Economic Growth Theory

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Standard growth accounting

- Solow residuals: measure of technological improvement or TFP: Total Factor Productivity.
- The "measure of our ignorance".

$$Y = AF(K, L)$$

$$dY/Y = dA/A + \frac{AF_K K}{Y}(dK/K) + \frac{AF_L L}{Y}(dL/L)$$

- Under competitive markets $w = AF_L$ and $r = AF_K$ so
- $\frac{AF_K K}{Y} = S_K$ is the share of output paid to capital.
- $\frac{AF_L L}{Y} = S_L$ is the share of output paid to labor. Hence,

$$g_A = g_Y - S_K g_K - S_L g_L$$

- Using measures of K, L, Y, S_K, S_L we can obtain a measure of technological progress Solow g_A which explains most of observed growth.

Growth accounting caveats

- Growth accounting is not a theory of growth.
- Young (1995) performs growth accounting special for Asian tigers and concludes that most of their growth is explained by factor accumulation.
- Klenow and Rodríguez-Clare (1997) and Barro and Sala-i-Martin (2004) make the following point
- Suppose $Y_t = A^t K_t^{\alpha} L_t^{1-\alpha}$ with $A > 1$
- Productivity increase $\rightarrow \Delta^+$ Marg. Prod. K $\rightarrow$ Economy accumulates more K.
- If $A = 1$, K would remain constant.
- Even though the growth is solely generated by A, growth accounting will attribute some share to K.

Measuring inputs (1)

- Ideal measure: Capital service flow in equivalent units.
- No official data on capital stock. Some estimations for Chile are available at some points.
- Series are constructed using Perpetual Inventory Method.
- Take K_0, δ and a series of investment I_t (in Chile, *Formación Bruta de Capital Fijo*). Then, compute

$$K_{t+1} = K_t(1-\delta) + I_t$$

- Suitable K_0 choice is $I_0/(g+\delta)$.

Measuring inputs (2)

- Capital heterogeneity issues: different kinds of capital with different (perhaps time-varying) δ.
- Quality issues; economical versus accounting value.
- Intensity use issue: installed versus used capital.
- Some ideas to overcome this problem: use of electricity use as a proxy for utilization rate or direct answers from survey.
- Measuring labor: ideal measure is total of hours of equivalent units of labor effort.
- Intensity issues: only total hours are observed, effort is unobservable.
- Labor force heterogeneity and human capital: how to aggregate hours?

Adding Human Capital

- Human capital? Workers' attributes that potentially increase their labor productivity.
- These attributes can be accumulated by workers through investments.
- Becker (1965) and Mincer (1974) are the cornerstones of human capital theory,
- Two main ways of acquiring human capital:
    - Pre-labor market investments: schooling or formal education.
    - On-the-job investments: training or learning-by-doing, usually associated with labor experience.

Adding Human Capital

- Standard way to "measure" human capital is through Mincer equation (see Acemoglu (2009) chapter 10 for a neat microeconomic derivation)

$$\log \text{wage}_i = a_0 + a_1 \text{schooling}_i + a_2 \text{exper}_i + a_3 \text{exper}_i^2 + \epsilon_i$$

Adding Human Capital into the Solow Model

- Mankiw, Romer, and Weil (1992) argue that introducing human capital into the standard Solow model, a great deal of the cross-sectional differences in per capita GDP are explained.

$$Y_t = K_t^{\alpha} H_t^{\gamma} (A_t L_t)^{1-\alpha-\gamma} \quad \text{with } \alpha + \gamma < 1$$
$$\dot{k}(t) = s_k y(t) - (n + \delta + a) k(t)$$
$$\dot{h}(t) = s_h y(t) - (n + \delta + a) h(t)$$

- In steady state we have that

$$k^{\star} = \left(\frac{s_k^{1-\gamma} s_h^{\gamma}}{n + \delta + a} \right)^{\frac{1}{1-\alpha-\gamma}} \qquad h^{\star} = \left(\frac{s_k^{1-\alpha} s_h^{\alpha}}{n + \delta + a} \right)^{\frac{1}{1-\alpha-\gamma}}$$

Mankiw, Romer, and Weil (1992) (1)

- We get the regression equation

$$\log y = \ln A_0 + at - \frac{\alpha+\gamma}{1-\alpha-\gamma}\log(n+\delta+a) + \frac{\alpha}{1-\alpha-\gamma}\log s_K + \frac{\gamma}{1-\alpha-\gamma}\log s_H$$

- How to measure H is controversial though. Key is measuring $H/Y = s_h/(n+\delta+a)$. Mankiw et al. (1992) measure s_H as

$$s_H = \text{secondary school enrollment rate} \times \frac{\text{15-19 population}}{\text{15-64 population}}$$

- Log-linearizing around the SS the augmented Solow model we obtain

$$g_y \approx -\beta(\log y_{t-1} - \log y^\star) \quad \text{with } \beta \equiv (1-\alpha-\gamma)(n+\delta+a)$$

Mankiw, Romer, and Weil (1992) (2)

- Mankiw et al. (1992) argue that $\alpha = \gamma = 1/3$ and $n + \delta + a = 0.06$ is a reasonable parametrization which imply $\beta = 0.02$ and economy moves halfway to steady-state in 35 years.
- If $\gamma = 0$ as in the standard Solow model, then $\beta = 0.04$. Half of the gap closes in 17 years.
- Augmented Solow predicts much slower convergence which fits the data much better.

Mankiw, Romer, and Weil (1992) (3)

- Intuition: a larger share of output is due to some kind of capital. Economy is more "capital" intensive and the level of output is higher.
- Mankiw, Romer, and Weil (1992) conclude there is evidence for convergence. No need for endogenous growth models.
- Factor accumulation explains about 78% of cross country differences in per capita log income.

Mankiw, Romer, and Weil (1992) (4)

TABLE III
TESTS FOR UNCONDITIONAL CONVERGENCE

Dependent variable: log difference GDP per working-age person 1960–1985			
Sample:	Non-oil	Intermediate	OECD
Observations:	98	75	22
CONSTANT	−0.266	0.587	3.69
	(0.380)	(0.433)	(0.68)
ln(Y60)	0.0943	−0.00423	−0.341
	(0.0496)	(0.05484)	(0.079)
$\overline{R}^2$	0.03	−0.01	0.46
s.e.e.	0.44	0.41	0.18
Implied λ	−0.00360	0.00017	0.0167
	(0.00219)	(0.00218)	(0.0023)

Note. Standard errors are in parentheses. Y60 is GDP per working-age person in 1960.

Mankiw, Romer, and Weil (1992) (5)

TABLE IV
TESTS FOR CONDITIONAL CONVERGENCE

Dependent variable: log difference GDP per working-age person 1960–1985

Sample:	Non-oil	Intermediate	OECD
Observations:	98	75	22
CONSTANT	1.93	2.23	2.19
	(0.83)	(0.86)	(1.17)
ln(Y60)	−0.141	−0.228	−0.351
	(0.052)	(0.057)	(0.066)
ln(I/GDP)	0.647	0.644	0.392
	(0.087)	(0.104)	(0.176)
$\ln(n + g + \delta)$	−0.299	−0.464	−0.753
	(0.304)	(0.307)	(0.341)
$\overline{R}^2$	0.38	0.35	0.62
s.e.e.	0.35	0.33	0.15
Implied λ	0.00606	0.0104	0.0173
	(0.00182)	(0.0019)	(0.0019)

Note. Standard errors are in parentheses. Y60 is GDP per working-age person in 1960. The investment and population growth rates are averages for the period 1960–1985. $(g + \delta)$ is assumed to be 0.05.

Mankiw, Romer, and Weil (1992) (6)

TABLE V
TESTS FOR CONDITIONAL CONVERGENCE

Dependent variable: log difference GDP per working-age person 1960–1985

Sample:	Non-oil	Intermediate	OECD
Observations:	98	75	22
CONSTANT	3.04	3.69	2.81
	(0.83)	(0.91)	(1.19)
ln(Y60)	−0.289	−0.366	−0.398
	(0.062)	(0.067)	(0.070)
ln(I/GDP)	0.524	0.538	0.335
	(0.087)	(0.102)	(0.174)
$\ln(n + g + \delta)$	−0.505	−0.551	−0.844
	(0.288)	(0.288)	(0.334)
ln(SCHOOL)	0.233	0.271	0.223
	(0.060)	(0.081)	(0.144)
$\overline{R}^2$	0.46	0.43	0.65
s.e.e.	0.33	0.30	0.15
Implied λ	0.0137	0.0182	0.0203
	(0.0019)	(0.0020)	(0.0020)

Note. Standard errors are in parentheses. Y60 is GDP per working-age person in 1960. 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.

Reactions to Mankiw et al. (1992) (1)

- Acemoglu (2009) chapter 4 and McGrattan and Schmitz (1999) summarize criticisms.
- Endogeneity in regressions: Are s_K and s_H truly exogenous regressors?
- Same policies or institutions preventing countries from capital accumulation are likely to prevent technological adoption (omitted variable bias)
- Technology level affects physical and human capital decisions (reverse causality or simultaneity)

Reactions to Mankiw et al. (1992) (3)

- Klenow and Rodríguez-Clare (1997) make several relevant points wrt MRW approach
- Estimation of MRW equations via OLS is unreliable: policies affecting A also affect savings rates. They rely in *calibration*, that is they use independent micro-evidence to gauge parameters.
- Measuring s_H using primary, secondary and tertiary education factor accumulation only explains 40% of cross-country variation (compare to 78% of MRW)
- Using highly intensive human capital technology for producing human capital, they can explain only 33% of cross country variation.

Reactions to Mankiw et al. (1992) (4)

- Klenow and Rodríguez-Clare (1997) also use a more standard way to measure human capital in labor economics: Mincer regression.

$$\ln w_i = a_0 + a_1 \text{school}_i + a_2 \text{exper}_i + a_3 \text{exper}_i^2 + \epsilon_i$$

Reactions to Mankiw et al. (1992) (5)

- Hence, they obtain

$$H/Y = (AL/Y)\left(e^{a_1 \text{school}} \sum_i \omega_i e^{a_2 \text{exper}_i + a_3 \text{exper}_i^2}\right)^{\frac{1-\alpha}{\gamma}}$$

- With ω_i are weights for different age groups in the population.
- Cross-sectional variation of implicit s_H greatly falls.
- About 53%-34% of cross country variation is explained by factors K and H.

Alternative measures of H/Y

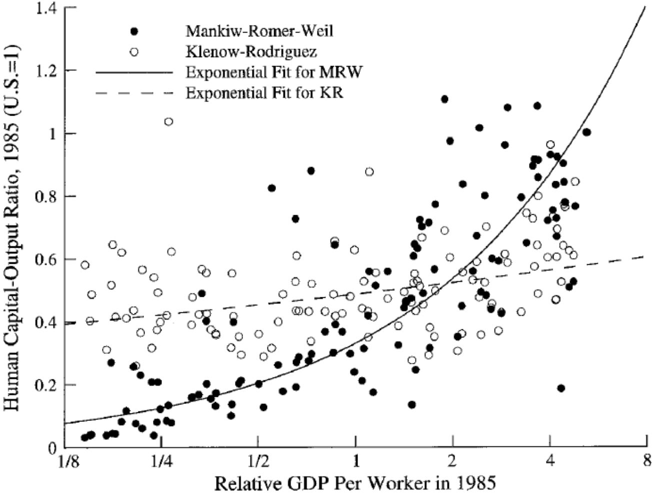

Fig. 8. Human capital–output ratio versus income, 1985.

Reactions to Mankiw et al. (1992) (5)

- Some simple calculations using MRW and Mincer estimates in Acemoglu (2009)[p 93-98]
- MRW s_H estimates range from $0.4\% - 12\%$. This implies a log difference of

$$\frac{\gamma}{1-\alpha-\gamma}(\log 12 - \log 0.4) = 0.66 \times 3.4 = 2.26$$

- Implied difference in human capital stock is $e^2.26 = 9.65$ times higher in top s_H country wrt lowest s_H country.
- Return to schooling is about 6%-10% per year. A 12-year difference of schooling generates differences in the range of $e^{0.06\times12} = 2.05$ to $e^{0.10\times12} = 3.32$
- MRW estimates are at odds with micro evidence of schooling returns!

Reactions to Mankiw et al. (1992) (6)

- Caselli (2005) updates earlier calculations.
- Calibration approach for capital-product share and computes individual human capital with schooling $h = e^s$.

Table 2
Success in sub-samples

Sub-sample	Obs.	var[log(y)]	var[log(y_{KH})]	$success_1$
Above the median	47	0.172	0.107	0.620
Below the median	47	0.624	0.254	0.407
OECD	24	0.083	0.050	0.606
Non-OECD	70	1.047	0.373	0.356
Africa	27	0.937	0.286	0.305
Americas	25	0.383	0.179	0.468
Asia and Oceania	25	0.673	0.292	0.434
Europe	17	0.136	0.032	0.233
All	94	1.297	0.500	0.385

Reactions to Mankiw et al. (1992) (7)

- Caselli (2005) summarizes a variety of alternative hypothesis to explain cross-country differences of per capita log income.
- Measurement differences of capital stock and depreciation cannot explain much variation.
- Measurement differences of labor (using hours) cannot explain much.

Reactions to Mankiw et al. (1992) (8)

- Differences in kinds of capital stock may have a great explanatory power if cross-substitution among capital types is low.
- Sectorial composition of product (agriculture vs. non-agriculture) can also explain a great deal of variation.
- Technical efficiency for using K and L (using a CES framework) can explain a great deal of variation.

Acemoglu, D. (2009).
Introduction to Modern Economic Growth.
Princeton University Press.

Barro, R. J. and X. Sala-i-Martin (2004).
Economic Growth (Second ed.).
The MIT Press.

Caselli, F. (2005).
Accounting for Cross-Country Income Differences, Volume Volume 1, Part 1 of *Handbook of Economic Growth*,, Chapter 9, pp. 679–741.
Elsevier.

Klenow, P. and A. Rodríguez-Clare (1997).
The Neoclassical Revival in Growth Economics: Has It Gone Too Far?, pp. 73–114.
NBER Chapters. National Bureau of Economic Research, Inc.

Mankiw, N. G., D. Romer, and D. N. Weil (1992).
A Contribution to the Empirics of Economic Growth.
The Quarterly Journal of Economics 107(2), 407–437.

McGrattan, E. R. and J. A. Schmitz (1999).
Explaining Cross-Country Income Differences, Volume 1 of *Handbook of Macroeconomics*, Chapter 10, pp. 669–737.
Elsevier.

Young, A. (1995).

The Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Growth Experience.
The Quarterly Journal of Economics 110(3), 641–680.