

6. Is Lucas right? On the role of human capital in growth theory

1. INTRODUCTION

In the previous chapters we laid the basis for analysing the applicability of the different growth theories in explaining economic growth. Here we will use the historical analysis and the newly constructed data to distinguish between the different growth models. The outcome has important consequences for the more detailed analysis of economic growth. Not only is it important for the empirical specification, but it also determines the effect institutions have. However, it is only in the next chapter that we will use the growth model, the data, and the historical interpretation to analyse the growth process more thoroughly.

In this chapter we try to distinguish between the new growth models. Basically, two branches have developed, pioneered by Romer (1990) and Lucas (1988). Empirically, the difference between the two groups of theories is that endogenous growth in the theory of Romer (1990) is caused by accumulating technology (or knowledge), thereby establishing a relation between the level of human capital and economic growth. In this vision, human capital is seen as ‘knowledge’ and ‘ideas’ that are non-rival and partly excludable. In the theory of Lucas it is the human capital formation itself that, by non-decreasing marginal returns, creates endogenous growth. In short, to achieve endogenous growth, the effort needed to produce an extra unit of human capital should be the same, independently of the level of human capital. This assumption has been much debated. A possible explanation can be that persons with higher levels of education more easily receive extra knowledge or skills. However, there are other choices like a rising quality of human capital over time and increasing intergenerational transfers of knowledge (L’Angevin and Laïb 2005). In the currently used proxies of human capital, these qualitative causes are rarely accounted for and hence empirical results are biased towards the model of Romer (1990) (see for example Sianesi and Van Reenen 2003, 164). This model thus sees human capital as a factor of production and, consequently, values human capital as ‘skills’ that are to some extent rival and excludable, that is they are part of a physical person.

Yet, the regressions based on these models, as argued by Kibritcioglu and Dibooglu (2001, 12-13), are often “difficult to interpret, unstable, and lack a coherent social science perspective.” The difficulties in estimating and interpreting these

regressions, on which Kibritcioglu and Dibooglu (2001) based their (too) strong attack, result from obstacles in empirically distinguishing between the different growth theories. A first obstacle is that current human capital proxies used to estimate the new growth models are often unsuited to distinguish between the different theories. Second, the implications of the different growth theories are much alike making a distinction between them even harder. For example, both theories imply an absence of conditional economic convergence. Third, the model of Romer (1990) is based on technological growth (that depends on the level of human capital), whereas the model of Lucas is based on human capital accumulation (the growth of human capital determines the growth of the economy). But Lucas (1988) did not state through what channels capital accumulation causes endogenous growth. This could well be by easier adaptation of technologies from technological frontier countries meaning that both theories lead to endogenous growth by technological growth. Fourth, it is possible the Lucas (1988) model is just an earlier stage in a development toward the Romer (1990) model. Because the Lucas (1988) model is based on constant marginal returns to human capital accumulation, it is unlikely that Lucasian growth can last indefinitely. As Romer (1990) based his model on the technological frontier country (the USA), it might be possible that endogenous growth moves from Lucasian to Romerian growth when a country approaches the technological frontier.

It is thus likely there are institutional settings both in forming human capital and adopting technologies that cause the growth rate of economies to differ. This is especially visible in India, Indonesia and Japan which were subject to exogenous influences both in technology and human capital development. But, whereas Japan is an example of a successful developer, India and Indonesia lagged behind. The next sections address the differences among these countries. In section 2-4 we use several tests to distinguish between the different growth models. In section 2 we present the human capital:output ratio. Alternatively, in section 3 we test for constant marginal returns to human capital accumulation, a characteristic of Lucasian growth. In section 4 we turn to the relation between per capita GDP growth and, on the other hand, the level and growth of human capital. In section 5 we turn the relation upside down and use the growth theories to explain the difference between the human capital variables. In section 6 we end with a brief conclusion.

2. HUMAN AND PHYSICAL CAPITAL RATIO

It is difficult to distinguish the different growth theories. Yet, because we estimated a new human capital stock in the previous chapter, this allows us to exploit the different predictions of the growth of GDP, physical, and human capital. As we have seen in chapter 2, both the Lucasian and Romerian model predict the growth of GDP and physical capital to be equal on a balanced growth path. However, the model of Lucas predicts that the growth of human capital is almost equal or (due to the positive external effect) slightly lower than that of physical capital and GDP, i.e.

$$\frac{\dot{y}}{y} = \frac{\dot{k}}{k} = \frac{I-\alpha+\gamma}{I-\alpha} B(I-u) = \frac{I-\alpha+\gamma}{I-\alpha} \cdot \frac{\dot{h}}{h} \quad (6.1)$$

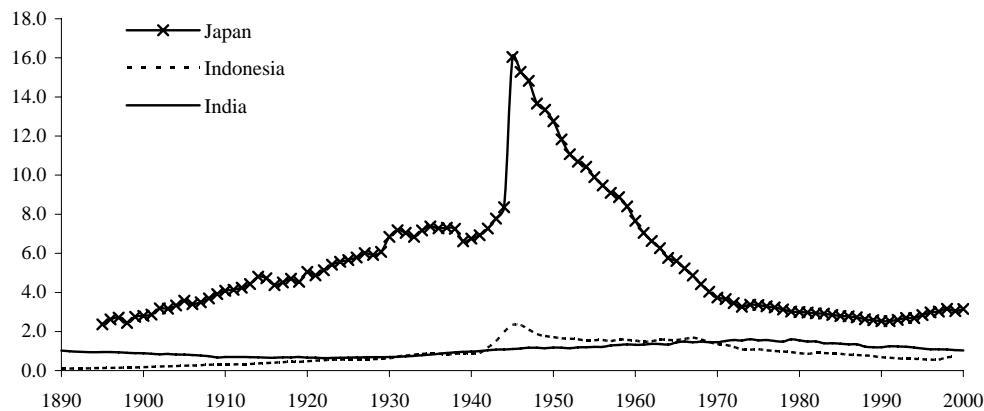
In the Romer (1990) model, however, human capital grows considerably slower than physical capital and GDP:

$$g = \dot{Y}/Y = \dot{K}/K = \dot{A}/A = \sigma H_A \quad (6.2)$$

In other words, if we find an almost constant ratio between human- and physical capital, or between human capital and GDP, than Lucasian growth dominates. If we find that the human capital:physical capital or human capital:GDP ratio declines markedly, Romerian growth dominates.

In chapter 5 (figure 5.5) we plotted the human-physical capital ratio. We can see that this ratio is almost constant in Indonesia and India. In Japan it increases slightly up to 1950 and decreases afterwards. The increase in the ratio in Indonesia around 1970

Figure 6.1
Human capital:output ratio (based on constant 1990 international USD, converted at PPP)



Source: Appendix A.2 and A.12.

was caused by a decline in physical capital investments, which was independent of GDP. This can be seen in figure 6.1. As the physical capital: output ratio is almost constant in all three countries (hence assuming a balanced growth path), the decline in the human capital:output ratio in Indonesia in the 1970s suggests that the relatively slower growth of physical capital must have been independent of GDP. Equally, the peak in the human capital:output ratio in Japan was caused by a fall in GDP during World War II. Yet, over-all the human capital:output ratio shows about the same pattern as the human:physical capital ratio. This suggests that the growth rates of per capita GDP and physical- and human capital are more or less in correspondence (Lucasian growth). The exception is Japan in the second half of the century, when the growth of human capital was considerably lower (Romerian growth).

3. MARGINAL RETURNS TO HUMAN CAPITAL ACCUMULATION

3.1 Introduction

A second distinctive feature of the theory of Lucas (1988) is that human capital is viewed as a factor of production. In this model, there are two sectors. In the first (productive) sector, human and physical capital is used to create income (or goods). In the second sector only human capital is used to produce human capital which can be employed in the productive (first) or in the human capital producing (second) sector.¹²⁰ If there is to be endogenous growth, it has to come from constant or increasing marginal returns to human capital accumulation. These constant or increasing marginal returns can exist in the second sector, where human capital is used as an input to form human capital. If in this second sector there are decreasing returns (the higher the level of human capital employed in this sector, the smaller impact it will have on human capital formation) the system approaches a steady state level of output and zero growth.

If there are constant or increasing returns in the second sector, there is endogenous growth¹²¹ and the Lucas-Uzawa model (Lucas 1988; Uzawa 1965) may be applicable to economic development. This model can be applied even if there are decreasing returns in the second sector. In the last century the time spent on human capital accumulation ($(1-u)$, see equation (6.3)) grew steadily, sometimes at an explosive rate, almost everywhere in the world. Even with diminishing returns, this may

¹²⁰ In Rebelo's (1991) model physical capital is employed in the second sector as well.

¹²¹ In other words, if the growth rate of the human capital that is formed in the second sector does not depend on the level of human capital employed (constant returns), there is endogenous growth.

have led to an increased growth rate. We will therefore test whether constant or increasing marginal returns are present in the second sector and, if decreasing returns are present, if there still is Lucasian growth.

We start with the standard equation in which per capita human capital formation takes place with human capital as an input. If an increase in the stock of human capital requires an identical effort no matter whatever level previously attained (non-decreasing marginal returns), and assuming constant returns to scale:

$$\dot{h}_t = h_t B(1 - u_t) - \delta h_t \quad (6.3)$$

, where \dot{h} is the increase of per capita human capital, and δ is its depreciation. Further, $B(1 - u_t)$ indicates human capital accumulation. In other words, B is a technical parameter indicating factors that influence the efficiency of investment in human capital and $(1 - u_t)$ is the time spent on human capital accumulation. We can rewrite equation (6.3) independent of its level:

$$\dot{h}_t/h_t = g_h = B(1 - u_t) - \delta \quad (6.4)$$

In other words, we have to estimate a regression in which the growth of the per capita human capital stock is regressed on the time spent on acquiring human capital (here assumed to be ‘average years of schooling’) and a constant (capturing depreciation).

In sum, there might be a connection between the growth of per capita human capital and the time spent on human capital formation. If B is positive, constant or increasing marginal returns are present.¹²² Yet, whether this relation is stable or even constant, is questionable. Thus we start with plotting this relation over time. Then, we move on to a regression analysis.

3.2 The relation between the growth of human capital and time spent on human capital formation

One has to be aware of a drawback of the above method.¹²³ It assumes constant marginal returns. Without constant marginal returns, equation (6.4) must be written as:

¹²² In this specification it is not possible that B is negative because we argue that $1-u$ increases the stock of human capital. B must be positive for this.

¹²³ Another drawback is that we used a human capital variables expressed in monetary units. However, Lucas used a multiplier, basically indicating how much one unit of labour in 1900 would be in, for example, 1990. In this respect, the use of attainment or ‘average years of education’ as a human capital proxy comes closer to this multiplier. Yet, this would create other problems. First, above equations cannot be estimated as we lack a proxy for the time spent on human capital accumulation. Second, if we use ‘average years of education’ in a growth regression not only must we use the level instead of the

$$\dot{h}_t/h_t = g_h = B(1-u_t)^\beta h_t^{\beta-1} - \delta \quad (6.5)$$

, where $\beta > 1$ gives increasing returns, $\beta < 1$ diminishing returns, and $\beta = 1$ constant returns. This means that one can estimate (6.3) (without depreciation) as:

$$\Delta \ln h_t = \ln B + \beta \ln(1-u_t) + (1-\beta) \ln h_t \quad (6.6)$$

Here, $1-u$ is proxied by ‘average years of education’. If $\beta = 1$, or $(\beta - 1) = 0$, there are constant marginal returns. Yet, Lucas’ model is a theoretical construction. Therefore, it might be difficult to assume that non-linearities are captured by a double-log equation. Constant returns can also emerge with other specifications. Therefore, we prefer to use the more general scatterplots (figure 6.2-6.4).

As pointed out, constant or increasing marginal returns to human capital accumulation mean that if the time spent on education rises by the same unit, the growth of the stock of per capita human capital remains the same, or rises. In other words, in equation (6.4) the B is positive. This is made visible in figures 6.2-6.4 below. These figures plot on the horizontal axis ‘average years of schooling’, $(1-u)$, and on the vertical axis the growth rate of the per capita human capital stock (\dot{h}_t/h_t) . They thus show the development of B over time, assuming depreciation constant.

However, as Monteils (2002) assumes, following Lucas (1988) that B is constant, this means that if the coefficient B of equation 6.4 decreases, this is because the relation between $(1-u)$ and the growth of human capital is non-linear. In other words, if she finds a negative coefficient, this cannot be caused by decreasing efficiency (B) as this was assumed constant, thus it must be caused by the situation that $\beta < 1$, i.e. diminishing marginal returns. Equally, a positive coefficient would mean that $\beta > 1$, thus suggesting increasing marginal returns. Following the line of reasoning of Monteils (2002), we may infer that if the trend in figures 6.2-6.4 is downwards, there are decreasing marginal returns, if it is upward, there are increasing marginal returns, and if the relation is insignificant (a horizontal line), there are constant marginal returns to an investment in human capital.

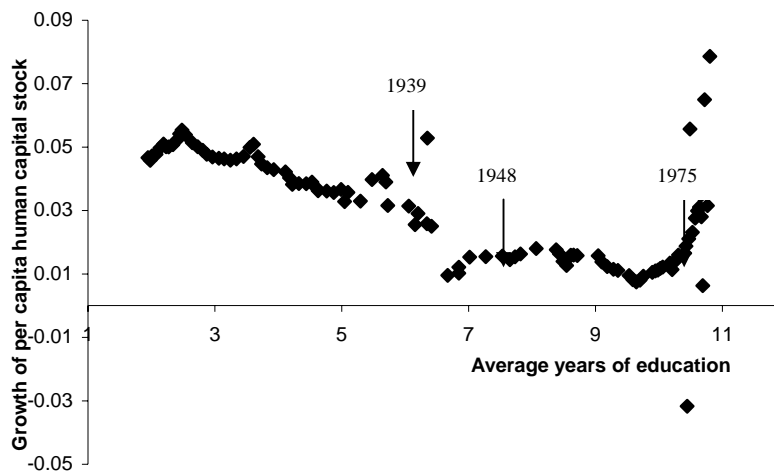
growth rate in the Lucas theory (as it indicates the time spent on human capital accumulation) but also the coefficient would be equal to $\beta \cdot B \cdot \lambda$, where we used λ to distinguish the factor share of human capital from the factor indicating the presence of constant marginal returns to human capital accumulation. As the factor share is likely to be around 0.3-0.6 and both β and B are likely to be on occasion smaller than 1, this might be one of the reasons why in the literature often a small coefficient (factor share) for the growth of human capital is found. For these reasons we prefer to use a human capital stock in monetary terms.

The figures show a remarkable pattern. Figure 6.2, for Japan, shows an almost constant relation until around 5.6 years of education and a fast declining trend between 5.6 and 6.7 years of education in the population. As we move forward in time, the ‘average years of education’ also rises. So, this figure displays a development where 5.6 years of education corresponds to circa 1939 and 6.7 years to 1948. After 1975 there is a clear upward trend.

The same pattern can be found in figures 6.3 and 6.4 for Indonesia and India. For Indonesia we find a decreasing trend until around 1957, a flat line between 1957 and 1987 and a strong increase afterwards. In India we found a rising trend until 1953, a declining trend from 1953 to 1981, and an increase from 1981 to 1997.¹²⁴ All three

Figure 6.2

Relation between average duration of training and growth rate of the per capita human capital stock in Japan

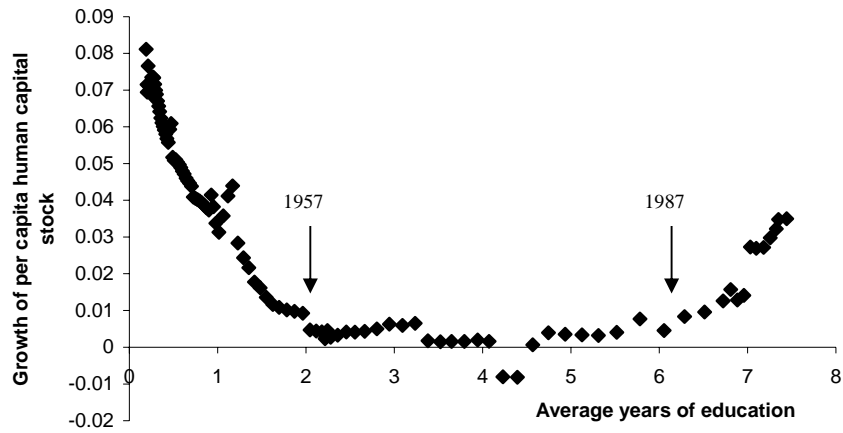


Source: Appendix A.7 and A.12

¹²⁴ It is likely that this different pattern for India is the result of the focus on secondary and higher education at the start of the twentieth century.

Figure 6.3

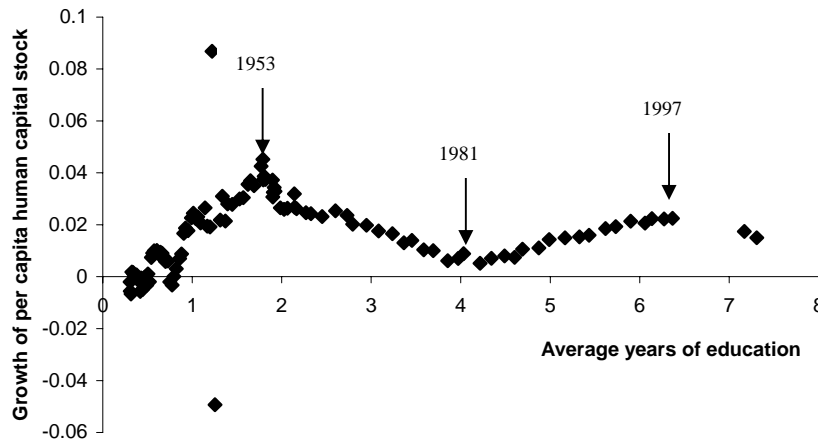
Relation between average duration of training and growth rate of the per capita human capital stock in Indonesia



Source: Appendix A.7 and A.12

Figure 6.4

Relation between average duration of training and growth rate of the per capita human capital stock in India



Source: Appendix A.7 and A.12

countries thus show periods of decreasing, constant, and rising trends in B .¹²⁵ This means that in all three countries there are periods of increasing, decreasing, and constant marginal returns to human capital accumulation.

3.3 Regression analyses

The results so far thus indicate that there are at least periods of Lucasian growth in all three countries. However, as pointed out, non-linearities in the relation between ‘average years of education’ and the growth of human capital may also have other causes than the presence of constant or decreasing marginal returns. One reason may be that the efficiency of human capital accumulation, B , is not constant over time. To provide a brief interpretation, we extend the method proposed by Monteils (2002) to capture these non-linearities. This is a simple method with many drawbacks, but, although not providing definitive proof, it shows that it is important to keep account of the efficiency of human capital accumulation.

We start, following Monteils (2002), by estimating equation (6.4). Using this equation, Monteils found strong evidence in favour of decreasing marginal returns to human capital in France. Yet, there are two problems with her findings. First, as indicated in the previous section, she assumes the efficiency of human capital accumulation (B) constant. This is a strong assumption as it is often argued in the literature that, especially for less developed countries, there was a decreasing efficiency of human capital accumulation in the decades after World War II (Stewart 1996, 332; Van der Kroef 1960). Second, she uses illiteracy as a measure of human capital. Illiteracy does not pick up the complete effect of human capital, especially not for periods when the process of increasing mass education had been completed and was replaced by increasing secondary and higher education. Consequently, using illiteracy data in such an analysis, one is bound to find decreasing marginal returns to human capital accumulation.

¹²⁵ Although this is an assumption which we cannot test here, we expect that the pattern of decreasing and later increasing marginal returns to human capital formation can be detected in most developing countries in the twentieth century. The reason is that they start with mass education in the first half of the twentieth century with generally low financial means, low quality of education, and a strong substitution of non-formal for formal education. The actual growth of the stock of human capital is thus far lower than the rise in ‘average years of education’. This is different in the 1960s-1980s when those countries as well as foreign institutions strongly invested in education. Furthermore, most substitution of non-formal into formal education had by then already taken place.

Using this regression method, table 6.1 reports for India and Japan a negative coefficient of ‘average years of schooling’ (the first regression for each country). Indeed, if we would draw a trend line through figures 6.2-6.4, we would find a decreasing trend (and therefore decreasing marginal returns). However, it does not decline as fast as Monteils finds for France. In addition, we even find a positive coefficient for Indonesia. Therefore, it is clear that our results differ from those of Monteils (2002) mainly because we estimated a new human capital stock that includes

Table 6.1: Estimation of the marginal returns to human capital accumulation*

EXPLAINED VARIABLE, $\Delta \ln h_t$: Growth of human capital stock

	Japan				Indonesia				India			
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)				
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Duration of training	-0.020	-11.3	-0.028	-16.1	0.011	13.9	-0.016	-8.81	-0.010	-8.55	-0.040	-8.05
Squared duration of training			0.001	7.71			0.003	15.2			0.003	6.22
R ²	0.87		0.92		0.92		0.97		0.71		0.79	

*The dummies, constant (picking up depreciation), and trend are not reported

aspects such as the quality of human capital, thus making the existence of constant or increasing marginal returns more likely.

The results of these regression analyses are thus more in accordance with the existence of constant or increasing marginal returns. This provides some evidence against the literature that criticizes the assumption of constant marginal returns (see for example Gong, Greiner, and Semmler 2004; Monteils 2002). Indeed, many other authors have argued there are good arguments for assuming constant marginal returns (Bratti and Bucci 2003; Glaeser 1994). However, we can bring this one step further as even the finding of periods with decreasing, increasing, and constant marginal returns is subject to a problem. As pointed out, it assumes the efficiency of human capital accumulation, B , to be constant. Indeed, it has even been brought forward that the apparent decrease in marginal returns is actually caused by a decrease in efficiency (B) of the second sector (the sector in which human capital is formed). For example Földvári and Van Leeuwen (2006) argue that B may change, and there might be non-

constant returns simultaneously. So with a 2nd order polynomial, one captures the latter directly.¹²⁶

To capture this effect, we estimated an alternative specification, including ‘average years of schooling’ squared as suggested by Földvári and Van Leeuwen (2006). The results are presented in table 6.1 (the second regression for each country). The interpretation is simple. Taking the marginal product results in the situation that only the coefficient of ‘average years of schooling’ squared indicates the relation between the time devoted to human capital accumulation and human capital formation. Only if this is positive and significant, there are increasing returns.¹²⁷ Table 6.1 shows that for all three countries these coefficient are positive and significant which shows that, without the possible inefficiency, Lucasian growth would be present in all three countries.

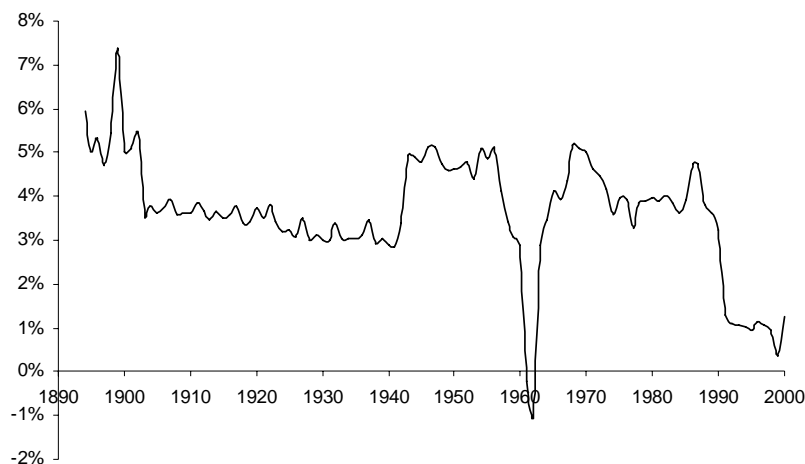
However, the estimated model is of course much too simple. Therefore, the question remains whether technical efficiency of the second sector indeed decreases in the mid-twentieth century. Looking at figures 6.2-6.4, it is difficult to escape the idea that technical inefficiency in the second sector plays an important role in all three countries. In Indonesia, the strongest decline occurred in the period up to 1957 while in India the decline only started after the Second World War. For both countries these years marked periods of increasing mass education. Hence, given the periodization of the peaks and troughs, we expect that a decline in B is caused by a shift from mass education to a focus on secondary education as all troughs (except for Japan which

¹²⁶ Admittedly, rewriting this into equation 6.2 gives strange results. However, empirically this is the easiest way to solve the problem. If Lucas’s assumption of constant returns in the second sector holds, the marginal effect of $(1-u)$ on the growth of the human capital stock equals B . Monteils (2002) estimates the equation $\Delta \ln h = B(1-u)$, and argues that if B decreases while $(1-u)$ grows, there must be decreasing returns, i.e. no endogenous growth. However, this is only true if the only factor that influences the marginal effect of $(1-u)$ on the growth of human capital has decreasing returns. This becomes different if we allow for a ‘technical efficiency’ (productive efficiency in the second sector). Therefore, when we use $B(1-u) + a(1-u)^2$, the marginal effect of $(1-u)$ on the growth of human capital becomes $B + 2a(1-u)$. Thereby we decompose the observed marginal effect into two parts: an effect not directly dependent on $(1-u)$, denoted by B (technical efficiency), and a part which directly depends on the level of $(1-u)$ denoted by $2a$ (marginal returns). If $2a$ is positive and significant, the larger level of $(1-u)$ leads to increasing growth of the human capital stock, i.e. increasing returns (endogenous growth). If $2a$ is negative and significant there are decreasing returns (thus no endogenous growth, at least not without positive external effects) and, if $2a$ is insignificant, there are constant returns (thus Lucas’ assumption holds and this results in endogenous growth).

¹²⁷ As we take the marginal product of a squared variable, we have to multiply the coefficient with 2 in order to get the actual effect of time on human capital formation. However, this does not change the finding of the sign or significance of the coefficient.

Figure 6.5

Growth of average years of education in Indonesia, 1890-2000



Source: Appendix A.7

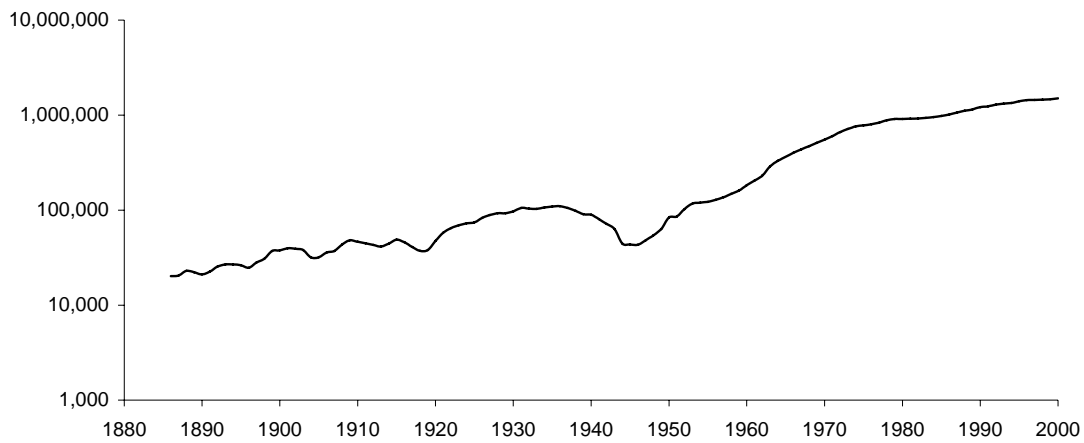
developed its education system earlier) signal periods of slower growth of education levels. This can clearly be seen in Indonesia in figure 6.5.¹²⁸ Comparing figure 6.5 with 6.3, we see that for the period 1940-1990 there was a fast increase in average years of education combined with an increase in technical efficiency while in the pre-1940 period there was a slower increase in mass education combined with a decrease in technical efficiency.

This increase in technical efficiency may also be partly caused by a decrease in per capita spending on education that took place in that period. The average per student expenditure on education in 1990 rupiah decreased from 156,000 in the 1930s to 28,000 in the 1950s after which it slowly increased again. The same patterns can also be found in India where per student public and private expenditure decreased from 875 constant 1990 Rupee per student in the 1930s to 569 Rupee in the 1940s. Hence, in India and Indonesia periods of fast growth of average years of education, combined with a decrease in per capita spending on education, coincided to a large extent with periods with decreasing technical efficiency in the human capital forming sector. In Japan, however, the faster growth of 'average years of schooling' had already taken place before 1950 (2.3% versus 0.8%). Equally, in Japan there was no significant decline in

¹²⁸ Here, the dip in the growth of 'average years of schooling' is mainly caused by the turmoil surrounding the coup against Sukarno in the early 1960s. During this periods, many secondary schools where closed.

Figure 6.6

Log of the sum of per student private and public expenditure on education in constant 1990 yen in Japan, 1886-2000



Source: Appendix A.8

per student expenditure on education. As figure 6.6 shows, both before 1936 and after 1945 there was an increase in per student expenditure, with a temporary decrease during World War II. Thus whereas in India and Indonesia the decreasing marginal returns may be attributed to decreasing technical efficiency in human capital accumulation as signalled by lower growth in average years of education and higher per student expenditure on education, this was not the case in Japan.

The analysis in this section suggests three things. First, in India and Indonesia, during a period in which the strong rise of formal education took place (and per capita expenditure on education decreased), it is likely the technical efficiency of human capital accumulation, B , increased. When formal education declined and the per capita expenditure on education increased, B was likely to decline. Using the model of Monteils (2002), this can result in falsely rejecting the presence of constant marginal returns. Second, it remains unclear, however, if the correction for the increase in technical inefficiency is enough to correct for diminishing marginal returns caused by a decline in the quality of human capital. Nevertheless, whether or not diminishing returns are present in India and Indonesia in this period, Lucasian growth remains present as, as we noted in section 3, the time devoted to human capital accumulation

increased strongly during this period thus creating economic growth.¹²⁹ This increase in the time devoted to human capital accumulation, even without constant marginal returns, can be argued to be an engine of endogenous growth although this growth asymptotically approaches zero. Third, neither an increase in the growth of ‘average years of schooling’ nor a decline in per student expenditure on education took place in Japan during this period. As a decreasing technical efficiency of human capital accumulation cannot explain the diminishing marginal returns in the second half of the twentieth century, combined with an accelerating economic growth, this means that no Lucasian growth was present. Or, as we will see in the next section, where in India and Indonesia the level of our newly estimated human capital stock, which includes both the quantity (average years of schooling) and the quality (expenditure on education) of human capital, will not significantly be correlated with per capita GDP growth, this relation is likely to be positive and significant in Japan.

4. LEVEL AND GROWTH EFFECTS OF HUMAN CAPITAL

4.1 Introduction

So far, we have found some evidence which favours the theory of Lucas (1988) as an explanation of the effect human capital has on economic growth, at least for India and Indonesia. In Japan, however, after the 1940s, the diminishing marginal returns to human capital accumulation could not be explained by inefficiency in human capital accumulation or a decrease in quality of human capital. Yet, there is a third distinction between the Lucas-Uzawa and Romer models.¹³⁰ As pointed out in chapter 2, Romer (1990) views human capital as an input in the R&D sector, thus creating technological change. So, the level of human capital determines the rate of growth; it is not a factor of production. Lucas (1988), on the other hand, sees human capital as a factor of production, limited to the individual who possesses it (human capital is rival and excludable) (Barro and Sala-i-Martin 2004). In other words, the growth of human capital causes economic growth.

¹²⁹ One could also argue that these are periods of Solowian growth.

¹³⁰ Another way to distinguish growth theories is to insert initial GDP in the equation to test for convergence. If the coefficient on initial GDP is negative, countries with a higher level of GDP show less economic growth, i.e. there is convergence. In theory only the neo-classical growth model exhibit convergence. Therefore, this method is used in many studies as a test for the presence of endogenous growth. However, also the neo-classical theory can sustain divergent economic development, for example if countries have changing adaptation and absorption capabilities of technology. Equally, the new growth theories have recently be argued to be able to also capture convergence.

Empirically we can test the difference between the two theories by regressing the per capita GDP growth on the level and the growth of the per capita stock of human capital. If the model of Romer is correct, we expect to find a positive and significant effect of the level of human capital on the growth of per capita GDP (see equation 6.2). But, if Lucas is correct, we expect to find a positive and significant effect of the growth of human capital on economic growth (see equation 6.1). Of course, these two theories are not mutually exclusive.¹³¹

4.2 Unit-roots and cointegration

If we want to test whether the level (Romer) or the growth (Lucas) of human capital in the long run affects economic growth, we first have to determine if both variables are stationary. If they are not, for example if they are trending upwards, regression analysis is likely to find a relation where in fact none exist. The only exception is if there is a steady long-run relationship between two non-stationary variables, hence the residual of the regression is stationary. In other words, if there is cointegration.

There are two options. First, the log-level of per capita human capital and GDP are both first order integrated, I(1). In this case, and if they are also cointegrated, Lucasian growth is likely.¹³² Second, if the log-level of per capita GDP is one order more integrated than the log level of per capita human capital (for example I(1) and I(0) or I(2) and I(1)). In that case, there is a long-run relationship between the growth of GDP and the log-level of human capital, hence Romerian growth.¹³³

The results of the (augmented) Dickey-Fuller test for the presence of stationarity are presented in table 6.2 and 6.3 below. We included a trend a constant and estimated it before 1940 and after 1950 in order to avoid data problems caused by World War II. Not surprisingly, stationarity is rejected for all level variables. To determine the

¹³¹ It is worth noting that Romer (1990) included human capital also as a factor of production in his specification. Therefore, in itself, the finding of a positive and significant coefficient of the growth of human capital is not enough to dismiss the Romer model. Yet, given our previous discussion on marginal returns and given our finding (see table 6.2-6.4) of the long-run effects between human capital and growth, we think that we might interpret these regressions as a test between the Romer (1990) and Lucas (1988) models.

¹³² Please note that the equation $\Delta \ln y_t = \alpha + \beta \Delta \ln h_t + \varepsilon_t$ is equal to $\ln y_t = \alpha + \beta \ln h_t + \varepsilon_t$ if there are no breakpoints.

¹³³ Please note that we excluded physical capital. As in both the theories of Romer and Lucas also include physical capital, this may lead to an omitted variable bias which may bias the estimates of the presence of cointegration.

Table 6.2: (Augmented) Dickey-Fuller test for India, Indonesia, and Japan, 1890-2000 (I(0))Unit-root null hypothesis: $\rho = 1$.

		India		Indonesia		Japan	
		$\ln h_t$	$\ln y_t$	$\ln h_t$	$\ln y_t$	$\ln h_t$	$\ln y_t$
±1890-1940	Sample size	29	29	37	41	31**	44**
	Lag order	4	1	5	1	11	2
	Estimated value of $\rho - 1$	-0.016	-0.084	0.001	-0.330	-0.006	-0.011
	Test statistic: tau_c(1)	-0.535	-1.213	0.063	-3.010	-2.369	-0.324
	Asymptotic p-value	0.982	0.907	0.997	0.129	0.151	0.919
±1950-2000	Sample size	26	26	21	21	36	36
	Lag order	1	0	1	3	1	1
	Estimated value of $\rho - 1$	-0.007	-0.769	-0.062	-0.388	-0.028	-0.035
	Test statistic: tau_c(1)	-0.484	-2.788	-0.642	-2.989	-1.370	-1.225
	Asymptotic p-value	0.984	0.214	0.976	0.135	0.870	0.905

* Significant at 10%, hence unit-root rejected (the variable is stationary).

** Japan 1890-1940 includes only a constant because the trend is not significant..

Notes:

Including constant and trend

p-values based on MacKinnon (1996).

order of the integration we also present a unit root test of the first difference in table 6.3.

Here we can see that all variables are I(1) with the exception of the level of per capita

Table 6.3 (Augmented) Dickey-Fuller test for India, Indonesia, and Japan, 1890-2000 (I(1))Unit-root null hypothesis: $\rho = 1$.

		India		Indonesia		Japan		
		$\Delta \ln h_t$	$\Delta \ln y_t$	$\Delta \ln h_t$	$\Delta \ln y_t$	$\Delta \ln h_t$	$\Delta \ln y_t$	$\Delta^2 \ln y_t$
±1890-1940	Sample size	41	41	43	43	35	38	
	Lag order	5	0	1	4	1	1	
	Estimated value of $\rho - 1$	-0.526	-1.037	-0.480	-1.375	-0.352	-1.632	n.a.
	Test statistic: tau_c(1)	-3.904	-4.235	-3.291	-4.460	-3.172	-6.893	
	Asymptotic p-value	0.012*	0.009*	0.068*	0.002*	0.090*	0.000*	
±1950-2000	Sample size	31	31	26	36	21	31	21**
	Lag order	4	3	1	5	1	1	0
	Estimated value of $\rho - 1$	-0.784	-2.289	-0.564	-0.963	-0.901	-0.589	-1.818
	Test statistic: tau_c(1)	-4.314	-4.133	-3.163	-3.147	-3.338	-2.952	-4.829
	Asymptotic p-value	0.003*	0.006*	0.092*	0.096*	0.088*	0.161	0.005*

* Significant at 10%, hence unit-root rejected (the variable is stationary).

** Japan 1950-2000 is second order stationary.

Notes:

Including constant and trend

p-values based on MacKinnon (1996).

GDP in Japan in the second half of the century which is I(2). In other words, per capita growth accelerated in Japan after 1950 until the 1980s.

These findings suggest the following long-run relation in India and Indonesia in the entire, and in Japan in the first half of the century: $\ln(y_t) = \alpha + \beta \ln(h_t) + \varepsilon_t$, hence, there is Lucasian growth. In Japan in the second half of the century the long-run growth

Table 6.4: Engle-Granger test: (Augmented) Dickey-Fuller test on the residual of the cointegrating regression $\ln y_t = \alpha + \beta \ln h_t + \gamma trend + \varepsilon_t$.

Unit-root null hypothesis: $\rho = 1$.

		India	Indonesia	Japan
±1890-1940	Sample size	23	34	41**
	Lag order	5	4	0
	Estimated value of $\rho - 1$	-0.643	-0.670	-0.552
	Test statistic: tau_c(1)	-3.650	-3.578	-3.427
	Asymptotic p-value	0.070*	0.083*	0.057*
±1950-2000	Sample size	24	33	29***
	Lag order	0	4	1
	Estimated value of $\rho - 1$	-1.087	-0.446	-0.988
	Test statistic: tau_c(1)	-3.955	-4.281	-4.214
	Asymptotic p-value	0.077*	0.012*	0.014*

* Significant at 10%, hence unit-root rejected (the variable is stationary) and there is a long-run (cointegrating) relationship.

** Japan 1890-1940 includes only a constant because the trend is not significant.

***Japan 1950-2000 uses $\Delta \ln y_t$ instead of $\ln y_t$. Hence, the cointegrating regression becomes $\Delta \ln y_t = \alpha + \beta \ln h_t + \gamma trend + \varepsilon_t$.

Notes:

Including constant and trend

p-values based on MacKinnon (1996).

is $\Delta \ln y_t = \alpha + \beta \ln h_t + \varepsilon_t$ (Romerian growth). To test whether these long-run relations actually exists, we have to test for cointegration. In other words, we have to test if the residual, ε_t , of both long-run relations, is stationary. These results are reported in table 6.4. We see that for all countries and periods a long run relation exist between $\ln(y_t)$ and $\ln(h_t)$, hence $\ln y_t = \alpha + \beta \ln h_t + \gamma trend + \varepsilon_t$. This means that for those countries and periods Lucasian growth seems to be present. The exception is Japan in the second half of the century when there is a cointegrating relation between $\Delta \ln y_t$ and $\ln h_t$, hence Romerian growth.

5. COMBINING LEVEL AND GROWTH EFFECTS WITH CONSTANT MARGINAL RETURNS: THE ROLE OF AVERAGE YEARS OF EDUCATION

5.1 Introduction

In the previous section our finding was that, with the exception of Japan after 1950, there was a long run relation between the level of GDP and human capital, hence Lucasian growth. However, in many studies focusing on human capital, the result is that the level of human capital affects the growth of GDP (see for example table 2.1 in chapter 2), hence these studies find Romerian growth. Why is this the case?

In more recent studies, often ‘average years of education’ is used to proxy human capital development. However, in a recent paper, Földvári and Van Leeuwen (forthcoming) show that ‘average years of education’ is, on a macro level¹³⁴, not a proxy of the level of human capital, but of the time devoted to human capital accumulation and, consequently, of the growth of human capital. This has two consequences. First, as we saw in table 6.3 that the growth of human capital was generally stationary, this means that the level of ‘average years of education’ must also be stationary. Second, as ‘average years of education’ is already a proxy for the stationary growth of human capital, we cannot estimate a cointegrating relation (because in that case both variables need to be I(1) and it is impossible to turn the level of ‘average years of education’ in a proxy for the level of human capital). Hence, instead of using:

$$\ln y_t = \alpha + \beta \ln h_t + \gamma \text{trend} + \varepsilon_t \quad (6.7)$$

we have to use

$$\Delta \ln y_t = \alpha + \beta \ln edu_t + \gamma \text{trend} + \varepsilon_t \quad (6.8)$$

, where *edu* is a ‘average years of education’ and thus proxies the growth of human capital, $\Delta \ln h_t$. This explains why in the literature often a positive effect of the level of human capital (proxied as ‘average years of education’) on economic growth is found while we, using an alternative human capital stock, find a relation between $\ln y_t$ and $\ln h_t$.

Földvári and Van Leeuwen (forthcoming) based their results solely on the use of ‘average years of education’ and relating the coefficients to economic theory. They indeed found that when ‘average years of education’ is interpreted as the growth of

¹³⁴ At a micro level this is not necessarily true.

human capital, all (theoretically strange) results from the literature could be explained. However, here we have both ‘average years of education’ and estimates of an alternative stock of human capital which allows us to review the role of ‘average years of education’ more directly.

5.2 Unit-root and and a Mincer equation

As indicated in section 5.1, if Földvári and Van Leeuwen (forthcoming) are correct, this means that the level of ‘average years of education’ should be stationary as it proxies the growth of human capital which was found to be stationary in table 6.3. The result of this test is presented in table 6.5 below. Indeed, the results are as expected. All series

Table 6.5: (Augmented) Dickey-Fuller test for India, Indonesia, and Japan, 1890-2000 (human capital proxied by average years of education)

Unit-root null hypothesis: $\rho = 1$.

		India $\ln edu_t$	Indonesia $\ln edu_t$	Japan $\ln edu_t$
±1890-1940	Sample size	26	35**	31**
	Lag order	5	4	3
	Estimated value of $\rho - 1$	-0.359	-0.018	-0.023
	Test statistic: tau_c(1)	-3.345	-2.625	-2.825
	Asymptotic p-value	0.059*	0.088*	0.055*
±1950-2000	Sample size	42	21	51**
	Lag order	5	1	5
	Estimated value of $\rho - 1$	-0.180	-0.363	-0.064
	Test statistic: tau_c(1)	-3.182	-3.405	-3.340
	Asymptotic p-value	0.088*	0.051*	0.013*

* Significant at 10%, hence unit-root rejected (the variable is stationary).

** With constant but without trend because the trend is not significant.

Notes:

Including constant and trend unless otherwise indicated.

p-values based on MacKinnon (1996).

are $I(0)$ and, hence, one order less integrated than those of human capital.

Ignoring the Romerian growth in Japan, we may summarize that both the growth of per capita GDP and the level of ‘average years of education’ are stationary. Thus, if we want to estimate the long-run relation we cannot use cointegration but we have to revert to an alternative such as the macro-Mincer equation.

Although some criticisms have been levied against the macro-Mincer¹³⁵, it is still a relatively simple way to gauge the effect of the level and the growth of the per capita stock of human capital. We start with a basic equation:

$$\Delta Lny_t = \alpha + kt + \beta_1 \Delta Lny_{t-1} + \beta_2 Lny_{t-1} + \beta_3 edu_{t-1} + \beta_4 \Delta edu_{t-1} + \varepsilon_t \quad (6.9)$$

, where y is per capita GDP, edu ‘average years of education’ in year t , t is the trend, and ε is the error term.¹³⁶ We used independent variables with one time lag to avoid simultaneity.¹³⁷ If we include ‘average years of education in the regression without logarithm, as a result of the underlying assumptions this is equal to inserting a monetary variable such as newly estimated human capital stock with a logarithm.¹³⁸

¹³⁵ Macro-Mincer regressions generally exclude variables indicating ‘experience’. Clearly this is a problem. It is argued that variables as life expectancy are almost certainly related to the standard of living. As a consequence, inserting average experience, which is related with life expectancy, would create a simultaneity bias. This would reduce the effect of human capital on economic growth as part of this effect works through life expectancy (Krueger and Lindahl 2001:1109-1110). Please note that the opposite might also be true: by omitting life expectancy, the effect of human capital on economic growth might be overestimated because part of the effect of life expectancy works through human capital. Another worry concerning the macro-Mincer equation is that it excludes physical capital. Just as with ‘experience’, excluding physical capital may cause a rise in the effect of human capital on economic growth.

¹³⁶ Admittedly we ignore many possibly relevant variables such as openness to external trade. Given our focus we assumed this here to be constant over time, an assumption which may be very well modified in the future. Another important variable we omit here is physical capital. Not only is it theoretically necessary to include it (see chapter 2 section 3) but also it might be related to foregone wages (see chapter 5) meaning that omitting it may also bias the results. However, it does not seem the case that the bias is particularly strong as we can see in chapter 7 section 4.

¹³⁷ This means that human capital may influence growth, but growth may influence human capital as well. Of the different possible options to correct this, we chose to simply use a proxy variable under the assumption that 1) the independent variable is intertemporal correlated and 2) both the first lag of the independent variable and the error term of the regression of the X-variable on its first lag are uncorrelated with the error term of the regression.

¹³⁸ Generally, studies nowadays include ‘average years of education’ in a regression (without a logarithm). We, on the other hand, also have an estimated human capital stock in monetary terms which we include in logarithmic form in the equation. So, how do we compare these two different human capital coefficients? First we look at why the variable ‘average years of education’ is inserted without a logarithm. This method is advanced by, among others, Krueger and Lindahl (2001), Soto (2002), and Topel (1999), who argue that the profit in year t from human capital depends on the profit in year 0 multiplied with the discount rate and the years elapsing, i.e.

$$h_t = h_0 (1+r)^t$$

, where I are the number of years of education. The subscript 0 indicates that we have the initial per capita stock of human capital, for example in 1970. Now taking logarithms, we get:

$$Lnh_t = Lnh_0 + I \ln(1+r)$$

Now if $\alpha = h_0$ and $\beta_3 = \ln(1+r)$, we can express the level of human capital as

$$Lnh_t = \alpha + \beta_3 I$$

Thus, if we want to estimate a regression where we want to regress the growth of per capita GDP on the log-level of the per capita stock of human capital, we get:

$$\Delta Lny_t = \alpha + \beta_3 I$$

, where I is the ‘average years of education’ and β_3 indicates the elasticity (how much percent the growth of per capita GDP rises as I rises with 1 year). As a consequence, when taking one time lag, above equation is equal to equation 6.9 with the exclusion of the growth of human capital and the lagged y -

We know that most periods and countries in our sample are dominated by Lucasian growth. This means that only if there is a relation between ‘average years of education’ and GDP and if ‘average years of education’ is indeed a proxy of the growth of human capital, we expect β_3 to be positive and significant.

The results are presented in table 6.6.¹³⁹ For all regressions, normality is not rejected. Equally the goodness of fit is between 36% and 87%. Basically, the results confirm the findings from the literature. The coefficient of the level of ‘average years of education’, β_3 , is positive, significant, but small, being between 1.5% and 4%. This is

Table 6.6: Results from a macro-Mincer equation for India, Indonesia, and Japan 1890-2000 using ‘average years of education’ as estimates of the growth and level of human capital*

Dependent variable: $\Delta \ln y_t$

	The variable h = average years of education **					
	India		Indonesia		Japan	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Constant	0.292	1.99	0.431	2.88	0.362	5.51
Trend	-0.0001	-0.571	0.00002	0.055	-0.002	-2.16
$\Delta \ln y_{t-1}$	-0.074	-0.855	0.394	5.67	0.018	0.454
$\ln y_{t-1}$	-0.047	-1.92	-0.064	-2.85	-0.058	-5.80
Δedu_{t-1}	-0.040	-1.29	0.006	0.065	-0.027	-0.689
edu_{t-1}	0.020	3.95	0.015	2.31	0.039	4.85
R ²	0.364		0.703		0.876	
Obs.	109		107		110	
AR1-1 (prob)	0.172		0.271		0.961	
Normality(prob)	0.997		0.154		0.050	

*Dummies not reported
 **‘average years of education’ is inserted in the equation without logarithms.

in accordance with the findings from the literature (see table 2.2 in chapter 2). It also confirms that ‘average years of education’ must be interpreted as a proxy of the growth of human capital. Indeed, this also explains why the coefficient of the growth of human capital (proxied by ‘average years of education’) is often found to be insignificant in the literature. The aim is to estimate the relation between $\Delta \ln y_t$ and $\Delta \ln h_t$, hence Lucasian growth. However, because ‘average years of education’ is actually a proxy of the growth of human capital, what one actually measures is:

variables, i.e. $\beta_3 I$ corresponds to $\beta_3 \ln h_{t-1}$. This means that in both cases what the equation actually says is that the growth of per capita GDP depends on the log-level of the stock of human capital.

¹³⁹ Although this specification is much used, some problems remain. For example, the data may exhibit breakpoints and the equations may suffer from an omitted variable bias, mainly due to the exclusion of for example physical capital.

$$\Delta Lny_t = a + kt + \beta_4 \Delta^2 \ln h_t + \varepsilon_t \quad (6.10)$$

Or, assuming no breakpoints:

$$Lny_t = a + kt + \beta_4 \Delta \ln h_t + \varepsilon_t \quad (6.11)$$

Hence, a permanent increase in the growth of human capital causes only a one-time increase in the level of human capital. This means that for permanent economic growth, the growth of human capital must continually accelerate. As this obviously is not the case, β_4 is either positive or negative, but in both cases insignificant.

5.3 Connecting the use of ‘average years of education’ as a human capital proxy to constant marginal returns to human capital accumulation

In the literature (Foldvari and Van Leeuwen, forthcoming), using unit–root tests in the previous sections, and using a Mincer-equation, it is suggested that ‘average years of education’ must be interpreted as a proxy for the growth of human capital. Indeed, in table 6.6 we found that the level of ‘average years of education had a positive effect on economic growth while table 6.4 showed it was the growth of our newly estimated human capital stock that effected economic growth.

Limiting ourselves to the theory of Lucas (1988), this means that if the growth of human capital determines economic growth while it is the level of ‘average years of education’ that affects economic growth, the level of ‘average years of education’ must determine the growth of the newly estimated stock of human capital. This is easy to see. We start with

$$\frac{\dot{y}}{y} = \alpha + \beta \frac{\dot{h}}{h} \quad (6.12)$$

, where the growth of per capita GDP depends on the growth of the per capita estimated human capital stock. This is roughly the equation describing the long-run growth in the model of Lucas (1988). However, if we look at the level of ‘average years of schooling’, we get:

$$\frac{\dot{y}}{y} = \gamma + \varphi educ \quad (6.13)$$

, where *educ*, the level of ‘average years of schooling’, determines the growth of per capita income. This is the regression following from the theory of Romer (1990).

However, combining equation (6.12) and (6.13) leads to:

$$\gamma + \varphi educ = \alpha + \beta \frac{\dot{h}}{h} \quad (6.14)$$

, which can be rewritten in the following fashion:

$$\frac{\dot{h}}{h} = \frac{\alpha - \gamma}{\beta} + \frac{\varphi}{\beta} educ \quad (6.15)$$

Therefore, the growth of human capital depends on the level of ‘average years of schooling’. If we, as we have done in section 3 of this chapter, see ‘average years of schooling’ as a proxy for the time devoted to human capital accumulation, we end up with exactly what Lucas argues to be the main source of endogenous growth: constant (or increasing) marginal returns to human capital accumulation which is present in India and Indonesia (see equation 6.4). Completing this way of thinking, one may (somewhat exaggerating) argue that studies that find evidence in favour of Romer’s theory from regressions based on average years of schooling as a proxy for human capital, basically confirmed Lucas’ theory without being aware of it (see for example Benhabib and Spiegel 1994; Krueger and Lindahl 2001; Portela *et al.* 2004).¹⁴⁰

6. CONCLUSION

We tried to apply the two main branches of the new growth theories on economic development. To this end, we used two formal tests to find out which growth theory best described the link between human capital and economic growth.

¹⁴⁰ As we pointed out in section 3.2 of this chapter, our estimated human capital stock is in monetary terms. This made it possible to directly estimate the Lucasian second sector which by definition means, as we can see in the text, that when the level of ‘average years of education’ is inserted in a growth equation, this is in fact a partial test for the Lucas theory. It is partial because 1) also Romer allows for the possibility that human capital is a factor of production and 2) The coefficient of this sort of regression is not equal to the factor share of human capital, but to the factor share of human capital multiplied with the efficiency of human capital accumulation and an indicator of constant marginal returns to human capital accumulation.

The situation that our estimated human capital stock is in monetary terms also allows for an extra test for the distinction between Romerian and Lucasian growth. Most studies assume that there are constant returns to scale in a production function. This means that, if we have $Y = K^\alpha H^\beta$, $\alpha + \beta = 1$. However, we have both physical and human capital in monetary units (for example USD). Consequently, if there are increasing returns to scale, for example, $\alpha + \beta = 2$, Y is expressed in dollars squared. Only if there are constant returns, Y is expressed in USD (to the power 1). Interestingly, our estimates are performed with solely human capital, thus excluding physical capital. We thus have only one production factor. In this case, the marginal returns to human capital accumulation (second sector) is equal to the returns to scale (first sector). As we pointed out, in order to have GDP in the right unit (USD) it is necessary that there are constant returns to scale and thus constant marginal returns to human capital accumulation. In above regressions this cannot be observed. However, in chapter 7 we run regressions for sub periods in which the human capital coefficient increases significantly and is often close to 1 meaning Lucasian growth.

The first way to evaluate the growth model is to look at the human: physical capital ratio and the human capital: output ratio. For Lucasian growth these ratios should be almost constant while they should decline during Romerian growth. The latter is found in Japan in the second half of the century while in the remaining countries and periods Lucasian growth dominated. This is confirmed by a second test, following Monteils (2002), which is based on the situation that in the theory of Lucas there are two sectors. In the first sector, human capital is used to produce output while in the second sector human capital is used to create new human capital. Therefore, if one ignores positive external effects of human capital, endogenous growth can only be possible if there are constant or increasing marginal returns to human capital accumulation. We found extended periods with constant or increasing marginal returns. This evidence supports the applicability of the Lucasian growth. If efficiency in the second sector has the shape of a trough parabola, we found for all three countries increasing returns. However, though rising growth of 'average years of schooling' and a decreasing quality of human capital can explain the diminishing marginal returns in India and Indonesia, this cannot provide an explanation for Japan in the second half of the twentieth century. Therefore, though India and Indonesia suffered from periods with increasing, constant, and diminishing marginal returns without leaving the phase of Lucasian growth, Japan moved from Lucasian growth in the first half of the century to Romerian growth in the second half.

Hence, in the first and second test there were indications that Romerian growth dominated in Japan in the second half of the century and Lucasian growth in the other countries and periods. This was confirmed in the third test. Here we estimated whether there was a long-run relation between human capital and economic growth. Given that Lucas (1988) saw human capital as a factor of production, the growth of human capital should have a positive influence on economic growth. As Romer saw human capital only as an input in the R&D sector, in his theory the level of human capital should have a positive effect on economic growth. Indeed, we found, with the exception of Japan after 1950, that there was a long-run relation between the level of GDP and human capital, i.e. Lucasian growth. For Japan after 1950 we found a relation between the growth of GDP and the level of human capital, hence Romerian growth.

Consequently, the three tests suggests that there are strong indications of a shift from Lucasian to Romerian growth in Japan while such a shift was absent in India and Indonesia. Some possible reason implicitly touched upon in this chapter included the

lower quality of education in the latter two countries and the higher level of human capital in Japan. This leads to a significantly different effect both in human capital formation and in the relationship between human capital and economic growth. As suggested in chapter 4, these differences may to a large extent be attributed to differences in the development of educational institutions. This resulted in two hypotheses on the relation between human capital and economic growth. Taking the growth model as outlined in this chapter, we will test these hypotheses in order to determine the effect of institutional development on cross-country growth divergence.