ISSN 2045-6557

The Returns to Education: A Review of the Macro-Economic Literature

Barbara Sianesi and John Van Reenen

CENTRE FOR THE ECONOMICS OF EDUCATION

November 2000

Published by
Centre for the Economics of Education
London School of Economics and Political Science
Houghton Street
London WC2A 2AE

ISBN 0 7530 1437 8

Individual copy price: £5

This work is from a forthcoming publication in the Department of Education and Employment Research Series.

EXECUTIVE SUMMARY

Over the last two decades there has been an outpouring of empirical work exploring the impact of 'human capital' – a concept of worker quality and skills generally measured by formal education – on the level and growth of productivity. In this report, we review the empirical macro-econometric literature on productivity and education with a particular focus on UK policy. We detail over twenty studies, giving both summaries and critiques, as well as attempting to put all the studies in a common quantitative form

The idea of positive educational externalities is that the benefits from education have the potential to spill-over to other individuals. The new growth theory emphasises the higher rate of innovation that can be generated by having more educated workers generating new ideas. There are also other types of education-related externalities that may have an effect on the level of GDP *per capita* (like lower unemployment, lower crime, etc.).

Key Findings

1. There are a host of methodological problems involved in estimating the impact of education on economic growth. Nonetheless, there is compelling evidence that human capital increases productivity, suggesting that education really is productivity-enhancing rather than just a device that individuals use to signal their level of ability to the employer. Indeed, taking the cross-country studies as a whole, increasing school enrolment rates (human capital flow) by one percentage point leads to an increase in per capita GDP growth of between 1 and 3 percentage points. An additional year of secondary education in the population (human capital stock) leads to over 1 percentage point faster growth each year. It is important to bear in mind that these results apply to pooled samples of both OECD and developing countries.

2. There is an important methodological distinction to be made between studies in the macro-economic literature on the returns to education. Some studies adopt a more conventional neo-classical approach whereas more recent work is based upon some of the new growth theories. In the neo-classical tradition a one-off permanent increase in the stock of human capital (e.g. average years of education in the population) will be associated with a one-off increase in the productivity growth. By contrast in the new growth theories, a one-off permanent increase in the stock of human capital is associated with a *permanent* increase in the growth rate of productivity.

3. Over a short-run planning horizon (4 years ahead) the empirical estimates of the change in GDP for a given increase in the human capital stock are of similar orders of magnitude in the two approaches discussed above. Over a longer horizon, the implied effects in the new growth approach appear implausibly large. We think the effect is overstated in the 'new growth' approach due to several methodological problems.

4. The neo-classical approach generates effects that are more consistent with the micro-economic evidence (e.g. for a pooled sample of developing and OECD countries doubling average years of secondary education in the labour force would typically increase output per worker by one third).

5. The impact of increases in various levels of education appear to vary greatly according to the level of a country's development, with tertiary education being the most important for growth in OECD countries.

6. Education has indirect effects on growth as well, in particular by stimulating physical capital investments and technology adoption.

7. Preliminary evidence suggests that the type of education, its quality and the efficiency with which investment in education is allocated all matter for growth.

8. The most pressing methodological problems are (a) the measurement of human capital; (b) systematic differences in the coefficient of education (as well as other parameters) across countries – for example the developing *vs*. developed countries; and (c) reverse causality – *e.g.* faster growing and richer countries may tend to invest more in education, rather than income growth being caused by rising education.

Future Research Recommendations

1. Reconciling micro and macro evidence by combining data at different levels of aggregation (individual, firm, industry and economy-wide);

2. Trying to control reverse causality by using more exogenous changes affecting education (such as policy shifts);

3. Attempting to improve the (time-varying) measurement of the stock of education;

4. Trying to explore the mechanisms through which human capital affects growth, *e.g.* regarding the relative effects of different stages of education (pre-school, primary, secondary, higher) and of types of education (vocational, academic).

The Returns to Education:
A Review of the Macro-Economic Literature

Barbara Sianesi and John Van Reenen

The Centre for the Economics of Education is financed by the DfEE

Acknowledgements

Barbara Sianesi and John Van Reenen are at the Institute for Fiscal Studies and University College London.

The Centre for the Economics of Education is an independent research centre funded by the Department of Education and Employment. The view expressed in this work are those of the authors and do not necessarily reflect the views of the Department of Education and Employment. All errors and omissions remain the authors.

This work is from a forthcoming publication in the Department of Education and Employment Research Series.

The Returns to Education:
A Review of the Macro-Economic Literature

A Report to the DfEE

Barbara Sianesi and John Van Reenen

1. Introduction

There is a huge literature on the benefits of education stretching back to antiquity. Still the essential problem for a modern government is the decision on how many resources should be transferred from tax revenue towards education (the optimal level of subsidy) and in what manner to deliver the pot of educational spending.

In this review we focus on a number of empirical economic studies which help shed light on these questions. Our primary objective is to critically review the literature that has tried to estimate the impact of human capital on economic growth, or, in other words, the returns to education that accrue at a macro-economic level. The potential economic externalities to education should, in principle, be captured at this level of aggregation. Individual level analyses (see Blundell, Dearden, Meghir and Sianesi, 1999, for a survey), on the other hand, focus on the estimation of the private returns to education, which may underestimate the full returns if education has characteristics of a public good. The larger are the social returns, the greater is the *prima facie* case for channelling public resources into education.

In particular, the main aims in the report are the following:

1) to highlight the key research findings which emerge from the macro regressions

We offer an extensive summary and discussion of the body of econometric literature trying to measure the links between education and economic growth.

In Section 4 the results of 25 empirical contributions to the debate are detailed. We have summarised these papers in several ways: Tables 4.1 and 4.2 offer an analytic summary of the studies where we have attempted to make quantitative comparisons of the implied effect of education across all the studies, while the Appendix has a one page summary of each paper including abstract, data, method, results and critique.

2) to provide an estimate of the most plausible social return to education

In addition, to help quantify such an effect for an economy sharing the relevant features of the UK, in Section 4.2 we give some quantitative estimates of the social returns in money terms based on the central estimates.

3) to report on other major findings in the literature

In particular, key differences in the effects of schooling in different types of countries; the impact of different types of schooling; and education quality and delivery issues are also addressed in Sections 4.1 and 4.3.

4) to identify gaps in the literature and to suggest ways to advance it

Areas in which future work is needed are suggested in Section 5.

Secondary issues, which however cannot be overlooked when trying to make sense of the results as well as evaluating their reliability, include:

5) to highlight the interplay between theoretical developments and empirical methods

Several approaches to modelling human capital and economic growth have been explored and we offer a methodological description, critique and evaluation of each.

As detailed in Section 2, a basic distinction is between the augmented neo-classical model and new endogenous growth theories. Such a distinction is important because if one believes the new growth theories then a policy intervention to raise the level of human capital (*e.g.* through greater schooling subsidies) has a much larger effect on economic welfare than it would do in the neo-classical model.

6) to discuss methodological issues

Section 3 offers a critique of these methodologies, including problems with data and econometrics.

If one were to crudely summarise the results they would run as follows:

Taking the studies as a whole, there is compelling evidence that human capital increases productivity, suggesting that education really is productivity-enhancing rather than just a device that individuals use to signal their level of ability to the employer.

The empirical literature is however still largely divided on whether education affects the long-run level or growth rate of the economy. Most of the evidence is from "Barro" style growth regressions that suggest that increasing school enrolment rates by one percentage points leads to an increase in *per capita* GDP growth of between 1 and 3 percentage points every year. An additional year of education in the population leads to over 1 percentage point faster growth. This is an extraordinarily large effect. We think the effect is overstated due to methodological problems such as correlation with omitted variables and unduly imposed restrictions. We conclude, therefore, that the evidence in favour of the new growth theories (especially for OECD countries) is quite weak due to a whole host of problems. Our baseline estimates follow Mankiw *et al* (1992) and look for effects of human capital on the level of output, although we compare this carefully with estimates from the alternative approach. Interestingly, it turns out that over the short-run planning horizon (4 years ahead) the empirical estimates of the change in GDP for a given increase in the human capital stock are of similar orders of magnitude in the two approaches.

There are more robust qualitative results such as:

(1) the fact that schooling returns are generally higher in LDCs than in the OECD;

(2) that the impact of increases in various levels of education appears to greatly depend on the level of a country's development (with tertiary education being the most relevant for OECD countries);

(3) that education yields additional indirect benefits to growth (in particular, by stimulating physical capital investments and technological development and adoption);

(4) that schooling quality, as well as the efficiency with which resources are allocated to the various levels of education is very important.

2. Theoretical Frameworks and Empirical Methods

2.1 Introduction

The aim of this section is to outline the main theoretical approaches modelling the linkages between human capital and economic performance, together with a methodological description of the empirical analyses erected upon such theory.
The section starts by introducing the important notion of educational externalities (2.2), a concept which largely explains why the prevalent modelling attempts take place at the macro level.

The two main **macro** approaches are the augmented Solow neo-classical approach (2.3) and the 'new growth theories' (2.4), with their respective empirical counterparts of growth accounting exercises (2.3) and macro regressions (2.5).

The augmented neo-classical model simply extends the basic production function framework to allow an extra input to enter the production function: human capital. Since this is estimated at the economy-wide level it does take into account human capital externalities which increase the *level* of output. The endogenous growth approach argues that there should be an additional effect of human capital over and above the static effect on the level of output. Researchers in this field argue that there should be an effect of increasing the level of human capital on the *growth* rate of productivity. This is because of an increase in the rate of innovation associated with economies richer in human capital.

The idea of positive educational externalities – benefits from education which spill over to others as well – is well established (though still largely untested). This partly explains the paucity and controversial nature of **micro** level studies of social rates of returns estimates (2.6). A few attempts have very recently emerged in the micro-econometric literature looking at educational externalities, defined however in a limited way, as the 'impact of average education on individual earnings' (2.7). The final sub-section (2.8) succinctly considers the micro-econometric literature on private individual returns to education, as well as its linkages to the macro approaches just discussed.

2.2 Externalities

Economists have long argued that the benefits of human capital accumulation may not be restricted to the direct recipient but might spill over to others as well. Some of the new growth theories (*cf.* 2.4) have distinguished themselves from the traditional neo-classical approach by explicitly proposing a role for education externalities in economic growth: educated workers may raise the productivity of their less educated co-workers, or there may be spill-over effects from technical progress/knowledge accumulation which in turn arise from investments in human capital; or an environment with a higher average level of human capital may entail a higher incidence of learning from others.

Another presumption as to the existence of such externalities derives from the observation that human capital often flows to countries already endowed with a high stock of such capital ('brain drain'), suggesting that the return to this 'unconventional' input is negatively related to its scarcity.

The existence of positive economy-wide educational spill-overs is an important economic justification for the public support of education, although the difficulties of actually verifying their size and thus calculating true social returns are formidable.

While there is a large amount of evidence arising from microeconometric studies on the returns to education to the individual, macro studies are especially relevant in terms of assessing the empirical importance of educational externalities, which are often assumed *a priori* by theorists and policymakers alike.

In fact, external social impacts of investments in human capital can in turn have indirect economic effects. More education has been found to be associated with better public health and parenting, lower crime, better environment, wider political and community participation and greater social cohesion, all of which is in turn likely to feed back into economic growth (see OECD, 1998 for a synthetic review and relevant references).

Regressions looking at the macroeconomic impact of human capital are thus well positioned to capture these wider effects of such investments on national economic growth.

In addition to these macro regressions (section 2.3, 2.5), a recent move towards trying to counter Topel's (1999) remark that "labour economists are conspicuous by their absence" on the subject of the social returns to education is represented by a few papers looking at the impact on individual wages of the average level of education in the individual's city or state of residence (section 2.7).

2.3 The Solow (or neo-classical) model and growth accounting

Consider the definition of the aggregate production function, where GDP is modelled as a function of the aggregate stock of physical capital in the economy, its labour force, and time, capturing an otherwise unmodelled 'technical progress'. In symbols:
$Y_t = f(K_t, L_t, t)$, where Y is output, K the stock of capital, L the labour force, t time. Define $MP_n \equiv df(.)/dn$ to be the marginal product of factor n, *i.e.* the contribution to output of an increment in input n, holding constant all other production factors. Simple algebra yields (where a dot denotes the derivative with respect to time):

$$\frac{\dot{Y}}{Y} = \frac{MP_K K}{Y}\frac{\dot{K}}{K} + \frac{MP_L L}{Y}\frac{\dot{L}}{L} + \frac{\partial f / \partial t}{Y}$$

Assuming perfect competition and constant returns to scale (so that price of factor n is equal to its marginal product – $p_n = MP_n$ – and factor shares exhaust output: $p_k K + p_l L = Y$) further gives:

$$g_Y = \theta g_K + (1-\theta) g_L + g_t$$

where $g_n \equiv \dot{n}/n$ is the percentage growth rate of factor n and θ is the share of output accruing to capital.

The rate of growth of output is thus decomposed into its constituent parts – the contribution of factor inputs and of residual total factor productivity g_t – by weighting the growth in each input by its relative factor share.

The parameters of the aggregate production function are mostly imposed (typically around 0.3 for both physical and human capital) or calibrated based on micro evidence. Note that this procedure rules out externalities *a priori*.

Growth accounting exercises are then mainly aimed at assessing the relative contribution of inputs (physical and human capital) versus residual total factor productivity (or the efficiency with which these inputs are used) to either growth in output or cross-country differences in output per worker.

More precisely, in growth accounting exercises, a country's growth in output is decomposed into the growth rates of inputs (*i.e.* input accumulation) and in residual productivity growth; in level accounting exercises, differences in output per worker across countries are decomposed into cross-country differences in productivity and in input intensities. In particular, according to the Solow model, cross-country differences in levels of real income per person and rates of economic growth should be explained by variations in national population growth and savings rates, where the lower the population growth rate and the higher the savings rate, the richer the economy.

The so-called puzzle of the 'residual' (the six sevenths proportion of output growth that could not be attributed to growth in capital and labour in Solow's seminal 1957 study) made it clear that the growth of real income *per capita* cannot be fully accounted for by increases in the quantities of the capital and labour inputs alone.

While growth theories began to be built around it, it stimulated a great amount of empirical work in the 1960s to diminish the importance of the residual by extending the framework. In particular *quality* of these inputs were explicitly included through investment in education (*i.e.* accumulation of human capital) and in R&D giving rise to technical change[1].

Despite these new developments, however, the fact remains that 'accounting is no explanation' (Griliches, 1997). Even if productivity growth has been allocated in detail to the various components the existence of such a positive correlation tells us nothing about causal relationships, about the mechanisms, the processes through which human capital accumulation affects economic growth.

2.4 The 'New Growth Theories'

In contrast to the traditional neo-classical Solow growth model, these recently emerged "new growth economics" theories emphasise the *endogenous* determination of growth rates, which are determined within the model (and can thus be affected *e.g.* by government policies), instead of being driven by exogenous technological progress.

While education has no role in traditional neo-classical theories of economic growth, these new approaches have explicitly brought the role of education to the fore. They provide the theoretical underpinnings for assuming that education can affect national economic growth *via* two main channels:

(a) Human capital is explicitly incorporated as a factor input in the production function, by – in contrast to the augmented neo-classical model – explicitly modelling individual educational investment choices, as well as by often allowing human capital to have external effects, thus departing from the constant returns to scale assumption.

(b) The factors leading to endogenous growth (in particular technological change) are explicitly related to the stock of human capital. This may be either because human capital is assumed to directly produce new knowledge/technology or because it is an essential input into a research sector which generates new knowledge/technology.

There are accordingly two strands of thought in the new growth approaches, which respectively focus on the effects of (a) the accumulation (or "flow") of human capital and of (b) the stock of human capital.

This distinction has implications. In particular, any measure such as a subsidy to education which raises the level of human capital will have a once-and-for-all effect on output in the first framework, but will increase the growth rate of the economy forever in the

[1] Also advances were made in measuring capital, allowing for different types and vintages.

second one. There is no consensus in the empirical literature over which is the appropriate approach[2].

In fact, the evidence on the neo-classical *vs*. endogenous growth models is still inconclusive. The available macro evidence does not allow us in general to distinguish between theories, since most of them (although hypothesising different ways in which human capital might enhance growth) are observationally equivalent. They yield similar predictions relating to the impact of some human capital variable on growth. For example, output growth is predicted to be a function of the rate of growth of human capital not only in the neo-classical growth accounting exercises, but also in the endogenous approach (a) above.
More generally, macro regressions have not really tried to test one theory against the other, but have tended to emphasise an expanded set of variables suggested by the new literature.

Most of these regressions include the stock of human capital as an explanatory factor and take inspiration and justification – albeit quite loosely – from the second endogenous growth strand outlined above (the 'stock of human capital approach').

It is important to note that in such cases the estimated increase in productivity is not simply a phenomenon in the transitional period as the increase in the flow of education leads to a gradual increase in the equilibrium human capital stock. Implicit is the claim that increasing average education in an economy will permanently increase the rate of economic growth, even after the human capital stock has adjusted to its new long-run level.

2.5 Macro regressions

Following the release of the Summers-Heston cross-country dataset, there has been an outpouring of cross-country empirical work carried out by macroeconomists trying to explain post-1960 cross-country growth performances.

Unlike conventional growth and level accounting (see section 2.3), this 'new growth evidence' exploits cross-country variation in the data to estimate, rather than impose the parameters (output elasticities) of the aggregate production function. It tries to explain cross-country variation - the unexplained total factor productivity growth from growth accounting exercises.

Most of these analyses group developing and developed countries together and there is considerable overlap in the data sets and specifications used by the different studies. These regression, sometimes termed 'Barro regressions', are informal *ad hoc* regressions, in which the choice of explanatory variables is largely driven by previous results in the literature and *a priori* considerations

The measure of productivity is often aggregate real GDP *per capita* (or per worker or per working-age person). Regressors typically include proxies of human capital, initial level of GDP, physical investment ratios, geographical dummies, and a number of variables that capture the role of governments, such as real government consumption ratios, political stability indicators, measures of market distortions and economic system indicators.

The aim of such macro regressions is to investigate the respective role of the various 'inputs' in contributing to economic growth, thus shedding some light on the origin of differences in growth rates across countries, and helping to identify those policy measures most likely to enhance growth.

Despite the prevailing use of cross-country variation, some recent studies have been trying to exploit the time-series information for one or more countries in a *panel* approach. The main advantages are the possibility of controlling for unobserved and thus omitted

[2] See Gemmel's (1996) attempt to bring some order in the confusing use by empirical studies of human capital variables supposedly proxying human capital levels or flows. In particular, school enrolment rates have commonly – and wrongly – been used to proxy both stocks of and investments in human capital.

variables that are constant over time but may be correlated with some of the regressors (like the initial level of technological efficiency) and the ability of using several lags of the instruments. The use of fixed-effects estimation techniques however prevents the analysis of the impact on growth of variables that do not change much over time, as well as exacerbating measurement error (for more detail, see Temple, 1999).

2.6 Social rates of return

The internal rate of return method is a purely accounting approach which evaluates the profitability – private or social – of any given investment by looking at the properly discounted flow of benefits and costs arising from that investment. The internal rate of return, which is given by that discount rate for which the discounted present value of the benefits arising from the investment net of its costs equals zero, can then be compared to the reference discount rate of the decision-maker.

When applied to the assessment of the social profitability of an investment in human capital, the 'social rate of return' is the internal rate of return of such an investment, evaluated from a social point of view. In other words, it is given by that discount rate for which the present discounted value of all social benefits equals the present discounted value of all social costs. A correctly calculated social rate of return should be the one guiding the decisions societies make to collectively finance education.

Compared to private rates of returns, these 'social' rates of return include *all* of the direct costs of schooling (and not just those borne by the individual) and use *pre*-tax (instead of post-tax) earnings. By contrast, the private rates of return estimates assume that the only cost of education is foregone earnings (because of public subsidy of direct schooling costs) and that earnings are net of taxes. Thus, in practice, the calculations performed are accounting exercises, which provide estimates of the returns to education that include net transfers (*i.e.* subsidies to education and income taxes).

These 'social' rate estimates should however be regarded as a lower bound of the full returns to education. All the costs of education are included while broader non-employment personal benefits are excluded (*e.g.* externalities in the form of macroeconomic and social gains, and the lower risk of unemployment faced by individuals with more education).

OECD (1998, Figure 4.4) reports social rates of return to different levels of education, calculated for various OECD countries. 'Social' rates are consistently found to be *lower* than private ones. In general, almost all the difference between the social and private rates of return appears to be due to the direct cost of schooling.

2.7 Wage regressions

A recently emerged methodology aims at identifying educational externalities by isolating the causal impact on *individual* wages of the *average* level of education in the city or state of residence of the individual.

The basic equation is of the form:

$$Y_{ijt} = X'_i m + d_j + d_t + g_1 \overline{S}_{jt} + g_{2i} s_i + u_{jt} + e_i \qquad (1)$$

where i denotes the individual, j the state (or the city) and t time. Individual log weekly wages Y are regressed on individual characteristics X, state-of-residence (or city) effects and year effects, state (or city) average schooling $\overline{S}$ and individual schooling s.

The main technical problem which has to be addressed in such a framework is the likely endogeneity of $\overline{S}$ and s due to the presence of unobserved factors affecting both wages and the amount of schooling an individual decides to invest in, or affecting wages as well as the percentage of educated workers in a state/city.

Other potential weaknesses relate to the very specific definition of educational externality adopted: positive effects may in fact accrue at a higher (national) or lower (firm) level of aggregation; and average education may provide externalities not captured by workers through their wages: individuals may benefit in a non-pecuniary form (*e.g.* type of tasks, supervisory effort, quality of working and living environment) and/or spill-over effects may in part accrue to employers instead.

The work by Moretti (1999) and by Acemoglu and Angrist (1999) reviewed in the Appendix provide examples of this approach.

2.8 Reconciling micro and macro

A first type of 'micro' studies concerning human capital investments is the social rate of returns approach outlined in Section 2.6. Such studies and the macro regressions are aimed at measuring two conceptually quite distinct quantities. Growth regressions try to 'allocate' cross-country differences in economic growth to the various 'inputs'. So, for education, they yield estimates of the impact that educational investments have had on macroeconomic growth.

By contrast, social rate of returns studies try to calculate the (social) internal return of educational investments, as that rate of return which exactly balances individual and tax benefits with social costs. The outcome of the exercise should thus be compared to other relevant rates (*e.g.* social discount rates, rate of other investments, interest to be paid on borrowed funds *etc.*) to decide (or predict) if the investment was worthwhile.

Thus, while allowing to explicitly include the largely neglected cost side, social rates of return studies do not include externalities in their calculation, while one justification for macro growth regressions is precisely their potential ability to capture economy-wide indirect spill-over effects from educational investments.

Traditional microeconometric evidence is usually based on estimating individual earnings equations of the form of equation (1) setting $?_1=0$. Card (1999) provides a comprehensive review of the literature that suggests that the coefficient on individual years of schooling when estimated by OLS is usually around 6-11%. Controlling for the potential endogeneity of schooling through using twins, "natural experiments" or other instrumental variables does not generally reduce the size of the private return (in fact the size of the coefficient usually increases). For example, the Angrist and Krueger (1991) study uses date of birth as an instrument: it is uncorrelated with an individual's innate productivity, while affecting how long children have to attend school (through the rules of mandatory schooling).

Still, *a priori*, the social return from education may be higher or lower than the private return estimated from such micro studies. It can be higher due to positive externalities arising from individual educational investments (*cf.* Section 2.2), but if educational degrees are simply used as a device to signal higher innate ability without raising individual productivity, the social rate will be less than the private one[3].

Although from the micro evidence it cannot be decided whether the social return to education exceeds the private gains. This body of evidence strongly suggests that unobserved factors (such as ability, which may cause us to overestimate the returns of schooling,) and measurement error (which biases the schooling effect towards zero) may cancel each other out. The finding that the 'true' private return to schooling may indeed be about 6-10% goes

[3] Another possibility pointed out by Krueger and Lindahl (1998) relates to the finding that in developing countries higher education is positively associated with unemployment, so that an increase in the level of education may actually reduce total output.

against the view that education is merely signalling innate ability and confirms the human capital view that education really increases individual productivity. In addition, other micro evidence points to positive externalities in the form of lower crime, reduced welfare dependence, better public health and parenting, all factors that are likely to positively affect economic productivity.

There is a much smaller body of literature which has estimated the return to human capital by entering schooling or training directly into a production function at the enterprise or industry level (see Dearden, Reed and Van Reenen, 1999, for a survey and analysis). The literature does hint that the returns to human capital are larger for firms than individuals suggesting that not all of the productivity gains are captured by workers.

As discussed above the macro estimates have the advantage that they should be able to capture externalities that are ruled out in the standard approach. The micro estimates could thus be used to estimate the private return and the macro estimates could be used to estimate the social returns. The problem, however, is that there are many more methodological problems in interpreting the coefficient on education in the macro approach than the micro approach. The larger coefficients in the macro literature could simply be due to "aggregation biases" of various sorts, as well as to the undue imposition of restrictions (notably of linearity and homogenous impact of education). We now turn to this set of methodological problems.

3. Methodological Issues[4]

3.1 Data and proxies

Measurement of human capital

A first issue is how to define, measure and compare skills and competencies over time and between countries. The best measures would be in terms of the output of education, but due to the difficulties of obtaining such measures, input measures tend to be used. It is very difficult to know how close proxies such as school enrolment; average years of education or the proportion of the labour force, which has received primary, secondary or tertiary education, are to their conceptual equivalents, so that failure to find positive evidence could be due to poor proxies.

In particular, such aggregate measures are likely to be affected by several problems:

- These studies are based on *formal* educational attainment only, without considering wider definitions of human capital investment encompassing on-the-job training, experience and learning-by-doing, and ignoring its depreciation.

- The *quality* of education is taken no account of.

- Different *types* of education may have differential impacts on economic performance.

- As to the conceptual variables and their empirical proxies, it is often unclear whether the widely used school enrolment rates variable is intended to capture the flow of investment in human capital or else its stock. "In practice, these rates may be a poor proxy for both" (Temple, 1999, p.139; *cf.* the work by Gemmel, 1996).

[4] Temple (1999) is the recommended source for a thorough and more technical discussion of the methodological issues involved in the various approaches.

Data quality

The quality of the data on the numerous variables used to explain income levels or growth rates varies widely across countries. Data on output (including missing information on the non-market sector) and other variables (in particular for net investment, capital stocks, labour force participation and working hours) is likely to be particularly poor (if not missing) for certain developing countries.

Few studies try to assess the sensitivity of their results to measurement error. In fact, even when accepting the proxies commonly used in the literature, a problem which may severely bias the estimates concerns measurement error in schooling data, further exacerbated when changes in education are calculated. Krueger and Lindahl (1998), for instance, find that the correlation between the measures of average education from two main sources of educational data (Barro-Lee and Kyriacou) is 0.86, decreasing further to 0.34 if changes in schooling are considered. They also find that measurement error is particularly severe for years of secondary and tertiary education, and that measurement errors are positively correlated over time.

Data sources

Datasets for the various studies are typically collated from a variety of sources, depending on the focus of the analysis (the Appendix includes a succinct data description for each study). The first version of the "Penn World Tables" by Summers and Heston in 1991 has probably been the most influential one. The Summers-Heston dataset provide GDP measures constructed in a roughly consistent way for the various countries. This has now been updated and combined with other 'popular' data collections, such as the one by Barro and Lee (which has education measures) or the alternative source of schooling data provided by Kyriacou.

The measure of productivity is either aggregate, per worker, *per capita* or per working-age person real GDP, labour productivity or total factor productivity. Proxies of human capital are either indicators of human capital stock and flows constructed by each author; else school enrolment rates by gender and sometimes by level (primary, secondary, tertiary); average years of education; and/or the proportion of the labour force which has received education at different levels.

Typical regressors include: other human capital indicators – life expectancy, fertility rates; the initial level of GDP; physical investment ratios; geographical dummies; terms of trade changes; and a number of variables that capture the role of governments (real government consumption ratios, inflation rates, political stability indicators, measures of market distortions, democracy indexes, rule of law indexes and economic system indicators).

3.2 Endogeneity bias

As income grows, educational standards rise, but we cannot be confident that economic growth is *caused* by higher educational standards.

There are in fact reverse causality problems with education: the association of education and productivity growth may reflect the demand for education, as well as its supply effects. Education contains a large consumption component; if the demand for it is highly income-elastic, income growth is likely to lead to an increased demand for education. Industrialised countries' governments in turn will be more able to respond with an increase in public spending for education and an enlargement of access to it.

Also, in countries at higher income levels that have already gone through the stages of development, a larger incidence of the service sector and of the modern, high-tech production sectors will require a better-educated workforce. The question is whether the upgrading process is sparked and made possible by an (exogenously) increasingly available educated workforce (impact of human capital accumulation on growth) or whether the structural change induces larger fractions of the population to achieve higher educational standards (impact of economic growth on human capital accumulation). The most plausible answer is that both influences are simultaneously at work, so that there is a bi-directional causality between human capital accumulation and economic growth.

These considerations point to the fact that human capital accumulation is likely to be endogenous, and failure to control for this may lead to a simultaneity bias.

Other endogeneity problems are likely to affect several widely used variables as well, such as the investment ratio. Given the wide range of variables used to explain growth, there is a shortage of plausible instruments.

The standard approach of relating growth to the initial value of an explanatory variable (such as the 1960 school enrolment) may not be robust. First, it does not avoid the danger that there may be some other factor, like the political regime, which jointly affects growth and variables like initial school enrolment (Aghion and Howitt, 1998). Secondly, expected favourable future economic prospects may induce individuals to invest more in education. When longitudinal datasets are available, one possibility is to use lags of the endogenous variables as instruments. The exogeneity of such lagged variables can be questioned (Temple, 1999), especially since there may be long – and unknown – delays in the effect of human or physical capital accumulation on growth.

3.3 Parameter heterogeneity

Cross-country growth studies tend to include countries at very dissimilar levels of development in order to maximise the size of their samples, and the models estimated invariably assume – and constrain – the impact of education to be homogenous across countries.

The results are thus an average from very heterogeneous countries, resulting from a comparison of mean attainment across the different countries, whose systems vary widely in terms of content, sequence and quality (see Lee, Peseran and Smith, 1997).

On the other hand, when estimating the relationship for a subgroup of more homogeneous countries (*e.g.* OECD), the results have to be interpreted with care due to the small size of the sample. In fact, most authors note that the estimates for the OECD subgroup alone are much less precise. Splitting the sample according to the level of development clearly shows however that various regressors have a different impact for the two (or three) sub-samples. Such a heterogeneous impact is also consistent with the micro evidence, which points out that the (individual) returns to education vary considerably across countries, and even across regions within countries.

There is considerable evidence on the existence of heterogeneity across countries in the parameters of the growth regression. This raises questions of how much such regressions tell us about parameter averages and of how reliable it is to extrapolate results obtained on such a mixed sample to policy prescriptions for specific countries. In particular, it is quite dubious to use an estimate derived from a pool of such diverse countries to make inference as to the impact of educational expansions in the UK.

Krueger and Lindahl (1998) are the only study that has so far, to our knowledge, tried to assess the impact of relaxing the constant-education-slope assumption commonly maintained in the macro growth regressions. They find such an assumption to be strongly rejected by the data, and that the average effect of education is statistically insignificant. They conclude that 'these results cast doubt on the interpretation of education in the constrained [to have a homogenous impact] macro growth equation common in the literature' (p.34).

3.4 Model uncertainty

The correlations found in the literature have been found to crucially depend on the choice of the additional regressors included (Levine and Renelt, 1992). In particular, most regressors have been found very fragile, in the sense that their estimated parameter change sign or become statistically insignificant when a different group of regressors is included. Together with the fact that many alternative regressions have equal theoretical status, such findings call for a great deal of care in the interpretation of cross-country results.

3.5 Non-linearities

Given the mostly *ad hoc* nature of the macro-economic specifications there is no strong *a priori* reason to assume a linear relationship between human capital and productivity levels or growth. In fact one might expect diminishing returns to a factor (as in the conventional log-log Cobb-Douglas production function). One of the few studies that has examined this issue is Krueger and Lindahl (1998). They find evidence for non-linearities, in particular they find that a quadratic form for schooling fits the data better (a squared term is significant). The inverted-U pattern suggests that there are diminishing returns to education, with the peak effect at about 7.5 years[5]. The presence of non-linearities is also consistent with other forms of misspecification (generally simple aggregation of a non-linear micro relationship renders the coefficients on the nonlinear macro equation uninterpretable).

4. Results

4.1 Comparing the empirical magnitudes of the effects of human capital on growth

The estimates of the impact of human capital on economic performance that have been produced by the various studies reviewed here are not directly comparable.

A first crucial difference is the one between cross-country regressions and growth (and level) accounting. Such a difference arises from the different methodology and different aim of the respective empirical investigations.

4.1.1 Growth and level accounting

Accounting exercises (*cf.* Section 2.3) are mainly aimed at assessing the relative contribution of inputs (physical and human capital) versus residual total factor productivity (or the efficiency with which these inputs are used) to either growth in output or cross-country differences in output per worker. For this line of research, the relevant figures to compare are thus the weight (in terms of percentage contribution to explaining the growth in output or the cross-country variance in output) of physical and human factors on the one hand and of productivity on the other.

[5] Most OECD countries have passed this peak (average is 8.4 years for OECD in Barro-Lee) implying that, at the margin, additional years of schooling have a negative effect on productivity.

Table 4.1 contrasts some major studies conducted along these lines (for more detail, see the relevant parts in the Appendix).

Y is the outcome being evaluated (cross-country differences in GDP per worker in a given year, cross-country differences in GDP per worker growth rates over a given period or GDP growth rates of a given country over time). The analyst tries to apportion the outcome between the contribution of (unexplained) total factor productivity (or efficiency) *A* and measured factor inputs *X* – themselves then broken down between physical capital stock *K* and labour (including human capital) *H*.

The core of the debate concerns the relative weight of *A versus X*. Older studies (*e.g.* Jorgenson and Fraumeni, 1992 and Mankiw *et al*. 1992) seem to point to the importance of factor intensities and accumulation. From the table the basic findings from the first study, for instance, can be summarised as follows: investments in human and physical capital account for most (83%) of US economic growth between 1948 and 1986. Growth in labour input in particular accounts for 61% of economic growth, of which less than half (42%) is due to increases in labour quality.

By contrast, more recent studies have questioned such results and the methodologies underlying them. Hall and Jones (1999) as well as Klenow and Rodriquez-Clare (1997), for instance, claim that residual productivity (*A*) is by far the most important component. International output differences are largely (over 60%) accounted for by differences in productivity, and similarly, differences in growth rates of income per worker derive overwhelmingly (up to 90%) from differences in growth rates of *A*.

It is important to stress that output elasticities with respect to inputs are either imposed (typically around 0.3 for both physical and human capital) or equated to their shares in value added (the latter requiring perfect competition and constant returns to scale). In this framework, then, the question of how much output would increase if human capital were increased by 1% is misplaced, the answer being imposed *a priori* and not resulting from the analysis. A second issue is that the 'human capital' aspect of the labour input is not in general easy to be separately identified. This is because the 'labour' input used is often a combined measure of various educational, demographic and labour force variables (*i.e.* account is taken of changes in the age, sex and educational composition of the workforce, as well as of hours of work).

Finally, as mentioned in Section 2.3, 'accounting is no explanation'. Apportioning income or income growth to measured and unmeasured 'inputs' provides no insight as to the mechanisms which may underlie such contributions. Especially results showing the overwhelming importance of total factor productivity need to be further explored as to examine the fundamental sources of such a factor. The study by Hall and Jones (1999) is a promising attempt in this direction (more on this in Section 4.3.5).

4.1.2 Macro growth regressions

Cross-country growth regressions are (in contrast to growth or level accounting) more focused on identifying the sources of economic growth and in actually quantifying such correlations. Ideally, the aim would be to assess the causal impact of, say, average years of education or school enrolment rates on a country's rate of income growth.

Even within this approach, however, the various estimates are not directly comparable, due to

1. Different dependent variables

Although most studies focus on explaining cross-country differences in real *per capita* GDP growth rates, other choices include: overall real GDP growth rates, growth of labour productivity or of total factor productivity and the log of the ratio of real (*per capita* or overall) GDP in two periods. Mankiw, Romer and Weil's (1992) work should not actually be counted among 'growth' regressions, since it centres around cross-country differences in levels (more precisely, in the log of GDP *per capita*).

2. Different human capital regressor

A first fundamental difference is between studies that consider the impact of the level (stock) of human capital and those looking at the flow of (investment in) human capital. The former tend to use average years of education in the labour force, and the latter school enrolment rates although some authors have developed and constructed their own measures of human capital stocks and flows. Gemmel (1996), however, shows that school enrolment rates compound the effects of human capital stock and accumulation. These independently constructed measures have the advantage of possibly overcoming some of the shortcomings of commonly used proxies, at the cost however of not being particularly transparent, thus lacking immediate policy interpretation.

Secondly, both stocks and flows have been considered by different studies either at the primary, secondary and/or tertiary levels, so that various estimates more often than not relate to a different level of education.

3. Different sample

Most studies integrate developing and developed countries in a single framework, while some focus on OECD countries only, and some others split their samples into sub-samples according to the countries' level of development. The studies using two (or three) sub-samples have found that the impacts of human capital flow and stock – both of which were considered at the primary, secondary and tertiary level – vary considerably, both in statistical significance and in magnitude, according to the level of development of the countries considered. All this makes it extremely hazardous to try to lump estimates on such more restricted samples with those representing an average over more diverse countries.

After this discussion it should have become clear that it would not be particularly sensible, if at all possible, to try and force all the estimates on a common denominator.

Instead, Table 4.2 (see appendix) contrasts the various studies, highlighting the dependent variable analysed, the schooling regressor used, if the study was meant to capture the flow or the level of human capital, the estimated coefficient as reported in the paper and an interpretation of the implied impact. The sample combines developed and developing countries if not otherwise specified. Where provided in the papers, the mean of the human capital proxy is reported.

It is important to understand that the main aim of such studies is to identify statistically significant and possibly robust relationships between various factors and economic growth. Ideally, such estimates should reflect, through appropriate methodologies, not simple statistical correlations, but *causal* relationships and thus identify *sources* of economic growth. In practice, it is still debatable if such a result has been actually achieved (*cf.* Section 3, in particular 3.2).

The authors are thus satisfied with showing that a variable shows a significant correlation to growth (*i.e.* that such correlation is *statistically different from zero*) and to compare the relative impact, statistical significance and robustness of this variable. Robustness is defined implicitly as a relationship that remains significant and of the same sign when including different sets of other regressors, or using slightly different data, samples or methodologies of the various regressors. The main message the authors seek to convey to the reader is that a given factor does indeed positively – or negatively – affect growth, and is more – or less – important than another. Methodological and especially data constraints seem to severely hinder a precise numerical quantification of the effects, so that the actual magnitude of the estimated effect is almost invariably ignored. The most notable

exception among the studies surveyed is Barro (1997), who actually states that 'on impact, an extra year of male upper-level schooling is therefore estimated to raise the growth rate by a substantial 1.2 percentage points per year' (p.19).

For ease of interpretation and comparisons, the 'Interpretation of Impact' column of Table 4.2 tries to replicate a statement along these lines for all the studies reviewed. To ease the 'visualisation' of what the estimates imply in monetary terms, the following section simulates the impact on national output of a reform increasing the human capital stock in an economy similar to the UK. We use a number of estimates that are in the range of those found in the studies summarised in Table 4.2 (see appendix) .

Still the reader is advised to keep the above-mentioned *caveat* in mind; by far the most reliable results are those expressed in qualitative terms (summarised in Section 4.3).

4.1.3 Stages, levels and types of education

Ideally, the macro regressions would also look at education in a more disaggregated way, and provide information regarding the growth impact of the various stages, levels and types of education, as well as on their interactions.

In particular, the answer to the following questions would provide extremely valuable information for the policy-maker:

(a) stages of education: what are the relative growth returns of pre-school, primary, secondary and higher education, with important implications for how resources should be divided between the different stages of education;

(b) levels:
- are there decreasing returns to additional years of schooling;
- does the impact of expanding a stage of education (say, higher education) depend on the initial levels of attainment in that stage;

(c) types of education: what is the impact on growth of *e.g.* vocational *versus* academic education;

(d) interactions between stages: does the impact of expanding a stage of education (say, post-compulsory schooling) depend on the initial levels of attainment in the previous stage (compulsory education).

Unfortunately, the available literature is still only tentatively and marginally able to provide reliable findings that could shed some light on such relevant issues.

The major constraint appears to be the inappropriateness of the macro data. Such questions have been successfully addressed at the individual level by microeconometric studies, able to exploit huge data sets with a large amount of detailed individual information.

As to the macro data requirements, one would ideally look at the country of interest, say the UK, using a very long time series of observations on economic growth. The relevant factors would include including averages of the various stages, levels and types of education in the population, and allow for non-linearities and interactions in the estimation, while properly controlling for endogeneity. It is clear that, to date, time series sufficiently long to allow precise estimates of sophisticated models are not available. The study by Jenkins (1995), for instance, is a promising first step, using time series data for the UK from 1971 to

1992. Still, the size of her time series sample (22 observations) means that her estimates are imprecisely determined and difficult to draw conclusions from.

The second-best 'solution' adopted by most of the macro studies is to increase the sample size by using cross-country information. Such samples include countries at very disparate stages of development, which carries with it the limitation (in addition to the implicit restriction of homogeneous effects) that the variables – and thus questions – analysed have to be restricted to the smallest common denominator. It has proven already difficult to construct roughly comparable indicators of years of education and school enrolment rates across all countries, the only disaggregation reached consisting in primary and secondary schooling. Most less developed countries lack (reliable) data on tertiary, let alone pre-school education or specific types of education.

Having explained why the information relating to the above questions is disappointingly scarce and fragile, the following can be derived from the available evidence. To our knowledge, question (d) has not been tackled in the macro literature.

a) stages of education[6]

- Effect of pre-school – or pre-compulsory – education on economic growth

There are some micro-econometric studies addressing the impact of pre-school education (*e.g.* Headstart, the Perry Pre-School experiments) on various labour market as well as social indicators at the individual level. At the macro level, however, the evidence on this issue is, to our knowledge, completely absent.

- Effect of primary education on economic growth

For the full sample of countries, a 1 percentage point increase in primary school enrolment rates is estimated to lead to a 2 percentage points increase in the *per capita* GDP growth rate, while the same increase in the stock of primary human capital would lead to less than 1 percentage point increase in the growth rate. Both types of impact are larger for the sub-sample of the poorest developing countries, while not considered in the regressions for OECD countries (there would not be enough variability within this more homogenous sample of advanced economies).

- Effect of secondary education on economic growth

A 1 percentage point increase in secondary school enrolment rates is shown to lead to a 2.5-3 percentage points increase in growth in the full sample, the effect being smaller (around 1.5 or even zero) for OECD countries. As to the stock, an additional year of education seems to lead to a 0.5-1.2 percentage points faster growth, again with no impact for OECD countries.

- Effect of tertiary education on economic growth

The main study considered here is Gemmel (1996). He finds evidence for endogenous growth in the sense that there is an effect of the 1960 level of schooling on growth even after conditioning on the 1960-85 growth rate of human capital. For OECD countries, a one percentage point increase in the annual growth of human capital increases growth by 5.9 percentage points[7]. Conditional on this growth, countries with a one percent increase in the initial human capital stock contributes to a 1.1 percentage point increase in growth[8]. Tertiary

[6] The following is a synthesis from the results in Table 4.2.

[7] Note that the coefficient on the growth of human capital combines both an endogenous growth effect and a neo-classical effect. This is why the coefficient is larger than on the flow.

[8] No authors comment on the relative size of increases in flows and stocks of human capital. In fact, one should not try to compare them, since stock and flows – even when (though rarely) both considered in the same study –

education was not included in the non-OECD countries regressions because of limited availability and reliability of such data.

b) levels of education and decreasing returns

The main reference concerning this issue is Krueger and Lindahl (1998), who explicitly consider the robustness of the traditional macro regressions to various assumptions implicitly relied upon, among which the one that the effect of education on growth is linear (*cf.* Section 3.5). They find these restrictions rejected by the data, which seem to prefer a quadratic specification, with an inverted-U shaped relationship between the stock of human capital and economic growth. Even more interesting, they find the peak at 7.5 years of education that is *before* the average 1990 OECD education level of 8.4. The finding that the average OECD country is consistently found to be on the downward-sloping portion of the education-growth profile, "casts doubt on the likelihood that there are large growth externalities from the initial level of education, especially in OECD countries" (p.38). If their results were taken literally, the quoted statement would need to be taken further, since the findings imply the uncomfortable presence of *negative* growth returns of further expansion in education in developed countries.

c) types of education

One study, which has tried to investigate if the allocation of students to different types of education matters for growth, is Murphy *et al.* (1991). For the sub-sample of countries with a large student population (over 10,000 college students), they find that the relative importance of engineering in education (as captured by the ratio of college enrolments in engineering to total college enrolments) has a positive impact on growth, while the relative importance of legal studies has a negative effect. It has to be said, however, that these results, based on such a small sample, are hardly reliable; in fact, the former effect is not statistically significant, while the latter just borders significance.

4.2 Some quantitative effects to illustrate the approaches

As it should have now become apparent, reconciling the quantitative implications of the studies we survey is no easy task. Nevertheless it is useful to have some numbers to fix ideas of how large the effects are.

In order to get a feel of what magnitude of effects on output the estimates imply, we first outline the core of the econometric models used by the two approaches – the augmented neo-classical and the new growth approach.

We then simulate the impact on national output of a reform increasing the human capital stock in an economy with the basic feature of the UK, using a number of estimates which are in the range of those found in major studies.

First, consider the augmented neo-classical model. Here human capital enters as another factor of production. In the Mankiw *et al.* (1992) paper, for example, the production function is estimated to be constant returns Cobb-Douglas of the form:

$$Y(t) = A(t)H(t)^{a} L(t)^{b} K(t)^{1-a-b}$$

are measured in different units, so that 'a 1 percentage point increase' does not mean the same increment when related to flows (like school enrolment rates) or stocks (like the constructed measure of Gemmel, 1996). In addition, the increase in the stock is often in terms of average numbers of years.

Where *Y(t)* is output at time *t*, *A* the level of technology, *H* the human capital stock in the labour force (say, total years of schooling), *L* the labour force and *K* the physical capital stock.

Dividing by *L* and expressing all the variables in *per capita* terms (denoting them with the corresponding lower-case letter) yields:

$$y(t) = A(t)h(t)^{a}\, k(t)^{1-a-b}$$

where in particular $h \equiv H/L$ is the stock of human capital per worker (say, average years of schooling in the labour force).

In Mankiw *et al.* α is econometrically estimated to be about one third. In their study, *h* is implicitly proxied by average years of secondary schooling. Thus, doubling average years of attainment in secondary schooling in the population increases output per capital (productivity) by one third.

We call this a **levels specification** because the level of (per capita) human capital (*h*) affects the level of (per capita) productivity (*y*).

Suppose now that at time 0, human capital is h_0, and a reform is implemented which at time *T* increases human capital by *m* years, so that at $t=T$, $h_T=h_0+m$. Some simple algebra then yields:

$$y(T) = y(0)\left(1+\frac{m}{h_0}\right)^{a}$$

By contrast a productivity **growth model** (as in Barro, 1997) has something like

$$\frac{y(t)-y(t-1)}{y(t)} = b\ h(t)+\ldots$$

where the left hand side variable is the growth rate of income *per capita* ($y \equiv Y/L$) and *h* is again human capital per capita.

Rearranging and moving to continuous time, yields:

$$y(t) = y(0)e^{b\, h_0\, t}$$

Following the same reform as outlined above (*i.e.* an increase in average human capital by *m* years from $t=T$), yields:

$$y(t) = \left(y(0)e^{b\, h_0\, t}\right)e^{b\, m\, t} \quad \text{for } t \geq T$$

If we denote income at time *t* in the presence of the reform as $y^1(t)$ and the counterfactual income – the level of income the economy would have achieved in the absence of the reform – by $y^0(t)$, then the preceding equation becomes:

$$y^1(t) = y^0(t)\ e^{b\, m\, t} \qquad \text{for } t \geq T$$

Note that by construction, in both approaches the returns to increases in human capital are linear, with *x* years of extra education having *x* times the impact of one extra year of education.

Consider now an experiment that increases the average human capital stock by increasing secondary and higher schooling by one month for the population in an economy like the UK's, where average schooling is about 5.6 years (taken from the 1996/7 Family Resources Survey). This corresponds to an increase of m=0.083 years[9]. Initial income *per capita* y_0 is set to £25,000, with a labour force of 30 million.

In Table 4.3 (see appendix) , the ‘coefficient on human capital’ in column (1) is α for the 'levels' specification in the upper panel and β for the 'growth' specification in the lower panel.

We simulate the effect of this reform under three different parameter values of (α and β) which encompass most of the central estimates in the literature. In order to have a common basis, the values chosen are from studies which use the same measure of the human capital stock – average years of (male) secondary (and higher) schooling in the population, as well a similar sample. Unfortunately, the latter requirement prevents us from using those few studies which focus on OECD or developed countries alone: their estimates are either insignificant, or relate to measures of human capital constructed by the author and thus lacking direct policy implications. It has thus to be kept in mind that the parameters used as the basis for the simulations have been estimated from samples including quite diverse types of countries (in particular a large number of developing countries), so that the additional *caveats* concerning parameter heterogeneity (*cf.* 3.3) apply.

Two main types of simulations are performed:

1. In the first one (columns (2) and (3)), it is assumed that the adjustment to the new average level of human capital is immediate, and the corresponding steady states are compared.
2. in the second one (columns (4) to (7)), it is more realistically assumed that the adjustment works through an increase in the flow of human capital, so that the human capital stock only gradually and linearly increases from h_0 to h_0+m takes place linearly over a period 40 years, where each year an increase of $m/40$ is achieved.

For the interested reader we provide the system of equations corresponding to the second type of simulations (in continuous time):

- levels specification:

$$y(t) = \begin{cases} y_0 e^{a \frac{m}{h_0} \frac{t}{40}} & 0 \le t \le 40 \\ y_0 e^{a \frac{m}{h_0}} & t \ge 40 \end{cases}$$

- growth specification:

$$y(t) = \begin{cases} y^0(t) e^{b m \frac{t^2}{40}} & 0 \le t \le 40 \\ y^0(t) e^{b m t} & t \ge 40 \end{cases} \qquad \text{where} \quad y^0(t) = y_0 e^{b h_0 t}$$

[9] This might seem like a small number, but we are considering plausible policy reforms here. Where secondary schooling is comp ulsory the main margin would be increased participation of 16-18 year olds.

It is important to note that we assume that the reform takes place *ceteris paribus, i.e.* that only human capital is increased, while all other relevant variables remain constant. For the levels approach, this implies that growth, in the absence of the reform, is zero, so that the counterfactual $y^0(t)$ remains in fact constant and equal to y_0, initial income per capita. By contrast, for the growth specification, *even in the absence of the reform*, the economy enjoys a positive growth rate, since, by construction, the growth rate is a positive function of the present level of human capital h_0.[10] In other words, unless the pre-reform human capital stock is zero, the economy would grow even in the absence of the reform, as can be seen from the explicit time-dependence of the counterfactual $y^0(t) = y_0 e^{b h_0 t}$. The gains from the reform presented in Table 4.3 are always calculated with respect to the counterfactual of a growing economy $y^0(t)$, whereas for the levels specification this is equal to initial income per capita, 25,000 for all t.

Also note that the present value calculations (all based on a social discount rate of 6%) are not net present value gains, but only concern the benefit side; *no account is taken of the costs* to achieve – and maintain – the higher human capital stock. In fact, average human capital in the population has not only to be increased by one month, but has then to be kept at this higher level forever, which means that all cohorts graduating from school have to have remained in secondary school for 1 month longer on average.

Turning to the first type of simulation (immediate adjustment), for the levels specification the policy experiment is seen to generate an increase in GDP by between £90 and £150 per capita. For an economy similar in size to that of the UK (c. 30m in labour force, £750bn GDP) this generates an increase of GDP of £3-4bn. By contrast, for the growth specification, the one-off gain is considerably lower, between £0.2 and 1bn.

If we allow for the more realistic scenario of gradual adjustment to the new human capital stock, we again see that the gains in the first years of the reform are considerably lower for the growth specification (around half of the levels effect for the first four years). However, already by the time when the new stock of human capital has been attained (*i.e.* after 40 years), the situation has turned. The growth specification producing a discounted gain of between £29bn and over £1,000bn, while the levels specification yielding a discounted cumulated increase in GDP of £15-20bn. From this moment onwards, the gap in gains from the two specifications widens massively.

In fact, in the levels specification the economy has returned to zero growth (albeit remaining at its larger size), so that the constant gain is discount more and more heavily back to today; it stabilises around £20-30bn, even over the infinite future.

By contrast, in the growth specification the economy continues to exponentially grow at the higher rate (for the three values of β, the economy grows at an *incremental* rate[11] of 0.3, 1.1 and 1.6 percentage points respectively). This massively increases the benefits of the intervention. Of course these numbers become huge – and even tiny differences in parameter values yield tremendous differences in cumulated gains – when discounting takes place over the infinite future.

Interestingly, although the theories underlying the empirical specifications are very different, it appears that in magnitude the effects are not all that different over the typical planning horizon of the government (four years).

Abandoning the shorter horizon, though, the implied effects of education on growth appear implausibly large in the standard Barro approach. We join Topel (1999) – "the

[10] Nothing really hangs on this. We could just as easily have generated a positive rate of growth in the levels specification by assuming an exogenous level of technical progress.

[11] The *incremental – i.e.* vis-à-vis the no-reform scenario –growth rate is given by $\Delta g = e^{bh_0}\left(e^{bm} - 1\right)$.

magnitude of the effect of education on growth is vastly too large to be interpreted as a causal force" – in finding it too hard to view such huge effects as uniquely the result of economy-wide externalities generated by the increase in average educational attainment.

Alternative explanations which cast doubts on the interpretation of such 'new growth' evidence as educational spill-overs include:

- reverse causality: cross-countries differences in education could be, in part at least, the result of anticipated economic growth
- omitted variable bias in cross-country analyses: countries that improve their education systems are likely to implement concomitant reforms and policies that enhance growth
- other more technical reasons for a positive and significant coefficient of the stock of human capital in a growth regression[12]
- some surprising findings – *e.g.* no or negative effect of *female* education at various levels, or no impact of male *primary* schooling in Barro (1997) – are left unexplained, and cast doubts as to the large significant effect found for male upper-level education only.

In addition,

- the checks by Krueger and Lindahl (1998) have shown how fragile the macro evidence of educational externalities is to relaxing the (data-rejected) restrictions of homogeneity and linearity of impact. In particular (*cf.* also Sections 3.3 and 3.5).
- the homogeneous-slope restriction is rejected by the data, and when estimating a variable-coefficient model (see also Islam, 1995). The finding of an insignificant effect of the average initial human capital stock on growth casts doubts on the interpretation of such a coefficient in the macro regressions which commonly constrain their model to a constant education slope.
- once relaxing the linearity assumption, the relationship between the stock of human capital and economic growth is found to be inverted-U shaped, peaking *before* the average OECD education level. The finding that the average OECD country is on the downward-sloping part of the education-growth profile (in all their specifications) raises doubts as to the existence of large educational externalities, especially for this group of countries.

In the light of this set of considerations, we too consider the estimates obtained by the Barro regressions likely to be partly flawed, with the implied simulated effects largely implausible.

The neo-classical approach, by contrast, generates effects that are both more reasonable on *a priori* grounds and more consistent with the micro-economic evidence.

4.3 Other important results in literature

Overall, the available evidence suggests that education has a positive impact on growth. This section summarises other key research findings on the link between educational investments and economic growth.

---

[12] Examples: an exogenous change (in particular, a rise) in the returns to education has taken place; the stock of education may be picking up the effect of the omitted change in education; or education may be a proxy for steady-state income. For more details, see Topel (1999) and Krueger and Lindahl (1998).

4.3.1 OECD countries and heterogeneous effects of different types of education

It may be helpful to reiterate the two main findings relating to the more homogeneous sub-sample of OECD countries which have quite consistently arisen in the empirical literature:

1. The regressors that appear to have an important impact on growth in samples including both OECD and developing countries are considerably less precise and have much less explanatory power when estimated for the OECD sub-sample alone (*cf. e.g.* Mankiw, Romer and Weil, 1992, Englander and Gurney, 1994, Gemmel, 1996). The smaller sample size as well as its more homogeneous nature are likely to explain the difficulty of identifying precise individual effects; in any case, care needs to be taken when extending inferences drawn from the wider sample to a particular high-income economy.

2. The impact of increases in various levels of education appears to vary greatly according to the level of a country's development. In particular, while primary and secondary skills appear to be related to growth in the poorest and in intermediate developing countries respectively, it is *tertiary* skills that are important for growth in OECD countries. Although the direction of causality is unclear (higher education is likely to have the largest consumption component and one may expect the demand for it to increase with rising income), both the initial level and the subsequent growth of tertiary education were found to be positively and significantly related to *per capita* income growth in OECD countries (*e.g.* Gemmel, 1996).

4.3.2 Indirect effects of human capital on growth

In addition to its direct impact on economic growth, human capital may also have an effect on other factors which affect growth, so that investments in education would have an additional *indirect* effect on economic performance. In particular, human capital may yield additional benefits to growth if it stimulates the accumulation of other productive inputs – *e.g.* physical capital, technology or health – which in turn foster growth, or if it discourages factors, like population growth or infant mortality, which hamper growth.

Using regression techniques similar to the ones aimed at identifying the determinants of economic growth, but with a different dependent variable, human capital has in fact consistently been found to have a positive indirect effect as well, *via* its impact on:

1. physical investment

Human capital appears to be associated with significantly larger investments (*e.g.* Barro, 1991, Gemmel, 1996, Benhabib and Spiegel, 1994). For OECD countries in particular, the stock of *secondary* human capital appears particularly important in stimulating investments, while direct growth effects come through increased *tertiary* human capital stock and accumulation.

2. technology transfer

Human capital displays a positive effect on rates of productivity growth by raising the rate at which leading-edge foreign technologies are adopted (*e.g.* Cameron, Proudman and Redding, 1998; Benhabib and Spiegel, 1994).

3. fertility

Human capital – in particular female education – appears to be associated with significantly lower net fertility and thus population growth (Barro, 1991; Barro and Lee, 1994).

4. other dimensions of human capital

Educational attainment has been found to be associated with higher life expectancy, lower infant mortality and higher levels of primary and secondary school enrolment rates (*cf.* Barro and Lee, 1994).

4.3.3 Quality of schooling

When assessing the impact of an additional year of education on economic performance, all cross-country regressions implicitly assume that one year of secondary schooling, say in the US is equivalent to a year at the same grade in *e.g.* Egypt. Hanushek and Kim (1995) by contrast recognise that pure quantity of education is only a very crude measure of skill differences, since school systems vary widely across countries in terms of resources, organisation, duration and the preparation of entering students. They thus try to adjust for differences in schooling quality by using direct measures of cognitive skills of individuals, often interpreted as a measure of schooling outcomes.

The basic conclusion is that labour force quality – as measured by student cognitive performance in various international comparative tests of academic achievement – has a robust and strong influence on economic growth. In addition, the marginal effect of quality appears to decline with an increase in the overall level of education in the population, and, similarly, the additional impact of one year of education is a decreasing function of the quality level. Finally, and most importantly in terms of the evaluation of macro regressions ignoring quality issues, controlling for labour force quality considerably *reduces* the magnitude of the measured impact of years of schooling on growth.

4.3.4 Allocation

Macro regressions investigating the role of education for economic growth also typically ignore how educational resources are allocated.

A study by Judson (1998), however, provides evidence that more than the level of educational investment, it is its allocation that matters for economic growth.

The efficiency of the allocations of educational spending between primary, secondary and tertiary education chosen by several countries – including less developed ones – between 1970 and 1990 is evaluated on the basis of a micro theoretical model of returns to education. Efficiency is defined as the ratio of the achieved rate of return to the maximum possible rate of return the country could obtain given its actual overall education budget and actual relative costs for each level of education. She finds that despite the fact that for many countries there is a considerable gap between actual and optimal enrolment rates, several economies seem to be allocating their educational resources in a nearly optimal way (most allocations yield at least 80% of the optimal rate of return).

She then turns to testing whether her constructed measure of efficiency in the allocation of educational resources impacts on how education itself affects growth, finding that the contribution of human capital to growth does indeed depend on the efficiency with which it is being accumulated. Those countries that have been identified as allocating their educational resources inefficiently gain little from their investments in human capital in terms of growth.

Despite some potential difficulties with her methodology (see the Appendix for further details), these results have important policy implications in terms of the importance of the allocation of educational resources.

Similarly (but on the basis of fragile results), Murphy *et al*. (1991) find that it is not just the quantity human capital, but also how this talent is allocated – to productive and innovative *vs*. rent-seeking activities– that may matter for growth (*cf.* 4.1.3c).

4.3.5 A wider framework

Moving beyond the quantitative assessment of the impacts on economic growth of various 'inputs' is the question of what makes some countries accumulate more human capital than others or what makes them more efficient than others in the use of such inputs. The work by Hall and Jones (1999) is a first investigation of the role of wider influences on growth – the 'fundamental' causes of economic performance – which may work through the proximate sources of input (physical and human capital) accumulation, or may also have a direct impact through total factor productivity. The wide-ranging notion they use, 'social infrastructure', relates to those institutions and government policies that shape the economic environment in which private agents – individuals and firms – make their investment decisions. A good social infrastructure gets the prices right, so that agents capture the social returns of their activities, be it productive activities, capital accumulation, skill acquisition, invention or technological transfer and adoption.

Economic performance, as represented by output per worker, appears to be strongly associated with measures of this fundamental cause of growth, social infrastructure, as proxied by combining an index of government anti-diversion policies and an index of openness to international trade. This is instrumented with various geographical and linguistic correlates to the extent of Western European influence.

Similarly, a good social infrastructure appears to be positively correlated to the proximate sources of economic performance, by stimulating both physical and human capital accumulation, as well as by positively affecting residual productivity.

4.3.6 Delivery of education and schooling inputs

As with the micro literature trying to assess the wage return to measured schooling quality, the few macro studies aiming at identifying a potential role for educational inputs in economic performance fail to find any significant effect.

As to *per capita* GDP growth, the student-teacher ratio at neither the primary nor secondary level is significant, with only the one for primary schools showing the expected negative sign (Barro, 1991). As to the measure of quality (student cognitive achievement as captured by test scores), inputs into education – pupil teacher ratio and a long list of schooling expenditure variables – do not display any systematic significant effect (Hanushek and Kim, 1995). Their estimated impact being either statistically insignificant, or significant but with the wrong sign.

Thus the important result that differences in labour force quality offer a very important contribution to growth (*cf.* 4.3.3) lacks specific policy prescriptions, since no relationship has apparently been found between that measure of quality and measured inputs into schooling.

5. Future Research Options

Despite the numerous interesting insights offered by this literature, the empirical evidence is still weak at various crucial points. Currently there is progress being made on the following issues, but much more needs to be done.

1. Does education affect the growth or the level of productivity?

This has been a major area of work, but there is still no consensus. Part of a serious examination of this issue needs to pay much more attention to the measurement of human capital. As Krueger and Lindahl (1998) stress, there is considerable measurement error, especially in the LDCs and more attention needs to be given to the stock *versus* flow of human capital distinction. The failure to find any effect of the growth of human capital on the growth of productivity (*e.g.* Benhabib and Spiegel, 1994) is suggestive of problems of measurement.

2. Reconciling micro with macro.

There is an urgent need to push further in estimating at different levels of aggregation (as has occurred in the R&D and productivity literature). There are now large datasets available with education, wage and productivity data at individual, enterprise, industry and economy-wide levels. More attention should be paid to matching enterprise data with human capital to estimate the effect of schooling productivity within and between firms. The work of Moretti (1999) and Acemoglu and Angrist (1999) on US wages are examples of alternative approaches to macro-style equations.

3. Reverse causality.

Endogeneity has been a major pre-occupation of the micro literature (*e.g.* Card, 1999) but hardly features at all in the macro literature. Yet growth may clearly be the cause rather than the consequence of education. More careful attention needs to be paid to this issue, and the sources of identifying information which exogeneously change education need to be examined.

4. Mechanisms between education and growth.

An overarching issue is that although we now have more knowledge of which factors affect growth, our understanding of both the *mechanisms* that create this impact and of the *determinants* of international variation in the accumulation or use of these factors is still poor. Thus although the available evidence does point out that human capital has a positive impact on growth, further research is still needed to investigate precisely *how* a higher level or a faster accumulation of human capital translates into faster growth or higher productivity. Similarly, the question of *why* some countries accumulate more human capital than others or are more efficient at using this as well as other inputs still needs to be thoroughly addressed. (An initial step in this direction is offered by the work of Hall and Jones, 1999).

5. Quality.

In fact it might be dubious to compare the quantity of schooling across countries which have very diverse educational systems. In addition, it would be very interesting to know how differences in schooling systems impact on productivity in the labour market and economic performance. A related interesting but unanswered question in the presence of a government education budget constraint concerns the possibility of a trade-off between quality and quantity of education. Leaving equity issues aside, what matters most for growth: breadth of access or school quality? Should governments concentrate resources in expanding education – aiming at increasing the percentage of the population covered by basic education in less developed countries and encouraging more individuals to go on to further education in industrialised countries – or rather in improving the quality of educational structures for existing students?

It has to be stressed, though, that such considerations apply to a context where the education system is in fact operating efficiently. By contrast, where the system is inefficient, it is possible to both widen the access of students to education and improve the quality of education without any increased spending. By adopting efficient modes of educational delivery[13], both better coverage and better quality may be achievable.

6. Stages and types of education.

As discussed in 4.1.3, there is still no reliable information regarding the relative growth returns of pre-school, primary, secondary and higher education, as well as of different types of education (*e.g.* vocational *versus* academic).

7. Are sustained improvements in educational attainment bound to lead to increased growth?

It would prove extremely fruitful to identify the conditions under which expending education is most beneficial. Issues which would deserve empirical investigation in this context include the questions of:

- whether there are decreasing returns to the expansion of education (possibly *via* declining average ability due to the expansion of schooling) (*cf.* 4.1.3). In particular, the incremental value of additional education in countries where average length of schooling is already high is less obvious, and probably largely depends on the type and quality of education.
- whether there is a limit to the contribution of education to growth. Industrialised countries have reached the upper bound for measures such as literacy rates and primary school enrolment rates, and in principle, the upper bound for secondary and then tertiary schooling rates could also be attained.
- whether there are general equilibrium effects of national policies designed to promote the acquisition of skills. Under normal conditions, an increased supply of educated workers would depress its relative return. In the context of the new growth theories, however, the expansion in the supply of educated labour is seen as being itself a cause of (possibly skill-biased) technological change so that it would raise the economy's growth rate and thus maintain or increase the educational wage premium. The rising relative wage of skilled workers observed in some countries in the presence of an increasing supply of educated labour does in fact suggest the presence of a rapidly expanding demand for skills. Perraton (1998) rightly emphasises that although, in principle, an increased supply of educated labour can lead to transformations in the economy that will ensure the demand for it, in practice, a number of conditions in the national political economy – not yet fully understood – appear also to be needed.

Although all these problems and needs may seem rather discomforting, it is worth re-iterating the words from an author of a recent overview of the growth literature, Temple (1999):

> "it is certainly true that, taken as a whole, the growth literature can seem something of a disappointment, […] it is always worth remembering how little we knew when we started" (p.151, 152)

[13] For example the adoption and effective use of information technology (particularly the internet) may allow a large number of students to be reached at relatively low cost and in ways which are at least as effective in terms of educational outcomes as traditional teaching methods.

6. Conclusions

In summary we will reiterate our main conclusions from the literature.

- There is an important theoretical distinction between studies in the **neo-classical tradition and the new growth theories**. The former argue that a one-off permanent increase in the human capital stock will be associated with a one-off increase in the economy's growth rate, until productivity per worker hour has reached its new (and permanently higher) steady-state level. New growth theories argue that the same one-off increase in human capital will be associated with a permanent increase in the *growth rate.* The social benefits of education will clearly tend to be much greater in this case.

- The estimation of macro economic production functions including education as a regressor presents a host of still unresolved **methodological problems**. The most important of these are the measurement of human capital (poor proxies of the theoretical concepts; affected by measurement error); systematic differences in parameters across countries (*e.g.* developing *vs*. developed countries); reverse causality (faster growing countries invest more in education).

- The estimates of the impact of human capital on economic performance which have been produced by the various studies reviewed are not directly comparable, due to different dependent variables, proxies for human capital (flows or stocks, primary, secondary or tertiary) and samples (in particular, including or excluding less developed countries). Nonetheless, taking the studies as a whole, there is compelling evidence that **human capital increases productivity**, suggesting that education really is productivity-enhancing rather than just a device that individuals use to signal their level of ability to the employer.

  Most evidence is from "Barro" style growth regressions which suggest that increasing school enrolment rates (human capital flow) by one percentage points leads to an increase in *per capita* GDP growth of between 1 and 3 percentage points, while an additional year of secondary education in the population (human capital stock) leads to over 1 percentage point faster growth each year.

- The empirical literature is still largely divided on whether education affects the long-run level or growth rate of the economy. The implied effects of the stock of human capital on growth appear implausibly large in **the 'new growth' approach**.

  We think the effect is overstated due to methodological problems such as correlation with omitted variables, (data-rejected) restrictions of homogeneity and linearity of impact, all of which cast serious doubts on the interpretation of such 'new growth' evidence as educational economy-wide spill-overs.

- A study exploring the issue of **linearity** of educational impacts, finds this commonly imposed restriction to be rejected by the data, which instead reveal an inverted-U shaped relationship between initial stock of human capital and economic growth, peaking *before* the average OECD education. The finding that the average OECD country is found to be on the downward-sloping portion of the education-growth profile further weakens the evidence in favour of the new growth theories (especially for OECD countries).

- The **neo-classical approach** generates effects that are both more reasonable on *a priori* grounds and more consistent with the micro-economic evidence. Our baseline estimates follow Mankiw *et al.* (1992) and look for effects of human capital on the level of output, although we compare this carefully with estimates from the alternative approach. Interestingly, it turns out that over the short-run planning horizon (4 years ahead) the empirical estimates of the change in GDP for a given increase in the human capital stock are of similar orders of magnitude in the two approaches.

- The most robust qualitative results include:

  1. The factors that appear to have an important impact on growth in samples including both **OECD and developing countries** are considerably less precise and have much less explanatory power when estimated for the OECD sub-sample alone.

  2. In particular, the effects of primary and secondary schooling not only appear more statistically significant but also larger in magnitude for less developed countries.

  3. The impact of increases in various **levels of education** appears to vary greatly according to the level of a country's development. In particular, while primary and secondary skills appear to be related to growth in the poorest and in intermediate developing countries respectively, it is tertiary skills that are important for growth in OECD countries.

  4. In addition to its direct contribution to growth, human capital has **indirect effects** as well, by stimulating the accumulation of other productive inputs – *e.g.* physical capital, technology or health – which in turn foster growth, and discouraging factors, like population growth or infant mortality, which hamper growth.

- From still preliminary evidence it appears that type, quality and efficiency of education all matter for growth:

  1. **type:** the measured growth returns to engineers appear to be higher than those to lawyers

  2. **quality:** labour force quality has a significant and positive impact on growth; such a result however lacks policy implications, since measured educational inputs fail to affect labour force quality, nor do they seem to directly affect economic growth

  3. **efficiency:** the contribution of human capital to growth has been found to depend on the efficiency with which resources are allocated to the various levels of education

- The main **research areas** that need supporting are:

  (a) work reconciling micro and macro evidence by combining data at different levels of aggregation (individual, firm, industry and economy-wide);

(b) trying to control reverse causality by using more exogenous changes affecting education;

(c) attempting to improve the (time-varying) measurement of the stock of education;

(d) opening the 'black box' of education by trying to explore the mechanisms through which human capital affects growth. For example, looking at more disaggregated issues in more detail and in a more satisfactory way than done to date

There are many methodological and conceptual problems in this literature, but it does give some guidance for policy. Taken as a whole we feel confident that there are important effects of education on growth. We are less confident that the effects of education on growth are as large as is claimed by the new growth literature. There needs to be a much more concerted attempt to combine the new growth theory with rigorous micro-studies to demonstrate the link between innovation and human capital.

Table 4.1: Growth and Level Accounting

Y=AX → contribution of A (residual total factor productivity) vs. X (input factors: physical and human capital)

	Y	**A**	**X**		**elasticities**
		TFP	**K** Fixed capital	**H** human capital	
Jorgenson-Fraumeni 92 → **X**	output growth rates US '48-86: 2.93% per year	17%	22%	61% (labour input) of which 42% accounted by labour quality → labour quality accounts for 26% of economic growth	Shares of the inputs in aggregate value added
Mankiw et al. 92 → **X**	cross-country differences in output per worker, 98 countries in '85	22%	29%	49%	Estimated
Hall-Jones 99 ® **A**	cross-country differences in output per worker (level) 127 countries in '88	61%	17%	22% (educ. attainment for the pop over 25) % contribution to the difference between y in the 5 countries with the highest level of y in '88 and the 5 lowest countries (y in the former was 32 times higher than in the latter)	α=0.3 Φ(E)=13.4 1-4 years = 10.1 5-8 years = 6.8 beyond 8 → each year of schooling contributes roughly 10% (the Mincerian return) to differences in output per worker
	For average country vis-à-vis US: 0.29	0.52	0.85	0.57 Average country has 57% of US human capital per worker and 30% of US output per worker; if human capital per worker were increased by 75% (i.e. no differences in h left), y would be increased by 47% (to 44% of US y) A 1% increase in h → a 0.6% increase in y	
Klenow-Rodriquez 97 → **A**	cross-country differences in output per worker, 98 countries in '85	67%	29%	4% If 1% higher y per capita (than the average country), expect 0.04% higher human capital per capita	α=0.30 β=0.28 → raising h by 1% leads to a 0.28% increase in output
	cross-country differences in 1960-85 growth in output per worker, 98 countries	85%-90%	3%	6%-12%	

Table 4.2: Cross-Country Growth Regressions

Study	Dependent Variable	Human Capital Proxy	Flow/ Stock	Estimated Coefficient	Interpretation of Impact
Barro (1991)	growth rate of real per capita GDP annual 1960-85	school enrolment rate: number of students enrolled in the designated grade levels (primary and secondary respectively) relative to the total population of the corresponding age group in 1960	initial flow mean: prim60=0.78 sec60=0.23	prim=0.025 sec=0.030	A 1 percentage point increase in primary (secondary) school enrolment rates is associated with a 2.5 (3.0) percentage points increase in per capita GDP growth rate
Levine and Renelt (1992)	growth rate of real per capita GDP annual 1960-89	secondary school enrolment rate in 1960	initial flow	high=3.71 base=3.17 low=2.5	A 1 percentage point increase in secondary school enrolment rate is associated with a between 2.5 and 3.7 percentage points increase in per capita GDP growth rate
Murphy, Schleifer and Vishny (1992)	growth rate of real per capita GDP between 1970-85	primary school enrolment rate in 1960	initial flow	full sample: 0.022 (OECD: not significant)	A 1 percentage point increase in primary school enrolment rate is associated with a 2.2 percentage points increase in per capita GDP growth rate
Barro (1997)	growth rate of real per capita GDP over 1965-75, 1975-85, 1985-90	average years of attainment for males aged 25 and over in secondary and higher schools at the start of each period	initial stocks in 1965, 75 and 85 mean in 1990 = 1.9 years	0.012	An extra year of male upper-level schooling is associated with a 1.2 percentage point increase in per capita GDP growth rate
Hanushek and Kim (1995)	growth rate of real per capita GDP (×100) between 60-90	average years of secondary schooling of adult male population at beginning of period	initial stock	0.36	An extra year of male secondary schooling is associated with a 0.36 percentage point increase in per capita GDP growth rate
Gemmel (1996)	growth rate of real per capita GDP annual 60-85	constructed human capital stock in 1960 and human capital annual average growth rates at primary, secondary and tertiary levels. These measures are both entered in the equation simultaneously.	initial stock mean: prim=72.8 sec=19.5 tert=4.0) annual flows mean: prim=2.5 sec=3.7 tert=2.7	full sample: prim stock =0.81 prim flow =2.68 poorest LDCs: prim stock =0.91 prim flow =4.19 intermediate LDCs: sec stock =1.09 OECD: tert stock =1.10 tert flow =5.89	For OECD: A 1 percent increase in tertiary human capital stock is associated with a 1.1 percentage point increase in per capita GDP growth rate. A 1 percentage point increase in tertiary human capital growth is associated with a 5.9 percentage points increase in per capita GDP growth rate.

Judson (1998)	growth rate of real GDP 5-years averages, 1960-90	growth of her constructed measure of human capital stock	period flows	10.8 low-efficiency countries =3.0 high-efficiency =12.9	A 1 percentage point increase in human capital growth is associated with an 11 percentage points increase in GDP growth rate.
Englander and Gurney (1994)	growth of labour productivity (and total factor productivity) over four time periods	school enrolment rates: number of students enrolled in secondary school relative to the total population of the corresponding age group in beginning of period	initial flow	OECD: 1.45-1.78	A 1 percentage point increase in secondary school enrolment rate is associated with around 1.5 percentage point increase productivity growth.
Barro and Lee (1994)	ΔlnGDP per worker	average years of secondary schooling of adult male population at beginning of period	initial stock	0.014	An extra year of male secondary schooling is associated with a 1.4 percent increase in per worker GDP growth.
Benhabib and Spiegel (1994)	ΔlnGDP per capita	human capital stock estimates from Kyriacou: average level of log human capital over the period (log of average level of human capital; log of average levels)	average stock	0.12-0.17	A 1 percent increase in the stock of human capital is associated with a 12 to 17 percent increase in per capita GDP growth.
Mankiw, Romer and Weil (1992)	lnGDP per working-age person	average percentage of working-age population in secondary school, 1960-85	period flow	0.66 implied output elasticity with respect to human capital stock = 0.3	A 1 percent increase in the average percentage of working-age population in secondary school is associated with a 0.7 percent increase in GDP per working-age person A 1 percent increase in human capital stock is associated with a 0.3 percent increase in GDP

Table 4.3: Experiment: Increase Human Capital Stock by 1 Month

(average years of male upper-level schooling in the population rise from 5.6 years to 5.6 years and one month)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Coefficient on human capital	**Steady-state change in GDP per capita (£)**	**Steady-state change in GDP (£bn)**	**Change in Present Value (£bn)**			
			4 years	**40 years**	**60 years**	**infinite horizon**
Levels Specification						
0.25	92.5	2.8	0.48	13.4	16.3	17.6
0.33	122.2	3.7	0.63	17.6	21.5	23.2
0.40	148.2	4.4	0.76	21.4	26.1	28.1
Growth Specification						
0.003	6.4	0.2	0.09	29.2	60.0	78.3
0.01	22.0	0.7	0.33	298.7	820.1	25,940
0.015	34.0	1.0	0.54	1,061.2	4,358.8	3.9×10^9

Notes:
1. In levels specification, column (1) is the elasticity of output to human capital stock in a Cobb-Douglas production function.
2. In growth specification, column (1) is the coefficient on human capital stock in a Barro-style growth equation.
3. Columns (2) and (3) assume the increase in human capital is immediate (*i.e.* stock not flow) so the economy immediately jumps to its new steady state.
4. Columns (4)-(7) are the cumulated present value of output over the respective horizon assuming a social discount rate of 6% and that it takes 40 years to linearly adjust to the new steady state.
5. We assume that there are 30 million in the labour force (*per capita* is per member of labour force), and that *per capita* initial income is £25,000.

Appendix Summary of the Studies Considered

How Large Are the Social Returns to Education? Evidence from Compulsory Schooling Laws

Daron Acemoglu and Joshua Angrist
Mimeo, MIT

Abstract

Average schooling in US states is highly correlated with state wage levels, even after controlling for the direct effect of schooling on individual wages. We use an instrumental variables strategy to determine whether this relationship is driven by social returns to education. The instruments for average schooling are derived from information on the child labor laws and compulsory attendance laws that affected men in our Census samples, while quarter of birth is used as an instrument for individual schooling. This results in precisely estimated private returns to education of about 7 percent, and small social returns, typically less than 1 percent, that are not significantly different from zero.

Data

Data for white men aged 40-49 from the 1960-80 US Censuses. (Some estimates are obtained including 1950 and 1990 data).

Methods

M(1) The aim of the paper is to estimate the social returns of education (where 'social' return as defined in this context refers to the impact of *average* schooling on *individual* wages). The basic equation is

$$Y_{ijt} = X'_i \mu + \delta_j + \delta_t + \gamma_1 \overline{S}_{jt} + \gamma_{2i} s_i + u_{jt} + \varepsilon_i$$

where *i* denotes the individual, *j* the state and *t* time. Individual log weekly wages are regressed on individual characteristics X (including state-of-birth and year-of-birth effects), state-of-residence and Census year effects, state average schooling $\overline{S}$ and individual schooling *s*.

OLS estimates would be biased due to the likely endogeneity of $\overline{S}$ and *s*, as well as from the fact that one regressor is the average of another regressor. Both variables thus need to be instrumented. Generating exogenous variation in both individual and average schooling requires a clever choice of instrumental variables, particularly in the light of the fact that what affects average education is very likely to affect individual education as well.

$\overline{S}$ is instrumented with compulsory schooling laws (constructed from data on compulsory attendance laws and child labour laws in states of birth), while *s* is instrumented with the individual's quarter of birth.

M(2) A second minor investigation concerns the issue of whether exogenous changes in aggregate schooling may affect the private returns to education. This is accomplished by estimating models including interactions terms between $\overline{S}$ and *s*.

Results

M(1) While basic OLS estimates show a strong positive relationship between average education and individual wages (a one-year increase in average schooling is associated with a 7% increase in average individual wages, over and above the roughly equal private return from individual education), IV estimates fail to find evidence of any significant social return: statistically insignificant estimates range between -1 to less than 2%, while the significantly positive social return obtained using 1990 data is found to be due to increased measurement error following changes in the way the education variable is recorded in the 1990 Census.

M(2) IV estimates suggest a positive relationship between private returns to education and average schooling, although the results are deemed too imprecise..

Critique

A very careful and innovative study, which overcomes several methodological hurdles in order to implement a relatively unexplored methodology to estimate wider returns to education. Although the main result is a negative one, it should be kept in mind that (a) estimates are derived for secondary education only, while it has often been argued that for more advanced countries, it is interactions among individuals with higher education that are likely to be most synergetic (cf. the recurrent finding that while primary and secondary schooling are relevant for economic growth in developing countries, it is higher education that drives growth in OECD countries); (b) positive effects may accrue at a higher (national) or lower (firm) level of aggregation; (c) average education may provide externalities not captured by workers through their wages: individuals may benefit in a non-pecuniary form (e.g. type of tasks, supervisory effort, quality of working and living environment) and/or spill-over effects may (partly) accrue to employers instead.

Determinants of Economic Growth: A Cross-Country Empirical Study

Robert J. Barro
1997, MIT Press

Abstract

Nothing matters more to the long-term economic welfare of a nation than its rate of economic growth. Compounded over many years, seemingly small differences in annual growth rates can lead to vast differences in standards of living. Research on economic growth has exploded in the past decade. Hundreds of empirical studies on economic growth across countries have highlighted the correlation between growth and a variety of variables. Determinants of Economic Growth, based on Robert Barro's Lionel Robbins Memorial Lectures, delivered at the London School of Economics in February 1996, summarizes this important literature.
The book contains three essays. The first is a survey of the research on the determinants of long-run growth through the estimation of panels of cross-country data. The second essay details the interplay between growth and political freedom or democracy and finds some evidence of a nonlinear relationship, At low levels of political rights, an expansion of rights stimulates growth; however, once a moderate level of democracy has been obtained, a further expansion of rights reduces growth. The final essay looks at the connection between inflation and economic growth. Its basic finding is that higher inflation goes along with a lower rate of economic growth.

Data

Barro-Lee dataset, with updated and improved educational variables.
Up to 87 countries.

Methods

Extension of the Barro (1991) cross-sectional framework to a panel setup.
Four types of regression of a system of equations of the growth rates of real per capita GDP over three periods (1965-75, 1975-85, 1985-90) on various explanatory variables:

- male secondary and higher schooling (average years of attainment for males aged 25 and over in secondary and higher schools at the start of each period),
  interaction of male schooling with initial level of GDP
- initial level of GDP, life expectancy, fertility rate, government consumption, an index in the maintenance of the rule of law, terms of trade change, democracy index, inflation rate

M(1) three-stage least squares estimation, but with different instruments (where some instruments are earlier values of the regressors) used for each equation
M(2) first-differenced version of the system to allow for unobserved fixed effects, estimated by the seemingly unrelated technique
M(3) ordinary least squares estimation of a pure cross section, where the dependent and independent variables are means over the three time periods
M(4) as (1) but using seemingly unrelated estimation instead of instrumental variables

Results

M(1)
- significantly positive effect on growth from years of male secondary and higher schooling (β=0.012; an extra year of male *upper-level* schooling raises the growth rate by 1.2 percentage points per year)
- by contrast male primary schooling has no significant impact on growth
- surprisingly, *female* schooling at various levels has a negative sign but no significant impact on growth (in contrast to Barro and Lee, 1994, who found a significant negative effect); female education also does not appear to foster growth through its indirect effect on lowering fertility
- more years of male upper-level education raise the sensitivity of growth to the starting level of GDP, thus speeding up convergence
- In contrast to Barro (1991), from a regression of real physical investment ratios on years of male education (among other regressors), human capital enters with a negative sign and is not significant.

M(2) The author does not believe in the reliability of this specification, due to the loss of cross-sectional variation and the worsening of measurement error problems. It is also harder to isolate the effects of regressors with little variation over time. As to male education, its coefficient is negative and insignificant.

M(3) and especially M(4) yield estimates extremely close to M(1).

Critique

A valuable extension to Barro (1991). 'Educational attainment' of a country's adult population is closer to a human capital stock measure. There is some experimenting with further estimation methods, although little space and discussion are devoted to (2), (3) and (4). Some surprising results are left unexplained (no effect of primary schooling and of female education) or unmentioned (no impact of human capital on physical investment).

Economic Growth in a Cross Section of Countries

Robert J. Barro

1991, Quarterly Journal of Economics, 106, 2, 407-443.

Abstract

For 98 countries in the period 1960-1985, the growth rate of real per capita GDP is positively related to initial human capital (proxied by 1960 school- enrollment rates) and negatively related to the initial (1960) level of real per capita GDP. Countries with higher human capital also have lower fertility rates and higher ratios of physical investment to GDP. Growth is inversely related to the share of government consumption in GDP, but insignificantly related to the share of public investment. Growth rates are positively related to measures of political stability and inversely related to a proxy for market distortions.

Data

Summer-Heston, UN, World Bank, Banks and Gastil; school enrolment rates at the primary and secondary level from UN.
98 countries, over the 1960-85 period.

Methods

'Barro regressions': OLS regressions of annual average 1960-85 growth rates of per capita real GDP on different combinations of a host of independent variables, among which:

- as a proxy for human capital: the number of students enrolled in the designated grade levels (primary and secondary respectively) relative to the total population of the corresponding age group in 1960 – a flow measure
- flows of investments in human capital could reflect a favourable situation leading to both high investments in education and rapid GDP growth. In some specification, lagged values of the school enrolment variables (SEC50 and PRIM50) are included to try to consider a more stock-related measure
- as an alternative human capital measure: adult literacy rate in 1960
- quality of education: student-teacher ratio in primary and secondary schools in 1960
- initial level of GDP, real government consumption to real GDP, political stability indicators, measure of market distortions, economic system indicators, geographical dummies
- in some specifications, real physical investment ratios and fertility

Results

(1) For a given starting value of per capita GDP, a country's subsequent growth rate is significantly and positively related to measures of the flow of investments in human capital (β=0.025 for primary and β=0.03 for secondary school enrolment rates); the effects become weaker in magnitude but still highly significant when trying to control for measurement error.

(2) As to the convergence debate, the findings imply that poorer countries tend to catch up with richer ones only if the poor countries have high human capital per capita (in relation to their level of GDP per capita).

(3) When including a more stock-related measure of initial human capital, 1950 school enrolment rates are found to be insignificant (while the 1960 enrolment rates remain positive and significant); one explanation being that the UN data for 1950 are less accurate than those for 1960 and later years.
Using the adult literacy rate instead yields a significantly positive impact on growth, but a negative one if the school enrolment rates are included as well, a finding the author finds difficult to interpret.

(4) The student-teacher ratio at neither level is significant, with only the one for primary schools with the expected negative sign.

(5) From separate regressions of fertility and of real physical investment ratios on school enrolment rates (among other regressors), human capital appears to be associated with significantly lower net fertility and significantly larger investments.

(6) Not surprisingly considered (5), the estimated coefficients of the school-enrolment variables in a regression controlling for investment and fertility are much smaller (both are 0.01) than in (1).

Critique

A comprehensive study looking at the relationship between growth and various factors, it is the cornerstone of the 'Barro regressions' tradition. Main problem is that it uncovers correlations among the variables, rather than any causal links; the exogeneity of some of the regressors "can surely be questioned" (p.428). Unobserved fixed effects (e.g. initial efficiency) which may be correlated with some regressors. No attempt is made to separate the direct effects of human capital on growth from its indirect effects via its impact on investment and fertility.

Sources of Economic Growth

Barro, R. J. and Lee, J.
Carnegie Rochester Conference Series on Public Policy, 40, 1994, 1-46

Abstract

For 116 countries from 1965 to 1985, the lowest quintile had an average growth rate of real per capita GDP of −1.3%, whereas the highest quintile had an average of 4.8%. We isolate five influences that discriminate reasonably well the slow- and fast-growers: a conditional convergence effect, whereby a country grows faster if it begins with a lower real per capita GDP relative to its initial level of human capital in the forms of educational attainment and health; a positive effect on growth from a high ratio of investment to GDP (although this effect is weaker than that reported in some previous studies); a negative effect from overly large government; a negative effect from government-induced distortions of markets; and a negative effect from political instability. Overall, the fitted growth rates for 85 countries for 1965-85 had a correlation of 0.8 with the actual values. We also find that female educational attainment has a pronounced negative effect on fertility, whereas female and male attainment are each positively related to life expectancy and negatively related to infant mortality. Male attainment plays a positive role in primary-school enrolment ratios, and male and female attainment relate positively to enrolment at the secondary level.

Data

Summers and Heston cross-country dataset, version 4. Analyse 85 developed and developing countries during 1965-75 and 95 developed and developing countries during 1975-85. Combined with UN data on life expectancy at birth and educational attainment data from Barro and Lee (1993), NBER Working Paper, 4349. The latter employs census/survey information on the level of schooling of the adult population (aged 25 and over) by sex at 5 year intervals from 1960-85. Census information is only available for about 40% of the observations. Information on adult illiteracy is used to expand coverage of the proportion of the population with no schooling. Remaining observations are filled by applying the perpetual inventory method to data on lagged values of school-enrolment ratios (used as a measure of flows of persons into different categories of educational attainment).

Methods

Panel data (random effects) estimation using Seemingly Unrelated Regressions (SUR) and Instrumental Variables (IV) (lagged values of explanatory variables used as instruments) estimation,

$$\ln(Y_{jt+T}/L_{jt+T})-\ln(Y_{jt}/L_{jt}) = \gamma_{0t} + \gamma_1.\ln(Y_{jt}/L_{jt}) + \gamma_2.I_{jt}/Y_{jt} + \gamma_3.G_{jt}/Y_{jt} + \gamma_4.S_{Mjt} + \gamma_5.S_{Fjt} + \gamma_6.\log(Life_{jt}) + \gamma_7.\ln(1+bmp_{jt}) + \gamma_8.rev_j + u_{jt} \quad (1)$$

where j indexes countries, t is either 1965 or 1975, T is 10 years, Y_{jt} is real GDP in year t, L_{jt} is working age population in year t, I_{jt}/Y_{jt} is the decade average ratio of real gross domestic investment to real GDP, G_{jt}/Y_{jt} is the decade average ratio of real government consumption (exclusive of defence and education) to real GDP, S_{Mjt} is years of male secondary schooling in year t, S_{Fj} is years of female secondary schooling in year t, $Life_{jt}$ is average life expectancy during either 1960-4 or 1970-4, bmp_{jt} is the decade average black market premium on foreign exchange, rev_j is average number of successful and unsuccessful revolutions per year during 1960-85, and u_{jt} is a stochastic error.

Results

(i) Determinants of growth. In the preferred IV estimates (column (2), Table 5),

(a) Controlling for the other determinants of growth, a country grows faster if it begins with lower real per-capita GDP (the conditional convergence effect). The estimated coefficient on initial income per capita implies that convergence occurs at the rate of about 3% per year.

(b) one additional year of male secondary schooling raises a country's rate of growth by 1.4 percentage points.

(c) one additional year of female secondary schooling has a negative effect on growth and reduces a country's rate of growth by 0.9 percentage points.

(d) a 10 per cent increase in life expectancy raises a country's growth rate by 0.8 per cent.

(e) a rise in the ratio of real investment to GDP by 10 percentage points raises a country's growth rate by 0.8 percentage points.

(ii) Fitted growth rates for 1965-85 that are derived from the regression estimates have a correlation with actual growth rates of about 0.8.

(iii) Determinants of fertility, health, and school enrolment (the 'quantity and quality' of children),

(a) Important role of female education in reducing fertility and hence population growth.

(b) Female and male educational attainment are each positively related to life expectancy and negatively related to infant mortality.

(c) Male educational attainment is positively correlated with primary-school enrolment, and male and female educational attainment are positively correlated with secondary-school enrolment.

Critique

(i) The random effects estimator requires unobserved heterogeneity to be uncorrelated with the independent variables. It is unclear that this assumption is satisfied. For example, unobserved changes in technology may be correlated with secondary schooling.

(ii) Relatively little attention paid to the role of outliers (see Temple, 1998) and the sensitivity of estimated coefficients to changes in the set of control variables (see Levine and Renelt, 1992).

(iii) Measurement error – census/survey information on the level of schooling of the adult population is only available for about 40% of the observations (see Krueger and Lindahl, 1998).

(iv) Parameter heterogeneity – assumption of a common coefficient on years of schooling across countries and over time (see Krueger and Lindahl, 1998 and Lee, Pesaran, and Smith, 1997).

(v) The estimated rate of convergence to long-run income per capita is subject to Galton's Fallacy – a negative coefficient on initial income may simply reflect mean reversion.

The Role of Human Capital in Economic Development: Evidence from Aggregate Cross-Country Data

Jess Benhabib and Mark M. Spiegel
1994, Journal of Monetary Economics, 33, 143-73.

Abstract

Using cross-country estimates of physical and human capital stocks, we run the growth accounting regressions implied by a Cobb-Douglas aggregate production function. Our results indicate that human capital enters insignificantly in explaining per capita growth rates. We next specify an alternative model in which the growth rate of total factor productivity depends on a nation's human capital stock level. Tests of this specification do indicate a positive role for human capital.

Data

Summers and Heston data; human capital stock estimates from Kyriacou.

Methods

M(1) Baseline model of a standard Cobb-Douglas production function in which human capital enters as a factor of production: $y_t = A_t K_t^a L_t^b H_t^g e_t$
where *y* is per capita income, *L* labour, *K* physical capital and *H* the human capital stock. The basic specification is thus:
$\Delta \ln y = \Delta \ln A + \alpha \Delta \ln K + \beta \Delta \ln L + \gamma \Delta \ln H + \Delta \ln \varepsilon$ (1)
where Δ is the 1985-65 change

M(2) Modify framework M(1) by allowing human capital stocks to enter into productivity: the term $\Delta \ln H$ in (1) is replaced by average level of human capital over the period. Also, some ancillary regressors are gradually entered (initial income level, geographical dummies, political stability and income distribution indicators).

M(3) A more structural specification considers a Cobb-Douglas technology of the form $y_t = A_t H_t K_t^a L_t^b e_t$, so that $\Delta \ln y = \Delta \ln AH + \alpha \Delta \ln K + \beta \Delta \ln L + \Delta \ln \varepsilon$ (3),
and models total factor productivity growth as a function of the *level* of human capital, through its impact on both domestic innovation and technological catch-up: for country *i*, the term $\Delta \ln AH_i$ in (3) is specified as

$$\left[\Delta \ln A \cdot H_i\right]_i = c + g \cdot H_i + m \cdot H_i \cdot \frac{y_{\max} - y_i}{y_i}$$

where *c* represents exogenous technological progress, *gH* captures endogenous technological progress associated with a country's ability to innovate domestically and $mH((y_{max}/y)/y)$ is the catch-up term reflecting technological adoption from the leader.

M(4) Determinants of physical capital accumulation are investigated by regressing the ratio of gross investment to capital stock on human capital stock, physical capital stock, labour force and various ancillary regressors.

Results

M(1) Human capital growth is found to have an insignificant, and generally negative impact on per capita income growth, a result which is robust to the inclusion of ancillary regressors, to the use of different proxies for human capital and of alternative sub-samples.

M(2) – M(3) By contrast, human capital levels are found to positively (though not always significantly) affect per capita income growth (γ being around 0.13 from M(2)). In addition, results from M(3) favour the catch-up role of human capital over endogenous, country-specific innovation. However and interestingly, these results are overturned in the sub-sample of the richest countries, for which endogenous technological progress gains in significance while the catch-up term becomes relatively unimportant.

M(4) Human capital stocks are found to play an important role in attracting, or stimulating, physical capital accumulation.

Critique

An innovative piece of work, which offers a more structural model which justifies the presence of human capital stocks in macro growth regressions and which allows to test the relative importance of two channels through which human capital levels may directly affect aggregate productivity growth. The results consistently point to a distinct role for human capital in facilitating the adoption of foreign technology in developing countries and the creation of new domestic technologies in richer countries, rather than entering on its own as a conventional factor of production.

This combination of results has however been shown (cf. Krueger and Lindahl, 1998) to be largely due to an extremely high and unaccounted rate of measurement error in first-differenced cross-country education data, as well as by the imposition of linearity and homogeneous-parameter assumptions – restrictions rejected by the data.

Productivity Convergence and International Openness

Cameron, G., Proudman, J. and Redding, S.
Chapter 6 in (eds) Proudman, J. and Redding, S., Openness and Growth, 1998,
Bank of England: London

Abstract

There is evidence of a strong partial correlation between openness and rates of productivity growth across UK manufacturing sectors. This paper investigates the relationship more formally, within a theoretical model of productivity catch-up. The model identifies three potential effects of international openness: openness may affect (a) domestic rates of innovation, (b) the quantity of technological know-how that may be transferred from the frontier to the less advanced economy, and (c) the rate at which this technology transfer occurs. From the theoretical framework, we derive an econometric equation which is used to estimate the relationship between productivity growth, the UK-US productivity gap and the degree of international openness. We find that international openness primarily affects the rate of productivity convergence, and that this relationship is robust to the inclusion of information on R&D intensity, human capital, unionisation, and capacity utilisation.

Data

Data on 14 manufacturing industries in the United Kingdom and United States during 1970-92. UK data from the Office for National Statistics; US data from the Bureau of Labour Statistics.

Methods

Single equation time series and panel data estimation. Preferred specification estimated using panel data techniques,

$$\Delta TFP_{UKjt} = \beta_0 + \beta_1.\Delta CU_{UKjt} + \beta_2.P_{UKjt-1} + \beta_3.R\&D_{UKjt} + \gamma_1.(TFPGAP_{jt-1}) + \gamma_2.(Open_{UKjt-1}).(TFPGAP_{jt-1}) + \gamma_3.(Human_{UKjt-1})(TFPGAP_{jt-1}) + u_{jt}$$

where j indexes industries and t time. ΔTFP is the logarithmic rate of total factor productivity growth, CU measures the degree of capacity utilisation, P is the log of the ratio of input to output prices, R&D is the log of the ratio of Business Enterprise R&D Expenditure to value-added, TFPGAP is the log of the relative level of US/UK total factor productivity, Open is the log of the ratio of either UK imports or exports to gross output, Human is the log of the proportion of workers holding high and medium education qualifications in the total workforce, and u is a stochastic error

Results

(i) Human capital is found to have a positive effect on rates of UK productivity growth by raising the rate at which US technologies are adopted in the United Kingdom. Holding constant the size of the technological gap from the United States, a 1% increase in the proportion of workers holding high and medium education qualifications is estimated to raise UK TFP growth by 0.08%.
(ii) Between 1970 and 1992 the mean estimated steady-state level of total factor productivity in the UK relative to the US rose by 18.4%. Of this 18.4% increase, 9.3% was due to increased international openness, 10.1% was due to increases in levels of human capital, 2.1% was due to the decline in the ratio of input to output prices, and -3.1% was due to decline in R&D intensity.

Critique

(i) The analysis focuses solely on the UK and US and does not allow the potential for technology transfer from other countries to the United Kingdom.
(ii) Potential endogeneity of international trade flows: in neoclassical trade theory, relative levels of technology are an important determinant of patterns of international trade. It would be preferable to have direct data on trade policies rather than endogenous trade flows.

Medium-Term Determinants of OECD Productivity

A. Steven Englander and Andrew Gurney
1994, OECD Economic Studies, 22, 49-109.

Abstract

This paper provides a summary of recent developments in the "new growth economics" literature and assesses the contribution of this literature to under- standing OECD productivity performance. It replicates some of the empirical results found in the recent growth literature in order to evaluate both the overall robustness of the key empirical relationships and their applicability to the OECD which, in the context of this literature, represents a sub-set of relatively rich and industrialised countries with better quality data. Finally it attempts to explain the evolution of productivity growth both over time and across OECD countries. Throughout, the policy implications of the analyses are emphasised.

A large part of the literature on "new growth theories" emphasises the endogenous determination of growth rates. In a formal sense endogenous growth means that the equilibrium growth rate of the economy is determined within the economy, rather than by exogenous technological progress, and that this growth rate is consistent with a competitive equilibrium. If there are diminishing returns to capital formation (where capital is defined broadly, including human, physical, and infrastructure capital), there will be an equilibrium level of productivity, but growth rates will be determined by exogenous technical progress as in the Solow model. Intuitively, if private returns do not fall as saving and (broadly defined) investment increase, there is nothing to impose a stop to accumulation. Endogenous growth models assume that some portion of the return to accumulation is public rather than private, and the limits to private returns determine the limits to accumulation.

The conditions for growth rates being completely endogenous are relatively strict and the empirical side of the new growth literature (as well as this paper) has tended to emphasize an expanded set of variables and their qualitative importance, rather than testing literally the hypotheses generated by the endogenous growth literature.

Data

Primary source is the OECD’s Analytical Data Bank, data on school enrolment rates from Barro (1991).

19 OECD countries over four time periods (1960s-73, 1973-79, 1979-85 and 1985-90)

Methods

M(1) investigates the determinants of the evolution of productivity growth both over time and over a cross-section of (OECD) countries in a ‘Barro regression’ framework.
Various specifications are estimated to test the robustness of the results.
The dependent variable is either average labour productivity growth or average total factor productivity growth in the 19 countries over the 4 time periods.
Explanatory variables include: secondary school enrolment rates at beginning of period, capital-to-labour ratio growth, labour force growth, business sector capital stock growth, business sector employment growth, R&D capital growth stock, infrastructure capital stock growth, average inflation rate, ratio of labour productivity to productivity of the leading country, government consumption to GDP, ratio of energy consumption to output in the business sector, country and time dummies.

M(2) replicates some previous results (Mankiw, Romer and Weil, 1992, Barro 1991, Levine and Renelt, 1992 and De Long and Summers, 1992) for the more homogeneous and higher-quality data sub-sample of OECD countries

Results

M(1) Secondary school enrolment rates is one of the only three variables which are found to be robustly correlated with labour productivity growth (the others being growth in capital to labour ratio and in the labour force). In particular, the increase in average OECD enrolment rates from 70% to 95% over the 1960-85 period is associated with about 0.6 percentage point per year faster productivity growth, a result in line with the micro estimates of the effects of incresed education on private earnings.

M(2) The regressors that appear to have an important impact on growth in samples including both OECD and LDCs have much less explanatory power when estimated for the OECD sub-sample alone. Although this may derive from the fact that the smaller size and more homogeneous nature of this sub-sample make it more difficult to identify precise individual effects, it may also signal a danger in extending inferences drawn from the wider sample to a particular industrialised country. The only (fairly) robust variables appear to be educational attainment and catch-up potential (initial productivity gap vis-à-vis the US).

Critique

One of the few studies explicitly aiming at assessing the determinants of growth for a more restricted and homogeneous group of industrialised countries. As to the important and robust role found for education, as acknowledged by the authors, the main problems are the possible endogenous nature of the education proxy, measurement issues and lack of international comparability, which make it difficult to view this coefficient as structural.
Of interest is also the attempt to replicate 'famous' previous results for this more homogeneous sub-sample.

Evaluating the impacts of human capital stocks and accumulation on economic growth: some new evidence

Norman Gemmell
1996, Oxford Bulletin of Economics and Statistics, 58, 1, 9-28.

Data

Mankiw-Romer-Weil dataset plus UNESCO for school-enrolment ratios and ILO for labour force.
98 countries.

Methods

The author uses the same dataset as well as the same approach of Mankiw, Romer and Weil (1992) to investigate the effects of including a superior measure of human capital.

After having shown that school enrolment rates – the most commonly used proxy for human capital in growth regressions – confound the effects of human capital stock and accumulation and cause coefficients on labour growth variables to partly include the effects of human capital, the author constructs a human capital measure that does not suffer from these shortcomings. This is accomplished by using 1960 school enrolment rates and data on the economically active working age population in 1960 to estimate initial stocks of primary, secondary and tertiary human capital; the flow of human capital at the three levels is estimated by combining data on the growth of working age population with school enrolment rates in years after 1960.

M(1) To investigate (a) the effects of human capital accumulation and of initial human capital stock, (b) whether the impact of different forms of human capital differs across countries and (c) whether it is the absolute size of the human capital stock or the proportion of educated labour that matters for per capita income growth, the following equation is estimated by OLS:

$$\Delta GDP_{60-85} = b_0 + b_1 \ln GDP_{60} + b_2 \ln I + b_3 \ln(dL / L) + \sum_i b_{4i} (dH_i / H_i) + \sum_i b_{5i} \ln H_{i,60} + b_6 \ln L_{60} \qquad i = p,s,t$$

where per capita GDP growth is regressed on the initial level of GDP per working age person, the investment/GDP ratio, labour force growth, primary, secondary and tertiary human capital accumulation, primary, secondary and tertiary human capital initial stock and initial labour force level.

M(2) Three-stage least squares regressions are used to test the impact of human capital simultaneously on investment and economic growth

Results

M(1) (a) Significant positive effects of human capital on growth both through initial stocks (β=1.1) and subsequent flows (β=5.9) (there is no evidence on endogeneity of human capital growth)
(b) Primary human capital seems to be relevant for the poorest LDCs, secondary human capital for intermediate LDCs, while tertiary human capital for OECD countries
(c) It is the relative size of initial human capital stocks that appears to be important

M(2) Significant positive effects of human capital on physical investment. Furthermore, human capital appears to have a *direct* positive impact on growth, in addition to its indirect impact via investment. For OECD countries, the stock of *secondary* human capital appears particularly important in stimulating investments, while direct growth effects come through increased *tertiary* human capital stock and accumulation.

Critique

An important contribution both on the methodological and the empirical level, the paper helps (a) clarify the different conceptual rationales for the inclusion of human capital in models of economic growth which have been proposed by the theoretical literature but only vaguely implemented by empirical studies, (b) proposes human capital measures able to separate stock and accumulation effects and tests and (c) highlights the potentially different roles of primary, secondary and tertiary education in a carefully specified and tested regression.

Why Do Some Countries Produce So Much More Output Per Worker Than Others?

Robert E. Hall and Charles I. Jones
1999, Quarterly Journal of Economics, 114, 1, 83-116.

Abstract

Output per worker varies enormously across countries. Why? On an accounting basis our analysis shows that differences in physical capital and educational attainment can only partially explain the variation in output per worker - we find a large amount of variation in the level of the Solow residual across countries. At a deeper level, we document that the differences in capital accumulation, productivity, and therefore output per worker are driven by differences in institutions and government policies, which we call social infrastructure. We treat social infrastructure as endogenous, determined historically by location and other factors captured in part by language.

Data

Summers-Heston; Barro-Lee for educational attainment; International Country Risk Guide and Sachs-Warner for indices of social infrastructure.
127 countries in 1988.

Methods

The authors investigate the proximate causes of economic success - factor accumulation and productivity - and the more fundamental determinant.

M(1) They start with 'levels' accounting, using the aggregate production function to break down differences in output per worker across countries between differences in productivity (*A*) and in the two inputs capital-output ratio and human capital per worker ($H/L= e^{\Phi(E)}$, where E is years of schooling):

$$\frac{Y_i}{L_i} = A_i \left(\frac{K_i}{Y_i}\right)^{\alpha/(1-\alpha)} e^{\Phi(E_i)}$$

Output elasticities with respect to physical (α) and human capital (a piecewise linear $\Phi(E)$) are imposed.

M(2) They subsequently explore to what extent such differences reflect differences in 'social infrastructure', defined as those institutions and government policies which determine the economic environment and thus the incentives that individuals and firm face. Social infrastructure is proxied by combining an index of government antidiversion policies and an index of openness to international trade.
Since social infrastructure is likely to be endogenous, they instrument it with various correlates of the extent of Western European influence (geographical and linguistic characteristics of individual economies). The authors also assess the impact of measurement error.

Results

M(1) Differences in physical capital and educational attainment appear to explain only a small amount of the difference in output per worker across countries (while differences in productivity contributed a factor of 8.3 in the difference in output per worker between the 5 richest and the five poorest counries, differences in capital intensity and in human capital per worker contributed factors of mere 1.8 and 2.2, respectively).

M(2) Output per worker appears to be strongly associated with measures of social infrastructure: a difference of 0.01 in social infrastructure is associated with a statistically highly significant difference in output per worker of 5.14.
Looking at the impact of social infrastructure on factor intensities and productivity, a good social infrastructure is found in countries with high capital intensities, high human capital per worker and high productivity.

Critique

An important step forward in trying to trace the more fundamental causes of economic success, this careful contribution moves beyond the 'frontier' trying to simultaneously address the questions of why some countries invest more than others in physical and human capital and are so much more productive than others in their use of these inputs, and thus producing higher levels of output per worker. Its results - which take account of endogeneity and measurement error in proxying social infrastructure - highlight the important role of governments and national institutions in promoting a productive environment conducive to private firms' and individuals' investment decisions.

Schooling, Labour Force Quality, and Economic Growth

Eric A. Hanushek and Dongwook Kim
NBER Working Paper 5399, December 1995.

Abstract

Human capital is almost always identified as a crucial ingredient for growing economies, but empirical investigations of cross-national growth have done little to clarify the dimensions of relevant human capital or any implications for policy. This paper concentrates on the importance of labor force quality, measured by cognitive skills in mathematics and science. By linking international test scores across countries, a direct measure of quality is developed, and this proves to have a strong and robust influence on growth. One standard deviation in measured cognitive skills translates into one percent difference in average annual real growth rates-an effect much stronger than changes in average years of schooling, the more standard quantity measure of labor force skills. Further, the estimated growth effects of improved labor force quality are very robust to the precise specification of the regressions, The use of measures of quality significantly improves the predictions of growth rates, particularly at the high and low ends of the distribution. The importance of quality implies a policy dilemma, because production function estimates indicate that simple resource approaches to improving cognitive skills appear generally ineffective.

Data

Summers and Heston data, 1960-1990 combined with international test score data for mathematics and science from the International Association for the Evaluation of Educational Achievement (IEA) and the International Assessment of Educational Progress (IAEP) over the years 1963, 1970, 1981, 1985, 1988 and 1991.

Methodology

(1) Seeks to correct for differences in the quality of the workforce when considering the impact of quantity of education (years) on growth.
(2) Measures the impact of labour force quality on growth.
(3) Attempts to identify the factors underlying better quality of the labour force.

The approach used is a simple Barro-type regression of the 1960 to 1990 growth on the quantity of schooling and on standardised measures of labour force quality for a number of countries. A distinguishing feature of the approach is the use of measured achievement as a quality indicator, as opposed to using measured school inputs, which may or may not explain well actual achievement. Two methods are followed to estimate the impact of labour force quality on growth. In one, a variable for missing test scores is introduced if the country does not have any test scores. In the other, the test scores are imputed whenever missing.
Subsequently a regression of labour force quality on schooling inputs (primary school pupil teacher ratio and education expenditure per GDP) is run to measure the relationship between observed policy variables and the quality indicators.

Results

The basic conclusion is that differences in labour force quality are a very important explanatory factor for growth. Adding labour force quality improves the R2 measure in a simple growth regression by at least 50% (from 0.230 to 0.365 or more). It also considerably reduces the magnitude of the measured impact of years of schooling on growth; the latter remains significant however.
The results lack specific policy implications, though, since there is no apparent relationship between the measure of quality (test scores) and measured inputs into schooling. Neither the pupil teacher ratio nor the schooling expenditure variables have any systematic significant effect.

Critique

The point made by this paper is very important; it is very hard to see what sense it makes to compare the quantity of schooling across countries with very different schooling systems and very different schooling inputs. The results make sense.

However there are two important shortcomings that need to be taken into account when judging whether the orders of magnitude of the estimates are accurate. First, the results are based on test scores for a limited number of countries taken within 30 years. Only two countries (USA and UK) participated in all waves of the tests; overall only 38 countries have contributed at least once. Second, the issue of reverse causality between growth, quantity of schooling and labour force quality (test score results) is not dealt with.

Growth Empirics: a Panel Data Approach

Nazrul Islam
Quarterly Journal of Economics, November, 1995, 1127-70

Abstract

A panel data approach is advocated and implemented for studying growth convergence. The familiar equation for testing convergence is reformulated as a dynamic panel data model, and different panel data estimators are used to estimate it. The main usefulness of the panel approach lies in its ability to allow for differences in the aggregate production function across economies. This leads to results that are significantly different from those obtained from single cross-country regressions. In the process of identifying the individual 'country effect', we can also see the point where neoclassical growth empirics meets development economics.

Data

Summers-Heston data 1960-85. The samples considered differ slightly from those in Mankiw, Romer, and Weil (1992) (henceforth MRW), because data for the some of the initial years is not available in Indonesia and Burkina Faso. The three samples considered are therefore: (i) non-oil (96 countries), (ii) intermediate (74 countries), and (iii) OECD (22 countries). When the human capital variable is included in the regressions, the sample sizes are slightly reduced: (i) non-oil (79 countries), (ii) intermediate (67 countries), and (iii) OECD (22 countries). The human capital variable used differs from that that in MRW and is average schooling years in the total population over age 25 (from Barro and Lee (1994)).

Methods

The conditional convergence regression (equation (2)) in MRW is reformulated as an equation for income per capita at time t_2 as a function of income per capita at t_1 and estimated using panel data techniques (using both 'within groups' or Least Squares Dummy Variables (LSDV) estimation and Chamberlain's Minimum Distance (MD) estimator). The model is estimated both with physical capital only (equation (1)) and with human capital (equation (2)),

$$\ln(Y_j/L_j(t_2)) = \varphi_j + \gamma_1.\ln(Y_j/L_j(t_1)) + \gamma_2.\ln(I_j/Y_j) + \gamma_3.\ln(n_j+g+\delta) + \gamma_4.\text{time} + v_j(t_2) \qquad (1)$$

$$\ln(Y_j/L_j(t_2)) = \varphi_j + \gamma_1.\ln(Y_j/L_j(t_1)) + \gamma_2.\ln(I_j/Y_j) + \gamma_3.\ln(n_j+g+\delta) + \gamma_4.\text{time} + \gamma_5.\ln S_j + v_j(t_2) \qquad (2)$$

where j indexes countries. t_2 denotes the end year and t_1 denotes the initial year in each of the following five year periods: 1960-65, 1965-70, 1970-75, 1975-80, and 1980-85. This yields a panel with five time series observations for each country in the sample. Y_j is real GDP, L_j is total population, I_j/Y_j is the average ratio of real investment (including government investment) to GDP during each five-year period, n_j is the average rate of growth of the total population during each five-year period, g is exogenous rate of technological progress, and δ is rate of depreciation of physical capital (following MRW, the author assumes $g+\delta=0.05$ in all five-year periods). S_j is average schooling years in the total population over age 25, and v_j is a stochastic error term. φ_j is a country-specific fixed effect, which is interpreted as controlling for unobserved variation in levels of technical efficiency across countries.

Results

(i) Estimation results with physical capital only. Using both the LSDV and MD estimators, find,
(a) higher estimated rate of convergence of income per capita towards its steady-state level than in a cross-section regression of the form estimated by MRW.
(b) higher and more plausible estimated coefficient on the physical investment share. Using LSDV estimation for the non-oil sample and imposing constant returns to scale, the implied exponent on physical capital in the production technology is 0.4 ($Y_j=A_j.K^{0.4}.L^{0.6}$), compared with an implied exponent on physical capital of 0.8 ($Y_j=A.K^{0.8}.L^{0.2}$) from a cross-section regression of the form estimated by MRW.
(ii) Estimation results with both physical and human capital. When human capital is included in the model and panel data estimation techniques are used, find,

(a) estimated rate of convergence of income per capita towards its steady-state level is smaller than in the model without human capital, though higher than in a cross-section regression of the form estimated by MRW.
(b) the human capital variable is negatively signed and statistically significant in the non-oil sample, and negatively signed, though statistically insignificant, in the intermediate and OECD samples.
(c) the estimated coefficient on the physical investment share is similar to that in the model without human capital. For the non-oil sample, the implied exponent on physical capital is 0.5.
(iii) Estimated fixed effects imply substantial differences in relative levels of technical efficiency across countries

Critique

(i) The human capital variable has the advantage of being a direct measure of the stock of human capital. However, it includes information on all levels of schooling (primary, secondary, and higher, complete and incomplete), and gives equal weight to a year of each of these levels of schooling.
(ii) In the presence of a lagged dependent variables (as in equations (1) and (2) above), the LSDV is subject to a finite sample bias that declines asymptotically in the number of time periods T rather than the number of countries N (and there are only five time periods in this application). More appropriate econometric techniques exist for dynamic panel data models including GMM estimation following Arellano and Bond (1991) and GMM systems estimation following Blundell and Bond (1998).
(iii) Following Benhabib and Spiegel (1994), levels of human capital may themselves influence relative levels of technical efficiency, and, in a panel data context, it may be hard to identify an effect of human capital against a country-specific fixed effect (especially if the cross-section variation in the human capital variable is large relative to the time series variation).
(iv) Although panel data estimation allows for unobserved heterogeneity across countries in levels of technical efficiency, the coefficients on explanatory variables such as human capital may also vary across countries (see for example Krueger and Lindahl, 1998 and Lee, Pesaran, and Smith, 1997).

Education and Production in the United Kingdom

Helen Jenkins
1995, Nuffield College, Oxford, Economics Discussion Paper No. 101

Abstract

This paper establishes a testable model of a production function which captures the relationship between output and the stock of human capital, measured as workforce qualifications. The analysis vindicates investment in education by suggesting that highly-qualified workers can be up to twice as productive as those with no qualifications. A redefinition of productivity measures to include human capital calls into question the 'Thatcher miracle', suggesting that productivity growth in the 1980s was actually very similar to that under the Labour governments of the 1970s.

Data

Uses UK time series data from 1971 to 1992. Output, employment and capacity utilisation data came from the CEP OECD data set; capital stock from the CSO Blue Book; qualifications from the General Household Survey.

Methods

The paper establishes a testable model of a production function which captures the relationship between output and the stock of human capital, measured as workforce qualifications.
Argues that when considering how general education and qualifications affect an economy's performance, interest should firstly focus on the production function and the relationship between the *stock* of human capital and the *level* of output. She argues there are no clear theoretical grounds for claiming an equilibrium relationship between the *level* of human capital and output *growth*.

She begins by estimating the following equation:

$$\ln Y_t = a_1 + a_2 \times trend + a_3 \ln(cu_t) + a \ln K_t + b \ln L_t + d \ln[g_1 q_{1t} + g_2 q_{2t} + q_{3t}] \quad (1)$$

where Y_t is output at time t, the constant term is decomposed into trend and cyclical components where cu_t it a measure of capacity utilisation, K is physical capital, and L is the total workforce, and q_i is the proportion of the workforce with qualifications i (=1 high, =2 intermediate, =3 unqualified). A highly (intermediate) qualified worker has a marginal product g_1 (g_2) times that of an unqualified worker. By imposing a particular value for b (the elasticity of output with respect to labour), from (1) she derives an estimating equation in terms of total factor productivity (*TFP*):

$$TFP_t = \ln Y_t - (1-b)\ln K_t - b \ln L_t = a_1 + a_2 \times trend + a_3 \ln(cu_t) + b \ln[g_1 q_{1t} + g_2 q_{2t} + q_{3t}] \quad (2)$$

Results

(1) The results she obtains from estimating equation (1) are imprecisely determined and difficult to draw conclusions from.
(2) The restrictions required for estimating (2) result in greater precision, but are sensitive to the value of *b* chosen. She considers 3 possible values, 0.41 (unrestricted estimate from (1)), 0.58 (the sample average value of labour's share in total output) and 0.7 (sample average value scaled up to correct for bias due to imperfectly competitive markets which is widely used in the literature).
(3) Holding a tertiary qualification (high) doubles the productivity of a worker (compared to no qualifications) for the higher values of *b* (99%-137%) and results in about 30% higher productivity even with the lowest value of *b*. Holding intermediate qualification results in around 50% higher productivity (46%-66%) with higher values of *b*, but only 8 per cent higher productivity than unqualified workers if *b*=0.41.

Critique

This paper is one of the few attempts to estimate the relationship between the stock of human capital and output in the UK. What is particularly novel is the way she distinguishes between different types of labour input. Her results suggest that investment in human capital increases productivity. However, the size of her time series sample means that her unrestricted estimates are imprecisely determined. When restrictions are imposed, her results are reasonably sensitive to the assumptions made about the value of b. Measurement error, aggregation bias and the possible endogeniety of education are also completely ignored.

Investment in Education and U.S. Economic Growth

Dale W. Jorgenson and Barbara M. Fraumeni
1992, Scandinavian Journal of Economics, 94, Supplement, S51-70.

Abstract

The purpose of this paper is to measure the impact of investment in education on U.S. economic growth. Education is treated as an investment in human capital, since benefits accrue to an educated individual over a lifetime of activities. One of the most important benefits is higher income from labor market participation. This is the key to understanding the link between investment in education and economic growth. Our most important finding is that investment in human and nonhuman capital accounts for an overwhelming proportion of the growth of the U.S. economy during the post-war period. Educational investment will continue to predominate in the investment requirements for more rapid growth.

Data

National Income and Product Accounts of the US, 1948-1986, as modified in Jorgenson and Fraumeni (1992b).

Methods

The aim of the paper is to quantify the impact of investment in education on US economic growth.

(1) First, US National Accounts are adjusted to include the value added of the educational sector. Educational output is valued on the basis of the present value of the increments in lifetime labour income flows for individuals with higher levels of educational attainment, while educational inputs include both outlays of educational institutions and the time invested by students in learning.
(2) Growth accounting methodology is used on the growth of (a) the education sector, (b) the non-education (business and government) sectors and (c) a new measure of the US economy, one which aggregates both education and non-education sectors. The contributions of the various inputs to growth in output are obtained by weighting the growth rates of these inputs by their shares in that sector's value added. The contributions of capital and labour inputs are subsequently decomposed into the separate contributions of capital stock and capital quality, and of hours worked and labour quality.

Results

(1) Investment in human and physical capital accounts for an overwhelming proportion of the growth of the US economy during the post-war period (99% for the education sector, 69% for the non-education sector and 83% for the US economy).
(2) As to the contribution of labour, growth in such input accounts for 29% of non-education sectors growth, but for 61% of US economic growth (i.e. taking both education and non-education sectors).
(3) Labour quality accounts for 24% of labour contribution in the non-education sector and for 42% of labour contribution in the overall economy.
(4) Using the new measure of aggregate output instead of the conventional one, is found to raise the contribution to economic growth of improved labour quality from barely 7% to 26%, surpassing even the contribution of capital (22%).

Critique

A very serious and detailed attempt to measure the contribution of the educational sector. In contrast to conventional outlay-based approaches to measure investment in human capital, their income-based method allows to capture the crucial time dimension of such type of investment. The estimated investment in human capital, however, crucially depends on the assumptions invoked for the calculations, among which that differences in earnings correspond to differences in marginal products, that these differences are in fact due to education, absence of production externalities from education, no depreciation of knowledge and education, ex ante and ex post estimates of the impact of education on individual lifetime incomes are the same (ruling out, e.g. general equilibrium effects), constant retirement age of 75 for the whole period, several assumptions in imputing non-market income. These delicate choices, in addition to the exclusion of non-market sectors other than the education one (e.g. health, other government services, environment, banking) from the ‘overall’ economy, make the procedure, and the very high figures obtained, controversial.

Economic Growth and Investment in Education: How Allocation Matters

Ruth Judson

1998, Journal of Economic Growth, 3, 4, 337-359.

Abstract

This article proposes an approach to answering two questions: first, does investment in education help growth; second, does the allocation of investment in education matter. I develop a model where individual ability is heterogeneous and education both trains students and reveals their suitability for further training. I use UNESCO data on educational enrollments and spending to estimate the efficiency of existing educational allocations in a panel of countries. A cross-country growth decomposition regression shows that the correlation of human capital accumulation and GDP growth is not significant in countries with poor allocations but is significant and positive in countries with better allocations.

Data

Summers-Heston data, physical capital stock growth from Nehru, Swanson and Dubey, human capital stock growth from Barro-Lee and Nehru *et al*, enrolment and spending from the UNESCO educational database.
Panel data on 138 countries and 31 years (1960-1990).

Methods

The estimation strategy can be divided into two main parts:

M(1) The author first evaluates the efficiency of the allocations of educational spending between primary, secondary and tertiary education chosen by several countries between 1970 and 1990. Based on her micro theoretical model of returns to education, for each country and time period, she calculates the relative returns to both actual and optimal allocations. Efficiency is defined as the ratio of the achieved rate of return to the maximum possible rate of return the country could obtain given its actual overall education budget and actual relative costs for each level of education.

M(2) She subsequently tests the hypothesis that the allocation of educational resources between primary, secondary and tertiary education matters for growth. This is accomplished by estimating cross-country panel generalised least squares of per capita GDP growth on per capita capital stock growth and per capita human capital stock growth, and experimenting with specifications which include interaction terms of the human capital stock growth variable with the calculated efficiency score (or with efficiency dummies), and dummies for efficiency.

Results

M(1) - many countries seem to be allocating their educational resources in a nearly optimal way, with most allocations yielding at least 80% of the optimal rate of return

- in many countries there is however a substantial gap between actual and optimal enrolment rates
- universal primary education is not necessarily part of the optimal allocation for very poor countries.
- nonetheless, on average, countries should be allocating a higher share of their resources to primary education as they currently do.

M(2) More than the level of educational investment, it is its allocation that matters for economic growth: the correlation between human capital accumulation and growth is lower for those countries which have been identified as allocating their educational resources inefficiently. These countries gain little from their investments in human capital (compared to countries with more efficient allocations, the effect of human capital growth on GDP growth is significantly lower and not significantly different from zero).

Critique

An innovative paper that provides a bridge between the micro studies looking at the different returns to individuals from investments in various levels of education and the macro studies

investigating the role of education for national economic performance without considering how educational resources are allocated. The finding that the contribution of human capital to growth depends on the efficiency with which it is being accumulated has an important policy implication in terms of the importance of the allocation of educational resources.
A potentially important assumption the author would like to relax by focusing on a more restricted and homogeneous sample with richer datasets is the one of a common rate of return to education for all countries. A final remark is that it is not very clear what is actually being evaluated, if the contribution to growth of efficiency as measured by her approach or her method to measure and evaluate educational allocation efficiency ("We can thus conclude that my assessment of the efficiency of allocation schemes is supported by the growth regressions" p.352).

The Neoclassical Revival in Growth Economics: Has it Gone Too Far?

Peter Klenow and Andrés Rodríquez-Clare
1997, NBER Macroeconomics Annual.

Data

Latest Summers-Heston, Barro-Lee, UN.
98 countries.

Methods

Put it simply, given the production function Y=AX, where A is productivity and X encompasses both physical and human capital, the aim of the paper is to offer new evidence on the importance of total factor productivity (A) vs. physical and human capital (X) in explaining international differences in levels and growth rates of output.
The issue is investigated by calibration and subsequent growth 'accounting' in several ways:

M(1) Re-examine and update Mankiw, Romer and Weil's (1992) methodology for estimating human capital by (a) updating their data, (b) adding primary and tertiary education and (c) incorporating evidence that the production of human capital is more labour- and less capital-intensive than the production of other goods, and then decompose differences in output per worker across countries into the contribution from productivity A and the contribution from inputs X

M(2) Combine evidence from Mincer regressions of an average (across countries) 9.5% wage gain associated with an additional year of education with data on schooling attainment and estimates of school quality to produce measures of human capital stocks for the countries in the sample and to apportion the difference in 1985 GDP per worker between A and X.

M(3) Same type of analysis of (2), but for the 1960-85 per capita output growth rates.

M(4) Compare and contrast their findings with those, apparently at odd, of Young (1995).

Results

M(1) The cumulative effects of the modifications is to massively increase the 'explanatory' role of productivity, mainly at the expense of human capital: the original Mankiw-Romer-Weil (X=(contribution of K, contribution of H), A) decomposition of (78%=(29%, 49%), 22%) is now (33%=(29%, 4%), 67%).

M(2) Productivity differences account for half or more of level differences in 1985 GDP per worker.

M(3) Productivity differences account for the overwhelming majority of per capita growth differences (91%), leaving a small role for human capital (9%). The positive correlation between the growth rates of productivity and of schooling intensity however suggests an indirect role for education in fuelling growth through its effect on technology adoption/innovation.

M(4) In line with Young's findings, growth in output in the four East Asian miracles came primarily from input accumulation (and, as Young, they find a very modest role for growth in human capital per worker in explaining growth); however, for three of these countries, growth in output *per worker* came mostly from productivity gains.

Critique

An interesting contribution which highlights the importance of how human capital is measured, of adding experience and of correcting for school quality in attributing differences in output to differences in productivity vs. differences in capital (physical and human) intensity. The main conclusion is a negative one: "human capital's importance has been seriously overstated in previous research" (p.95) and the call is for restoring the focus of theoretical research on international productivity differences.
The main problem is the delicate role of the key parameters the authors *calibrate*; while their results are necessarily sensitive to the choice of such values, there is still much uncertainty as to which the 'true' values are.

Education for Growth: Why and for Whom?

Alan Krueger and Mikael Lindahl
mimeo, Princeton University, 1998.

Abstract

This paper tries to reconcile evidence on the effect of schooling on income and on GDP growth from the microeconometric and empirical macro growth literatures. Much microeconometric evidence suggests that education is an important causal determinant of income for individuals within countries. At a national level, however, recent studies have found that increases in educational attainment are unrelated to economic growth. This finding is shown to be a spurious result of the extremely high rate of measurement error in first-differenced cross-country education data. After accounting for measurement error, the effect of changes in educational attainment on income growth in cross-country data exceeds microeconometric estimates of the return to years of schooling. Another finding of the macro growth literature – that economic growth depends positively on the initial stock of human capital – is shown to result from imposing linearity and constant-coefficient assumptions on the estimates. These restrictions are rejected by the data, and once either assumption is relaxed, the initial level of education has little effect on economic growth for the average country.

Data

Summers-Heston data 1960-1990; education data from Barro-Lee, Kyriacou and World Values Survey. Up to 108 countries.

Methods

Criticises findings of Barro (1997) and Benhabib and Speigel (1994) that initial level of education strong determinant of future GDP growth and that growth of education does not effect GDP growth.

The basic equation considered is

? $Y_{jt} = ß_0 + ß_1 Y_{jt-1} + ß_2 S_{jt-1} + ß_3$? $S_{jt} + u_{jt}$

where ? denotes an (annualised) change, j = country, Y = log(GDP per capita), S = schooling. Only other controls are time dummies.

The authors consider the robustness of the cross country growth regressions to various econometric problems:

(1) measurement error in the education variables. This is assessed (a) by calculating the reliability ratios of different measures of education from three different sources; (b) by comparing short and long differenced estimates; (c) instrumenting one education variable with another.
(2) assumption of common cross country coefficients on education. They allow $ß_2$ to differ across countries
(3) assumption that coefficient on education does not vary over time. This implies a different interpretation of $ß_2$
(4) assumption that the effect of education on growth is linear. They allow a quadratic in initial education.

Results

(1) Growth of education does affect GDP growth. Other studies do not find this because of large measurement error in education variables which is exacerbated when variables are differenced. The attenuation bias pushes the OLS coefficient to zero because there is a low signal to noise ratio, especially in differences. For example, the Kyriacou data have a reliability ratio 0.97 in the cross section, but only 0.2 in the time series dimension (i.e. the coefficient on the growth of education is 80% "too low"). This problem is made worse by conditioning on other variable like capital which "soak away" any of the remaining explanatory power of education.
(2) Initial level of education is not positively related to future growth for the average country when one relaxes linearity and the constant coefficient assumption on education. In fact initial level is often negative and significant

(3) Estimated social rate of return is high. In measurement error corrected version, $ß_3 = 0.3$, about 3-4 times the private rate of return from micro data (p.26).

Critique

A mainly methodological contribution attempting to reconcile micro and macro estimates. Main point is a negative one: that the macro estimates that are unreliable as conventionally estimated. They do not believe their estimates of the social rate of return and argue that they are implausibly large. Main suspect is endogeneity bias, i.e. that countries growing richer will expand their education systems. Nevertheless, the authors do not seek to deal with this problem but call upon the macro literature to follow the micro literature in a search for natural experiments. Their positive result of an effect of growth in education on growth in productivity is vulnerable to their failure to control for other variables (e.g. capital, institutions)

Sensitivity Analysis of Cross-Country Growth Regressions

Ross Levine and David Renelt

1992, American Economic Review, 82, 4, 942-963.

Abstract

A vast literature uses cross-country regressions to search for empirical linkages between long-run growth rates and a variety of economic policy, political, and institutional indicators. This paper examines whether the conclusions from existing studies are robust or fragile to small changes in the conditioning information set. We find that almost all results are fragile. We do, however, identify a positive, robust correlation between growth and the share of investment in GDP and between the investment share and the ratio of international trade to GDP. We clarify the conditions under which there is evidence of per capita output convergence.

Data

Perform the analyses for data both from the World Bank and International Monetary Fund and from Barro (1991) (based on Summers-Heston), 1960(1974)-1989.
119 countries.

Methods

The aim of the paper is to assess the robustness of several (over 50) variables that have been found to significantly affect economic growth by the vast literature on cross-country growth regressions.
The method used is extreme-bounds analysis, which tests the robustness of coefficient estimates to alterations in the conditioning set.

$$\mathbf{Y} = b_{\mathrm{i}}\mathbf{I} + b_m\mathbf{M} + b_z\mathbf{Z} + \mathbf{u}$$

where Y is the average annual growth rate of per capita GDP, I is the set of variables always included (investment share of GDP, 1960 initial level of GDP per capita, initial secondary school enrolment rate and average annual population growth), M is the variable of interest, and Z is a subset of variables chosen from a pool of variables identified by past studies as potentially important explanatory variables (among which, rate of government expenditures to GDP, ratio of exports to GDP, inflation rate, domestic credit growth rate, number of revolutions and coups).
The method involves varying the subset of Z-variables included to find the widest range of coefficient estimates on M that standard hypothesis tests do not reject. The relationship Y-M is deemed 'fragile' if the coefficient does not remain significant or changes sign.
They finally test the sensitivity of their type of analysis.

Results

(1) The cross-country statistical correlations between average growth rates and basically all variables considered in the literature are extremely fragile; small alterations in the set of the other regressors cancel or overturn past results. The only robust correlation is the positive one between economic growth and the share of investment in GDP.
(2) As to the educational proxy (included in set I), initial secondary school enrolment rates (but other measures have been tried as well with similar results) enter with a significantly positive and robust (to variations in the Z set) coefficient between 2.5 and 3.7.
The union of the two sets of explanatory variables from Kormendi and Meguire (1985) and Barro (1991) however drives the educational variables to insignificance and leaves none of the economic policy indicators significantly correlated with growth, though it should be pointed out that none of the regressors added to the Barro (1991) specification is significant.

Critique

A conceptually simple, yet powerful methodological contribution. As the authors state at the beginning, their aim is not to identify growth determinants or improve the measurement of potential factors affecting growth. Their scope is restricted to test if those partial correlations identified in the literature are robust to small alterations of the conditioning set. The main message is a negative one: correlations found in the literature crucially depend on the choice of the additional regressors included. Together with the fact that many alternative regressions have equal theoretical status, the findings of the paper call for a great deal of care in the interpretation of cross-country results. As to role of human capital, however, the findings are much more encouraging, indicating that initial secondary school enrolment rates are fairly robust to the choice of the other regressors.

A Contribution to the Empirics of Economic Growth

Mankiw, N., Romer, D. and Weil, D.
Quarterly Journal of Economics, May, 1992, 407-38.

Abstract

This paper examines whether the Solow growth model is consistent with the international variation in the standard of living. It shows that an augmented Solow model that includes accumulation of human as well as physical capital provides an excellent description of the cross-country data. The paper also examines the implications of the Solow model for convergence in standards of living, that is, for whether poor countries tend to grow faster than rich countries. The evidence indicates, that holding population growth and capital accumulation constant, countries converge at about the rate the augmented Solow model predicts.

Data

Summers-Heston data 1960-85. Secondary school enrolment ratios from the UNESCO yearbook. Consider three samples: (i) Non-oil - all countries except those for which oil production is the dominant industry (98 countries), (ii) Intermediate - same as previous sample, but excluding countries whose real income figures are based on little primary data and countries whose populations in 1960 were less than 1 million (75 countries), (iii) OECD – the 22 OECD countries.

Methods

Estimates the Solow-Swan neoclassical model of growth, augmented with human capital, using cross-country regressions. Estimate equations for (i) long-run income per capita (estimated using 1985 data),

$$\ln(Y_{j85}/L_{j85}) = \beta_0 + \beta_1.\ln(I_j/Y_j) + \beta_2.\ln(n_j+g+\delta) + \beta_3.\ln S_j + u_j \quad (1)$$

(ii) medium-run growth as the economy converges to long-run income per capita (estimating used 1960-85 data),

$$\ln(Y_{j85}/L_{j85})-\ln(Y_{j60}/L_{j60}) = \gamma_0 + \gamma_1.\ln(Y_{j60}/L_{j60}) + \gamma_2.\ln(I_j/Y_j) + \gamma_3.\ln(n_j+g+\delta) \quad (2)$$
$$+ \gamma_4.S_j + v_j$$

where j indexes countries, 85 denotes the year 1985, and 60 denotes the year 1960. Y_j is real GDP, L_j is working age population, I_j/Y_j is the average ratio of real investment (including government investment) to GDP during 1960-85, n_j is the average rate of growth of working age population during 1960-85, g is exogenous rate of technological progress, and δ is rate of depreciation of physical capital (authors assume $g+\delta=0.05$)), S_j is a proxy for the rate of human capital accumulation (the average percentage of the working-age population in secondary school during 1960-85), and u_j and v_j are stochastic error terms.

Results

(i) Neoclassical Solow-Swan model, augmented with human capital explains over 70% of the variation in estimated steady-state income per capita across countries (equation (1)) in samples (i) and (ii)
(ii) In the non-oil sample, a 1% increase in the average percentage of the working-age population in secondary school estimated to lead to a 0.66% increase in long-run income per capita
(iii) The data are consistent with a Cobb-Douglas production function of the form $Y=K^{1/3}.H^{1/3}.L^{1/3}$, where H is the economy's stock of human capital
(iv) Countries with similar technologies, rates of accumulation of human and physical capital, and rates of population growth should converge in income per capita. The estimated coefficient on initial income in equation implies that an economy closes half of the gap between actual and steady-state income every 35 years.

Critique

(i) Parameter heterogeneity. In particular, cross-section regression analysis fails to control for unobserved heterogeneity across countries, which may be correlated with the explanatory variables. See Islam (1995) and Lee, Pesaran and Smith (1997) for panel data analyses.
(ii) Relatively little attention paid to the role of outliers (see Temple, 1998) and the sensitivity of estimated coefficients to changes in the set of control variables (see Levine and Renelt, 1992).
(iii) Measurement error – the average percentage of the working-age population in secondary school during 1960-85 may be a poor proxy for the rate of human capital accumulation.
(iv) It is unclear whether one should include the level human capital or the rate of human capital accumulation on the right hand side of equations (1) and (2) (see Benhabib and Spiegel, 1994).
(v) The estimated rate of convergence to long-run income per capita is subject to Galton's Fallacy – a negative coefficient on initial income may simply reflect mean reversion.
(vi) The rate of technological progress is assumed to be the same in all countries. Thus, in steady-state, all countries exhibit the same rate of growth of income per capita.

Estimating the External Return to Education: Evidence from Repeated Cross-Sectional and Longitudinal Data

Enrico Moretti
1999, mimeo, UC Berkeley

Abstract

In this paper, I estimate the external return to education by comparing wages for otherwise similar individuals who work in cities with higher and lower average levels of education. A key issue in this comparison is the presence of city-wide unobservable factors that may raise wages and attract more highly educated workers to different cities. I use wage changes across the 1980 and 1990 Censuses to abstract from any permanent sources of unobserved heterogeneity across cities. To further control for the potential endogeneity of the growth in education across cities, I use three instrumental variables: the presence of a land-grant college; city demographic structure; and the cost of tuition at state colleges and universities. I then investigate the hypothesis that the correlation between average education and wages is due to omitted individual characteristics, such as ability. I turn to the National Longitudinal Survey of Youth (NLSY) to build a richer econometric model of non- random selection of workers among cities. In the model, different cities reward workers' skills -both observed and unobserved--differently, and mobility decisions are based on comparative advantage. By observing the same individual over time and in different cities, I can control for permanent factors that make an individual-city match particularly productive. The results from the NLSY sample are remarkably consistent with those based on Census data. A 1% increase in the supply of college graduates raises high-school drop-outs' wages by 1.3%, high-school graduates' wages by 1.2%, the wages of college graduates by 1.0%. The effect is larger for less educated groups, as predicted by a conventional demand and supply model. But even for college graduates, an increase in the supply of college graduates increases wages, as predicted by a model that includes both conventional demand and supply factors and externalities.

Data

US Censuses (1970, 1980 and 1990) and US National Longitudinal Survey of Youths (1979-1994).

Methods

The author aims at isolating the causal impact on individual wages of the average level of education in the city of residence of the individual by taking account of possible sources of bias in the form of unobserved factors affecting both wages and the percentage of educated workers in a city.

M(1) The starting specification is a two-stage procedure:

1. $\ln w_{ict} = a_{ct} + X_{it} b_{it} + v_{ict}$

where *i* is the individual, *c* the city and *t* time, w is hourly wage, X is a vector of individual characteristics including education and α is a set of city-time specific dummy variables interpreted as a vector of adjusted city average wages.

2. $\hat{a}_{ct} = d_c + d_t + pS_{ct} + aZ_{ct} + e_{ct}$

where *S* is average education, *Z* are observed city characteristics and d_c, d_t are city and year dummies. The coefficient of interest is π.

M(2) First-differenced models of (1) allow to abstract from permanent unobserved city-specific differences in labour demand and supply that are correlated with average education.

M(3) To account for possible transitory unobserved city-specific factors correlated with changes in average education and wages across cities, these shocks are directly estimated with a measure of demand shifts and, alternatively, instrumental variable techniques are used (three instruments are considered in turn: the presence of a land-grant college in the city, the 1970 city age structure and the cost of tuition at colleges and universities).

M(4) To allow for unobserved individual characteristics (e.g. ability) that are correlated with average education and wages across cities, the panel structure of the NLSY is exploited to estimate a richer model of self-selection of workers across cities, in which different cities reward workers' skills differently and mobility decisions are based on their comparative advantage. Various approaches are followed: correlated random fixed effects, quasi-differencing, IV and semiparametric correction based on the propensity score.

M(5) To provide more direct evidence on educational externalities, a more general specification is estimated separately for each education group.

Results

M(1)-M(4) Omitted city characteristics do not seem to affect estimates, while results emerging from the mobility model are remarkably consistent with those based on Census data. The robust finding that a one year increase in average education in a city raises average wages by 8 to 15% (after controlling for the private return to education) does however not necessarily point to an externality effect, since it may be due to complementarity between high and low educated workers.

M(5) By contrast, estimates of the effect of changes in the fraction of highly skilled workers on different education groups shows that a 1 percentage point increase in the labour force share of college graduates increases the wages of high-school drop-outs and of high-school graduates by 1.3% and 1.2% respectively, while it also increases the wages of college graduates by 1.0%. For a one year increase in city average education, the corresponding figures are 22.2%, 11.7% and 9.8%. For the best-educated group then, these results would imply that the educational externality is strong enough to out-compete the negative impact of relative demand and supply.

Critique

An extremely thorough study, which offers a credible methodology for identifying and measuring the external return to education. Local labour markets as identified by metropolitan areas seem a natural unit. The focus on higher education allows to look at what has often been argued is the main source of externalities in advanced economies. The main problem appears to be the treatment of individual education as exogenous.

The Allocation of Talent: Implications for Growth

Kevin M. Murphy, Andrei Shleifer and Robert W. Vishny
1991, Quarterly Journal of Economics, 106, 2, 503-30.

Abstract

A country's most talented people typically organize production by others, so they can spread their ability advantage over a larger scale. When they start firms, they innovate and foster growth, but when they become rent seekers, they only redistribute wealth and reduce growth. Occupational choice depends on returns to ability and to scale in each sector, on market size, and on compensation contracts. In most countries, rent seeking rewards talent more than entrepreneurship does, leading to stagnation. Our evidence shows that countries with a higher proportion of engineering college majors grow faster; whereas countries with a higher proportion of law concentrators grow more slowly.

Data

Barro's (1991) dataset that augments the Summers and Heston one; data on college enrollments in law and in engineering from UNESCO.
91 and 55 countries (the latter sample for countries with more than 10,000 college students).

Methods

Extend Barro's (1991) regressions to test the hypothesis that the allocation of talented individuals to entrepreneurship favours growth, while their allocation to rent seeking leads to slower growth.

They estimate the following model:

$$\Delta Y_j = b_0 + \mathbf{b}'\mathbf{X}_j + b_1 S_j + b_2 ENG_j + b_3 LAW_j + u_j$$

where j denotes the country, ΔY is the 1970-85 growth rate of real GDP per capita; X includes real GDP per capita in 1960, the 1970-85 average of real government consumption over real GDP, the 1970-85 average of real private investment over real GDP and the number of revolutions and coups; S is primary school enrolment rate in 1960; ENG (LAW) is the ratio of college enrolments in engineering (law) to total college enrolment in 1970.

The authors then decompose the total effect on growth of the fractions of college majors in engineering and in law into direct and indirect effects, regressing X and S on LAW and ENG.

Results

(1) primary school enrolment offers a statistically significant contribution to growth only for the larger sample
(2) by contrast, the allocation of talent – as captured by enrolment in the two fields over total college enrolment – appears to matter for growth, but only for the countries with large student populations. More precisely, the direct effect of engineering is positive (albeit hardly significant) and the effect of lawyers is negative and significant.
(3) From their auxiliary regressions, they find that while most of the effect of lawyers on growth is direct, engineers have large positive indirect effects on growth, being correlated with high investments in human capital and physical capital, low government consumption and few revolutions and coups.

Critique

Depart from the usual approach by providing empirical evidence that it is not just the quantity, but also the *type* of human capital that may matter for growth. Due to the proxy chosen for the rent-seekers, their results are likely to be relevant especially for more developed countries.
A potential problem is reverse causality: an expected acceleration in economic growth, by enhancing the attractiveness of innovation and entrepreneurship, may itself trigger an increase in relative enrolment in engineering. In fact, the positive correlation found between engineering

enrolments and the ‘fundamentals’ of the economy (large investments in human capital and in physical capital, low government consumption and high political stability) indicates that individuals choose engineering when other growth-enhancing macro conditions make such an investment worthwhile.

Robustness Tests of the Augmented Solow Model

Jonathan Temple
Journal of Applied Econometrics, 13, 1998, 361-75

Abstract

This paper demonstrates some techniques for testing the robustness of cross-section and panel data regressions, and applies them to the influential augmented Solow growth model. The paper focuses on robust estimation and analysis of sensitivity to measurement error. In particular, it is shown that estimated technology parameters and convergence rates are highly sensitive to measurement error.

Data

Summers-Heston data 1960-85. Secondary school enrolment ratios from the UNESCO yearbook. Consider the same three samples as in Mankiw, Romer, and Weil (1992) (henceforth MRW): (i) non-oil (98 countries), (ii) intermediate (75 countries), and (iii) OECD (22 countries).

Methods

Tests the robustness of the regression results from the augmented Solow model of MRW using cross-country regressions. Estimate equations for (i) long-run income per capita (estimated using 1985 data),

$$\ln(Y_{j85}/L_{j85}) = \beta_0 + \beta_1.\ln(I_j/Y_j) + \beta_2.\ln(n_j+g+\delta) + \beta_3.\ln S_j + u_j \quad (1)$$

(ii) medium-run growth as the economy converges to long-run income per capita (estimating used 1960-85 data),

$$\ln(Y_{j85}/L_{j85})-\ln(Y_{j60}/L_{j60}) = \gamma_0 + \gamma_1.\ln(Y_{j60}/L_{j60}) + \gamma_2.\ln(I_j/Y_j) + \gamma_3.\ln(n_j+g+\delta) + \gamma_4.S_j + v_j \quad (2)$$

where j indexes countries and the definition of variables is the same as for MRW. Two main robustness tests are considered: (i) Robustness of parameter estimates to existence of outliers – model is estimated using Reweighted Least Squares (RWLS). This is a two-stage estimation process. In the first stage, the model is by minimising the sum of squares over half the observations, choosing the half with the smallest residual sum of squares. Some observations are classified as unrepresentative and are excluded from the sample. In the second stage, the model is estimated on the remaining sample using OLS.
(ii) Measurement error – examine the robustness of the parameter estimates to classical measurement error (measurement error uncorrelated with the explanatory variables) using both multivariate reverse regression and classical method-of-moments estimators.

Results

It is argued that aspects of the cross-section evidence are inconsistent with the MRW model,
(i) Once outliers are excluded from the OECD sample, the model for steady-state income per capita (equation (1)) has almost no explanatory power. Removing Portugal and Turkey from the OECD sample results in a fall in the R^2 from 0.35 to 0.02.
(ii) Once outliers are excluded and regional dummies are included for all three samples, the human capital variable is no longer significant in the conditional convergence regression (equation (2)). If the OECD countries are removed from the non-oil and intermediate samples, outliers are excluded, and regional dummies are included the human capital variable becomes negatively signed and remains insignificant.
(iii) If the non-oil sample is divided into quartiles based on levels of income per capita in 1960 and the conditional convergence regression (equation (2)) is re-estimated, there is evidence of substantial variation across quartiles in the rate of convergence of income per capita towards its steady-state level

(iv) The estimated coefficient on human capital and the rate of convergence of income per capita towards its steady-state level is highly sensitive to measurement error in initial income per capita and in the conditioning variables determining steady-state income per capita.

Critique

(i) Parameter heterogeneity – the cross-section regressions fail to control for unobserved heterogeneity (fixed effects) across countries, except in so far as these are either captured by the regional dummies or dealt with by excluding some observations as outliers. See Islam (1995) and Lee, Pesaran, and Smith (1997) for panel data analyses.
(ii) The paper proposes no model of the growth process in countries classified as outliers. Indeed, the very existence of outliers may suggest that the growth model itself should be revised. By removing countries classified as outliers from the sample, one is throwing away information.
(iii) As in MRW, the rate of technological progress is assumed to be the same in all countries. Thus, in steady-state, all countries exhibit the same rate of growth of income per capita.
(iv) The paper argues that aspects of the cross-section evidence are inconsistent with the MRW model, but makes no positive suggestions as to how the model of growth can be improved.

The Tyranny of Numbers:
Confronting the Statistical Realities of the East Asian Growth Experience

Alwyn Young
1995, Quarterly Journal of Economics, 110, 2, 641-80.

Abstract

This paper documents the fundamental role played by factor accumulation in explaining the extraordinary post-war growth of Hong Kong, Singapore, South Korea and Taiwan. Participation rates, educational levels, and (excepting Hong Kong) investment rates have risen rapidly in all four economies. In addition, in most cases there has been a large intersectoral transfer of labour into manufacturing, which has helped fuel growth in that sector. Once one accounts for the dramatic rise in factor inputs, one arrives at the estimated total factor productivity growth rates that are closely approximated by the historical performance of many of the OECD and Latin American economies. While growth of output and manufacturing exports in the newly industrialising countries of East Asia is virtually unprecedented, the growth of total factor productivity in these economies is not.

Data

Various specific and highly detailed data sources for the four countries studied: Singapore, Hong Kong, Taiwan and South Korea.

Methods

The method implemented is growth accounting, whereby output growth is decomposed into factor accumulation and residual total factor productivity growth. The focus is on two aggregate inputs, capital and labour, which are subdivided into finer subcategories.
An extremely careful analysis done on a country-by-country basis, which gradually adjusts for various effects:

(1) increased participation rates
(2) non-agricultural sector - i.e. taking into account intersectoral transfers of labour
(3) actual, estimated, share of labour
(4) weighting of labour - i.e. taking into account changes in the age, sex and educational composition of the workforce and adjusting for hours of work
(5) capital deepening (expanding investment to GDP ratio)

Results

The naive estimate of total factor productivity growth of 3.4 to 4.1% per annum is gradually reduced to a mere 0.2 to 2.3%.
As to human capital accumulation, the results indicate that the improvement of educational attainment of the workforce in the NICs has contributed to about 1% per annum additional growth in labour input in each of these four countries.

Critique

An important contribution to the debate over whether fast growth rates in some countries stem from factor accumulation or productivity growth, the paper shows that the East Asian miracle countries grew mostly through input accumulation, and thus that the neo-classical growth framework can account for most differential performance of the NICs and other economies. Like all growth accounting exercises, its importance lies in highlighting the historical patterns of output growth, factor accumulation and productivity growth in the specific countries analysed. It does not try to unveil causal links, nor can this evidence be readily extended to other countries and other periods.

References

Acemoglu, D. and Angrist, J. (1999), 'How Large Are the Social Returns to Education? Evidence from Compulsory Schooling Laws', mimeo, MIT.

Aghion, P. and Howitt, P. (1998), *Endogenous Growth Theory*, MIT Press.

Angrist, J. D. and Krueger, A. B. (1991), 'Does Compulsory School Attendance Affect Schooling and Earnings?' *Quarterly Journal of Economics*, 106, pp.979-1014.

Barro, R. (1997), *Determinants of Economic Growth: A Cross-Country Empirical Study*, MIT Press: Cambridge, MA.

Barro, R. (1991), 'Economic Growth in a Cross Section of Countries', Quarterly Journal of Economics, 106, pp.407-443.

Barro, R. and Lee, J. W. (1994), 'Sources of Economic Growth', *Carnegie-Rochester Conference Series on Public Policy*, 40, pp.1-46.

Benhabib, J. and Spiegel, M. (1994), 'The Role of Human Capital in Economic Development: Evidence from Aggregate Cross-Country Data', Journal of Monetary Economics, 34, pp.143-173.

Blundell, R., Dearden, L., Meghir, C. and Sianesi, B. (1999), *The Returns from Education and Training to the Individual, the Firm and the Economy: A Review of the Theoretical and Empirical Literature*, Technical Report to the DfEE Skills Task Force, Institute for Fiscal Studies: London, 202pp.

Cameron, G., Proudman, J. and Redding, S. (1998), 'Productivity Convergence and International Openness', Chapter 6 in (eds.), Proudman, J and Redding, S, *Openness and Growth*, Bank of England, London.

Card, D. (1999), 'The Causal Effect of Education on Earnings', in Ashenfelter, O. and Card, D. (eds.), *Handbook of Labour Economics*, North-Holland: Amsterdam.

Dearden, L., Reed, H. and Van Reenen, J. (1999), 'Who Gains When Workers Train? Training and Corporate Productivity in a Panel of British Industries', Institute for Fiscal Studies, Working Paper No. W00/04.

Englander, A. S. and Gurney, A. (1994), 'Medium-Term Determinants of OECD Productivity', *OECD Economic Studies*, 22, pp.49-109.

Gemmell, N. (1996), 'Evaluating the Impacts of Human Capital Stocks and Accumulation on Economic Growth: Some New Evidence', Oxford Bulletin of Economics and Statistics, 58, pp.9-28.

Griliches, Z. (1997), 'The Simon Kuznets Memorial Lectures', draft, October.

Hall, R and Jones, C. (1999), 'Why Do Some Countries Produce So Much More Output Per Worker Than Others?', Quarterly Journal of Economics, 114, 1, pp.83-116.

Hanushek, E. A. and Kim, D. (1995), 'Schooling, Labor Force Quality, and Economic Growth', National Bureau of Economic Research Working Paper: 5399.

Islam, N. (1995), 'Growth Empirics: A Panel Data Approach', Quarterly Journal of Economics, 110, 4, pp.1127-1170.

Jenkins, H. (1995), 'Education and Production in the United Kingdom', Nuffield College, Oxford, Economics Discussion Paper No. 101.

Jorgenson, D. W. and Fraumeni, B. (1992), 'Investment in Education and U.S. Economic Growth', Scandinavian Journal of Economics, 94, S51-70.

Judson, R (1998), 'Economic Growth and Investment in Education: How Allocation Matters', Journal of Economic Growth, 3(4), pp.337-360.

Klenow, P. and Rodriquez-Clare, A. (1997), 'The Neoclassical Revival in Growth Economics: Has it Gone Too Far?', NBER Macroeconomics Annual.

Krueger, A. B. and Lindahl, M. (1998), 'Education for Growth: Why and For Whom?', mimeo, Princeton University.

Lee, K., Pesaran, M. H. and Smith, R. (1997), 'Growth and Convergence in a Multi-Country Empirical Stochastic Solow Model', Journal of Applied Econometrics, 12(4), pp.357-392.

Levine, R. and Renelt, D. (1992), 'A Sensitivity Analysis of Cross-Country Growth Regressions', American Economic Review, 82, 4, pp.942-963.

Mankiw, N. G., Romer, D. and Weil, D. N. (1992), 'A Contribution to the Empirics of Economic Growth', Quarterly Journal of Economics, pp.407-437.

Moretti, E. (1999), 'Estimating the External Return to Education: Evidence from Repeated Cross-Sectional and Longitudinal Data', mimeo, Berkeley, University of California.

Murphy, K, Shleifer, A, and Vishny, R (1991), 'The Allocation of Talent: Implications for Growth', Quarterly Journal of Economics, pp.503-530.

OECD (1998), 'Returns to Investment in Human Capital', ch.4 in *Human Capital Investment – An International Comparison*, Paris: OECD, Centre for Educational Research and Innovation.

Perraton, J. (1998), 'Debate: Education and Growth: Introduction', New Political Economy, 3(1), pp.121-123.

Prichett, L (1996), 'Where Has All the Education Gone?', World Bank Working Paper, 1581, March.

Solow, R. (1957), 'Technical Change and the Aggregate Production Function', *Review of Economics and Statistics*, 39(3), pp.312-320.

Temple, J. (1999), 'The New Growth Evidence', Journal of Economic Literature, 37, pp.112-156.

Topel, R. (1999), 'Labour Market and Economic Growth', in Ashenfelter, O. and Card, D. (eds.), *The Handbook of Labour Economics*, North-Holland: Amsterdam.

CENTRE FOR THE ECONOMICS OF EDUCATION

Recent Discussion Papers

1	A. Vignoles T. Desai E. Montado	An Audit of the Data Needs of the DfEE Centres for the Economics of Education and the Wider Benefits of Learning
2	A. Vignoles R. Leva…if J. Walker S. Machin D. Reynolds	The Relationship Between Resource Allocation and Pupil Attainment: A Review
3	S. McIntosh A. Vignoles	Measuring and Assessing the Impact of Basic Skills on Labour Market Outcomes
4	L. Dearden S. McIntosh M. Myck A. Vignoles	The Returns to Academic and Vocational Qualifications in Britain
5	C. Harmon H. Osterbeek I. Walker	The Returns to Education A Review of Evidence, Issues and Deficiencies in the Literature

To order a discussion paper, please contact the Publications Unit
Tel 020 7955 7673 Fax 020 7955 7595