2. Literature on the relation between human capital and economic growth: definitions and problems

1. INTRODUCTION

Human capital is one of the big unknowns of research on the determinants of economic development. The majority of empirical and theoretical literature suggests the existence of a relationship between social indicators and economic growth. Human capital is deemed an important and special component of social development, which can be accumulated and probably has external effects. Another important aspect of human capital is that it can be quantified.

For any empirical research into the relationship between human capital and economic development, one needs to assess the possibilities of gaining knowledge about human capital either by using proxies or by estimation methods. These options will be discussed in section 2. Even when one has the necessary data, it remains an important question how to use these in empirical specifications, that is, how they can be related to theoretical constructions. This is what we focus on in section 3. In section 4, we offer a definition of human capital that we will adhere to in the rest of this thesis. Finally, section 5 deals with the effect of institutional changes on the relationship between human capital and economic growth.

2. AN OVERVIEW OF HUMAN CAPITAL MEASURES

2.1 Broad measures of human capital in economic historical research

The notion of human capital arose out of the awareness that physical capital alone was not enough to explain long run growth. Many social indicators such as educational enrolments and life expectancy became combined in a common term: human capital. Often, human capital is implicitly referred to as formal and informal education. Yet, it can also contain factors such as the costs of raising children, health costs, and ability.

Human capital became especially popular in historical research after the rise of growth theory in the 1950s and the human capital theory advocated by Becker (1964) and Schultz (1961). Yet, historians already used human capital, education, or skills in their work before that period. As Nakamura (1981, 263) remarks: ‘Historians, from the time that they began to ply their trade, have tended to feature the human factor as the central and critical instrument for the achievement of progress and the betterment of life.’ Yet, in the period before the 1950s, historians generally included human capital in a very general way in their research. In these works it is often referred to as either literacy or skills (see for example Cipolla 1969; Houston 1983).

Following the human capital revolution in the 1960s, however, a dichotomy took place in historical research. Historians researching pre-modern economies remained with their old proxies[20] because no better were available. In research focusing on modern economies (the late nineteenth and the twentieth centuries), historians and economist used mostly the same proxies.

The definitions of human capital applied by historians of pre-modern economies remained very broad. For example Nakamura (1981, 265), for pre-modern Japan, defines human capital broadly as 'labor skills, managerial skills, and entrepreneurial and innovative abilities-plus such physical attributes as health and strength'. Newland and San Segundo (1996, 699) also use several measures as indicators of human capital of slaves in Peru and La Plata in the eighteenth century such as physical strength and skills. As such they see human capital on the one hand as ability and education of an individual and, on the other, as the costs of physically raising a child or its health. Some exceptions to this broad definition of human capital in historical research for the pre-modern period come from more quantitatively oriented economic historians (Sandberg 1979; Rosés 1998; Van Zanden 2004; Reis 2005). For example Van Zanden (2004, 11-15) measures the price of human capital as the relative wage of skilled labourers such as carpenters and bricklayers compared with unskilled labour. This measure, which includes factors such as on the job training and experience is the same as used by Rosés (1998) while Reis and Sandberg (1979, 225) restrict their definition largely to literacy thus also ignoring for example ability and experience.[21]

After the rise of the growth theory and the human capital proxies in the 1950s and 1960s, in much historical research focusing on the late nineteenth and early twentieth century models including human capital in some form were also estimated. These studies tend to narrow[22] the scope of human capital proxies, first to better resemble the ones used by economists and, second, to make appropriate use of the available data. There are many examples of such analyses. To name just a few, Ljungberg (2002) uses enrolment and expenditure on education to look at the causality between education and growth in Sweden

[20] Of course, literacy is still much used as more comprehensive human capital measures are still hard to get by.
[21] It is interesting that many studies which, before the 1970s used terms like 'literacy' and 'skills', started to use the term 'human capital' for the same variables. Examples before 1965 are Smith (1952, 7) who points at the importance of education for the richer peasants in Japan during the Tokugawa period and Eckaus (1961, 291). The same vision that literacy is important for economic and social development is given by De Vries and Van der Woude (1997, 169) although they phrase the same variables in terms of human capital.
[22] They are called 'narrow' because they exclude the costs of raising a physical person.

between 1867 and 1995, Nunes (2003) considers the cyclical behaviour of government expenditure on education in Portugal between 1852 and 1995, and Marchand and Thélot (1997) estimated an index of human capital for France for over 200 years using the number of economically active persons and an indicator of the quality of labour based on the productivity by years of schooling. Yet, although these estimates constitute an improvement over earlier, often broader defined measures of human capital, they still are only to a limited extent connected with economic theory. For example Broadberry and Crafts (1992, 543) used earnings per operative to proxy for human capital per worker. They also treat the question of a possible endogenous relation (higher productivity means higher wages, but higher wages indicate a higher productivity) and of distortions in the wage structure by trade union bargaining by saying that these factors outweigh each other. However, it is not perfectly clear how to interpret this variable. Can we, for example, treat it as a proxy for a stock or a flow variable? According to human capital theory this should be seen as a flow variable since it neither keeps track of all investments in human capital nor of all possible future extra earnings. Nevertheless, it also encompasses education, ability, and on the job training which also affect wage. In the same line of reasoning, however, one may argue that it ignores the costs of raising a child and is thus a much narrower definition of human capital than the one used by Nakamura (1981) and Newland and San Segundo (1996).

2.2 Education stock[23]

Compared to most historians (maybe with the exception of economic history research on the nineteenth and twentieth century after the human capital revolution in the 1960s), economists are somewhat more restrictive in their definitions of human capital. This is partly because they work with relatively recent data and partly because economists often focus on the relation between two variables while historians tend to look at a broad spectrum of factors influencing a certain development.

But even when a narrow definition of human capital is used, calculating a human capital stock series in monetary terms is very data- and time intensive. As economists generally work with datasets that consist of a large number of countries, they prefer to use relatively easy collectable data that reflect the movement of the human capital stock over time. Therefore, the most popular method to proxy the human capital stock is the educational stock-approach. In essence it is an umbrella term for proxies of human capital, variables supposed

[23] Sections 2.2 and 2.3 are largely based on Le, Gibson, and Oxley (2003) and Wößmann (2003).

to reflect the fluctuations of human capital. These proxies are based on formal education such as enrolment ratios and literacy rates.

One of the earliest forms in which human capital proxies were included in growth theories was in growth accounting exercises. Labour inputs were augmented by such categories as age and education (Denison 1967) to account for the heterogeneity of labour. However, these studies are restricted both in the time period and the number of countries under study. With the availability of the Penn World Tables (Summers and Heston 1988; 1991) it became possible to perform cross-country analyses which required a large human capital database. Therefore, human capital was proxied by easily accessible variables such as adult literacy ratios and school enrolment ratios (Azariadis and Drazen 1990; Romer 1990). These proxies, however, have some disadvantages. First, the enrolment ratios are flow, and not stock, variables. Second, school enrolment is a measure of the number of students (who do not take part in the labour force yet) only, while adult literacy, by definition, only focuses on one effect of primary education and ignores other components of knowledge and human capital. Therefore, these variables were soon replaced with proxies that better conformed to the development of human capital, most notably 'average years of education' in the adult population. This is at the moment the state of art (Benhabib and Spiegel 1994; Islam 1995; Barro and Sala-i-Martin 1995; Barro 1997, 2001; Temple 1999; Krueger and Lindahl 2001).

'Average years of schooling' can be estimated in three different ways. The first way (Lau *et al.* 1991; and Nehru *et al.* 1995) is to use a Perpetual Inventory Method (PIM). Factors as enrolment, mortality and repeaters are aggregated to obtain estimates of 'average years of education'. The second method is the projection method (Kyriacou 1991). Here the 'average years of schooling' from the mid-1970s censuses is used as a benchmark. Data on lagged enrolment ratios are then used to project average years of schooling in the labour force for further countries and years. Kyriacou (1991) estimates the regression:

$$S_t^{PRO} = \alpha_0 + \alpha_1 e_{pri,t-15} + \alpha_2 e_{\sec,t-5} + \alpha_3 e_{high,t-5} + \varepsilon , \qquad (2.1)$$

where S_t^{PRO} is the projected average years of schooling in time *t*, $e_{a,t}$ is the enrolment ratio per level a (primary, secondary, higher) at time *t*. Next, he uses the estimated relation to estimate 'average years of schooling' for other years. Although he finds a strong relationship between 'average years of schooling' and lagged enrolment rates, his assumption that this relationship is stable remains doubtful. The third, and most comprehensive, method is the attainment census method. In this method attainment figures are directly taken from censuses (Psacharopoulos and Arriagada 1986). On this basis the 'average years of education' in the labour force is calculated. Yet, the number of censuses is limited, being generally available only once every 10 years. Because the attainment census method thus suffers from lack of data, Barro and Lee (1993) developed a method to interpolate the census data to obtain estimates of 'average years of education' for every fifth year.[24]

There are serious limitations to this proxy, though. For example, Portela *et al.* (2004, 5) have argued that the PIM using enrolment ratios underestimates attainment due to the assumption that mortality is not correlated with education. Yet, results from analyses based on proxies should be interpreted with great care since, even though proxies are related with the unobserved human capital, they are by no means identical.

If we want to capture all forms of gathering knowledge, whose efficiency may even change over time, 'average years of education' can hardly suit our needs. For example, it is possible that an extra year in higher education raises the human capital stock more than an extra year in primary education. Also, because these proxies are not expressed in monetary units, it is difficult to compare them with physical capital or to include them in the national accounts.[25] Parallel to the educational-stock method, alternative methods have been developed for the estimation of human capital stock. Although these are frequently in monetary units, they are often so data intensive that up till today no large dataset has been created. These alternatives will be discussed more in detail in section 2.3.

2.3 Pro and retrospective methods

Parallel to the educational stock method, other, more comprehensive, methods for estimating the stock of human capital have also been developed. Traditionally, these can be divided into two main categories: the income based approach (prospective) and the cost-based approach (retrospective).

We start with the cost-based approach. This method takes all costs of forming human capital into account retrospectively. Since this means that almost every aspect of human capital has to be calculated separately (education finance, food, health, etc.) this method is often far less broad than the prospective method. Engel (1883) was the first to apply a cost-based method when he estimated human capital from the costs of rearing a child. He argued that since it is difficult to anticipate future earnings, the production costs of human capital can be better sources of the estimation. The retrospective method remained very popular up to the

[24] For the data between two census or survey points, they used a weighted average of the forward flow and an interpolation between the two data points. For the points estimated before the first or after the last census point, they used the perpetual inventory method (PIM) to calculate the backward and forward flow respectively.

[25] An exception to the rule of using a non-money variable is Judson (1995, 16) who uses spending on education.

1930s (Dagum and Slottje 2000, 75). As a weakness, however, it should be noted that this method excludes social costs and the depreciation (or appreciation) of the human capital investments.[26]

In the 1960s Schultz (1961) and Machlup (1962) extended Engel's approach. They calculated human capital so that 'the depreciated value of the dollar amount spent on those items defined as investments in human capital is equal to the stock of human capital' (Le, Gibson, and Oxley 2003, 274). A more popular application (see for example Pyo and Jin 2000) of the cost-based approach is developed by Kendrick (1976). Kendrick estimated the human capital for the United States in the period 1929-1969 by estimating the tangible costs (rearing a child until age 14) and the intangible costs (health, safety, education, and the opportunity costs of students attending school).

A second method is the income-based approach (prospective method), which is based on future earnings. This is the oldest of all methods, starting with Petty (1690) who calculated the human capital of England as the difference between his estimates of the national income and property income, capitalized in perpetuity at a 5% interest rate (Dagum and Slottje 2000, 72). The basic idea behind the income-based approach is that human capital embodied in individuals is valued as the total income that could be generated in the labour market over a lifetime (Le, Gibson, and Oxley 2003, 273). This method was applied by Farr (1853) who created a formula to calculate the stock of human capital. The method was popular in the first half of the twentieth century (De Foville 1905; Barriol 1910; Dublin and Lotka 1930), but lost its popularity in favour of the cost-based approach after the 1940s. Two notable exceptions are the studies of Jorgenson and Fraumeni (1989) and Macklem (1997) about the USA and Canada respectively.

In general the income based methods produce somewhat higher estimates than the cost-based methods. This is largely because cost-based methods sum all investments in human capital whereas income-based methods sum all the extra earnings caused by human capital. Not only does the latter method in generally includes more aspects of human capital (for example ability) but it is also doubtful of all extra earnings are generated by human capital and not, for example, by class difference. However, more important is that these methods suffer from some weaknesses if one wants to insert them in growth regressions as is the aim of this thesis. First, in the retrospective method there is no necessary relation between the investment in human capital and the quality of output. This is the same in physical capital

[26] Of course, most studies make assumptions about this.

stock estimates, as the cost-based approach is based on investments and not on the market value of the output. Second, especially in the prospective method, also factors such as 'health' are included. These costs are, however, only important when one wants to calculate the money value of the labour force. Though, in a large part of the empirical applications of the new growth theories, the human capital stock is inserted next to the labour force. As a consequence, the broader definition of human capital as consisting of the total value of an individual cannot be used when one wants to insert a human capital variable besides labour in a regression equation. Third, the prospective method also rests on the assumption that wage differentials reflect differences in productivity. Fourth, data on earnings are not as widely available as data on investments, i.e. expenditure on education (Le, Gibson, and Oxley 2003, 281-283).

2.4 Combined approaches

Both the income- and the cost-based approach have their advantages and disadvantages. Therefore some authors have tried to integrate these two approaches. Besides computational ease, it also has the consequence of arriving at a measure of human capital that generally is more extended than those of the cost-based, but smaller than the income-based methods. Therefore, and because these methods are generally capable of getting round the main obstacles in both the cost- and income based measures, we elaborate on these methods in this section.

An important example of the combined method is Dagum and Slottje (2000). They equate the 'monetary value of a person's human capital with the average lifetime earnings of the population, weighted by the level of human capital that he has relative to the average human capital of the population' (Le, Gibson, and Oxley 2003, 293). By using a latent variable approach Dagum and Slottje (2000) try to remove the omitted variable bias, which plagues the income approach, i.e. ignoring the education of the parents (e.g. innate ability). Because people with more ability are less costly to educate, and because people with more ability generally earn more irrespective of their human capital, this might create a bias in the human capital estimates.[27]

[27] An ability bias is likely to occur for people with only lower or no education and people with higher education. The main idea is that people with only lower education either are not stimulated or do not have enough income to pursue more education irrespective of their ability. However, people in secondary education generally have the means to pursue further education, but, if they do not, are less likely to have an ability that exceeds their education level.

Another important example is Tao and Stinson (1997). The underlying idea in their work is that investments in human capital determine the human capital stock (cost-based method), while human capital determines earnings for individuals through the income based approach (Le, Gibson, and Oxley 2003, 290). They first establish an earnings function:

$$E_{i,j}^{s} = w_t h_{i,j}^{s}, \tag{2.2}$$

where *s*, *i*, and *j* indicate sex, age, and educational level of and individual. Furthermore, w_t is the human capital rental rate (i.e. the returns to human capital) in year *t* and *E* are the earnings. As both the rental rate and human capital are unobservable, Tao and Stinson standardize the human capital stock of the base entrants. As they enter the labour force after completing college they still do not have experience or on-the-job-training affecting their human capital. After correcting for ability, for which they use the SAT score (a voluntary test for students which they use to reflect ability), it is possible to use the cost-based approach to estimate their human capital stock which is assumed to be the accumulated real expenditure on all education. As now for the base entrants both *h* and *E* are known, it is possible to estimate the rental rate, *w*, which is assumed to be constant across cohorts. Together with the earnings equation, the human capital for other groups can then be estimated.

The advantage of the Tao and Stinson (1997) method is that the cost method is only used to estimate the human capital of the base entrants; using this to estimate the other cohorts avoids the problem of what defines investment in human capital. Second, this method does not require an assumption of depreciation or appreciation of human capital. The method, however, also has some disadvantages. Because we want to use human capital in growth regressions, we would like to omit ability because it is no part of formal learning. Yet, in both combined methods ability is only to a limited extent treated. Dagum and Slottje (2000) try to correct using a latent variable estimation while Tao and Stinson (1997) use a SAT score which might be an imperfect measure of ability. In addition, both methods are very data demanding.[28] Therefore, if we want to estimate time series of the stock of human capital for the use in growth regressions, the combined approach is the best alternative but needs to be modified to become less data demanding and to avoid the inclusion of innate ability.

[28] A simplified method of Dagum and Slottje (2000) was applied in some cases. For example Wei (2001) applied it to Australia, Oxley and Zhu (2002) to New Zealand, and Földvári and Van Leeuwen (2005) to several Eastern European countries.

3 HUMAN CAPITAL IN GROWTH REGRESSIONS

3.1 Introduction

Even when a comprehensive stock of human capital is available, the question remains how to insert it in growth regressions. This is by no means easy to answer as it depends both on the theoretical specification used and on the empirical problems encountered. Human capital is inserted differently in empirical specifications depending on the theory. For example, as we will see in section 3.2, in the theory of Romer (1990) the growth of GDP is regressed on the level of human capital while in the theory of Lucas (1988) the growth of GDP is regressed on the growth of human capital. Equally, the effect of human capital on growth depends strongly on the empirical specification, a topic treated in section 3.3. For example, the inclusion of physical capital in the equation may structurally lower the human capital coefficient.

3.2 Theoretical use of human capital in growth regressions

3.2.1 Exogenous growth: the augmented Solow-Swan model[29]

The Solowian exogenous growth theory that was developed in the 1950s, at the height of the wave of newly independent countries, can be considered the immediate predecessor of the new growth theories that emerged in the 1980s and 1990s. Originally, it only included labour, *L*, physical capital, *K*, and technology, *A*, the latter exogenously explaining long-run growth. However, with the human capital revolution also human capital was augmented to this model. Yet, because also for human capital diminishing returns were assumed, no real difference took place in the structure of the theory.

The standard Solow-Swan model (Solow 1956; 1957; Swan 1956), augmented with human capital and starting with a Cobb-Douglas production function, can be written as:

$$Y_t = K_t^{\alpha} H_t^{\beta} \left(A_t L_t\right)^{1-\alpha-\beta} \tag{2.3}$$

Here, *Y* is GDP, *K* is physical capital and *AL* is effective labour, and $0 < \alpha < 1$ and $0 < \beta < 1$ are the given capital intensities of physical- and human capital which have decreasing returns.

Now, we can postulate that *Y* is either used for consumption or investment in human- and physical capital:

$$Y_t = C_t + \dot{K}_t + \delta_k K_t + \dot{H}_t + \delta_h H_t \tag{2.4}$$

[29] This section is based on Mankiw, Romer, and Weil (1992).

Here, δ is depreciation and C is consumption. As one may notice, A-type capital (technology) does not use Y. Hence, just as labour, it is exogenous. We assume that technology and labour grow at a constant rate g and n:

$$A_t = A_0 e^{gt} \tag{2.5}$$

$$L_t = L_0 e^{nt} \tag{2.6}$$

Per capita physical (k) and human (h) capital accumulation is endogenous (it depends on Y) and can be written as:

$$k_{t+1} - k_t = s_k y_t - (\delta + g + n) k_t \tag{2.7}$$

$$h_{t+1} - h_t = s_h y_t - (\delta + g + n) h_t \tag{2.8}$$

Here, s is the saving rate of physical capital, k, and human capital, h, and δ is the depreciation (assumed equal for physical and human capital).

Based on (2.7) and (2.8), inserting the per capita production function, and assuming that $s_k / s_h = k/h$, we arrive at the steady states of k and h:

$$k^* = \left(\frac{s_k^{1-\beta} s_h^{\beta}}{n + g + \delta} \right)^{1/(1-\alpha-\beta)} \tag{2.9}$$

$$h^* = \left(\frac{s_k^{\alpha} s_h^{1-\alpha}}{n + g + \delta} \right)^{1/(1-\alpha-\beta)} \tag{2.10}$$

If we substitute (2.9) and (2.10) in the production function and take the logs, we derive the steady state level of per capita GDP:

$$ln\left(\frac{Y_t}{L_t}\right) = ln\, A_0 + gt - \frac{\alpha + \beta}{1 - \alpha - \beta} ln(n + g + \delta) + \frac{\alpha}{1 - \alpha - \beta} ln(s_k) + \frac{\beta}{1 - \alpha - \beta} ln(s_h) \tag{2.11}$$

We obtain the following for the growth rate of the steady-state per capita income:

$$ln\left(\frac{Y_t}{L_t}\right) - ln\left(\frac{Y_{t-1}}{L_{t-1}}\right) = g \tag{2.12}$$

However, this exogenous growth model is only to a limited extent suited to answer our main question how long-run growth takes place in India, Indonesia and Japan and how this affects cross country growth divergence. First, the exogenous growth theories do not explain long-run growth as it is determined exogenously. For example Bernanke and Gurkaynak (2001, 15) point out that '"explaining" growth by assuming that growth rates differ exogenously across countries is not particularly helpful. Once it is allowed that long-run growth rates differ across countries, we are naturally pushed to consider explanations for these differences, as offered by endogenous growth models.' Second, the exogenous growth theories also do not explain economic divergence, which did to some extent take place.[30] Third, there is plenty of evidence against the exogenous theories. Bernanke and Gurkaynak (2001) argue, based on the characteristics of the Solow model, that endogenous growth theories explain long-run growth better. Equally, there exist a large literature that shows that permanent changes in government policy have a permanent effect on national income growth, which is characteristic for the new growth theories (see for example Kocherlakota and Yi 1996; 1997). In addition, we estimated equation (2.11) and (2.12) jointly for India, Indonesia, and Japan using a Seemingly Unrelated Regression (SUR)[31]. The growth of per capita GDP (equation (2.12)) should not be determined by population growth, and investments in physical- and human capital. Therefore, we test of the sum of these coefficients in this equation is zero. This is rejected, which means that, under the assumption of a steady state, exogenous (thus Solowian) growth is rejected.[32] Therefore, we further focus solely on the new (endogenous) growth theories.

3.2.2 The new growth theories

In the neo-classical growth model from the 1950s (Solow 1956; 1957) no special attention was given to human capital. Basically, it was argued that the growth of physical capital had an effect on the growth of GDP while the unexplained residual, labelled Total Factor Productivity (TFP), explained economic growth in the long-run. The rise of human capital theory (Schultz 1961; Becker 1964) led to the inclusion of human capital. Yet, although this reduced TFP, still long-run growth was completely explained by this unobserved component. The growing awareness that the neo-classical growth theory was not able to explain long-run

[30] Of course one can modify exogenous growth theories to such as extent that one includes endogenous human capital growth a la Lucas. This sort of model can explain divergence among groups of countries (such as developed and developing countries) and, at the same time, convergence in countries with comparable levels of human capital. However, as our aim is mainly directed at the between group properties, there is here no direct need to make things more difficult and we remain with the endogenous theories.
[31] Because both equations have the same independent variables, the errors may be correlated.
[32] In Indonesia and Japan the null hypothesis is rejected. This is not the case for India. However, it is possible that no steady state is present. In addition, in chapter 6, section 3, we found that for extensive periods there are constant marginal returns to human capital accumulation which also points to the rejection of exogenous growth.

growth led to the introduction of the new growth theories. In these theories, human capital was (in a direct or indirect way) modelled as a factor of long-run growth.

One of the first main new growth theories is the Romer (1986) model. However, this model is less suited to answer our main question on long-run growth and the role of human capital. Basically, this model looks at non-decreasing returns to scale in capital alone which makes it difficult to study differences among countries. However, the currently much used theories of Lucas (1988) and Romer (1990) have the rate of technological progress determined endogenously. This can differ permanently across countries reflecting structural differences.[33] To see this lets start with the Romer (1986) model. The standard production function is:

$$Y_i = F\left(K_i, A_i L_i\right) \tag{2.13}$$

Here, Y is GDP, K is physical capital, A is technology, and L is labour in firm i. Based on Arrow (1962), Romer (1986) made two assumptions about productivity growth. First, 'learning by doing' works through investments by firms. This means that an increase in a firm's capital stock, K_i, leads to a simultaneous increase in its stock of knowledge, A_i. Second, each firm's knowledge is free available to all other firms. This means that the increase in one firm's technology, $\dot{A}_i$, is equal to the development of the knowledge in the entire economy, $\dot{A}$. This, in turn, is equal to the change in the capital stock in the economy, $\dot{K}$. This means that we can replace A_i is equation (2.13) with K_i:

$$Y_i = F\left(K_i, K L_i\right) \tag{2.14}$$

We now also use the assumption of constant returns, which means that if each factor doubles, output doubles. As technology grows proportionally with capital, an increase in physical capital leads to knowledge, which leads to a proportional increase in technology. Hence, a doubling of physical capital leads to a doubling of technology and hence, due to constant returns, a doubling a GDP. In this way, endogenous growth is achieved.

Yet, as indicated, this model is less suited to answer our main question. Therefore, we focus on the two main branches of the new growth theories that are used today, namely the Lucas (1988) and the Romer (1990) model. The first branch, pioneered by Uzawa (1965) and Lucas (1988), sees human capital as a factor of production. Consequently, human capital was defined as the skills embodied in a labourer. As each person is the master of his or her own

[33] In addition, it is a razor blade model. Only if physical capital grows exactly proportionally with knowledge, there is endogenous growth. In the other cases growth is either explosive or tends to zero in the long-run (Diebolt and Monteils 2000, 17). Endogenous growth is thus only one out of many possibilities in this model.

skills and the use in one occupation precludes the use in another occupation: these skills are rival and excludable. The basic difference from the neo-classical growth theory is that the Lucas (1988) model has two sectors. In the first sector, human- and physical capital is used to produce output, leading to the following production function:

$$Y = AK^{\alpha}\left(uhL\right)^{1-\alpha} h_a^{\gamma} \tag{2.15}$$

where A is the level of technology, K is physical capital, u is the time devoted to productive activities, h is per capita human capital, L is the size of the labour force, and h_a^{γ} is the average positive external effect of human capital. If we rewrote (2.15) in terms of a growth rates, we would, just as in the neo-classical growth theory, arrive at an equation where the growth of GDP is explained by the growth of physical and human capital. The difference between his branch of the new growth theories and the neo-classical thus arises out of the main source for endogenous growth: the second sector.

In the second sector, a share of human capital that is not utilized in the productive sector is used to produce extra human capital.[34] Only if this exhibits non-diminishing returns there is endogenous growth. This can be written as:

$$\dot{h}_t = h_t B\left(1-u_t\right) - \delta h_t \tag{2.16}$$

, where δ is the depreciation of human capital, $\left(h\right)$, $B\left(1-u_t\right)$ indicates the increase in the amount of human capital. In other words, B is a technical parameter determining at what rate investments in the second sector are converted to a growth of human capital, and $\left(1-u_t\right)$ is the share of human capital that is devoted to human capital formation. Equation (2.16) has constant marginal returns because the growth of human capital is independent of its level, i.e. an increase in human capital for a higher educated person requires the same effort as for someone at primary school. Consequently, the growth of human capital can be written independent of its level:

$$g_h = \dot{h}_t / h_t = B\left(1-u_t\right) - \delta \tag{2.17}$$

From equation (2.15) and (2.17) we can obtain the growth rate of GDP. We can rewrite equation (2.15) as:

$$Y = AK^{\alpha}\left(uL\right)^{1-\alpha} h^{1-\alpha+\gamma} \tag{2.18}$$

Now rewrite equation (2.18) in growth rates:

[34] One could argue that human capital formation needs both physical and human capital inputs although its formation is generally human capital intensive. However, we are inclined to say that all spending (so also spending on school buildings etc) can be argued to be human capital investments. Under this assumption the accumulation of human capital depends solely on human capital investments.

$$\frac{\dot{Y}}{Y}=\frac{\dot{A}}{A}+\alpha\frac{\dot{K}}{K}+\left(1-\alpha\right)\left(\frac{\dot{u}}{u}+\frac{\dot{L}}{L}\right)+\left(1-\alpha+\gamma\right)\frac{\dot{h}}{h} \tag{2.19}$$

Now assuming A and u constant, equation (2.19) becomes:

$$\frac{\dot{Y}}{Y}=\alpha\frac{\dot{K}}{K}+\left(1-\alpha\right)\frac{\dot{L}}{L}+\left(1-\alpha+\gamma\right)\frac{\dot{h}}{h} \tag{2.20}$$

Now assuming no depreciation in equation (2.17) $\left(\dot{h}_t/h_t=B\left(1-u_t\right)\right)$, and a balanced growth path $\left(\frac{\dot{K}}{K}=\frac{\dot{Y}}{Y}\right)$, equation (2.20) becomes:

$$\frac{\dot{Y}}{Y}-\alpha\frac{\dot{Y}}{Y}=\left(1-\alpha\right)\frac{\dot{L}}{L}+\left(1-\alpha+\gamma\right)B\left(1-u\right) \tag{2.21}$$

We can write this in per capita terms as:

$$\frac{\dot{y}}{y}\left(1-\alpha\right)=\left(1-\alpha+\gamma\right)B\left(1-u\right) \tag{2.22}$$

Rewriting:

$$\frac{\dot{y}}{y}=\frac{1-\alpha+\gamma}{1-\alpha}B\left(1-u\right)=\frac{1-\alpha+\gamma}{1-\alpha}\cdot\frac{\dot{h}}{h} \tag{2.23}$$

This is exactly the result obtained by Diebolt and Monteils (2000, 9). Growth can thus be caused by the effectiveness of human capital accumulation, B, the positive externalities of human capital, γ, and the share of human capital devoted to human capital accumulation, $1\text{-}u$. All growth in output is thus derived from human capital growth. This means that endogenous growth can only exist if there is a constant growth of human capital, which in turn can only be the case if there are constant or increasing marginal returns to human capital accumulation.[35] As can be seen in equation (2.23), this causes growth in production even without the presence of positive external effects. Positive external effects can accelerate growth, but in itself cannot cause endogenous growth.

The second major branch of the new growth theories is pioneered by Romer (1990). This model has three sectors: a technology producing sector, an intermediate goods producing sector where capital goods are produced, and a final output producing sector. In the first sector, technology is used as targeted knowledge, e.g. a set of institutions that makes it possible to manufacture capital goods for the second sector (Diebolt and Monteils 2000, 13). Hence, 'knowledge' in the definition of Romer (1990) is not a part of the individual as is the case in the theory of Lucas (1988). The part of human capital that is not used directly in the

[35] Then, unlike the physical capital stock which is subject to an upper limit, human capital could grow infinitely.

sector producing final output is used to create new technologies. The level of human capital, *H*, thus has a positive effect on the growth of technology, *A*. The growth of technology in the first sector can thus be given as:

$$\dot{A} = \sigma H_A A \qquad (2.24)$$

Here $\dot{A}$ and A are the growth and level of a technology index respectively. H_A is the amount of human capital devoted to the accumulation of technology ($\dot{A}$) and σ is a productivity parameter. Please note that the inclusion of the level of technology (*A*) in above equation is largely a matter of convenience (as Romer (1990, S84) also admits) as it makes the log-linearization easier. Its only effect is that a higher level of technology creates a higher absolute effect of *H* on the accumulation of technology. However, in relative terms (see equation (2.27)) the inclusion of the level of technology has no effect.

In the second sector, each new *A* creates a new intermediate product, *x*., which in turn determine capital, *K*. Hence, K depends on the number of intermediate products, *t=1...A*, and the price of a unit of *x* expressed in consumption, η:

$$K = \eta \sum_{i=1}^{A} x_i \qquad (2.25)$$

The function for the third, final output, sector thus becomes:

$$Y = H_Y^{\alpha} L^{\beta} K^{1-\alpha-\beta} \qquad (2.26)$$

Here, H_Y is an exogenous variable indicating the amount of human capital not used in the technology producing first sector. In other words, it is the amount of knowledge used to apply technologies to the production process.

In this model, endogenous growth thus stems from the positive effect of research on innovations whereas more innovations increase productivity of researchers in the future. In other words, if we see equation (2.24) in terms of the Lucasian second sector (without depreciation) we can argue that the source of endogenous growth is the existence of constant marginal returns to technology accumulation which is indeed implicitly assumed in equation (2.24). This has the consequence that, on a balanced growth path, the level of human capital increases output growth, i.e.:

$$g = \dot{Y}/Y = \dot{K}/K = \dot{A}/A = \sigma H_A \qquad (2.27)$$

It is worth noticing that, because we are looking at the growth rates (hence log-linearizing the equations), the accumulation of technology becomes independent of *A* in equation (2.24) thus arriving at σH_A in equation (2.27).

3.3 Empirical models

Although the theoretical differences between the two models are quite pronounced, it is not as easy to empirically distinguish between them. First, it is difficult to distinguish the new growth theories from the neo-classical theory. As pointed out in the previous sub-section, the Lucas (1988) model predicts that the growth of human- and physical capital determine the growth of GDP. This is the same as in the neo-classical model. Second, it is sometimes argued that the neo-classical growth theory predicts convergence among countries while convergence is not present in the new growth theories. In those cases, often initial GDP is included in regressions. If, when other variables are included to pick up the difference in steady state level, its coefficient is negative, this means that the higher initial GDP is (the more advanced an economy is), the slower its subsequent growth, i.e. conditional convergence.[36] If no (conditional) convergence is found, it is assumed that the new growth theories are applicable and vice versa. Yet, as Pack (1994, 65) argues, even in neo-classical theory sustained differences in economic development can exist if the ability to obtain international technologies varies among countries. On the other hand, convergence is now also possible in the new growth theories. Indeed, as Islam (2003, 311) argues, 'as a consequence of the give and take between the NCGT and NGT, it is now possible, generally speaking, to explain both convergence and non-convergence behavior by appropriately chosen models of growth theory of both these varieties.'

It is also difficult to distinguish between the new growth theories. Although the theoretical differences among the competing models are identified, the lack of data often prevents empirical testing. In addition, the Romer (1990) model does not exclude the Lucas (1988) model, rather complements it. While human capital facilitates technological development, it remains in the model as a factor of production as well. Consequently, finding a positive effect of the level of human capital on growth is in itself not sufficient evidence to reject the Romer (1990) model. Finally, both theories have a different view on human capital. Theories focusing on human capital as a factor of production see human capital as individual

[36] As we have seen in equation (2.11), the steady state relation for per capita GDP in the augmented Solow model depends on the following elements A_0, g, α, β, n, δ, s_k, s_h. Unconditional convergence implies that all these elements are the same for the countries considered. This means that if the level of initial per capita GDP is inserted in an equation with the growth of per capita GDP as the dependent variable, it should always have a negative coefficient (the higher initial GDP, the lower growth) even if no other variable were inserted on the right hand of the equation. Conditional convergence, however, implies the existence of more steady states. This means that the appropriate other elements should be inserted to control for these different steady states. For an excellent description of growth theories and convergence see Islam (2003).

skills of a labourer which are rival and excludable. Yet, if human capital is seen as a facilitator of technology, human capital is viewed upon as 'knowledge' and 'ideas' which are largely non-rival and non-excludable.[37] Given the character of the difference, it is often difficult to directly compare these two theories.

However, these drawbacks did not prevent scholars from performing regression analyses. Two types of estimates can be distinguished. First, the bare model which consist of human capital and GDP alone. This can be traced back to a Macro-Mincer equation.[38] In the original micro equation, as proposed by Mincer (1974), the log wage of an individual is regressed on its education level. Soon this regression was also applied to macro-data. In the latter regressions mostly the growth of per capita GDP was regressed on the growth and level of the stock of human capital. A typical Mincer macro growth regression in a panel is:

$$ln\, y_{it} = \beta_{0,it} + \beta_{1,it} Educ_{it} + \varepsilon_{it}\,, \tag{2.28}$$

where $\ln y$ is the logarithm of per capita GDP[39], and *Educ* are 'average years of education' in country *i* in year *t*. This model is based on empirical microeconomics literature (see for example Psacharopoulos 1994). It is important to note that both the education and GDP variable are in levels. If there are no breakpoints in coefficient of the education variable, this would be equivalent to saying that the growth of per capita GDP is regressed on the growth of education, i.e. the theory of Lucas. However, if a time series component is used, it might be better to take first differences of this model, i.e. regressing the growth of per capita GDP on the growth of per capita human capital, or to estimate a cointegration relation in order to avoid a spurious regression.[40] However, it is doubtful if one can simply use a micro-regression at the macro level. Yet, Heckman and Klenow (1997) and Acemoglu and Angrist (1999) argue that, if they control for life-expectancy to proxy for technological differences in countries, the micro and macro regressions yield similar estimates.

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[37] As mentioned in the introduction, often there is a strong correlation between the two forms of human capital. This makes it possible to use either one of them to insert it in a regression in the form of the level and growth in order to test which growth theory seems to best fit.

[38] For example, in the technology models, human capital is seen as 'ideas' which are non-rival and only partly excludable. This makes it difficult to attribute human capital to the individual worker as is done in the micro Mincer equations. Equally, increasing marginal returns to human capital accumulations in the Lucas theory are possible if, for example, the quality of human capital increases or if successive generations inherit human capital accumulated by their parents (L'Angevin and Laib 2005, 7). This effect is unlikely to be picked up by a micro Mincer, except when using monozygotical twins or using panel with more generations. In addition, as generally a Mincer equation is used for individual persons, per definition increasing returns are hard to get. Consequently, in our vision, what is called a 'macro-Mincer' equation is actually a growth equation with solely human capital as the dependent variable. The equation looses its characteristics of the original Mincer equation.

[39] In a micro Mincer equation, this would be replaced by the wage of individual *i*.

[40] As most researchers find it difficult to make an *a priori* distinction between both branches of the new growth theories. They therefore include both the level and growth of education in this model.

The second group of empirical models also includes other variables besides human capital. These can either be structural regressions including human- and physical capital, or *ad hoc* Barro-regressions containing all variables deemed to have an influence on economic growth. Often these are investment ratios, geography dummies, and initial GDP. Yet, the robustness of these variables is doubtful (see for example Levine and Renelt 1992).

3.4 Some results from the literature

The result of the theoretical and methodological problems is that there are many empirical analyses where the growth of GDP is regressed on both the growth and the level of human capital while the main differences between the specifications is in the extra independent variables. Although the augmented Solow model is of less use for this thesis, we will present some of its results in table 2.1 because it is often difficult to disentangle these results from Romerian or Lucasian growth. Because elasticities are generally imposed, we report the

Table 2.1: Overview of the effect of human capital on economic growth in an (Augmented) Solow model *

Author	Output	TFP	Physical capital	Human capital	Comments
Mankiw, Romer, and Weil (1992)	Level accounting: cross-country differences in output per worker, 98 countries in 1985.	22%	29%	49%	K=0.31; H=0.28
Bosworth, Collins, and Chen (1995)	Growth accounting: cross-country differences in 1960-92 growth in output per worker, industrial countries.	44%	43%	13%	K=0.3 (0.4 for developing countries) H= 0.7 (0.6 for developing countries)
Bosworth, Collins, and Chen (1995)	Growth accounting: cross-country differences in 1960-92 growth in output per worker, Asia (excluding China.	26%	62%	12%	
Hall and Jones (1999)	Level accounting: cross-country differences in output per worker, 127 countries in 1988.	61%	17%	22% (educational attainment of the population of 25 year and older.	K=0.3; H= piecewise linear to years of education.
Klenow and Rodriquez (1997)	Level accounting: cross-country differences in output per worker, 98 countries in 1985.	67%	29%	4%	K=0.30 H=0.28
Klenow and Rodriquez (1997)	Growth accounting: cross-country differences in 1960-85 growth in output per worker, 98 countries.	85-90%	3%	6-12%	

* Level and growth accounting n the form Y=AX. Contribution of each factor TFP, human- and physical capital to output.

percentage effect on GDP (growth). Basically, we can see that the more modern the studies are, the higher the effect of TFP growth on per labourer growth is (see also Sianesi and Van Reenen 2003, 172). The role of human capital, however, seems to decline in favour of TFP.

Besides a change in estimation technique, this may be attributed to two developments. First, the effect of TFP growth seems to increase over time (see for example table 1.1 in chapter 1). As later studies generally use samples that shift forward in time (and have a changing and expanding set of countries in their sample), it might be possible that newer studies find a higher effect of TFP growth on GDP growth. Second, older studies often use different human capital variables. As we have seen in the previous sections, originally studies focused on variables such as literacy and enrolment rates. However, in more recent studies the focus has shifted toward 'average years of education'. Yet, with all their problems, literacy and enrolment rates are obvious proxies for the level and growth of human capital respectively. But 'average years of education', as we will discuss in section 5 in chapter 6, although generally used as a proxy of the level of human capital, might also be interpreted as a proxy of the growth of human capital. If the latter is true, this means that, when using the growth rate of 'average years of education' to proxy the growth of human capital, one is actually proxying the growth of the growth of human capital. Obviously this reduces the effect of human capital on growth considerably, even with imposed elasticities.

However, as pointed out in section 3.2.1 in this chapter, Solowian growth is unlikely to have taken place in India, Indonesia, and Japan during the period of our study and, anyway, does not allow directly answering our main question about long-run growth and economic divergence. This has been the field of the new growth theories. As we can see in table 2.2, and as has been indicated in much of the literature (Romer 1990a, 280; Monteils 2002) the effect of the accumulation of human capital on the growth of GDP does not seem to be large. As can be seen from table 2.2, the effect of a 1% increase in the level of human capital results in an increase in the growth of human capital between 5.7 and 0.3 percentage point.[41] The effect of the growth of human capital on economic growth, however, gives an insignificant coefficient, a negative coefficient as in the famous study of Benhabib and Spiegel (1994), or a low positive coefficient.[42]

These results suggest that the model of Romer (1990) seems to fit the data better than does the model of Lucas. However, discussion on both in the specification of the regression and the quality of the underlying data make it difficult to make an objective judgement about

[41] If you have continuous time than a 1% increase in the level of average years of education causes an x percentage point increase in the growth of per capita GDP. However, if you regress the log-level of per capita GDP on the log-level of average years of education, the coefficient indicates that if average years of education increases with 1%, per capita GDP growth increases with x%. A third option is if you regress the growth of per capita GDP on the level (thus not in logarithmic form) of average years of education. In this case a one year increase in average years of education increases the per capita GDP with x percentage points.
[42] An exception is the corrected Barro & Lee data used by Portela *et al.* (2004).

Table 2.2: Overview of human capital coefficients by technique, theory (level or change variable), and type of regression

Author	Human Capital Variable	Technique	Coefficient	HC in regression inserted as:
Krueger&Lindahl (2001)	Log Kyriacou average years of schooling	Pooled OLS, annualized data	0.003	Level
Benhabib and Spiegel (1994)	Log Kyriacou average years of schooling	Pooled OLS, Annualized data	0.010	level
Barro and Lee (1993)	Log of Barro & Lee average years of schooling	Pooled OLS	0.057	Level
Cohen and Soto (2001)	Corrected Barro & Lee average years of schooling	Pooled OLS, Annualized data	0.0032	Level
Portela *et al*. (2004)	Corrected Barro & Lee average years of schooling	Pooled OLS, Annualized data	0.0037	Level
Portela *et al*. (2004)	Corrected Barro & Lee average years of schooling	Pooled OLS, Annualized data	0.0486	Change
Levine and Renelt (1992)	Initial secondary school enrolment rate	Pooled OLS, Annualized data	0.032**	Change
Krueger&Lindahl (2001)	Log change Kyriacou average Years of schooling	Pooled OLS, Annualized data	0.012*	Change
Benhabib and Spiegel (1994)	Log change Kyriacou average Years of schooling	Pooled OLS, Annualized data	-0.072	Change

* Insignificant
** Base estimate

which human capital theory approaches the actual process best. This is also true because even those studies that insert human capital as a level often find human capital coefficients that are lower than might be expected on the basis of micro studies.

Indeed, the specification of the equation may be important for finding these results. First, Topel (1999) argues that Benhabib and Spiegels findings of an insignificant and negative sign of the effect of schooling changes on GDP (see table 2.2) is due to their log-specification of education.[43] The log-log specification follows if one assumes that schooling enters an aggregate Cobb-Douglas production function linearly. Given the success of the Mincer model, however, it is more natural to specify human capital as an exponential function of schooling in a Cobb-Douglas production function, so the change in linear years of schooling would enter the growth equation. Second, in Benhabib and Spiegel's work (just as in most other studies) the education change variable is highly dependent upon physical capital. This is caused by the situation that the education variable conveys almost no signal conditional on the other variables. This is largely due to mismeasurement of human capital and to a possible simultaneity bias in physical capital causing an upward bias in the

[43] Benhabib and Spiegel's (1994) work as indicated in table 2.1, was based on Kyriacou's data which, as we have seen (section 2), is estimated as a stable relation between census data and enrolment figures. This is a serious reason for noise as this stable relation is not sure to hold for all periods or countries.

coefficient of physical capital.[44] Third, put forward by De la Fuente and Doménech (2000, 18), another problem with inserting physical capital in growth equations with human capital is that during periods with declining growth rates of production, physical capital investments also decline. If the human capital stock exhibits a constant growth rate or even an increasing growth rate, it would create an insignificant or even negative human capital coefficient. If taken in levels, inclusion of physical capital in the regression causes the human capital variable to become significant. This becomes especially clear if one looks at the change variable in the Mincer equation. Contrary to the production function specifications that include physical capital, the coefficient here is positive and statistically significant.

Finally, there is the problem of mismeasurement of the human capital proxies (De la Fuente and Doménech 2000; Krueger and Lindahl 2001; Portela *et al*. 2004).[45] In section 2, we already went into the discussion that many of these proxies, also those using average years of schooling, are an imperfect measure of human capital. Krueger and Lindahl (2001, 1117) point to the fact that, of those proxies, the Barro and Lee data convey more signal[46] when expressed in changes than the Kyriacou data. However, we need to be aware that '[d]espite the greater reliability of the Barro-Lee data, there is still little signal left over in these data conditional on the other variables' (Krueger and Lindahl 2001, 1117). One obvious point is that the measurement error in the level of human capital is aggravated when using growth rates.[47] Thus the coefficient of the growth of human capital may be hit harder by measurement errors than does the coefficient of the level of human capital.[48] This means that the low

[44] Richer countries (with more physical capital) invest more in physical capital.
[45] Besides the measurement errors of the underlying data, many criticisms have been raised against the perpetual inventory method which Barro & Lee (1993) used to interpolate the missing years. For example De La Fuente and Doménech (2002) constructed a revised dataset with the Barro and Lee data for 21 OECD countries. They used more data sources and, when more figures were available for the same country and year, they used the most plausible to avoid implausible jumps in the data. Their results show an increase in the coefficients of both the level and the change regressions (De la Fuente and Doménech 2002, 16-17). Furthermore, Cohen and Soto (2001) extend the work of de la Fuente and Doménech (2002), although the former was published earlier, to include 95 countries. They use 10 year intervals and try to minimize the extrapolations as many censuses are at 10 year intervals. They also argue that economic growth is too erratic to be explained by the growth of human capital (Cohen and Soto 2001, 23). From the point of view of human capital this is to some extent accepted by Portela *et al* (2004). They argue that assuming the mortality rate independent of education level creates a serious downward bias in Barro&Lee estimates which accumulates over time as long as there is no other census. As this bias decreases the variance, it increases the human capital coefficient.
[46] Signal indicates how well the data 'signal' the information we want to know, *in casu* the level of human capital.
[47] This is easy to see. If a human capital stock is for example 100 and rises in years t+1 to 120. The measurement error in years t+1 is 10. This means that the measurement error of the level of HC in year t+1 is 10/120= 8.3%. However, the measurement error of the change of human capital is 10/20=50%.
[48] Indeed, given the standard attenuation bias this means that increasing variance causes a lower human capital coefficient in regressions based on changes in education. However, Krueger and Lindahl (2001, 1118) also argue that the serial correlation in the Barro-Lee data is higher. As a consequence, as the serial correlation of the errors

coefficients found in regressions including the change of human capital may to some extent be attributed to this problem.

It is clear that, although some progress is made in data quality leading to improved estimates of change in education on change in growth[49], most regressions still lead to low, insignificant, or even negative coefficients. Nevertheless the data of Barro & Lee (1993) and its derivatives are superior in that they exhibit more signal and produce in general somewhat higher coefficients.[50] Yet, the low coefficients, combined with questionable specifications, still make it difficult to distinguish between the different available growth theories. Therefore, it is necessary to estimate a new stock of human capital, based on the pro- and retrospective methods, that has a clear definition and which may encompass the definitions of human capital from both branches of the growth theories.

4. A DEFINITION OF HUMAN CAPITAL

We are thus in need for a way of estimating a human capital stock that encompasses both the qualitative and quantitative development of skills in the labour force and can be inserted in growth equations. Most of the present proxies only partially conform to these requirements. For example, the databases of Nehru (1995), Kyriacou (1991), and Barro and Lee (1993; 2001), disregarding how they are measured, are all proxies of the average years of education. As we already saw in section 2.2, this approach is based on a very narrow concept of human capital. For one, it excludes experience. Especially for the theories advancing technological development this is worrisome as technology is often implemented within a firm either through experience or 'on the job training'. 'Average years of education' does not reflect the increase in quality of human capita either, which could lead to constant marginal returns to human capital accumulation and, as a consequence, endogenous economic growth. Therefore, 'average years of education' seems to be an imperfect indicator of human capital.

We thus have to look for a definition of human capital that includes both the quantitative and the qualitative aspects of human capital, i.e. all 'educational' and 'experience' components. That is, it has to include all aspects of learning but has to exclude all components associated with the physical body. Costs such as 'raising a child' or 'health' are already accounted for in the data on the labour force. Including them would therefore

is lower than that of the serial correlation of 'true' schooling, the reliability of first differences of education in the Barro-Lee data will be lower.

[49] In other words, by reducing the measurement error, the bias towards zero in the coefficient is reduced.

[50] Nevertheless, it is important to note that this problem manifest itself in the short-term effect. Portela *et al* (2004) and Teulings and Van Rens (2002) have argued that the short term effect of human capital is small (4%) while the long run effect can be as high as 66%. However it can well take a century to fully materialize.

create double counting in a production function. Therefore we will follow a definition in which human capital consists of all forms of knowledge acquiring which is defined by the OECD (2001, 18) as '**the knowledge, skills and competencies embodied in individuals that facilitate the creation of personal, social and economic well-being**.'[51] This excludes human 'attributes', which is included in the standard OECD definition. The main reason is that innate human characteristics neither have an investment component nor do they increase human capital. They may make investments cheaper as children can study more easily, but do not as such increase the stock of human capital.

This approach has three advantages. First, it leaves a difference between human capital and physical labour. This difference is crucial when human capital is inserted into an equation besides labour. Second, it allows for the possibility of directly comparing the theories of Lucas (1988) and Romer (1990). Admittedly, the definition of human capital used here does conform better to the model of Lucas than to that of Romer. However, as human capital may also be used as an input in the R&D sector, no doubt there is a strong correlation between both forms of human capital.[52] Therefore, it does not seem to be unreasonable to assume that any human capital stock created with this definition may be used to test the differences between both branches of the new growth theories. Third, this definition of human capital avoids the problem, which has plagued the cost-based approach, of determining which expenditures are investments in human capital and which are consumption. These problems mainly arise for goods and services that are intended to sustain a physical person, not for increasing his or her knowledge. For example, are food and clothes consumption investments if you consider raising a child being part of human capital formation? We agree with Bowman (1962) that raising a person is no human capital formation, which corresponds to the above definition.[53]

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[51] Laroche *et al*. (1999) further extend this notion to include 'innate abilities'. However, we exclude these. The main reason is that innate ability is no part of the physical body. In addition, its division among groups in society is probably normal. It would be strange to expect ability to be larger or smaller by older or younger persons or by Chinese or Indonesians. As a consequence, ability can be picked up by the labour force or population variables. Therefore, also including it in human capital would create double accounting.

[52] In fact, in chapter 6 and 8, using a correlation with the R&D investments in Japan, we briefly mention that this is indeed the case.

[53] A fourth advantage of this definition could be that, if for example food would be an investment in human capital, we would have to assume that human capital is further extended after pension. This means that investment continues without any chance on returns to this investment. This would be a strange interpretation and also runs counter to the human capital theory as proposed by Becker (1964).

5 DEVELOPMENT OF EDUCATION INSTITUTIONS IN HUMAN CAPITAL FORMATION

5.1 Introduction

So far, we mainly attributed the low human capital coefficient to poor data quality which we dealt with in the previous sections. There were problems as a bad specification of human capital, measurement problems, and low signal. In short, we considered the estimation of human capital and its use in growth regressions with an almost complete disregard for the fact that countries may have different policies and institutions. Yet, human capital coefficients are often estimated with cross-sectional or panel data, consisting of a very heterogeneous set of countries. These cross-country differences and the effect of the changes in institutions and policy remain unobserved. In addition, since little historical research is done into these factors, even when breaks and regime changes are identified, it is difficult to relate them to their causes and offer an interpretation.

5.2 Changes in the effect of human capital on economic growth over time

Many institutional and political developments can be held responsible for changes in the effect of human capital on economic growth. Indeed, one important problem of estimating a stable human capital coefficient is that the effect of human capital on economic growth can change over time. On a more methodological level, the existence of regimes in human capital may lead to parameter inconsistency. Parameter inconsistency means that the human capital coefficient in different periods has structurally different values, which leads to a downward bias in the estimated human capital coefficient. Because the human capital stock used in growth regressions generally does not go further back in time than 1960, and is often estimated on cross-sectional data with the time series aspect neglected, the parameter inconsistency problem is not often dealt with.

Therefore, parameter inconsistency seems to be an important problem in growth regressions, especially if one estimates a cross-section regression with a heterogeneous group of countries, or if one estimates a time series. In the work of Psacharopoulos (1994) and MacMahon (1998), for example, there are indications that the importance of secondary and higher education increases over time. This results in a different rate of return and structurally different human capital coefficient, creating an identification problem.[54] The consequences for the empirical model can be demonstrated as follows.

[54] An identification problem means that there is either more or less than one unique coefficient. If there is more than one structural coefficient, the equation is overidentified.

First, we take a macro-Mincer equation where we used Y to indicate that we are considering the macro level:

$$\ln Y_{jt}^{g} = \beta_{0jt} + \beta_{1jt} Educ_{jt} + \varepsilon_{jt} \qquad (2.29)$$

where $ln\,Y_{jt}^{g}$ is the geometric mean wage (or, if you wish, GDP per capita) and $Educ_{jt}$ is mean years of education in country j at time t. Differencing this equation yields:

$$\Delta ln\,Y_{jt}^{g} = \beta_{1jt} Educ_{jt} - \beta_{1jt-1} Educ_{jt-1} + \Delta\varepsilon_{jt} \qquad (2.30)$$

$\Delta ln\,Y_{jt}^{g}$ is the first difference of the geometric mean wage. Differencing removes any permanent effect of differences in technology. If the return to schooling is constant over time, we get:

$$\Delta ln\,Y_{jt}^{g} = \beta_{1j} \Delta Educ_{j} + \Delta\varepsilon_{jt} \qquad (2.31)$$

If, however, the return to schooling changes over time, then we obtain:

$$\Delta ln\,Y_{jt}^{g} = \beta_{1jt} \Delta Educ_{j} - \delta Educ_{jt-1} + \Delta\varepsilon_{jt}, \qquad (2.32)$$

where δ is the change in the return to schooling $\left(\Delta\beta_{1j}\right)$ (Krueger and Lindahl 2001, 1110). If the returns to schooling increase over time, the initial level of education will enter positively into the above equation. This would lead to structurally different coefficients in these two periods. However, since after the 1960s the share of secondary and higher education rose sharply, we would expect a decline in the general returns to education because micro-regressions suggest secondary and higher education having lower returns than primary education on average. This means that the initial level of education is likely to be on average negative.

Indeed, this finding of different effects of human capital is also confirmed by Petrakis and Stamatakis (2002, 518-519). They show that each education level has a different effect on economic growth. In addition, they also find that the effect of each level of formal education on economic growth differs among countries of different 'economic maturity'. In short, the more developed a country is, the more important secondary and higher education become compared with primary education. This means that the coefficients of education are shifting over time, and the positive or negative coefficient of initial schooling reflects exogenous change in the rate of return to schooling. As a consequence, the equations used in this context are likely to be overidentified. Still, in the majority of literature on macroeconomic growth, the rate of return is assumed to be constant over time. This might be valid for constant coefficient panel regressions on a group of relatively homogenous countries, of over a relatively short period of time, but is unlikely to hold even within the same country for an extended period.

5.3 Changes in the effect of human capital on economic growth among countries

Indeed, a more historical oriented research is important if one seeks to identify the institutional and social changes over time that cause a change in the effect of human capital on economic growth. These (and other) factors, however, may cause the relation between human capital and growth to differ across countries as well.

It is not only necessary to look at regimes (and try to correct for their existence by, for example, using dummies or initial GDP), but it is also important to keep account of the country specific factors. Not many studies are available that look thoroughly at the structure of the relation between human capital and economic growth. Some notable exceptions are Azariadis and Drazen (1990), Liu and Stengos (1999), and Kalaitzidakis, Mamuneas, Savvides, and Stengos (2001). Although Azariades and Drazen (1990, 519) point out that they ignore country specific effects and try to explain the differences between countries in terms of their economic structures, they still note that country specific circumstances may alter the relation between human capital and growth as '[i]n reality, other factors could mean that the potential growth benefits of a highly qualified labor force could be "wasted"'. In other words, institutional structures in different countries may cause differences in the effect of human capital on economic growth. Nevertheless, both Azariadis and Drazen (1990) and Liu and Stengos (1999) found evidence that, although there are regimes which they represent with certain threshold levels of human capital, the direct relation between human capital and economic growth seems linear and constant.

Yet, Kalaitzidakis *et al.* (2001) doubt whether the relation between education and growth remains constant even in the same regime. Independently of this, they still assume that there is only one regime for all countries. This may be the cause of the non-constant relationship they find. In other words, because they assume away the existence of regimes, they necessarily find non-linearities in the relationship between human capital and growth. Yet, they are not the only one to argue the existence of non-linearities as well (see for example Henderson and Russell 2005).

As a consequence, neither of these studies seems to disentangle the possible effects of regimes and of country specific effects on the relation between human capital and economic growth. The inclusion of dummies and other variables, intended to capture non-linearities, can generally capture only a part of the effect of regimes and country specific differences. These proxies might even be correlated with human capital formation itself, causing biased estimation. Therefore, more economic historical case studies seem to be necessary in this field.

6 CONCLUSION

The explanation of human capital in growth theory so far has suffered from three main problems. First, there is an enormous variety of human capital variables. Second, there is some controversy how to insert human capital in growth equations. Third, human capital accumulation is most likely subject to (country-specific) developments of education institutions and policy effects. This may have a strong impact on the estimated human capital coefficients.

First, the concept of human capital is abundantly used in both historical and economic research. However, due to the diverse use of human capital in the different fields of research, the lack of data, and theoretical debates, there is no clear consensus of what human capital actually should include.

Second, besides definition issues, numerous problems have plagued the use of human capital in macroeconomic growth regressions. Some are due to empirical specification and the inclusion of further regressors such as physical capital which may cause biased coefficients. An even more serious problem is that there is no appropriate measure of human capital, even if we use the narrowest definition of human capital. As is shown in many studies, the popular proxy 'average years of education' conveys almost no signal conditional on other variables. Another serious omission is that most proxies only reflect a part of the human capital stock as defined. For example, the qualitative aspect of human capital, which becomes more important at the end of the twentieth century, is completely unobserved. This in turn may lead to the rejection of the branch of new growth theories in which human capital is inserted as a factor of production.

Third, there is the problem of the (country-specific) institutional development of human capital accumulation. This may be crucial because most estimates of the relationship between human capital and economic growth are based on cross sectional or panel data of heterogeneous countries with the assumption of a homogenous effect of human capital on growth. Life is generally not this mechanical, however. The relationship between human capital and growth may change over time or across countries, which may bias the estimates of the coefficients. Therefore, the dynamic and cross-country factors should be identified by a historical research.

The next chapters will address these three problems. Chapters 3-5 will deal with the human capital accumulation in both a quantitative and a historical way. In chapter 3 we discuss the data, mostly on formal education, in chapter 4 we offer a historical analysis of human capital accumulation, and in chapter 5 we estimate the stock of human capital. The specification of the growth equation and the estimation results are presented in chapters 6-7.