Gundlach, Erich

Working Paper

Human capital and economic development : a macroeconomic assessment

Kieler Arbeitspapiere, No. 778

Kiel Institute of World Economics
Düsternbrooker Weg 120, D-24105 Kiel
Department IV

Working Paper No. 778

HUMAN CAPITAL AND ECONOMIC DEVELOPMENT:

A Macroeconomic Assessment

by

Erich Gundlach

November 1996

Human Capital and Economic Development:
A Macroeconomic Assessment

ABSTRACT

Despite abundant microeconomic level evidence, the role of human capital in economic development has not been well documented at the macroeconomic level. Up to now, many empirical macro studies lack a consistent theoretical foundation. In addition, the wide range of published results seems to result from measurement problems due to a very narrow concept of human capital focusing on formal education. Future empirical research should take into account other important determinants of human capital such as the quality of education, the experience of the workforce, and the health status and the nutritional status of the population.

JEL: O 41

Erich Gundlach
Kiel Institute of World Economics
P.O. Box 4309
D-24100 Kiel, Germany
Phone: 49 431 8814284
Fax: 49 431 8814500
E-mail: egundlach@ifw.uni-kiel.de

I. INTRODUCTION*

When asked about the major determinants of economic development in an international perspective, the average economist, or the World Bank, is likely to point to the important role of human capital formation. Taking a closer look at this common sense argument, it becomes less clear how the average economist world justify the presumed role of human capital at the macroeconomic level. The question is why one should believe in the above average importance of human capital formation in the presence of an almost endless list of other potential explanatory variables.[1] Obviously, empirical evidence is necessary to support the belief in the central role of human capital formation in economic development. But statistical correlations alone will not suffice to establish a convincing case. What is more, very often correlations between measures of human capital and measures of economic development turn out to be statistically insignificant.

To have a starting point for any serious discussion of the role of human capital in economic development, it takes a combination of an explicit theory about economic development and empirical evidence based on this theory. A useful

* For helpful comments on an earlier version, I thank the participants of the conference on "Human Capital Formation as an Engine of Growth: The East Asian Experience" which was jointly organized by the Institute of Southeast Asian Studies (ISEAS), Singapore, and the Kiel Institute of World Economics.

1 For empirical research on the determinants of economic development using long lists of explanatory variables, see, e.g., Kormendi and Meguire (1985), Levine and Renelt (1992), Levine and Zervos (1993).

theory of economic development would predict the quantitative impact of human capital formation by identifying parameters that can be measured. Applied research then has to show whether the theoretical predictions are more ore less in line with the empirical evidence. If so, the theory may be used as a framework for discussing the role of human capital formation as an engine of growth.

Over the last ten years or so, the availability of large cross-country data sets has renewed the interest of the profession in theories of economic development, labeled "new" or "endogenous" growth theory.[2] As a result of this research program, some new insights have been established, especially on the role of human capital formation in economic development. But this is not to deny that some old puzzles have remained and some new puzzles have emerged. At present, growth theory is far from being a settled issue and so is the research program that tries to assess the empirical relevance of human capital formation for an explanation of international differences in economic development.

In this paper, I try to present a brief overview of recent empirical findings. As is self evident, the scope of the paper is necessarily selective. The literature in this field has grown so rapidly that it would definitely take more than a single paper to lay out the many different views and alternative estimation results thoroughly.

---

2 The seminal papers in this field are Romer (1986) and Lucas (1988). Ever since, the literature has exploded. For recent summaries, see, e.g., Lucas (1993) and the contributions in Symposium New Growth Theory (1994).

Therefore, I will focus on my own views on the subject in order to provide a benchmark for the possible role of human capital in economic development. I begin with an outline of a basic theoretical foundation of the presumed macroeconomic role of human capital formation (section II). This theoretical framework is used for an assessment of the plausibility of recent alternative empirical findings (section III). Perspectives for further research are outlined in the last section.

II. THE NEOCLASSICAL GROWTH MODEL WITH AND WITHOUT HUMAN CAPITAL

Beginning about ten years ago, endogenous growth theories were advocated as a major improvement compared to the traditional neoclassical growth model as invented by Solow (1956).[3] With some justification, the neoclassical model was said to be not overly illuminating on the causes of persistent economic growth. Today, what comes as a surprise is that the advances in growth theory have not been matched by similar advances in empirical research based on the new theories. That is, whenever it comes to the empirics of economic growth, the basic neoclassical model still seems to be a good choice to begin with.[4] The reason is

[3] Major proponents of this view are Romer (1986), Lucas (1988), Stokey (1988), Grossman and Helpman (1991), and Young (1991), to name but a few.

[4] For example, the widely cited empirical studies of the determinants of economic growth of Hong Kong, Singapore, South Korea and Taiwan by Young (1992; 1995), one of the leading proponents of new growth theories, basically rely on the neoclassical growth accounting framework suggested by Solow (1957).

that despite its simplicity, the Solow model has many predictions with regard to the international variation in income per person. And these predictions are broadly consistent with data on factor prices given the assumption that factors of production earn their marginal products.

For instance, the most simple Solow model predicts that in the steady state, the marginal product of capital is constant and the marginal product of labor grows at the rate of technological change. Furthermore, income per person should also grow with the rate of technological change. These predictions are by and large confirmed for the United States, where the long-run growth rate of income per person equals the growth rate of real wages and the profit rate exhibits little trend.

But not all is well with the basic Solow model of economic growth. Its main weakness is that it does not consider human capital formation as a separate factor of production like physical capital and labor. Augmenting the basic model by explicit consideration of a human capital variable (Mankiw et al. 1992) substantially expands its scope and applicability. If – and only if – human capital enters as an additional factor of production, the neoclassical growth model appears to be an extremely useful instrument for studying the international variation in income per person, although it may be a bad choice for studying the ultimate causes of economic growth.

To see why this is so recall that the Solow model, pretty close to what Karl Marx would have predicted, explains international differences in income per person as the result of international differences in capital accumulation. Hence in this model, poor countries are predicted to be poor because they have less capital per worker than rich countries. Moreover, again in line with Karl Marx, the profit rate is expected to be governed the law of diminishing marginal returns. Therefore, the rate of return to capital should be higher in poor countries than in rich countries just because they have less capital. But once the rate of return to capital is higher in poor countries, one should expect a stronger incentive for capital accumulation in poor than in rich countries. This, in turn, should lead to a faster growth rate of income per person in poor countries and thus to a cross-country convergence of income per person, at least as long as the determinants of the steady state are held constant. On all three aspects, namely the magnitude of international income differences, the international rate of return differentials, and the rate of convergence, the Solow model comes up with quantitative predictions that can be compared with the empirical evidence.

To begin with, one must obviously have interpretations of the term capital and of its return. Traditionally, capital has been thought of including an economy's stock of equipment machinery and buildings, i.e. its physical capital. The rate of return to this concept of capital is the profit received by the owners of equipment machinery and buildings. These profits are part of the National Accounts Statistics. A standard figure is that in industrialized countries, physical capital accounts for about 30 percent of total factor income (Maddison 1987).

But physical capital is not the only kind of capital that can be accumulated whenever one foregoes consumption today in order to produce more income tomorrow. The acquisition of skills – both through schooling and on-the-job training – can also be considered as an important form of capital accumulation. If so, it is justified to take a much broader view of capital which includes human capital. As a consequence, the capital share that can be directly calculated from the National Accounts Statistics in likely to underestimate the true capital share of an economy.

This insight has important quantitative implications for the predictions of the neoclassical growth model regarding the rate of convergence as well as international differences in income per person and rates of return. To keep the analysis as simple as possible, consider a Cobb-Douglas production function of the form

(1) $$Y = K^{\alpha} H^{\beta} (AL)^{1-\alpha-\beta} ,$$

where Y is output, K is physical capital, H is human capital, L is labor, and A is a measure of the level of technology, so AL is a measure of the labor force in efficiency units. With the central assumptions that factors of production earn their marginal products and constant returns to scale prevail, the production elasticities for physical (α) and human (β) capital should equal the factor shares of physical and human capital in total factor income. Mankiw et al. (1992) and Mankiw (1995) show how equation (1) can be manipulated to derive expressions for the predicted change in income per person and the rate of return to physical capital, and the convergence rate. As it turns out, a broad capital share combining physical and human capital is the central parameter in all three cases.[5]

For a start, changes in income per person should follow

$$(2) \qquad \frac{\Delta(Y/L)}{Y/L} = \frac{\gamma}{1-\gamma}\left(\frac{\Delta S}{S}\right) - \frac{\Delta(n+g+\delta)}{n+g+\delta} \ ,$$

where *Y/L* is income per person, *S* is the saving rate in percent of GDP, *n* is the rate of population growth, *g* is the rate of technological progress, δ is the common depreciation rate of physical and human capital, and Δ is the first difference operator. The combined factor share of physical and human capital is represented by γ. Equation (2) can be used to show the magnitude of income differences the neoclassical model can explain. Consider first that γ equals about one third as in the model without human capital, so $\gamma/(1-\gamma)$ equals one half. In this case, leaving aside differences in population growth, the predicted difference

5 The subsequent presentation largely follows Mankiw (1995).

in income per person would be the square root of the relative difference in the saving rates. International saving rates as proxied by investment rates differ by a factor of about four (PWT 5.6) Hence international income per person is predicted to differ by a factor of two [$4^{0.5}$]. However, international income per person differs by more than a factor of ten (PWT 5.6).

The introduction of human capital helps to solve this problem. In the model with human capital, γ increases and so does the predicted difference in international income per person. E.g., if γ is about $2/3$, representing factor shares of one third each for human and for physical capital, income per person is predicted to differ by a factor of 16 [4^2]. This is roughly in line with the empirical evidence.

This reasoning is also confirmed by the implications to be derived from an assessment of international differencens in the rate of return to physical capital. The neoclassical model predicts that the return to physical capital (*r*) should vary inversely with the level of income per person:

(3) $$\Delta r / r = -\left(\frac{1-\gamma}{\sigma\gamma}\right)\frac{\Delta(Y/L)}{Y/L},$$

where σ is the elasticity of substitution between capital and labor, which equals one in case of a Cobb-Douglas production function. Equation (3) implies that the rate of return differences should be a multiple of the differences in income per person, with capital's share in factor income again being the crucial parameter. Once only physical capital is considered, with γ of one third, the model would predict enormous rate of return differentials between poor and rich economies: The rate of return to physical capital should differ by a factor of 100, if income per person differs by a factor of ten [$(1/10)^2$]. Hence, with an average profit rate of about 10 percent in rich countries, poor countries should have profit rates of 1000 percent, which is far beyond any empirical plausibility.

But with a larger capital share, the predicted rate of return differentials reduce to more reasonable figures. For instance, if physical and human capital together account for two thirds of total factor income as before, the model would predict that profit rates in poor and rich economies should differ by a factor of about 3 [$(1/10)^{0.5}$]. That is, once again the explicit consideration of human capital helps to correct the quantitative predictions of the model towards quite reasonable magnitudes.[6]

The inclusion of human capital as a third factor of production also helps to bring in line the predicted and the actually observed rate of convergence. The

6 Note that the calculated return differentials are gross of taxes and political risks. Moreover, assuming a higher elasticity of substitution than one would further reduce the predicted return differentials.

neoclassical growth model predicts that convergence towards the steady state is given by

(4) $\lambda = (1-\gamma)(n+g+\delta)$,

where λ is the rate of convergence. Numerous empirical studies have shown[7] that the value for λ appears to be about 2 percent. With standard parameterizations for the rate of population growth (*n*) of 1 percent, a rate of technological progress of 2 percent, and a depreciation rate of 5 percent (Barro et al. 1995), it again becomes clear that the model without human capital would not predict the observed convergence rate: If γ equals one third, λ is predicted to be about 5 percent. But once γ is assumed to equal two thirds due to the inclusion of human capital, the convergence rate predicted by the model comes pretty close to the observed convergence rate.

Hence, in all three cases considered, the introduction of human capital greatly improves the explanatory power of the neoclassical growth model. Overall, a broad capital share of about 70 percent appears to be a lower limit for successfully predicting observed international income differences, rate of return differences, and the speed of convergence. For industrialized countries, with a physical capital share in factor income of about 30 percent, one would, therefore,

---

[7] For a survey, see Sala-i-Martin (1996). Recent studies for large developing countries include Bajpai and Sachs (1995), Gundlach (1996a), Jian et al. (1996), and Zini and Sachs (1996).

expect a share of human capital of about 40 percent. For developing countries, with a higher physical capital share of about 60 percent (Lau et al. 1991, Gundlach 1996b), one should expect to find human capital shares of about 10 percent at least. So the question that arises naturally is whether empirical evidence actually supports the calibration exercises for human capital's share in factor income.

III. HUMAN CAPITAL'S SHARE IN FACTOR INCOME

1. Back-of-the-Envelope Calculations

The absence of appropriate data is an obvious difficulty in calculating human capital's share in factor income. Unlike the return to physical capital, the return to human capital is not a separate part of the National Accounts Statistics, but is included in labor's share in total factor income. Labor with human capital (skilled labor) and labor without human capital (unskilled labor) together account for total labor income. If either the rate of return on unskilled labor or on skilled labor were known, it would be possible to assess human capital's share in labor income. Given this information, it would be straightforward to calculate human capital's share in total factor income.

Consider first that the minimum wage has historically been about half of the average wage in the US (Pritchett 1996a). If the minimum wage is taken to reflect the return for workers with no human capital (unskilled labor), it follows that the return to human capital is about two thirds of labor income. And since labor income is about 70 percent of total factor income in the US and other industrialized countries, human capital's share in total factor income should be about 45 percent. So one ends up with a broad capital share of about 75 percent. This finding fits well into the calibration exercises of the last section.

The problem with this kind of benchmark estimate is that comparable data for other countries are difficult to come by. Especially in developing countries, the minimum wage is less enforced and less likely to be applicable and solid data are harder to obtain in any case. An alternative approach to derive a benchmark estimate is to focus on the rate of return to education and average years of schooling, thereby assuming that investment in education is the same thing or at least highly correlated with an increase in the stock of human capital. The reason for such an approach is that many empirical studies find that each year of schooling substantially raises a worker's income.[8] If so, it becomes possible to calculate the difference between incomes achieved with human capital (proxied by schooling) and without human capital.

8 For a summary of the literature on the returns to investment in education, see Psacharopoulos (1993).

For the world as a whole, a social rate of return[9] to secondary education of 13 percent and an average of 8 years of schooling have been estimated (Psacharopoulos 1993). The resulting growth impact of human capital, measured by schooling, can be calculated as average years of schooling times the rate of return to schooling raised to the power of *e*. So for the world as a whole, one would conclude that the average worker earns about three times $[e^{8 \cdot 0.13}]$ as much as he would without any human capital.

The derived average multiplier of human capital in the range of three can be replicated for various regions of the world. Regions with above average years of schooling tend to have lower than average rates of return, and regions with below average years of schooling tend to have higher than average rates of return. For instance, Sub-Saharan Africa has 5.9 years of schooling and a social rate of return to secondary education of 18.2 percent; non-OECD Asia has 8.4 years of schooling and a rate of return of 13.3 percent; Latin America has 7.9 years of schooling and a rate of return of 12.8 percent; and the OECD has 10.9 years of schooling and a rate of return of 10.2 percent.[10] The resulting multipliers are 2.93 for Sub-Saharan Africa, 3.06 for non-OECD Asia, 2.75 for Latin America, and

---

9 At the macroeconomic level, the social rate of return to education rather than the private rate has to be considered for an assessment of the role of human capital in economic development.

10 All figures are taken from Psacharopoulos (1993, Table 1 and Table 4).

3.04 for the OECD. All this is pretty close to an average multiplier in the range of three.

Hence, the international empirical evidence on the rates of return to education suggests that the income of the average worker can be expected to be three times as high with human capital than without. Therefore, human capital's share in labor income should be about two thirds, as was suggested by the calculations based on the minimum wage. By implication, human capital's share in total factor income should be about 45 percent in industrialized countries, which exhibit a profit share of about 30 percent. And in developing countries, where the profit share is about 60 percent (Lau et al. 1991; Gundlach 1996b), human capital's share in factor income should be about 25 percent. On average, one ends up with a broad capital share of about 80 percent.

These parameter values almost perfectly solve same of the puzzling implications of the traditional neoclassical growth model. As it seems, the inclusion of human capital into the model receives strong empirical support from back-of-the-envelope calculations. The natural question is whether econometric estimates of the central parameters also support the presumed role of human capital in economic development.

2. Econometric Estimates

As an alternative to back-of-the-envelope calculations, the production elasticity of human capital can be estimated by regression analysis. Under competitive output and input markets, the assumption of profit maximization implies that the production elasticity of human capital is equal to human capital's share in factor income. So the estimation of production functions provides a relatively straightforward way to assess the empirical relevance of human capital formation in economic development.

Somewhat surprisingly, at the aggregate, macroeconomic level, the effect of human capital formation on output has not been well documented, contrary to the abundance of microeconomic level empirical evidence.[11] Only recently, this is beginning to change, with mixed results. Very often, the variable used to proxy human capital formation is found to have a relatively small or even statistically insignificant impact on output. This result has led some researchers (Pritchett 1996b) to question the empirical relevance of human capital accumulation as an engine of growth. However, a closer look at the statistical problems involved should help to avoid some pitfalls in interpreting the results of empirical production function studies. Such pitfalls can easily lead to a rejection of a correct hypothesis.

---

[11] For a summary of the micro evidence see Schultz (1993).

Econometric Pitfalls

The multicollinearity of the data on the inputs is one reason why the effect of human capital formation is frequently found to be statistically insignificant in aggregate production function studies. For instance, physical and human capital stock data are likely to be highly correlated due to common trends. As a consequence, it is difficult if not impossible to identify the separate effects of physical and human capital using time series data from a single country.

Eliminating the trend by estimation in first differences is an often used remedy that is, however, unlikely to deliver convincing results. If the underlying production function is a cointegrating relationship, it should be estimated in levels rather than in first differences, especially if the long-run parameters are of interest (Fugle and Granger 1987). Put differently, estimation in first differences would imply that the underlying production function does not describe variables that tend to move together in the long-run, i.e. are cointegrated. But if the variables on the right-hand-side of the production function are not cointegrated, there simply is no production function and, therefore, production elasticities cannot be estimated. So the problem with time series estimation of a production function is that estimation in levels tends to produce statistically unconvincing results, whereas estimation in first differences may produce seemingly convincing results, but is neither supported by statistical nor by economic theory.

Fortunately enough, large international data sets have become available such as the Penn World Tables (PWT) introduced by Summers and Heston (1984); the most recent update is PWT 5.6 (1994). These data sets allow for a study of the empirics of growth in a cross-country setting, thereby avoiding the pitfalls of time series analysis. Nevertheless, the problem of multicollinearity can also arise in cross-country data, sometimes in an even more subtle way. For instance, high growth countries generally have higher investment rates, higher schooling rates, and lower population growth rates than poor countries. Multicollinearity reduces the precision with which regression coefficients can be estimated, which may again be the reason for the finding of a statistically insignificant output effect of human capital formation. But multicollinearity per se does not contaminate the inference drawn from cross-country data because it does not bias the regression coefficients and the standard errors. Therefore, multicollinearity might not seem like a problem as long as the reported standard errors of the regression coefficients are small. However, multicollinearity becomes a severe problem if it occurs in combination with measurement error (Mankiw 1995).

It is a standard econometric result that measurement error tends to bias downward the coefficient on the variable measured with error. And at the same time, it can bias upward the coefficients on variables correlated with the variable measured with error. Therefore, if variables used to measure human capital formation are more likely to be measured with error than others, downward biased regression coefficients on human capital variables will be the result, as well as upward based regression coefficients on variables correlated with the human capital variable. To see that this is a likely possibility, consider how capital stock data are usually calculated, which are required for the estimation of the structural form of the production function .

Capital stock data are usually calculated by the perpetual inventory method. This method requires a benchmark estimate for the capital stock of the initial period considered. Since initial capital stocks are generally unknown, the conventional procedure is to assume a benchmark value of zero for the first year of investment accumulation. With an assumed depreciation rate of 5 percent, the capital stock depreciates totally in about 20 years. Therefore, assuming a capital stock of zero for the benchmark year does not matter for empirical analyses that use capital stock data beginning about 20 years after the benchmark year used for the construction of the capital stock data series.

What seems to be a relatively reliable procedure for the construction of physical capital stocks is in fact more complicated for the case of human capital stocks. This is because of the time lag between investment (school enrollment) and addition to the human capital stock (entry into the labor force), as well as because of the presumed longer durability of human capital compared to physical capital (Lau et al. 1991). Hence, longer backward time series of investment in human capital are needed in order to derive stock data of comparable quality. Once such longer time series are available at all, one has to assume how depreciation, mortality, and migration may influence the country specific calculations. As a result, human capital stock data calculated by the perpetual inventory method are more likely to exhibit larger measurement errors than physical capital stock data. If so, regression coefficients on human capital stock variable should tend to be *downward* biased; and in the presence of multicollinearity, regression coefficients on physical capital stock variables should tend to be upward biased.

As a further complication, the bias could also go the other way round. The reason is the simultaneity problem that is prevalent in almost every regression analysis: The right-hand-side variables cannot be known to be exogenous regressors. This also holds for the human capital variable. For instance, based on panel and time series data describing the green-revolution period in India, Foster and Rosenzweig (1996) find empirical support for an endogenous role of human capital formation. If human capital is actually an endogenous variable, OLS estimation will produce an *upward* biased regression coefficient. A priori, it is difficult to tell which of the possible biases is likely to dominate.

Alternative Estimation Approaches

Conceding the danger of unjustified oversimplification, I consider three types of empirical macroeconomic studies that have been performed recently to study the role of human capital in economic development:

– Convergence rate regressions, where the growth rate of output per person is regressed on initial output per person and a sometimes long list of right-hand-side variables, including human capital,

– structural form regressions, where output per person is regressed on the *stocks* of physical and human capital, sometimes complemented by further auxiliary variables, and

– reduced form regressions, where output per person is regressed on the rate of population growth and on the *investment rates* of physical and human capital.

All these possibilities are more or less explicitly based on a production function like equation (1). They are not exclusive, because structural form specifications can easily be translated into reduced form specifications, either partially or completely, and convergence rate specifications can be considered as an approximation around the steady state determined by a production function like equation (1). However, these approaches differ in the interpretation of the estimated regression coefficients and in the extent to which possible econometric pitfalls can arise. As a general rule, all sorts of problems tend to increase if the equation to be estimated is not rigorously based on a production function.

Convergence rate regressions have been popularized in an influential study by Barro (1991) and are, therefore, often referred to as Barro-regressions. In my view, Barro regressions cannot lead to convincing empirical results, simply because too many variables are included. The problem is that the more variables are included on the right-hand-side of the regression equation, the less clear becomes the underlying production function. E.g., it may be intuitively plausible to include in the regression equation proxy variables for political stability (Barro 1991), openness (Sachs and Warner 1996), or the income distribution (Rodrik 1994). Nevertheless, it remains unclear which factor of production should account for the factor income generated by such variables. Whenever auxiliary variables enter the regression analysis in addition to the variables suggested by the theory of production or by growth theory, it follows that they should also have a production elasticity, at least unless something else is suggested by an alternative theoretical formulation. Once such a formulation is missing and factor accumulation is already accounted for by the inclusion of physical and human capital, the residual role for characteristics obviously correlated with investment rates appears to be rather limited.[12]

Put differently, once the list of right-hand-side variables is no longer based on an explicit production function context, it is no longer possible to recover the production elasticities from the estimated regression coefficients. Therefore, the interpretation of Barro-regressions results has to rely on the statistical significance of regression coefficients, rather than on their economic significance. Not surprisingly, Levine and Renelt (1992) have shown that Barro regressions deliver highly unstable results depending on the set of right-hand-side variables included. My conclusion from these exercises is that without a clear-cut theoretical foundation of the equation to be estimated, it is impossible to establish the empirical relevance or irrelevance of any variable supposed to determine economic development, say human capital formation. Just running a regression and looking for high *t*-values will not suffice as a proof of the pudding.

In contrast to results of Barro-regressions, the regression coefficient, say, on the human capital variable can be predicted in quantitative terms if the underlying production function is well specified. That is, the main, and possibly, only

[12] Maybe it would be more useful to include auxiliary variables in a two-stage model of economic growth which tries to answer the ultimate question why international saving rates (and investment rates) differ. In the neoclassical model, this variation is taken to be exogenous.

approach to testing the presumed productivity effect of human capital variable, however proxied, is to include it as a separate variable in a well-specified production function (Griliches 1996). To be more specific, consider the case of a Cobb-Douglas production function. Once a structural equation like

$$(5) \qquad \ln Y = \alpha \ln K + \beta \ln H + (1 - \alpha - \beta) \ln(AL)$$

is used, α and β are the production elasticities of physical all human capital to be estimated directly as the regression coefficients. Once a reduced form (see Mankiw et al. 1992) like

(6)

$$\ln(Y / L) = B - \frac{\alpha + \beta}{1 - \alpha - \beta} \ln(n + g + \delta) + \frac{\alpha}{1 - \alpha - \beta} \ln INV_K + \frac{\beta}{1 - \alpha - \beta} \ln INV_H ,$$

is used,[13] the production elasticities can be recovered from the regression coefficients on the investment rates of physical (INV_K) and human capital (INV_H).

The principal attractiveness of these equations for regression analysis results from two features. First, there are restrictions on the regression coefficients that can be imposed and tested. This property allows for a statistical evaluation of the estimation results beyond simple *t*-statistics of the regression coefficients.

---

13 *Y/L* is output per person, *B* is a regression constant representing the initial level of technology and the assumed constant growth rate of technology, INV_K is investment in physical capital and INV_H is investment in human capital.

Second, for constant returns to scale and competitive factor markets, the production elasticities should equal the respective factor shares. This property allows for an economic evaluation of the estimation results by comparing the size of expected and realized regression coefficients. Put differently, any macroeconomic assessment of the role of human capital in economic development would use factor shares for physical and human capital as benchmark figures for an economic evaluation of the estimated production elasticities. Hence, even in the presence of statistically significant regression coefficients, one may conclude that certain results do not make sense economically.

Selected Empirical Results

In a rather influential study, Benhabib and Spiegel (1994) use a variant of the structural form of the production function (see equation 5) to estimate the role of human capital for a sample of industrialized and developing countries. They report that in such a specification, the regression coefficient on human capital turns out to be statistically insignificant and sometimes even enters with a negative sign. In order to obtain a more positive role for human capital formation, they suggest an alternative growth model. In this new model, human capital externalities can be considered to be embodied in new physical capital (technology import) or in subsequent advances in knowledge, as suggested in the models of Lucas (1988) and Romer (1990). Their empirical results seem to suggest that the role of human capital is indeed one of facilitating adoption of technology from abroad and creation of appropriate domestic technologies rather than entering on its own as a separate factor of production.

But their model has an unpleasant implication. If it holds, the estimated production elasticity of physical capital should be much larger than its factor share. But it is not: the estimated regression coefficient of physical capital is pretty close to its expected factor share in the range of 30 percent. Therefore, some doubts remain as to the usefulness of the new model. Measurement error may be a simple alternative explanation for the initial finding of a statistically insignificant impact of human capital formation on economic growth. The human capital variable used is school enrollment data accumulated by the perpetual inventory method with a rather small number of benchmark estimates for intervening years (see Kyriacou 1991). Recently, a much improved international data set for average years of schooling has been provided by Barro and Lee (1994). These data are likely to provide better proxies for the stock of human capital than previous data sets.

Similar to Benhabib and Spiegel (1994), Lau et al. (1991) estimate a variant of the structural form of the production function. They relate aggregate real GDP to physical capital stock, labor force, land, and average education of the labor force as a proxy for the stock of human capital. For a sample of developing countries, they find production elasticities of physical capital of about 60 percent, but relatively small production elasticities of human capital in the range of 2 percent for various specifications. Once they allow for region specific effects, their estimates for the production elasticity of human capital increase to 20 percent for Latin America and East Asia. Together with the estimate of the production elasticity of physical capital, the latter results imply a broad capital share of about 80 percent as expected. Hence, it is tempting to conclude that measurement error is likely to be a more severe problem for developing countries in other regions than Latin America and East Asia.

Again based on a variant of the structural form of the production function, Kim and Lau (1992) find production elasticities of physical capital for industrialized countries which are close to conventional factor shares. However, the estimated production elasticities of human capital turn out to be rather small, covering a range from 10 percent (United States) to 20 percent (Japan). Applying the same approach to cross-sectional state data from Brazil, Lau et al. (1993) find a production elasticity of human capital of about 20 percent, which is in the expected range for a developing country. But this time, their estimate for the production elasticity of physical capital of about 10 percent is on the low side.

Taken together, macroeconomic studies based on the structural form of the production function seem to deliver highly unstable results. Simultaneity problems, multicollinearity, and measurement error, or, even worse, a combination of these can explain this unsatisfactory outcome. Estimation based on the reduced form of the production function promises relief, at least in principle.

Mankiw et al. (1992) is the seminal paper using a reduced form of the production function (see equation 6) to estimate production elasticities of physical and human capital. In an international cross-country analysis, they find production elasticities for both human and physical capital of about one third. Although these estimates may still suffer from all sorts of econometric problems, they obviously do less so than the previously presented estimates. To begin with, according to the underlying neoclassical growth theory as suggested by Solow (1995), the investment rate is assumed to be exogenous, so no simultaneity problem arises as long as the theory is correct. By implication, the stock variables used in the structural form (see equation 5) are necessarily endogenous if the Solow model is right. This is why reduced form estimation should be preferred, at least as long as appropriate instruments for the endogenous variables are notoriously difficult to come by at the macroeconomic level. Moreover, measurement error is likely to play a smaller role because investment rates (flows) are somewhat easier to measure than accumulated stock variables. And if measurement error is less likely to be a problem, so is multicollinearity, at least in a cross-country context.

Therefore, the estimated broad capital share of about two thirds can be considered as a rough confirmation of the underlying neoclassical model of economic growth. This is not to deny that the estimate for the production elasticity of human capital seems to be somewhat on the low side. Using a specification that combines the structural and reduced form representation with the stock of human capital rather than investment in human capital as a right-hand-side variable, I find that human capital's share in factor income is about two thirds rather than one third (Gundlach 1995). The results of alternative estimation techniques reveal that my finding does not suffer from an upward bias due to the potential endogeneity of the stock of human capital. At the same time, the Mankiw et al. finding does not seem to suffer from downward bias due to measurement error. This outcome has led me to suggest an alternative growth model which is capable of explaining both sets of results. However, an unpleasant implication turns up again. If human capital has a factor share of two thirds and physical capital has a factor share of one third, one ends up with a broad capital share of 100 percent. This total capital share is not compatible with observed rates of (conditional) convergence (see section II).

Another extension of the Mankiw et al.-framework is suggested by Gemmel (1996) who uses an alternative measure of human capital formation and finds that initial stocks *and* subsequent growth of human capital play a role in fostering faster economic growth. However, the theoretical foundation of the underlying regression equation remains somewhat unclear. If both the stock and the flow of human capital are included in the regression equation, as could be motivated by endogenous growth models such as Romer (1990), it is no longer clear what kind of growth model is actually estimated. But if the model to be estimated is not known a priori, the reported regression coefficients cannot be interpreted in economic terms. Accordingly, Gemmel (1996) evaluates his findings solely on the basis of statistical significance. Yet statistically significant regression coefficients are not necessarily meaningful from an economic point of view even if they have the right sign. Here, the estimated regression coefficients on initial income provide a case in point, because they have a negative sign and are statistically different from zero. Unfortunately, they are larger than 1 in absolute value. This result is incompatible with the rate of convergence predicted by the neoclassical growth model. Therefore, this model cannot be used as a justification for the specification of the regression equation. But if an endogenous growth model is used, initial income should have a positive regression coefficient or may not enter the regression equation at all.

Knight et al. (1993) use the Mankiw et al.-framework to employ a technique for using a panel of cross-section and time series data for a large number of countries. This technique allows them to determine the quantitative impact on economic growth of both country-specific and time-varying factors. Their most preferred regression results imply a physical capital share of about 40 percent and a rather small factor share of human capital in the range of 20 percent, thereby reproducing a broad capital share of about 60 percent close to the Mankiw et al. (1992) finding.

Still, it remains unclear whether the move from cross-sectional to panel data actually improves the estimates. This is because the amount of statistical information being added is not obvious, despite an increase in the number of observations (Mankiw 1995). The reason is that the new observations are not independent of the old ones. While this problem may be handled by appropriate estimation techniques, the question arises how business-cycle effects can be distinguished from growth effects in panel data. This distinction is important because determinants of long-run growth such as investment rates strongly fluctuate over the business cycle.

Also based on a reduced form specification in the tradition of Mankiw et al. like equation (6), I estimate production elasticities of human and physical capital for a sample of 29 Chinese provinces (Gundlach 1996a). After controlling for simultaneity bias and possible measurement error by instrumental variables estimation and an error-in-variables model, I find a production elasticity of human capital in the range of 60 percent and a production elasticity of physical capital of about 25 percent. As it turns out, these production elasticities can explain the observed 2 percent rate of convergence of output per person across Chinese provinces. Nevertheless, a human capital share of about 60 percent for a developing country like China somehow comes as a surprise.

On balance, it seems to me that the econometric results do not allow for a clear-cut assessment of the role of human capital in economic development at the macroeconomic level. The results that come closest to a priori expectations share two properties. First, a specification of the regression equation that is rigorously based on the underlying theory, and, second, a functional form of the regression equation that tends to reduce econometric problems. While the findings for the production elasticity of physical capital come close to conventional factor shares, the findings for the production elasticity of human capital tend to be on the low side in most cases. An apparent reason for this result is measurement bias.

IV. PERSPECTIVES FOR FUTURE RESEARCH

Up to now, the evidence at the macroeconomic level is largely based on measures of formal education as a proxy for human capital formation. But one has to keep in mind that not all education produces human capital and, even more importantly, not all human capital is produced by education (Knight 1996). What has been neglected so far are, e.g., international differences in the quality of education, the impact of learning on the job (experience) as compared to formal schooling, and the role of nutrition and health as preconditions for a successful accumulation of human capital. Once systematic international evidence on these factors becomes available, it should be possible to improve the estimates of the macroeconomic role of human capital formation in economic development. First research efforts in these directions come up with encouraging results.

A challenging problem for measures of average years of schooling comes from the lack of adjustment for extent and quality of schooling. Typical school years vary from under 100 days to over 200 days. And even holding constant school days, it is quite obvious that a year of secondary schooling, say, in Japan is not equivalent to a year at the same grade level in, say, Tanzania. Given these variations, it would be somehow surprising to find that average years of schooling completed is a good proxy for the amount of human capital of the labor force: The quality of schooling seems to matter. But the quantitative measurement of school quality has proved to be a difficult and controversial issue, especially when it comes to international comparisons. This is mainly because standard measures of schooling quality based on inputs such as pupil-teacher ratios, class size, and teacher characteristics apparently do not effectively explain the cognitive achievement of students and their linkage to future labor market performance has also been questioned (Hanushek and Kim 1995).

As an alternative to conventional measures of schooling input, Hanushek and Kim (1995) construct a new measure of international schooling quality based on student cognitive performance in various standardized tests of academic achievement. The constructed index is based on six international tests to assess student achievement in the fields of mathematics and science. Four of these tests were administered by the International Association for the Evaluation of Educational Achievement (IEA) and two by International Assessment of Educational Progress (IAEP). Combining all the information available on mathematics and science scores for each category, the final sample consists of 39 observations. Including this measure of labor force quality into a Barro-regression (see section III), Kim and Hanushek find that the quality variable has a statistically significant positive impact on the rate of economic growth. Based on a different specification of the Barro-regression, the same finding is also reported by Lee and Lee (1995), who use a smaller sample of 17 observations based on international test scores of student achievement in science only. These results point to the potential usefulness of variables measuring international differences in the quality of education. Nevertheless, up to now it has not been explored whether the reported regression coefficients stand up to a meaningful economic interpretation.

Since the work of Becker (1964) and Mincer (1974), both schooling and experience of workers have been considered as major determinants of individual human capital formation. Hence along with the quality of schooling, a comprehensive measure of human capital should also include the experience gained by learning on the job. This experience is usually proxied by the age structure of the workforce. In a seminal paper, Krueger (1968) uses this insight to calculate that part of observed international income differences which can be accounted for by difference in the stock of human capital as measured by education and experience. With data for the 1950, she finds that more than half the difference in income per person between the United States and a sample of developing countries can be explained by differences in the stock of human capital.

These results can be interpreted as giving the maximum income attainable for a worker from a developing country if he or she were working with the average physical capital endowment of a US worker, leaving the remaining income difference to be explained by differences in human capital. From the production function context outlined in section II, it follows that these income figures have the dimension of the relative (to the US) human capital stocks raised to the power of labor's share. By implication, it becomes possible to calculate an aggregate stock of human capital that represents both schooling and experience of the workforce.

Such a broader measure of human capital can be compared with the estimates based on schooling alone that have been used in the regression analyses referred to in section III. With data for the 1980s, I show that there are substantial differences between the two types of estimates with regard to level and variance across countries (Gundlach 1994). Especially the estimates for average years of schooling by Kyriacou (1991) and Lau et al. (1991) deviate from my figures derived by the Krueger-method, while the estimates by Barro and Lee (1994) differ by less. As a consequence, macroeconomic studies that use the Kyriacou-data or the Lau et al.-data as a proxy for human capital could be more likely to find small or statistically insignificant regression coefficients on the human capital variable than studies that use the Barro and Lee-data. To substantiate this hypothesis, further research should extend and update the sample of countries for which the estimated stock of human capital includes a measure of experience.

Another possible bias in the measurement of the stock of human capital could result from the neglect of international differences in the health status and basic nutrition of the workforce. This is because many empirical micro studies show that health status and nutrition are strongly associated with educational achievement.[14] Hence health status and nutrition should be considered as further factors that determine the aggregate stock of human capital together with the quality of schooling and the experience of the workforce. However, quantitative findings about the effect of health and nutrition on schooling success are difficult to come by empirically, because statistical association per se does not indicate the direction of causality. Put differently, investing in health and the current nutritional intake are probably not predetermined before education and labor productivity, at least once redistribution within the family is taken into account. That is, if present earnings determined by individual education and labor productivity are used partly to improve health or nutrition, then it will be difficult to find instrumental variables to disentangle only the one-way effect of health and nutrition on labor productivity. Moreover, measurement errors in health status and nutrition may be a similar problem as with education (Schultz 1993).

14 For a recent survey, see Behrman (1996).

One possibility to address these problems at the macroeconomic level is suggested by recent work of economic historians,[15] which shows a remarkable growth in the height of the average person in Western European populations in recent centuries. Height is believed to be largely determined by nutritional status of the individual before reaching age four. If so, height can be viewed as an indicator of nutritional status and health status that is essentially fixed in early childhood. Therefore, it may be treated as an exogenous variable for an explanation for the adult's productivity.

Based on this reasoning, Fogel (1990) argues that the improvement in diet that contributed to the increase in adult height is responsible for a third of the growth of labor productivity in Western Europe from 1750 to 1980. The implication of these findings for today's poor countries is that childhood stunting due to malnutrition has a long reach, predicting chronic disease rates at young adult and later ages, with negative consequences for average productivity growth. First empirical studies of low-income countries indeed confirm a strong relationship between individual incomes and height (Thomas and Strauss 1992). All this seems to indicate that the observed gains in stature and longevity are responsible for some portion of modern economic growth, both in developing countries and in industrialized countries. Nevertheless, research on this topic has not yet

---

[15] For recent overviews, see Fogel (1994) and Steckel (1995).

reached a stage that would allow for detailed quantitative assessments. Further research on long-run changes in adult height as a determinant of labor productivity promises high rewards, especially for developing countries.

Taken together, substantial statistical improvements seem to be necessary before the role of human capital can be appropriately evaluated at the macroeconomic level. International differences in the quality of schooling, the experience of the workforce, the nutritional status, and the health status all point to possible measurement errors that are likely to arise when only the quantity of formal education is used as a proxy for human capital. The results of a number of recent econometric studies based on such inferior estimates of human capital indicate that there is ample room for an improvement of the empirical estimates. In the meantime, economic theory has to carry the bulk of the argument which favors the view that human capital formation is one of the most important determinants of economic development.

REFERENCES

Bajpai, Nirupam, Jeffrey D. Sachs (1995). Trends in Inter-State Inequalities of Income in India. Harvard University, mimeo.

Barro, Robert J. (1991). Economic Growth in a Cross Section of Countries. Quarterly Journal of Economics 106: 407-443.

Barro, Robert J., Jong-Wha Lee (1993). International Comparisons of Educational Attainment. Journal of Monetary Economics 32: 363-394.

Barro, Robert J., N. Gregory Mankiw, Xavier Sala-i-Martin (1995). Capital Mobility in Neoclassical Models of Economic Growth. American Economic Review 85 (1): 103-115.

Becker, Gary S. (1964). Human Capital. A Theoretical and Empirical Analysis with Special Reference to Education. National Bureau of Economic Research. New York.

Behrman, Jere R. (1996). The Impact of Health and Nutrition on Education. World Bank Research Observer 11: 23-27.

Benhabib, Jess, Mark M. Spiegel (1994). The Role of Human Capital in Economic Development: Evidence from Aggregate Cross-Country and Regional U.S. Data. Journal of Monetary Economics 34: 143-173.

Engle, Robert F., Clive W. Granger (1987). Co-Integration and Error Correction: Representation, Estimation, and Testing. Econometrica 55: 251-276.

Fogel, Robert W. (1990). The Conquest of High Mortality and Hunger in Europe and America: Timing and Mechanisms. NBER Working Paper Series on Historical Factors in Long Run Growth, 16.

Fogel, Robert W. (1994). Economic Growth, Population Theory, and Physiology: The Bearing of Long-Term Processes on the Making of Economic Policy. American Economic Review 84 (3): 369-395.

Foster, Andrew D., Mark R. Rosenzweig (1996). Technical Change and Human Capital Returns and Investments: Evidence from the Green Revolution. American Economic Review 86 (4): 931-953.

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

Griliches, Zvi (1996). Education, Human Capital and Growth: A Personal Perspective. Harvard Institute of Economic Research, Discussion Paper, 1745, January.

Grossman, Gene M., Elhanan Helpman (1991). Innovation and Growth in the Global Economy. Cambridge, MA.

Gundlach, Erich (1994). Accounting for the Stock of Human Capital: Selected Evidence and Potential Implications. Weltwirtschaftliches Archiv 130: 350-374.

Gundlach, Erich (1995). The Role of Human Capital in Economic Growth: New Results and Alternative Interpretations. Weltwirtschaftliches Archiv 131: 383-402.

Gundlach, Erich (1996a). Solow Meets Market Socialism: Regional Convergence of Output per Worker in China. Kiel Institute of World Economics, Working Paper, 726, February.

Gundlach, Erich (1996b). Openness and Economic Growth in Developing Countries. Kiel Institute of World Economics, Working Paper, 749, June.

Hanushek, Eric A., Dongwook Kim (1995). Schooling, Labor Force Quality, and Economic Growth. NBER Working Paper, 5399. December.

Jian, Tianlun, Jeffrey D. Sachs, Andrew M. Warner (1996). Trends in Regional Inequality in China. NBER Working Paper, 5412, January.

Kim, Jong-Il, Lawrence J. Lau (1992). Human Capital and Aggregate Productivity: Some Empirical Evidence from the Group-of-Five Countries. Stanford University, September (mimeo).

Knight, John (1996). Human Capital in Economic Development. Editorial Introduction. Oxford Bulletin of Economics and Statistics 58: 5-8.

Knight, Malcolm, Norman Loayza, Delan Villanueva (1993). Testing the Neoclassical Theory of Economic Growth: A Panel Data Approach. IMF Staff Papers 40: 512-541.

Kormendi, Roger C., Philip G. Meguire (1985). Macroeconomic Determinants of Growth. Cross-Country Evidence. Journal of Monetary Economics 16: 141-163.

Krueger, Anne O. (1968). Factor Endowments and Per Capita Income Differences Among Countries. Economic Journal 78: 641-659.

Kyriacou, George A. (1991). Level and Growth Effects of Human Capital: A Cross-Country Study of the Convergence Hypothesis. New York University, May (mimeo).

Lau, Lawrence J., Dean T. Jamison, Frederic F. Louat (1991). Education and Productivity in Developing Countries. World Bank, Policy Research Working Papers, 612, March.

Lau, Lawrence J., Dean T. Jamison, Shu-Cheng Lin, Steven Rivkin (1993). Education and Economic Growth. Some Cross-Sectional Evidence from Brazil. Journal of Development Economics 41: 45-70.

Lee, Doo Won, Tong Hun Lee (1995). Human Capital and Economic Growth. Tests Based on the International Evaluation of Educational Achievement. Economics Letters 47: 219-225.

Levine, Ross, David Renelt (1992). A Sensivity Analysis of Cross-Country Growth Regressions. American Economic Review 82: 942-963.

Levine, Ross, Sara Zervos (1993). Looking at the Facts. What We Know about Policy and Growth from Cross-Country Analysis. American Economic Review, Papers and Proceedings 83: 426-430.

Lucas jr., Robert E. (1988). On the Mechanics of Economic Development. Journal of Monetary Economics 22: 3-42.

Maddison, Angus (1987). Growth and Slowdown in Advanced Capitalist Economies. Techniques of Quantitative Assessment. Journal of Economic Literature 25: 649-698.

Mankiw, N. Gregory (1995). The Growth of Nations. Brookings Papers on Economic Activity (1): 275-326.

Mankiw, N. Gregory, David Romer, David N. Weil (1992). A Contribution to the Empirics of Economic Growth. Quarterly Journal of Economics 107: 408-437.

Mincer, Jacob (1974). Schooling, Experience, and Earnings. National Bureau of Economic Research. New York.

Penn World Table (PWT) 5.6 (1994). Read-only file maintained by the NBER, Cambridge, MA.

Pritchett, Lant (1996a). Population Growth, Factor Accumulation, and Productivity. World Bank, Policy Research Working Papers, 1567, January.

Pritchett, Lant (1996b). Where Has All the Education Gone? World Bank, Policy Research Working Papers, 1581, March.

Psacharopoulos, George (1993). Returns to Investment in Education. A Global Update. World Bank, Policy Research Working Papers, 1067, January.

Rodrik, Dani (1994). King Kong Meets Godzilla: The World Bank and *The East Asian Miracle*. CEPR Discussion Paper, 944, April.

Romer, Paul M. (1986). Increasing Returns and Long-Run Growth. Journal of Political Economy 94: 1002-1037.

Romer, Paul M. (1990). Endogenous Technological Change. Journal of Political Economy 89 (5,2): 71-102.

Sachs, Jeffrey D., Andrew Warner (1995). Economic Convergence and Economic Policies. NBER Working Paper, 5039, February.

Sala-i-Martin, Xavier (1996). The Classical Approach to Convergence Analysis. Economic Journal 106: 1019-1036.

Solow, Robert M. (1956). A Contribution to the Theory of Economic Growth. Quarterly Journal of Economics 70: 65-94.

Solow, Robert M. (1957). Technical Change and the Aggregate Production Function. Review of Economics and Statistics 39: 312-320.

Schultz, T. Paul (1993). The Role of Education and Human Capital in Economic Development: An Empirical Assessment. In: Horst Siebert (ed.), Economic Growth in the World Economy. Symposium 1992. Tübingen: 145-164.

Steckel, Richard H. (1995). Stature and the Standard of Living. Journal of Economic Literature 33: 1903-1940.

Stokey, Nancy L. (1988). Learning by Doing and the Introduction of New Goods. Journal of Political Economy 96: 701-717.

Summers, Robert, Alan Heston (1984). Improved International Comparisons of Real Product and Its Composition: 1950-80. Review of Income and Wealth 30 (2): 207-262.

Symposium New Growth Theory (1994). Journal of Economic Perspectives 8: 3-72.

Thomas, Duncan, John Strauss (1992). Health, Wealth and Labor Market Outcomes of Men and Women: Evidence from Brazil. Paper presented at the

Conference on Women's Human Capital and Development, Bellagio, Italy (mimeo).

Young, Alwyn (1991). Learning by Doing and the Dynamic Effects of International Trade. Quarterly Journal of Economics 106: 369-405.

Young, Alwyn (1992). A Tale of Two Cities: Factor Accumulation and Technical Change in Hong Kong and Singapore. In: Oliver Blanchard and Stanley Fischer (eds.). NBER Macroeconomics Annual 1992. Cambridge, MA: 13-54.

Young, Alwyn (1995). The Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Growth Experience. Quarterly Journal of Economics 110: 641-680.

Zini jr., Álvaro Antônío, Jeffrey D. Sachs (1996). Regional Income Convergence in Brazil. April (mimeo).