E C O N O M I C S   B U L L E T I N

Returns to Education and the Mankiw-Romer-Weil result.

Terence Huw Edwards
Loughborough University

Abstract

Mankiw, Romer and Weil [1992] found that, by adding a measure of school enrolment to capital and labour, a cross-country regression displays income convergence. However, their assumption that this derives from an augmented Solow model requires implausible differences in educational productivity across countries. By contrast, if educational productivity is constant, their fitted equation would be consistent with AK-type spillovers in goods production, but where educational costs damp growth. The MRW result suggests that endogenous growth theorists can be right about either technological spillovers or rising educational productivity, but not about both.

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I. Introduction.

Neoclassical growth theory, in the form of one-sector, closed economy models, has regained respectability in recent years[1]. Central to this renaissance has been Mankiw, Romer and Weil's [1993] paper, in which the traditional Solow [1956] growth model was augmented by including estimates of human capital as well as physical capital. By widening the definition of capital, Mankiw et al were able to increase greatly the proportion of cross-country income differences which could be explained by factor endowments. This provided powerful evidence that productivity is a function of education as well as physical capital per head, and that a long-run levels relationship across countries performed satisfactorily statistically, with apparently plausible factor values[2].

In this short note, I contest the view that Mankiw et al's findings necessarily resurrect the Solow model. The conditional levels relationship they found between savings, educational enrolment and productivity is consistent with a whole class of models, including modified versions of popular endogenous growth formulations. In addition, there are strong reasons to doubt Mankiw et al's interpretation of educational data. When corrected for this, Mankiw et al's fitted equations may well indicate near constant returns to capital accumulation, but with a damp on growth in the long run resulting from increasing costs of education as wages rise.

The major objection to the neoclassical approach is the difficulty of reconciling observed patterns of output, growth and factor accumulation with a number of awkward 'stylised facts' (Easterly and Levine [2001]). Wages of both skilled and unskilled labour are vastly higher in education-rich countries, while skilled and unskilled labour and often capital tend to flow in the same direction between countries - a result ruled out by neoclassical theorists, unless sizeable cross-country variations in TFP can entirely be attributed to random factors. This latter point is also undermined by the finding of Bernanke and Gurkaynak [2001] that TFP growth is itself positively correlated with both schooling and savings rates.

In reassessing Mankiw et al's contribution, my starting point is the economic interpretation of the levels equation which they estimate. It is beyond the scope of this paper to examine econometric criticisms of Mankiw et al.'s estimation or the quality of data[3]: rather, I take their results as given, but question the interpretation.

II. Outline of the revived neoclassical approach

Mankiw et al. [1993] argued that the familiar Cobb-Douglas formulation of Solow's growth model should be extended to include human capital, H, as well as physical capital, K. This would imply an underlying aggregate production function of the form

$$Y_{ct} = K_{ct}^{\alpha} H_{ct}^{\beta} (A_{ct} L_{ct})^{1-\alpha-\beta}, \tag{1}$$

where Y is total income, L is the labour supply and A is a technology parameter, with L growing at an annual rate n and A growing at rate g.

Following Solow, Mankiw et al. rewrite income, physical and human capital in (1) in terms of quantities per unit of effective labour, $y_t = Y_t/A_t L_t$ etc. The changes over time in physical and human capital per unit effective labour are

$$k_t' = s_k y_t - (n + g + \delta) k_t, \tag{2}$$

[1] In contrast to this view, macroeconomic 'new growth theorists' (e.g. Romer, [1986] , Lucas, [1988]) espouse models where technological spillovers at the national level destroy any long-run levels relationship, and where savings and educational enrolment rates determine only the growth rates of economies. Finally some sceptics (e.g. Nelson and Pack [1999]) argue growth is a more complicated process driven by the assimilation of global best-practice technology in combination with skill-upgrading and capital investment.

[2] The fit of Mankiw et al's cross-sectional levels model was broadly upheld by Bernanke and Gurkaynak [2001] using more recent data.

[3] See, for example, Temple [1998]. Also Benhabib and Spiegel [1994] and Temple [1999].

$$h_t' = s_h y_t - (n + g + \delta) h_t, \tag{3}$$

where δ is proportionate depreciation for both physical and human capital. Savings rates for physical and human capital, s_k and s_h respectively, are assumed to be constant over time, though not across countries. Solving for steady-state solutions k^* and h^*, Mankiw et al. derive an equation for steady-state income growth

$$\begin{aligned} \ln(Y_t/L_t) &= \ln A_0 + gt - ((\alpha+\beta)/(1-\alpha-\beta)) \ln(n+g+\delta) \\ &+ (\alpha/(1-\alpha-\beta)) \ln s_k + (\beta/(1-\alpha-\beta)) \ln s_{h.} \end{aligned} \tag{4}$$

The physical capital savings rate, s_k, was approximated by the investment share in GDP, while the human capital savings rate s_h was measured by the proportion of the working age population at any one time enrolled in secondary school - 'SCHOOL' in the Mankiw et al. estimated equations. Estimation on cross-section samples of 98 and 75 countries respectively in 1985 yielded greatly improved fit compared to the Solow model excluding human capital, and the parameter restrictions implied in equation (4) were not rejected statistically, while the implied income shares of physical and human capital, both around 0.3, were judged to be plausible.[4]

III. The treatment of human capital in the neoclassical framework

Arguably, equations (2) and (3) should both contain measures of the costs of acquiring physical and human capital, since these may differ between countries. Prices of both types of capital may change relatively to those of consumer goods as income levels alter. More formal analysis should include separate production functions for both capital goods. However, I suggest that it may not be too bad an approximation here to equate physical capital and consumer goods prices.

With human capital the problem is much more serious. Equation (3) measures the volume of human capital in terms of income foregone during education - meaning a year of schooling would be around 40 times more valuable in terms of units of human capital acquired in Norway (1985 GDP per adult $19,723) than in Chad (GDP $462 per adult). This assumption almost certainly results in Mankiw et al. seriously overestimating the difference in stocks of human capital per head[5].

To understand the significance of the modelling approach for human capital, first we should compare this with the Lucas-Uzawa treatment.[6] This popular endogenous growth approach replaces equations (1) and (3) with equations in the form

$$Y_{ct} = K_{ct}^{\alpha} A_{ct}^{1-\alpha} H_{ct}, \tag{1a}$$

where

$$(H/\widetilde{L})' = B\theta(H_{ct}/\widetilde{L}_{ct}). \tag{3a}$$

$\widetilde{L}$ is the labour force excluding those being educated, B is interpreted as an educational productivity parameter, which implies that educational productivity is assumed to rise in direct proportion to average human capital per head. Hence Lucas is essentially at one with Mankiw et al. in assuming that educational productivity (human capital gained per person-year in education) is vastly higher in rich countries than poor ones. However, (1a) assumes the presence of sizeable external returns to both human and physical capital formation, which just happen to be sufficient to make output homogeneous

[4] A third regression, on 22 OECD countries, did not perform well.

[5] Note that a doctor or engineer trained in Norway would not earn 40 times the wage paid to a colleague who had migrated from Chad.

[6] Lucas [1988].

of degree 1 (h.d.1) in the two types of capital.[7] The combination of output which is h.d.1 in the two types of capital and a linear relationship between output per head and human capital means output growth rates in the Lucas-Uzawa framework are a linear function of school enrolment, θ, but there is no levels relationship between income, savings rates and school enrolment. Hence the fit of the Mankiw et al. equation would be seen as a surprising result for an endogenous growth theorist.

However, one potential defence of the Mankiw et al. result is to follow the spirit of equation (3a) and explicitly link educational productivity to the overall productivity of an economy, while maintaining the augmented Solow equation (1), rather than the endogenous growth equation (1a). Hence, I suggest a slightly modified model, where education is a separate sector and the total potential workforce, $\overline{L}$ is split into proportions θ being educated and $(1-\theta)$ working. Ignoring unemployment, the ratio of those being educated per worker is therefore $(\theta/(1-\theta))$. θ, which I take as exogenous, is essentially the same variable Mankiw et al. used to proxy s_k.

Further, assume human capital accumulation is a linear function of years of schooling, so that the change in average human capital per unit of 'augmented' labour is

$$h_t' = \eta(\theta/(1-\theta)) - (n+g+\delta)h_t, \tag{5}$$

where η is a scale parameter. Mankiw et al. implicitly assume that η is proportional to total factor productivity across the whole economy. I suggest we consider a more general formulation where educational labour productivity is related to average labour productivity in the rest of the economy with a uniform elasticity

$$\eta_c = \overline{\eta}{y_c}^{\phi} \tag{6}$$

for each country c. Since education is a service sector, the Balassa-Samuelson literature would suggest $0 \leqslant \phi \leqslant 1$.Of particular interest are the cases a) where educational productivity is a linear function of overall output per head ($\phi = 1$) and b) where educational productivity is constant across all countries ($\phi = 0$).

As a minor simplification, it is assumed that the resources employed in education (mostly the people being educated) are not measured in official GDP. Simplifying to ignore residual terms[8], we can derive:

$$y_{ct} = k_{ct}^{\alpha} h_{ct}^{\beta}, \tag{7}$$

and it follows that the equilibrium conditions for h and k for each country (denoted now with ^{*AS} to denote the augmented Solow model equilibrium) are then

$$h_{ct}^{*AS} = y_c^{*AS\phi}(\theta/(1-\theta))/(n+g+\delta), \tag{8}$$

$$k_{ct}^{*AS} = s_k y_{ct}^{*AS}/(n+g+\delta) \tag{9}$$

Substituting for h^{*AS} and k^{*AS} into (9) we therefore obtain y^{**AS}, which can be written in logs as

$$\begin{aligned} \ln(Y_c^{*AS}/L_c) &= \ln A_0 + gt \\ &-((\alpha+\beta)/(1-\alpha-\beta\phi))\ln(n+g+\delta) + (\alpha/(1-\alpha-\beta\phi))\ln s_{kc} \\ &+(\beta/(1-\alpha-\beta\phi))\ln\theta_c - (\beta/(1-\alpha-\beta\phi))\ln(1-\theta_c)). \end{aligned} \tag{10}$$

While this contains the same parameters as equation (4) it can be seen that the parameter restrictions are different, reflecting a different underlying model. Nevertheless, the key coefficients on $ln(n+g+\delta), \ln s_k$ and $\ln s_h$ are still in the same relative proportions.

[7] These returns have to include spillovers external to the firm, in order to square factor returns with the observed division of national income, yet these externalities are generally assumed by endogenous growth theorists to stop at national boundaries.

[8] Inclusion of a residual term would require the derivation of an ergodic set for the variables in the model.

It follows that the only differences are that the terms in equation (10) apart from lnA_0 and gt are just those in equation (4) scaled up by $(1-\alpha-\beta)/(1-\alpha-\beta\phi)$, and that there is the one extra term $-(\beta/(1-\alpha-\beta\phi))\ln(1-\theta_c))$.In fact, however, the extra term will not greatly change the regression, since for 'low' values of θ_c (in practice, the highest value of Mankiw et al's SCHOOL variable is 12.1% in Bahrain and Barbados), $\ln\theta_c - \ln(1-\theta_c)$ is very nearly approximated by a linear function of $\ln\theta_c$ with a very small intercept and a slope coefficient only slightly less than 1.[9] A_0 is just a constant scalar.When the model is estimated over a cross-section sample in a single year only, the differences in coefficients on gt become irrelevant.We can therefore approximately relate the models in (10) and (4):

$$(Y_c^{*AS}/L_c) \approx (Y_c^{*MRW}/L_c)^{(1-\alpha-\beta\phi)/(1-\alpha-\beta)}. \tag{11}$$

IV. Interpretation of levels equations

In this note, I concentrate on the steady-state cross-country version of the Mankiw et al. model, and ignore the later set of estimates based upon changes in income 1960-85 using a modified partial adjustment version of the model[10]. Mankiw et al fitted first an unrestricted and then a restricted version of equation (4)/(10). Their key results were that the coefficient on $ln(s_k)$ and that on θ (which I argue could quite easily be a proxy for $\theta/(1-\theta)$ with virtually no effect on fit) are both very close to unity, while that on $(n+g+\delta)$ is approximately minus 2.

To understand the ambiguity of these results, consider the interpretation of a rough version of their estimated cross-country equation

$$\ln Y = CONSTANT + \ln sk + \ln SCHOOL - 2\ln(n+g+\delta) + residual. \tag{12}$$

To fit this, again ignoring the residual term, α and β would have to satisfy approximately the following equations:

$$\alpha/(1-\alpha-\beta\phi) = 1; \tag{13}$$

$$\beta/(1-\alpha-\beta\phi) = 1; \tag{14}$$

$$(\alpha+\beta)/(1-\alpha-\beta\phi) = 2. \tag{15}$$

(15) is just linear combination of the other two. (12)-(13) will be satisfied by values

$$\beta = \alpha = 1/(2+\phi). \tag{16}$$

Working from data on factor income shares in GDP, Mankiw et al. express a prior expectation that α and β should both be close to 1/3. But those are exactly the values implied by (16) when $\phi = 1$. Therefore, if one were to accept that educational productivity is directly proportional to GDP, the implied factor shares in an augmented Solow model would be very close to the fitted coefficients of their restricted regression. However, for values of $\phi < 1$, the fitted regression can only be satisfied by values of α and β greater than 1/3, which would be inconsistent with a neoclassical model, at least within a Cobb-Douglas framework and given observed income shares. Hence, on a more plausible model of education, the Mankiw et al. model is not consistent with an augmented Solow model.

[9] A regression on Mankiw et al's cross-country data set (118 observations) gave: $\ln(SCHOOL_c/100) = -0.173 + 0.963\ln(SCHOOL_c/(100-SCHOOL_c)) + \varepsilon_c$. The t statistic on the slope coefficient was 664.7 and the adjusted R squared was 0.9997.

[10] The results of the dynamic equations were somewhat less plausible, giving a larger coefficient for physical capital and smaller for human capital than the static equation. The loglinear adjustment model Mankiw et al. use for off-steady-state convergence (based on a Taylor approximation around the steady-state point) may well be too approximate to apply to growth rates over a 25 year period.

Nevertheless, a broader class of models does fit the restricted Mankiw et al. equation: namely models with technological spillovers external to the firm.[11] Say

$$y = k^{\widehat{\alpha}} h^{\widehat{\beta}}, \tag{17}$$

where the fitted values of $\widehat{\alpha}$ and $\widehat{\beta}$ still need to satisfy

$$\widehat{\beta} = \widehat{\alpha} = 1/(2+\phi), \tag{18}$$

but that now these can be decomposed into

$$\widehat{\alpha} = \alpha + \gamma \tag{19}$$

and

$$\widehat{\beta} = \beta + \delta, \tag{20}$$

where $\alpha = \beta = 1/3$ and γ and δ represent external technological spillovers. In this case, (12) would be satisfied by

$$\delta = \gamma = (1-\phi)/(6+3\phi). \tag{21}$$

This shows that, to fit (12), technological spillovers are only zero when $\phi = 1$. When $\phi = 0$, so that educational productivity is constant across countries, $\widehat{\beta} = \widehat{\alpha} = 1/2$. In this case, the long-run steady state levels of income per capita are given by

$$y^{**} = k^{**1/2} h^{**1/2}. \tag{22}$$

This is essentially the same as equation (1a) in the Lucas-Uzawa framework. However, this model is not the Lucas-Uzawa model, since for (1a) to be consistent with convergence to a levels equation, educational productivity needs to be constant.

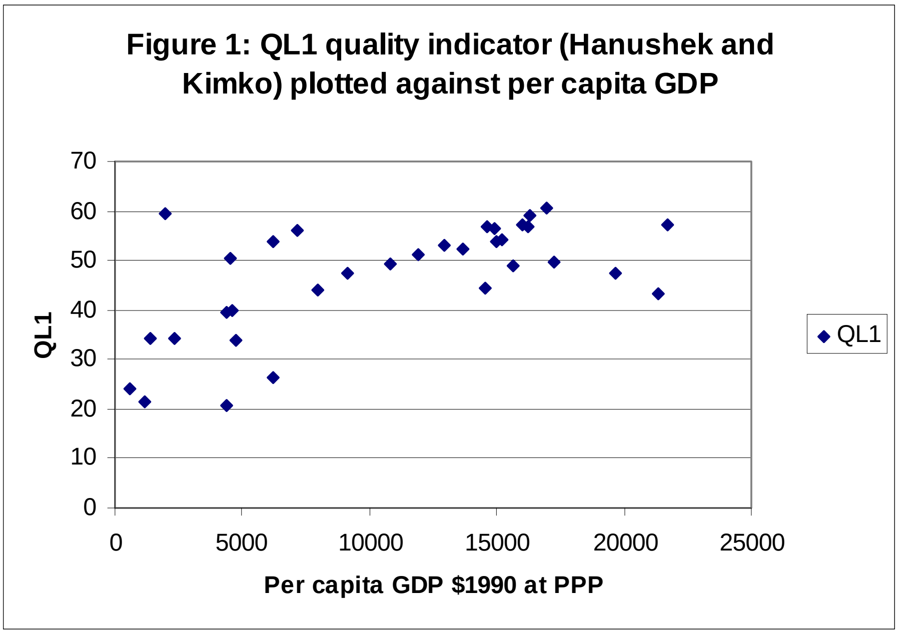
The tentative implications of this discussion are that the neoclassical school appear to be correct about convergence, but observed factor returns strongly suggest the assumption of equal technology and constant returns across countries is flawed. Meanwhile the endogenous growth school can either be correct regarding technological and educational spillages, or they can be correct regarding educational productivity - but it does not seem they can be right on both counts.

It should be added that an intermediate solution - with some rising educational productivity and some spillovers in goods production (but not enough to generate constant returns to scale) - is also consistent with the MRW equation, and may be supported by empirical evidence. In particular, studies by Hanushek and Kimko [2000] and Hanushek and Wöβman [2007] indicate that educational productivity, when measured in terms of standard measures of cognitive achievement, is variable across nations, though not of the order of magnitude implied by Mankiw et al. A casual inspection of *Figure 1,* below, indicates that educational productivity probably rises with income for low or medium levels of income (though with a good deal of cross-country variability), but that this relationship breaks down for higher income levels: the curve looks flat over about \$10,000.

V. Implications

Mankiw et al.'s estimated model is consistent with a general class of models, not just the augmented Solow model they favour. All of these models produce roughly the same convergence pattern as documented. However, unless educational attainment per hour study time is vastly higher in rich than in poor countries, the augmented Solow model cannot be supported by their result. By contrast, a model

[11] Actually, Bernanke and Gurkaynak argue that the Mankiw et al equation is consistent with any balanced growth path.



with technical spillovers, but which shows convergence due to the lack of difference in educational sector productivity is more credible for several reasons: not least the observation that skilled labour tends to flow from poor countries to richer ones, where it tends to earn more despite its abundance[12]. While the two models may have similar convergence properties in a closed economy, increasing trade, capital and labour flows between rich and poor countries since 1985 suggest the two models may have very different predictions today.

It is also worth noting that the existence or non-existence of technological spillovers has important implications in terms of optimal economic policies. For this reason alone, the ambiguity of Mankiw et al.'s result should cause people to treat their findings with due caution.

Even the tentative finding of conditional convergence needs to be taken with some scepticism, since it treats savings rates and educational investment rates as exogenous. Particularly in poor countries, institutional, social and legal barriers (including the lack of credit availability for those without collateral) can seriously affect this result, leading to potential poverty traps and multiple equilibria. I have also ignored the effects of openness to international trade, despite the fact that the most dramatic growth experiences in recent years have been in open, not closed economies, and that the potential for substitution between products in trade (as in the Heckscher-Ohlin-Samuelson framework) mean that the declining marginal returns to capital of traditional closed economy neoclassical models may barely apply for even quite large changes in factor levels[13]. More work on open economies and on dual economies is needed before any strong conclusions can be drawn on the conditional convergence results.

The overall conclusion of this paper is that, while the augmented Solow model provides important evidence, particularly for the role of educational investment in explaining cross-country income differences, the Mankiw et al finding of conditional convergence needs to be treated with some caution, and the resurrection of traditional, one-sector neoclassical growth models should be seen as highly questionable.

[12]High returns to education in poor countries, as noted by Mankiw et al, are because education is cheap, not because human capital is well paid.

[13]This can lead to very open economies appearing to have 'endogenous growth' but for quite different reasons to the standard endogenous growth literature.

References

[1] Benhabib, J., Spiegel, M.M.[1994]. 'The role of human capital in economic development: Evidence from aggregate cross-country data.' *Journal of Monetary Economics* 34, 143-173.

[2] Bernanke, B.S. and R.S.Gurkaynak [2001]: 'Is Growth Exogenous: taking Mankiw, Romer and Weil Seriously.' In *NBER Macroeconomics Annual*, 16:11–57

[3] Easterly, W. and R.Levine [2001]: 'Its Not Factor Accumulation: Stylised Facts and Growth Models'. *World Bank Economic Review* XV(2), (2001), 177-219.

[4] Hanushek, E.A. and D.D.Kimko [2000]: 'Schooling, labor force quality, and the growth of nations.' *American Economic Review* 90 (5), 1184-1208.

[5] Hanushek, E.A. and L.Wőβman [2007]: 'The Role of Education Quality in Economic Growth.' *World Bank Policy Research Working Paper* 4122.

[6] Lucas, R.E. [1988]: 'On the Mechanics of Economic Development', *Journal of Monetary Economics* XXII, 3-42.

[7] Mankiw, N.G., D.Romer and D.N.Weil [1992]: 'A Contribution to the Empirics of Economic Growth,' *Quarterly Journal of Economics*, CVII, 407-437.

[8] Nelson, R. and H.Pack [1999]: 'The Asian Growth Miracle and Modern Growth Theory', *Economic Journal* 109, 457:416-436, July 1999.

[9] Romer, P.M: 'Increasing Returns and Long-Run Growth' [1986]: *Journal of Political Economy* XCIV, (1986), 1002-38.

[10] Solow, R.M.: 'A Contribution to the Theory of Economic Growth' [1956]: *Quarterly Journal of Economics* LXX, (1956), 65-94.

[11] Temple, J.R.W [1998]: 'Robustness tests of the augmented Solow model', *Journal of Applied Econometric*s, July-August 1998, 13(4), 361-375.

[12] Temple, J.R.W. [1999]. 'A positive effect of human capital on growth.' *Economics Letters* 65, 131-134.

[13] Young, A. [1995], 'The tyranny of numbers: confronting the statistical realities of the East Asian growth experience', *Quarterly Journal of Economics*, 110, pp.641-680.