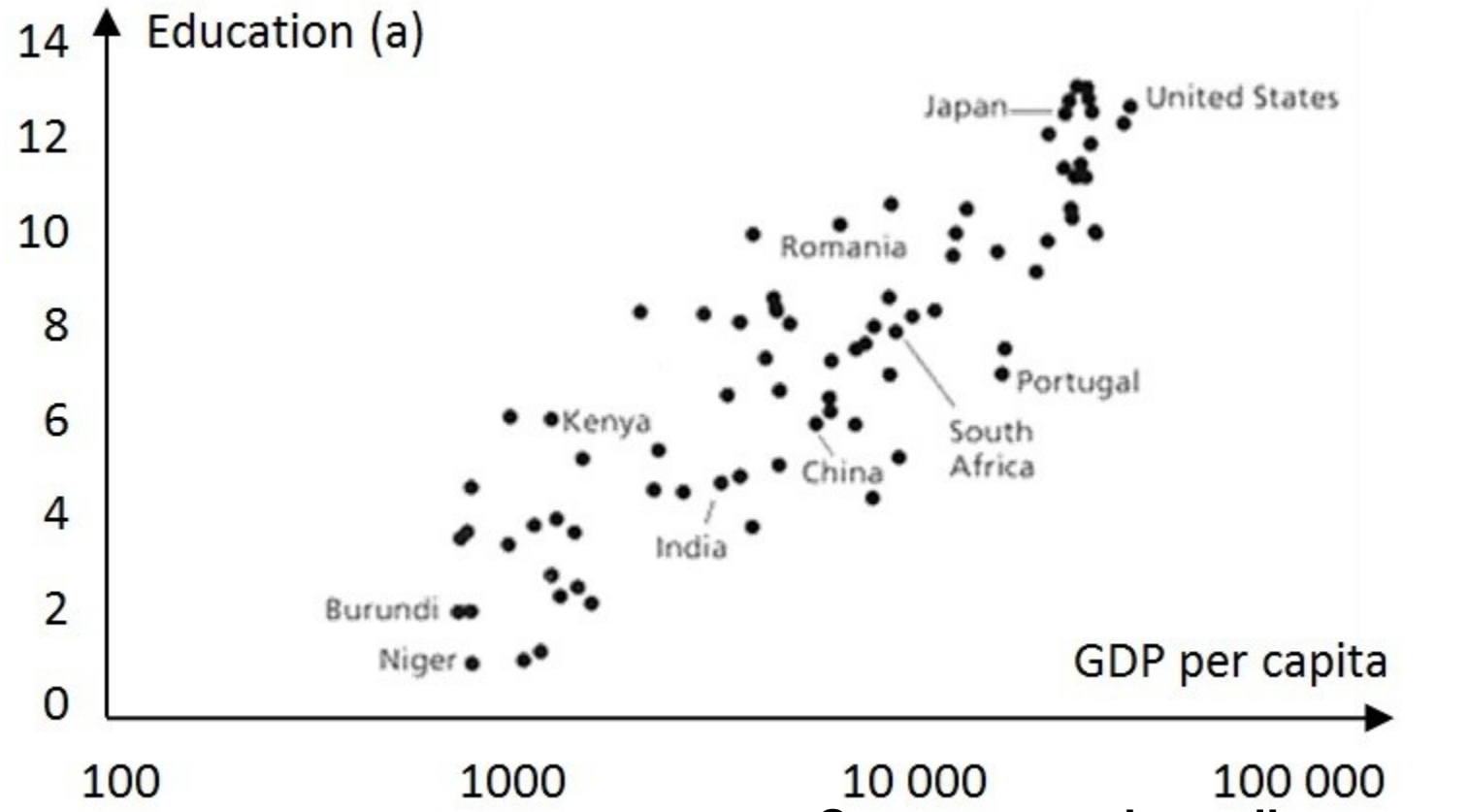
Education and Economic Growth

As a means and an end in itself

- Education (and similarly health) are important *objectives* of economic development in their own right
  - Note the composition of the 'Human Development Index'
- Education is also an important *determinant* of growth and development

Education and Economic Growth

Ave. # years



Source: www.boundless.com

Education and Economic Growth

Note, as usual in economics, correlation does not imply causality:

- Reverse causality
- Alternative theories of education
  - Human capital
  - Signalling

(open questions…)

Education and Economic Growth

- This lecture: extends the original Solow model to incorporate accumulation of human as well as physical capital.

- Closely follows: N. G. Mankiw, D. Romer & D. N. Weil (1992) “A Contribution to the Empirics of Economic Growth” *Quarterly Journal of Economics* vol. 107, no. 2, pp. 407-437.

A problem with the simple Solow model

Source: Mankiw, Romer and Weil

The Solow model predicts:

$$\log\left(\frac{Y}{N}\right) = \frac{\alpha}{1-\alpha}\log\left(\frac{s}{n+\lambda+\delta}\right) + \log(A)$$

(cf Solow-Swan Evidence lecture)

Assume that

A problem with the simple Solow model

Hence

In words: log GDP per capita should depend positively on savings, and negatively on the population growth rate

(Taking values of and as given, and .)

Moreover, the elasticity of to

A problem with the simple Solow model

Econometric Evidence:

Table 1 in Mankiw, Romer and Weil (next slide)

Key problem: Estimates of the elasticity of to s (measured as log investment/GDP) and are too high for the model.

TABLE I

ESTIMATION OF THE TEXTBOOK SOLOW MODEL

Dependent variable: log GDP per working-age person in 1985			
Sample:	Non-oil	Intermediate	OECD
Observations:	98	75	22
CONSTANT	5.48	5.36	7.97
	(1.59)	(1.55)	(2.48)
ln(I/GDP)	1.42	1.31	0.50
	(0.14)	(0.17)	(0.43)
$\ln(n + g + \delta)$	−1.97	−2.01	−0.76
	(0.56)	(0.53)	(0.84)
$\overline{R}^2$	0.59	0.59	0.01
s.e.e.	0.69	0.61	0.38
Restricted regression:			
CONSTANT	6.87	7.10	8.62
	(0.12)	(0.15)	(0.53)
$\ln(I/GDP) - \ln(n + g + \delta)$	1.48	1.43	0.56
	(0.12)	(0.14)	(0.36)
$\overline{R}^2$	0.59	0.59	0.06
s.e.e.	0.69	0.61	0.37
Test of restriction:			
p-value	0.38	0.26	0.79
Implied α	0.60	0.59	0.36
	(0.02)	(0.02)	(0.15)

Note. Standard errors are in parentheses. The investment and population growth rates are averages for the period 1960–1985. $(g + \delta)$ is assumed to be 0.05.

Adding Human Capital to the Solow model

A different production function:

Where *H* is human capital and other variables are defined as before.

Rewrite in ‘intensive form’ (dropping the time subscripts for convenience):

Where

Adding Human Capital to the Solow model

The 'equations of motion' for k and h are given by:

(note depreciation the same for both types of capital)

= fraction of income invested in physical capital.

= fraction of income invested in human capital.

Adding Human Capital to the Solow model

In the steady state, then both equations above are equal to zero. Solving simultaneously yields:

Adding Human Capital to the Solow model

Substituting into the production function yields:

Note *different* from the standard Solow 'steady state' solution. Hence:

(equation (11) in Mankiw, Romer & Weil, 1992).

Estimating the MRW (augmented Solow) model

Note key issues:

(i) Response of GDP to savings () now bigger: savings increases income, which increases human capital, which increases the returns to investment

(ii) measured as school enrolment rates (fraction of 12-17 year olds at school)

(iii) argued to be around 0.5. (e.g. difference between the average and minimum wage in the US).

Econometric Evidence:

Table 2 in Mankiw, Romer and Weil (next slide)

TABLE II

ESTIMATION OF THE AUGMENTED SOLOW MODEL

Dependent variable: log GDP per working-age person in 1985			
Sample:	Non-oil	Intermediate	OECD
Observations:	98	75	22
CONSTANT	6.89	7.81	8.63
	(1.17)	(1.19)	(2.19)
ln(I/GDP)	0.69	0.70	0.28
	(0.13)	(0.15)	(0.39)
$\ln(n + g + \delta)$	−1.73	−1.50	−1.07
	(0.41)	(0.40)	(0.75)
ln(SCHOOL)	0.66	0.73	0.76
	(0.07)	(0.10)	(0.29)
$\overline{R}^2$	0.78	0.77	0.24
s.e.e.	0.51	0.45	0.33
Restricted regression:			
CONSTANT	7.86	7.97	8.71
	(0.14)	(0.15)	(0.47)
$\ln(I/GDP) - \ln(n + g + \delta)$	0.73	0.71	0.29
	(0.12)	(0.14)	(0.33)
$\ln(SCHOOL) - \ln(n + g + \delta)$	0.67	0.74	0.76
	(0.07)	(0.09)	(0.28)
$\overline{R}^2$	0.78	0.77	0.28
s.e.e.	0.51	0.45	0.32
Test of restriction:			
p-value	0.41	0.89	0.97
Implied α	0.31	0.29	0.14
	(0.04)	(0.05)	(0.15)
Implied β	0.28	0.30	0.37
	(0.03)	(0.04)	(0.12)

Note. Standard errors are in parentheses. The investment and population growth rates are averages for the period 1960–1985. $(g + \delta)$ is assumed to be 0.05. SCHOOL is the average percentage of the working-age population in secondary school for the period 1960–1985.

Estimating the MRW model

Note findings:

(i) Response of GDP to savings () positive and statistically significant.

(ii) Response of GDP to () negative and 'large' as anticipated in (11).

(iii) Response of GDP to investment in schooling positive and significant in all cases.

Final Thoughts on MRW

Human capital is important in determining living standards

Model fits international data quite well, but:

1. Evidence could be indicating other mechanisms
   - Education as consumption?
   - Population growth as an *outcome* (indeed related to living standards) rather than exogenous?
   - High returns to investment are consistent with other models of economic growth.
2. Model still silent on the source of technological progress