7. The contribution of human capital to growth: some estimates

1. INTRODUCTION

So far we have noted that human capital seems to affect economic growth mainly through capital accumulation. As a consequence, human capital had to be interpreted as a factor of production in the Lucas (1988) theory. The exception was Japan in the second half of the twentieth century where we found Romerian growth. However, the estimates in chapter 6, based on the often used macro-Mincer equation, were of a general nature. Although they allow differentiating between the theories of Lucas (1988) and Romer (1990), these estimates still do only partly account for a possible imbalance effect and are only partly adapted to the historical development paths of the different countries. This may be the cause of the low coefficients of the growth of per capita human capital which we found.

In this chapter we will address these two issues in a provocative way. This is not intended to provide 'true' answers but only to indicate some possible directions in which research can progress. However, before doing so, we first have to elaborate on the empirical model. Since in the previous chapter we already compared the two branches within the new growth theory, here we will only discus some extensions and implications.

Second, we turn to the institutional effects. In our analysis in chapter 4 we distinguished two hypotheses on the ways in which the institutional development may affect the relationship between human capital and economic growth expressed as the human capital coefficient: the existence of comparable educational regimes in all three countries, and a more efficient relation between human capital and economic growth (and thus a higher coefficient) in Japan. If such institutional effects are present, they may cause non-linearities in the regressions. Because most studies using regressions with human capital use cross-section or panel data, they are confronted with differences in the efficiency of human capital and regimes among countries. In such cases, possible non-linearities may be attributed to cross-country institutional differences or changing phases in educational development (or a non-human capital related factor). Yet, these factors are difficult to disentangle. For example, if the educational phases in Japan precede those in India, are the observed non-linearities in the human capital coefficient caused by institutional differences or by educational regimes? Nevertheless, it is important to disentangle them. Not only is it crucial to be able to interpret the coefficients, but it is also necessary in order to insert the right variables. As argued in chapter 4, it were the developed countries such as Japan which experienced an educational development that was closely connected with both their societal and economic development. However, in developing countries the development of the education system was largely influenced by external factors, creating a less strong connection with their national economies. Consequently, the relation between human capital and economic growth in the latter countries is likely to be less efficient. In such cases, a country dummy (or a developing country dummy) might be the appropriate way to deal with these non-linearities. However, if there are non-linearities because the countries included in the sample are in a different educational phase, including a country dummy will not correct for the phases but for the relative development level. In those cases it would be more appropriate to either estimate regressions over shorter periods in order to avoid breakpoints, or to include a multiplicative dummy for each educational phase.

Third, we will elaborate on the imbalance effect. Although, in this study, we are not interested in the imbalance effect *sec*, we discuss it because its inclusion in the regressions not only influences the human capital coefficient[141], but it is also directly related to the inclusion of physical capital in the regression, and because it offers an alternative way of testing the difference between Lucasian and Romerian growth. The basic notion behind imbalance effect is that under optimal choice, the ratio of human to physical capital is constant. Any deviations from this ratio may affect the growth rate of output. Theoretically, there is a U-curve where an excess of human or physical capital increases the growth rate of output. Yet, in practice it is also possible that an excess of physical capital leads to a reduction in economic growth (Barro and Sala-i-Martin 2004, 246). Because in some periods there will be an excess of human- and in other periods an excess of physical capital, in the long run its effect on growth fluctuates around zero. So, although in the long run, there should be no effect, if we estimate shorter regressions (as we will do in section 3 to correct for possible breakpoints) it is possible that the effect for some periods is positive and for other periods negative. This means that in the long run it is necessary to include a polynomial of the log-level of the ratio of human to physical capital to capture these effects. Theoretically, as this is an imbalance effect, the average marginal effect on economic growth should be close to zero. But it is

[141] It is necessary to include, besides the steady state, also the imbalance effects. If one excludes the latter, the effects of the steady state may be distorted (See for example Nili 2002, 1).

possible, as we will briefly argue in section 5, that that a low elasticity of substitution between skilled and unskilled labour leads to an on average negative effect on long run growth. If this is true, omitting the imbalance effect might affect the human capital coefficient.

It is necessary to note, however, that the imbalance effect is characteristic of the Lucas (1988) model. Therefore, we can use the presence of an imbalance effect as an additional test for the existence of Lucasian growth. We must simply include the growth of physical capital, next to the growth of human capital, as an independent variable.[142] If the combined effect of the coefficients of the growth of human and physical capital equal that of the coefficient of the growth of human capital (when inserted in an equation without the growth of physical capital) than this provides another indication of the presence of an imbalance effect and therefore of Lucasian growth.

Above three points will be discussed in this chapter. We start in section 2 with extending the empirical model. In section 3 we turn to the effect the historical development of human capital generating institutions has on the relation between human capital and economic growth. Using time series analysis to avoid cross-country differences, we try to determine the effect of the institutional development of human capital in India, Indonesia, and Japan. Do the breakpoints in the coefficients correspond with the phases in found in chapter 4? Is there a time lag of India and Indonesia compared to Japan? Are the coefficients in Japan indeed higher than those in India and Indonesia? In section 4 we will use the basic model, extended for the imbalance effects, to look at the effect this has on the previously obtained estimates. In addition, we provide an extra test for the existence of an imbalance effect. Section 5 discusses some possible explanations for the different growth patterns we found in India, Indonesia, and Japan. We end in section 6 with a brief conclusion.

2. THE MODEL

2.1 Introduction

We started in chapter 6 with the macro-Mincer equation (equation (6.9)):

$$\Delta Lny_t = \alpha + \beta_1 \Delta Lny_{t-1} + \beta_2 Lny_{t-1} + \beta_3 \ln h_{t-1} + \beta_4 \Delta \ln h_{t-1} + \varepsilon_t \qquad (7.1)$$

142 Some authors have argued that the inclusion of the growth of per capita physical capital, $\Delta \ln k_t$, decreases the human capital coefficient (De la Fuente and Doménech 2000, 18; Krueger and Lindahl 2001, 1126; Soto 2002, 14). However, excluding the stock of physical capital may also cause problems.

, where *y* is per capita GDP, *h* is an indicator for the per capita stock of human capital in year *t*, ε is the stochastic error term, and a one-period lag of the independent variables was included to avoid simultaneity. Before turning to the regressions in section 3 and 4 we will discuss some extensions and interpretations of this empirical model.

The standard function of Lucas (1988) is:

$$Y_t = N_t c_t + \dot{K}_t = AK_t^{\beta}\left[u_t h_t N_t\right]^{1-\beta} h_{at}^{\gamma} \tag{7.2}$$

, where β is an indicator of the returns to scale of physical capital, *K*, $1-\beta$ gives the returns to human capital, and γ indicates the positive external effect of the per capita stock of human capital, for example if someone's production increases because his or her co-worker has a higher level of human capital. The subscript *a* is preserved in the per capita human capital in order to indicate that the positive external effect is homogenous. However, it is assumed that all labour is essentially homogenous and therefore there is no difference between the two per capita stocks of human capital in the equation. Technology, *A*, is assumed to be constant, *N* is population and c_t is per capita consumption.

Equation (7.2) has two important consequences. First, together, the returns to human and physical capital (excluding the positive external effect) sum to 1. Because in this production function human capital accumulation (with non-decreasing marginal returns to human capital formation) replaces the labour input, it is possible to have endogenous growth even without positive external effects. In other words, even if the effect of positive externalities (γ) is 0 (that is, h_{at}^{γ} is removed from equation (7.2)) endogenous growth is still possible if human capital has non decreasing marginal returns to human capital formation. Second, equation (7.2) also indicates that any positive external effects are solely contributed to human capital.

2.2 The imbalance effect

If there is Lucasian growth, this also means that there is an imbalance effect: an excess of human or physical capital which may increase or decrease per capita GDP growth. The presence of such an effect is easy to see. We start with a simple production function with constant technology, physical, and human capital:

$$Y = AK^{\alpha}H^{1-\alpha} \tag{7.3}$$

Taking the marginal product of both *K* and *H* gives:

$$\frac{\partial Y}{\partial K} = \alpha A K^{\alpha-1} H^{1-\alpha} \tag{7.4}$$

$$\frac{\partial Y}{\partial H} = (1-\alpha) A K^{\alpha} H^{-\alpha} \tag{7.5}$$

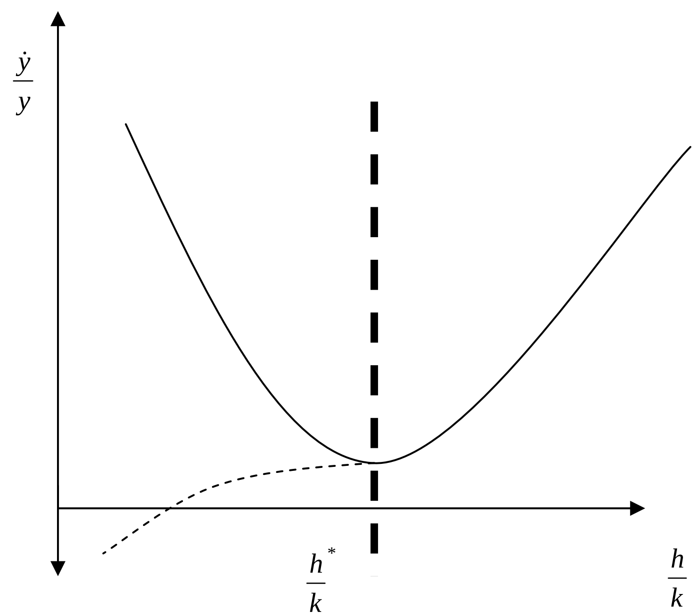
Now we can set equation (7.4) and (7.5) equal. This can be done because producing both physical (K) and human (H) capital costs GDP (Y). Then, using dynamic optimization will result in the optimum condition that their net marginal product (gross marginal product minus depreciation) must be equal. This gives the ratio of physical to human capital

$$\frac{\alpha}{1-\alpha} = \frac{K}{H} \tag{7.6}$$

This means that an excess of either human or physical capital may increase the growth

Figure 7.1

Imbalance effect in the Lucas theory



rate of output (see figure 7.1). However, as indicated by the downward sloping dashed line, empirically an excess of physical capital may also have a neutral or even negative effect on GDP growth.

Therefore, we have to adapt equation (7.1) in order to capture these non-linear effects. The model now becomes:

$$\Delta Lny_t = \alpha + \kappa t + \beta_1 \Delta \ln y_{t-1} + \beta_2 \ln y_{t-1} + \beta_4 \Delta \ln h_{t-1} + \beta_3 \ln\left(\frac{h}{k}\right)_{t-1} + \beta_5 \left(\ln\left(\frac{h}{k}\right)\right)^2_{t-1} \quad (7.7)$$

This equation is equal to the Mincer-regression from equation (7.1), except that we inserted a second degree polynomial of $\ln\left(\frac{h}{k}\right)_{t-1}$.[143] This polynomial is intended to pick up the imbalance effects caused by technology through the level of human and

Table 7.1 Estimation of the effect of the growth of human capital on economic growth in India and Indonesia over the twentieth century*

Dependent variable: $\Delta \ln y_t$

	India				Indonesia			
	1		2		1		2	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Constant	0.446	2.34	1.502	0.83	0.501	4.56	0.590	3.90
Trend	0.001	1.90	0.000	0.02	0.002	5.30	0.002	4.74
$\Delta \ln y_{t-1}$	-0.003	-0.04	-0.031	-0.35	0.309	5.01	0.311	5.03
$\ln y_{t-1}$	-0.072	-2.28	-0.055	-1.29	-0.089	-4.84	-0.097	-4.74
$\Delta \ln h_{t-1}$	0.034	0.19	0.128	0.60	0.931	2.62	0.853	2.32
$\ln\left(\frac{h}{k}\right)_{t-1}$	-0.081	-2.69	n.a.		-0.011	-1.50	n.a.	
$\left(\ln\left(\frac{h}{k}\right)\right)^2_{t-1}$	0.099	2.63	n.a.		-		-	
$\ln h_{t-1}$	n.a.		-0.923	-1.05	n.a.		-0.020	-1.55
$\ln k_{t-1}$	n.a.		0.551	1.00	n.a.		0.012	1.66
$(\ln h)^2_{t-1}$	n.a.		0.230	1.39	n.a.		-	
$(\ln k)^2_{t-1}$	n.a.		0.125	1.45	n.a.		-	
$(\ln k \cdot \ln h)_{t-1}$	n.a.		-0.325	-1.36	n.a.		-	
R^2	0.415		0.438		0.839		0.841	
Obs.	109		109		109		109	
AR1-1 (prob)	0.436		0.922		0.952		0.999	
Normality(prob)	0.905		0.846		0.733		0.820	

*Dummies not reported

[143] The presence of an imbalance effect during Lucasian growth also suggests that that the ratio h/k must be stationary. This can be seen in chapter 6, section 2, where we showed that the human-physical capital ratio remained almost constant during Lucasian growth. Therefore, during Lucasian growth, this ratio should be stationary. For all periods for which Lucasian growth is present, using an Augmented Dickey-Fuller test, a unit root is rejected with 10% significance.

physical capital which may change over time.[144]

Now we estimate equation (7.7) for the entire century. The results are reported in table 7.1 (India and Indonesia) and 7.2 (Japan). The regression for Japan is somewhat more complicated because, as we argued in the previous chapter, in the first half of the twentieth century Lucasian growth dominated while in the second half Romerian growth dominated. After some testing we decided to capture these effects by multiplicative variables. Hence, the growth of human capital and the imbalance effect

Table 7.2 Estimation of the effect of the growth of human capital on economic growth in Japan over the twentieth century*

Dependent variable: $\Delta ln\, y_t$

	Japan			
	1		2	
	Coefficient	t-value	Coefficient	t-value
Constant	0.453	4.63	0.454	4.46
Trend	0.002	1.58	0.002	1.48
$\Delta ln\, y_{t-1}$	-0.024	-0.54	-0.025	-0.54
$ln\, y_{t-1}$	-0.068	-3.40	-0.068	-3.24
Lucasian growth				
$D1890-1945 \cdot \Delta ln\, h_{t-1}$	2.428	1.68	3.17	1.15
$D1890-1945 \cdot ln\left(\frac{h}{k}\right)_{t-1}$	-0.226	-2.20	n.a.	
$D1890-1945 \cdot \left(ln\left(\frac{h}{k}\right)\right)^2_{t-1}$	0.081	2.27	n.a.	
$D1890-1945 \cdot ln\, h_{t-1}$	n.a.		-1.247	-0.77
$D1890-1945 \cdot ln\, k_{t-1}$	n.a.		1.580	0.75
$D1890-1945 \cdot \left(ln\, h\right)^2_{t-1}$	n.a.		-0.555	-0.50
$D1890-1945 \cdot \left(ln\, k\right)^2_{t-1}$	n.a.		-1.271	-0.63
$D1890-1945 \cdot \left(ln\, k \cdot ln\, h\right)_{t-1}$	n.a.		1.700	0.57
Romerian growth				
$D1950-2002 \cdot ln\, h_{t-1}$	0.007	3.69	0.007	3.61
R^2	0.850		0.852	
Obs.	103		103	
AR1-1 (prob)	0.174		0.199	
Normality(prob)	0.163		0.183	

*Dummies not reported

[144] Alternatively one can insert the log-level of either human-or physical capital. We ran some regressions using a polynomial of the level of per capita human capital and the results suggest that, although the coefficients shift slightly, if one lacks enough data on either human-or physical capital the insertion of only one of the two to capture the imbalance effect is a fair approximation.

variables are multiplied with a dummy that is 1 in the period until 1945 and zero otherwise. The log- level of human capital is multiplied with a dummy that is 1 after 1950 and zero otherwise. In sum, this assumes Lucasian growth in the first half and Romerian growth in the second half of the century.

The regressions seem to improve compared with the results in the previous chapter. The coefficients in all three countries are as expected with positive values for the coefficient of the growth of human capital in periods with Lucasian growth and a positive effect of the log-level of human capital in periods with Romerian growth. We also find an increase in R^2 from the macro-Mincer model from table 6.2. This suggests that correcting for the imbalance effect may have a positive effect on the estimated coefficients. One objection, however, could be the presence of multicollinearity. The correlation matrices indicate that no serious problems exist. With the exception of the correlation between $ln\left(\frac{h}{k}\right)_{t-1}$ and $ln\left(\frac{h}{k}\right)_{t-1}^{2}$ almost all correlation coefficients are significantly below 0.8. The main problem rests in the inclusion of the quadratic imbalance effect for India and Japan. Yet, there are four reasons why this is less a problem as it may seem on first sight. First, as the inclusion of a quadratic term in principle does not cause a linear correlation, in the strictest sense this does not cause multicollinearity which assumes a linear correlation. In addition, even the correlation within the imbalance effect is on average only just above 0.9. Second, in tables 7.1 and 7.2 we do not observe small t-statistics which would, combined with a large R^2, be indicative of multicollinearity. Third, if we exclude the quadratic term we obtain for India a coefficient of $ln\left(\frac{h}{k}\right)_{t-1}$ of -0.053. From table 7.1 (regression 1) we can calculate that the marginal effect when we include the quadratic term is $\beta_3 + \beta_5 \cdot 2 \cdot ln\left(\frac{\overline{h}}{k}\right)_{t-1}$. If we take the average of $ln\left(\frac{h}{k}\right)_{t-1}$ over the period 1890-2000, the marginal effect thus becomes -0.081+0.099*2*-0.042 = -0.089. Hence, the difference when including the quadratic term is not very large. In the same way we can calculate including the quadratic term for Japan does not essentially alter the marginal effect and can thus be inserted in the equation. Fourth, we can test whether the inclusion of the first and second degree polynomial improves the model. The F-statistics show that for all three countries we can reject the 0-hypothesis of no improvement in the model.[145]

Given the applicability of the h/k ratio in above regressions, we may notice three things about the imbalance effect. First, it is interesting that this specification allows us to take a closer look at the imbalance effect which we do in the second regression for each country. Assuming that an imbalance effect exists makes it necessary to include the (polynomial of the) ratio of human to physical capital in the specification. Yet, this assumes a specific pattern of the coefficients of this imbalance effect. For example, if we have a one degree polynomial, $\beta_3 \, ln\left(\frac{h}{k}\right)_{t-1}$, we can rewrite it as $\beta_3 \, ln\, h_{t-1} - \beta_3 \, ln\, k_{t-1}$. Hence the coefficients of the log-level of per capita physical and human capital should in absolute terms be equal and have the reverse sign. This becomes more complicated in a second degree polynomial, $\beta_3 \, ln\left(\frac{h}{k}\right)_{t-1} + \beta_5 \left(ln\left(\frac{h}{k}\right)\right)_{t-1}^{2}$, as we have for both India and Japan. In this case we can write the imbalance effect as $\beta_3 \, ln\, h_{t-1} - \beta_3 \, ln\, k_{t-1} + \beta_5 \left(ln\, h\right)_{t-1}^{2} + \beta_5 \left(ln\, k\right)_{t-1}^{2} - 2\beta_5 \left(ln\, h \cdot ln\, k\right)_{t-1}$. Hence, just as in the one-degree polynomial the coefficients of the log-level of per capita human and physical capital should be the same in absolute value and have the opposite sign. In addition, the coefficients of the squared terms should have the same height and be of the same sign while the coefficient of the multiplicative term should be twice as high as that of the squared terms and have the reversed sign. Although not statistically significant, the coefficients in tables 7.1 and 7.2 (second regression for each country) show this pattern. This suggests that an equilibrium relationship exists between human and physical capital and, hence, an imbalance effect.

Second, the coefficient of the logarithm of the ratio human to physical capital switches sign for each degree of the polynomial. This indicates that the level of human capital behaves as an imbalance effect that has a cyclical pattern. Given that a second degree polynomial is inserted, the length of the cycle must be close to 100 years. Consequently, the periods with either growth above or below the long-runs steady state

---

[145] Japan: F(2,90) = 2.600 [0.0798].
India: F(4,97) = 2.584 [0.0418]
Indonesia: F(1,92) = 2.238 [0.1381]
This means that the hypothesis that the inclusion of the ratio ln(h/k) and, in the case of Japan and India, ln(h/k) squared, have no effect on the model is rejected at 10% (Japan), 5% (India), and at 15% (Indonesia).

level last for about 50 years which means that if one estimates this equation over shorter periods, the imbalance effect might well have a positive or negative effect on economic growth.

Third, it is important to note that the variables of the polynomial are in levels, which means that they are generally non-stationary, I(1). However, as pointed out, we have to take the polynomial of the levels of per capita human capital together to analyze the imbalance effects. As the average is by definition zero[146], the combined effect must be stationary. Consequently, in this specification, except for the case of Romerian growth where the level of human capital and per capita GDP growth may be cointegrated, we have to use an alternative interpretation of equation (7.7).

2.3 A Koyck model

Because in the Lucas (1988) model the growth of human capital affects the growth of per capita GDP, the steady state growth part of equation (7.7) is given by

$$\Delta Lny_t = \beta_2 \Delta \ln y_{t-1} + \beta_4 \Delta \ln h_{t-1} \tag{7.8}$$

This equilibrium growth path is in first differences and therefore I(0). This is a Koyck model (Koyck 1954). Consequently, we have to interpret equation (7.8) as an autoregressive equation with one autoregressive term ($\Delta \ln y_{t-1}$).[147] Assuming we have the optimum long-run per capita stock of human capital, $\Delta \ln h^*_{t-1}$, then we can estimate:

$$\Delta Lny_t = \chi \Delta \ln h^*_{t-1} \tag{7.9}$$

However, since $\Delta \ln h^*_{t-1}$ is not directly observable, we assume:

$$\Delta \ln h^*_{t-1} - \Delta \ln h^*_{t-2} = \eta \left(\Delta \ln h_{t-1} - \Delta \ln h^*_{t-2} \right) \tag{7.10}$$

, where η determines how fast the economy returns from its disequilibrium. Now we can rewrite equation (7.10) also as:

$$\Delta Lny_t = \left(1-\eta\right) \Delta \ln y_{t-1} + \eta \chi \Delta \ln h^*_{t-1} \tag{7.11}$$

Now if we say that $(1-\eta) = \beta_2$ and that $\eta\chi = \beta_4$, then we have equation (7.8) back. In other words, the short run effect of the growth of the per capita stock of human capital

[146] In section 5 of this chapter we suggested that in countries with a high elasticity of substitution between skilled and unskilled labour the imbalance effect might be slightly positive in the long run while in countries with a small elasticity of substitution the long-run effect might be negative.
[147] Ideally one should estimate an autoregressive moving average model to capture the moving average in the error term (Franses and Van Oest 2004). However, we find that this generally does not alter the coefficients. In addition, this is generally disregarded in the literature and therefore we will not elaborate on it.

on the growth of per capita GDP is $\eta\chi = \beta_4$, while the equilibrium long-run value is equal to $\frac{\beta_4}{1-\beta_2} = \frac{\eta\chi}{1-(1-\eta)} = \chi$.

3. REGIMES IN HUMAN CAPITAL AND ECONOMIC GROWTH

3.1 Breakpoints in the relation between human capital and growth

Using the model from the previous section, we shall now look at the effects institutional development in the formation of human capital has on the relation between human capital and growth. To do this, we will make use of the hypotheses derived from our analysis in chapter 4. These hypotheses say something about breakpoints in the relation between human capital and growth (this section) and the strength of the coefficients (section 3.2). The results are interpreted in section 3.3.[148] We will restrict ourselves to time series analyses in order to avoid cross-country differences which, as indicated in the introduction to this chapter, may in some cases be difficult to disentangle from the effect of the country-specific institutional development of human capital.

The theses mentioned in chapter 4 all relate to presence of educational regimes. These may lead to structural different human capital coefficients over time. Therefore, the first step is to look whether there indeed are breakpoints in the relation between human capital and economic growth. To that end, we will use the regressions as presented in tables 7.1 and 7.2.

There are several ways to test for the presence of breaks in the relation between human capital and growth. However, because of the small sample, we will restrict ourselves to some simple analyses. A common way is to look at the recursive graphs. Because of their recursive nature, it is possible to see where and when the coefficients move so strong from one steady value to another that they cross a certain border of significance. This allows us to determine breakpoints with some certainty. For example,

[148] Although we are convinced that the analysis of hypotheses from chapter 4 about the effect the educational institutions have on the relationship between human capital and economic growth clarifies some important points, we are aware that this analysis is very limited. It would be valuable to extend these theses with a further (econometric) analysis which we will touch upon in the 'suggestions for further research' in the next chapter. However, most of the alternative econometric analyses are cross-section in nature. Given that this study only focuses on three countries, it would be impossible to run such a regression because it is based on the effect that past institutions have on present economic development. In addition, the use of alternative variables and institutions such as government policies, property rights, and settler mortality are not directly related to our main question which focused on human capital and educational institutions. Finally, we use time series analysis and it is doubtful that variables such as property rights show much fluctuation over the period in our study. Although no doubt some change is present, it is exactly their path dependence and stability that makes them suited to proxy for institutions.

Figure 7.2

Recursive coefficient of $\Delta \ln h_{t-1}$ from table 7.2 for Japan (+/- 2 standard errors)

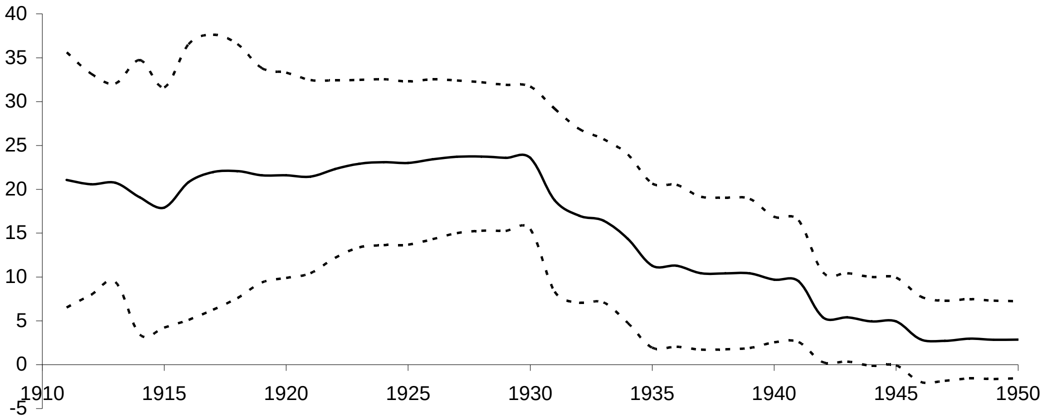


figure 7.2 shows the recursive coefficient of $\Delta \ln h_{t-1}$ for Japan. Around 1940 there is a break in the data (in that period the recursive value of the coefficient drops below the confidence interval of the previous period). Indeed, where until around 1940 the effect

Figure 7.3

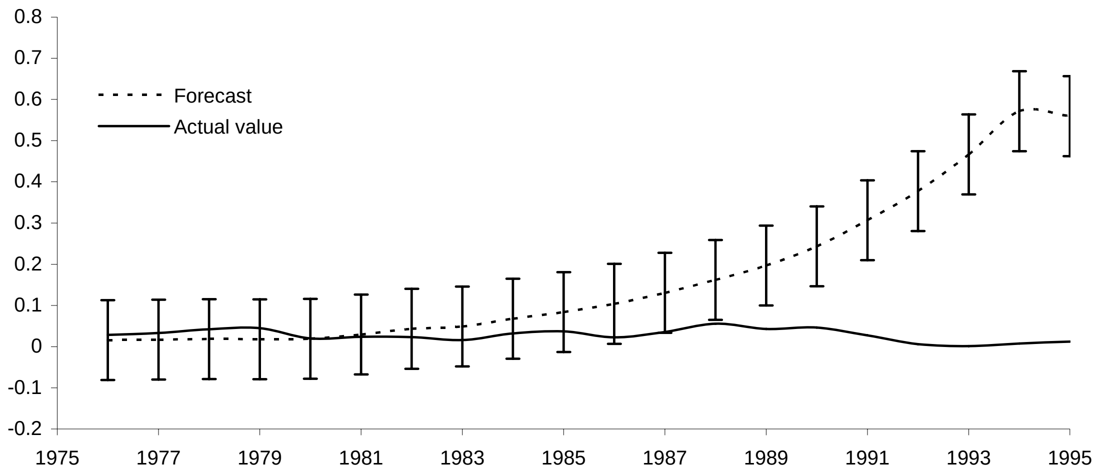
Recursive coefficient of $\ln h_{t-1}$ from table 7.2 for Japan (+/- 2 standard errors)

of the growth of human capital was dominant (see figure 7.2) after 1950 there is a stable effect of the coefficient of the level of human capital (figure 7.3).

However, there is one point of concern. As these estimations are recursive, it is likely that if there is more than one break present, the last break(s) will not (or only in a limited way) be observed. For example, in figure 7.2 we notice a strong break around 1945. However in figure 7.3 we do not notice a break even though there is a clear upward trend in the value of the coefficient of $ln\,h_{t-1}$ in the period after 1975. Indeed, if we plot the actual values and the forecasts for Japan between 1976 and 1995 (figure 7.4), we see that it diverges strongly from the actual values around 1988. We can determine this because from around 1988 the error bars do not overlap with the actual values of the growth of per capita GDP. Hence, the relation that existed before 1988 was different from the relation that existed afterwards. Therefore, the relation before

Figure 7.4

20-step forecasts for $\Delta \ln y_t$ (SE based on error variance only) for Japan, 1976-1995

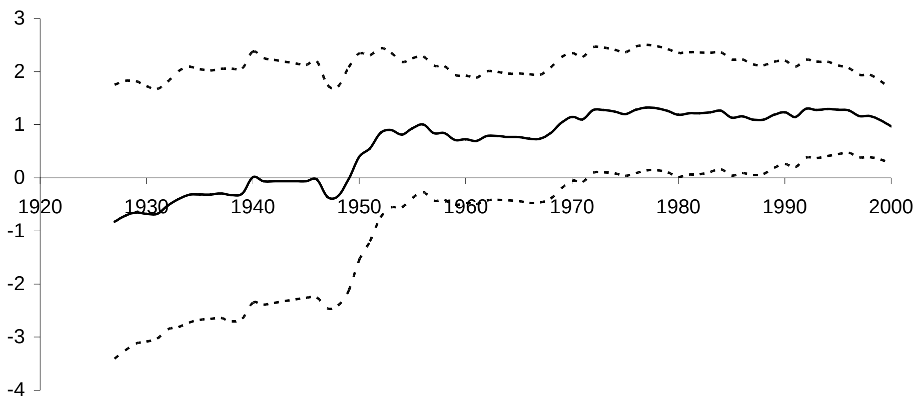


1988 cannot provide a good forecast of the development of per capita growth after 1988. This means that we indeed also have a breakpoint in the period around 1990, although this is not indicated in figure 7.3.

In the same way, we determine the breakpoints for Indonesia and India. Figure 7.5 shows the recursive coefficient of $\Delta ln\,h_{t-1}$ for Indonesia. We can see that there seems to be a break around 1950. Just as in Japan, the break in the mid-twentieth century dominates. However, if we look at the forecasts, other breaks are also present. Figure 7.6 shows that in Indonesia, the error bars of the forecasted value did no longer overlap with the actual value of per capita GDP growth around 1915. Hence, the relation that existed before 1915 was different than that existed after 1915, i.e. there is a

Figure 7.5

Recursive coefficient of $\Delta \ln h_{t-1}$ from table 7.1 for Indonesia (+/- 2 standard errors)



breakpoint. The same we see in figure 7.7. This clearly shows that one cannot forecast

Figure 7.6

15-step forecasts for $\Delta \ln y_t$ (SE based on error variance only) for Indonesia, 1909-1925.

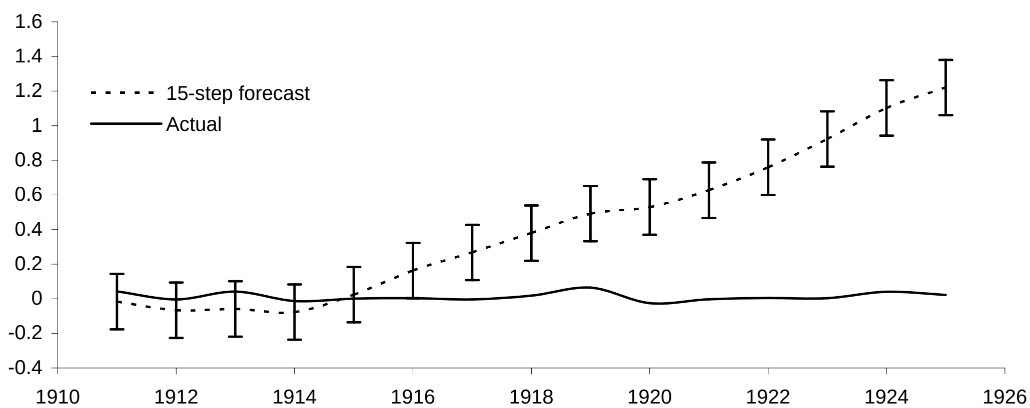
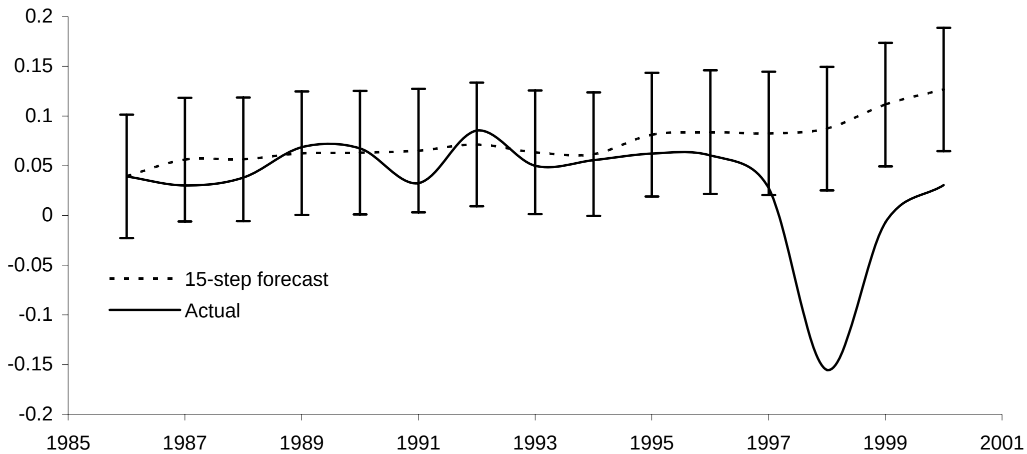


Figure 7.7

15-step forecasts for $\Delta \ln y_t$ *(SE based on error variance only) for Indonesia, 1986-2000.*

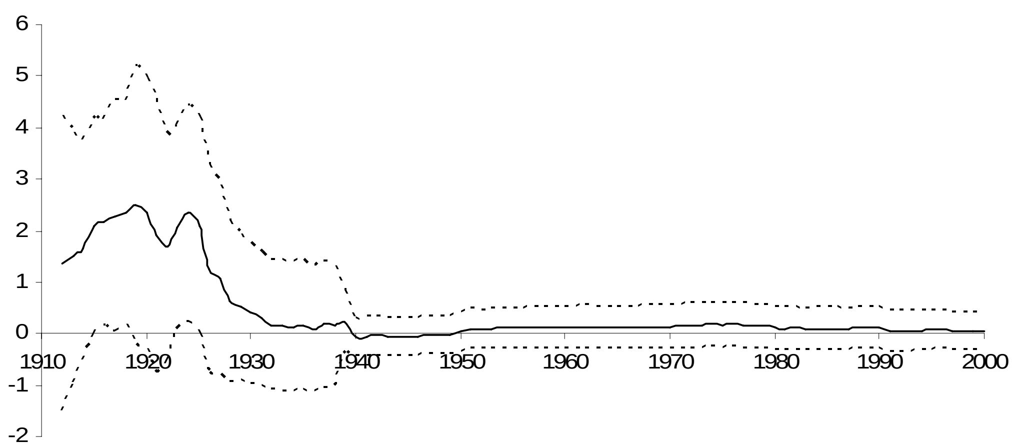


the development of per capita GDP growth after 1997 based on the relation between per capita human capital and per capita GDP growth between 1950 and 1990.

In India, there is a clear break in the recursive human capital coefficient in the 1920s (figure 7.8). However, les obvious breaks are also present. This is confirmed if we look at the forecasted value in figure 7.9 which shows a break in the 1940s when the

Figure 7.8

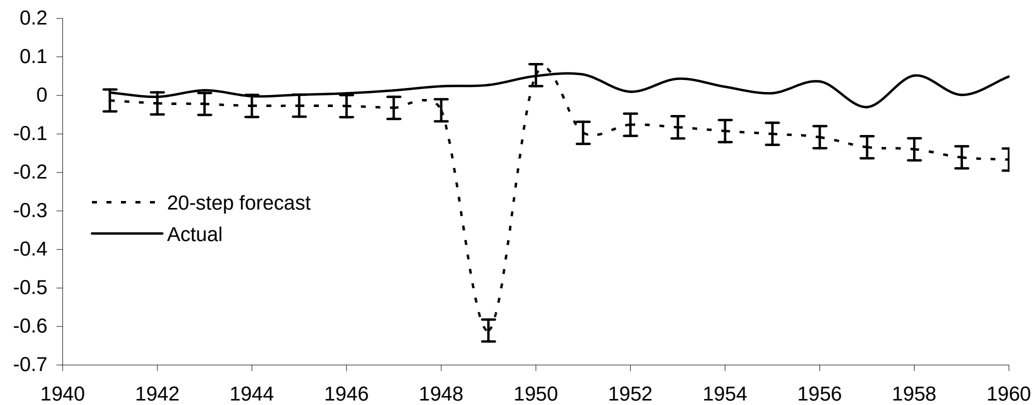
Recursive coefficient of $\Delta \ln h_{t-1}$ *from table 7.1 for India (+/- 2 standard errors)*



effect of the human capital coefficient starts to increase again after a drop in the 1930s. A final break one can distinguish in the 1990s. This is less visible because already two

Figure 7.9

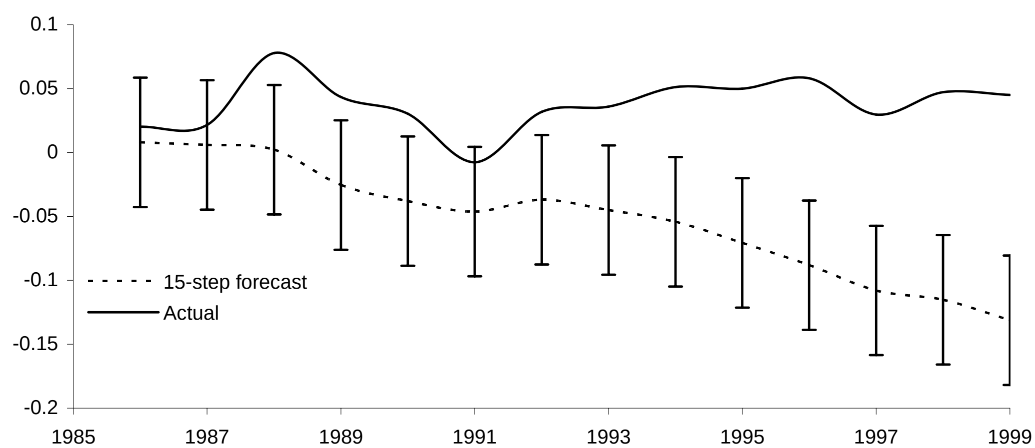
20-step forecasts for $\Delta \ln y_t$ (SE based on error variance only) for India, 1941-1960.



breaks preceded it. Yet, in figure 7.8 we still find a minor decline in the effect of human capital on economic growth. This is also confirmed in figure 7.10 which shows that the forecasted values diverge considerably from the actual values since the early 1990s.

Figure 7.10

15-step forecasts for $\Delta \ln y_t$ (SE based on error variance only) for India, 1986-1999.



In addition, the breakpoints for these three countries are confirmed when we include multiplicative dummies, i.e. variables that indicate 0 or 1 before or after a certain year and which are multiplied with the human capital coefficient. If they are significant, this means that the effect of human capital is significantly different in the two periods.[149]

In sum, we found breakpoints for Japan around 1945 and 1990. In Indonesia and India, however, we found no less than three breakpoints. In Indonesia the first one was present in 1915, the second around 1960 while there was also an indication of a break in the 1990s. In India there were changes in the value of the human capital coefficient around 1920, 1950, and 1990. These breakpoints correspond well with the breaks found in chapter 4 (around 1940 for Japan [to higher education]; around 1920 [to secondary education] and 1960 [to higher education] for Indonesia; around 1920 [to primary education], 1940s [to secondary education] and 1990 [to higher education] for India).[150]

3.2 Estimates

Breakpoints as found in section 3.1 may have a strong impact on he size of the coefficient. To correct for these breakpoints, we will estimate equation (7.7) for the several educational phases. Three points are worth remarking here. First, we excluded physical capital because it creates more problems than it solves. This will be elaborated upon in section 4. We did run some regressions with the growth of per capita physical capital, however, but this did not significantly alter the results. Second, we ran regressions for several time periods. However, in two cases these time periods do not follow up (there are some years after the end of one regime and the start of the following), i.e. in India 1942-1950 and in Japan 1945-1950. In both cases these were periods of great turmoil influencing both human capital and economic development (India during the Second World War and independence and Japan during the American occupation). Third, we included a polynomial of the level of per capita human– and

[149] We included multiplicative dummies for all three countries for all years. For each year we ran a separate regression. We found significant multiplicative dummies for 1950 and 1970 for Japan, for 1920, 1950, and 1970 for Indonesia, and for 1920, 1940 and 1970 for India. With some minor differences this seems to conform well to the breaks found using the recursive graphs. Of course, we have to be aware that the methods are also somewhat different. As the breaks do not take place from one year to the other (it is likely to take at least a decade) the use of a multiplicative dummy will be exactly between the two values of the human capital coefficient. Depending on how the human capital coefficient changes during the break, this can be both at the beginning and at the end of the break. As the recursive graphs indicates when the value of the coefficient moves out of its significance border, the exact place of the break depends on a) how the value of the coefficient changes (for example first slowly and then fast), and b) if other breaks have preceded this break.

[150] For India the enrolments compositions are fairly stable. However, the indicated breakpoints show mainly a shift in government focus to the respective education levels, often combined with a small increase in the share of enrolments (and a far greater rise in the absolute enrolments figures) at that level.

physical capital only where applicable. As we saw in table 7.1 and 7.2, generally we only include a second degree polynomial in a time series regression over 100 years. This means that the length of the cycle is around 100 years and, consequently, the peaks and troughs will each last for about 50 years. As the regimes found in the previous sub-section are around 30 or 40 years, this means that we generally have to include at most a first degree polynomial, i.e. only the level of the human- to physical capital ratio. Only if the regime covers a period where the coefficient of the imbalance effect is both above and below the average imbalance effect, a second degree polynomial is appropriate.

This brings us to the regression results, reported in table (7.3-7.5), which show an improvement over the earlier regressions in chapter 6 and in table 7.1-7.2. The first difference we note is that the R^2 increased in almost all cases, the sole exception being Indonesia between 1960 and 1992.[151] Second, in all regressions, normality of the residuals cannot be rejected. Consequently, we can interpret the *t*-values, even given the small samples, in the usual way.[152] Third, the coefficient of $\Delta \ln hc_{t-1}$ is far more stable, indicating that the regime changes have disappeared. Indeed, plotting some recursive

Table 7.3 Estimation of the effect of human capital in India between 1892 and 1990, corrected for breakpoints*

Dependent variable: $\Delta ln\, y_t$

	1892-1920		1920-1942		1950-1990	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Constant	3.813	4.66**	1.611	2.45**	2.591	4.07**
Trend	0.012	4.76**	-0.006	-6.57**	0.013	4.51**
$\Delta ln\, y_{t-1}$	0.167	1.01	-0.280	-1.70	-0.085	-0.685
$ln\, y_{t-1}$	-0.662	-4.65**	-0.221	-2.16**	-0.554	-4.29**
$\Delta ln\, h_{t-1}$	1.964	2.01**	1.906	4.12**	4.289	4.37**
$ln\left(\frac{h}{k}\right)_{t-1}$	0.271	3.02**	-		-	
R^2	0.765		0.795		0.629	
Obs.	29		23		41	
AR1-1 (prob)	0.422		0.732		0.986	
Normality(prob)	0.699		0.875		0.112	

*Dummies not reported
** Significant at 10% (because of the small sample the t-values must be bigger than 1.645 in order to be significant)

[151] Although interesting, this is not entirely surprising as the smaller sample sizes increase the R^2.
[152] Again, we must be aware that the small sample size makes it necessary to use higher t-values to determine the significance of individual variables.

Table 7.4 Estimation of the effect of human capital in Indonesia between 1892 and 1992, corrected for breakpoints*

Dependent variable: $\Delta ln\, y_t$

	1892-1920		1920-1960		1960-1992	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Constant	10.168	6.55**	0.613	2.86**	-0.060	-0.43
Trend	0.025	6.81**	0.002	1.62	n.a.	
$\Delta ln\, y_{t-1}$	0.766	3.78**	0.459	5.09**	0.118	0.782
$ln\, y_{t-1}$	-1.622	-6.60**	-0.108	-4.46**	0.012	0.625
$\Delta ln\, h_{t-1}$	1.455	2.10**	1.552	1.77**	1.483	1.11
$ln\left(\frac{h}{k}\right)_{t-1}$	-0.254	-6.35**	-		-	
R^2	0.906		0.943		0.577	
Obs.	29		41		33	
AR1-1 (prob)	0.054		0.358		0.738	
Normality(prob)	0.120		0.554		0.223	

*Dummies not reported
** Significant at 10% (because of the small sample the t-values must be bigger than 1.645 in order to be significant)

Table 7.5 Estimation of the effect of human capital in Japan between 1896 and 1990, corrected for breakpoints*

Dependent variable: $\Delta ln\, y_t$

	1896-1945		1950-1990	
	Coefficient	t-value	Coefficient	t-value
Constant	2.472	3.54**	-11.451	-3.56**
Trend	0.011	4.78**	-0.015	-5.41**
$\Delta ln\, y_{t-1}$	-0.048	-0.387	0.338	3.54**
$ln\, y_{t-1}$	-0.403	-3.95**	-0.038	-0.734
$\Delta ln\, h_{t-1}$	4.601	2.43**	-1.130	-0.580
$ln\left(\frac{h}{k}\right)_{t-1}$	-		n.a.	
$ln\, h_{t-1}$	n.a.		1.243	3.43**
R^2	0.883		0.887	
Obs.	50		41	
AR1-1 (prob)	0.706		0.328	
Normality (prob)	0.515		0.905	

*Dummies not reported
** Significant at 10% (because of the small sample the t-values must be bigger than 1.645 in order to be significant)

graphs showed no sign of breakpoints.[153] Fourth, almost all coefficients have the right sign. The growth of human capital, $\Delta \ln hc_{t-1}$, has a positive sign and always exerts an important influence on economic growth. Japan in the second half of the century proves an exception (due to Romerian growth) as its coefficient of the growth of human capital is negative, although not significant. The coefficient of the level of human capital, which is only present in Japan in the post World War II period due to Romerian growth, is positive and significant. Fifth, the value of the coefficients of the growth of human capital increases strongly when correcting for breakpoints and proves rather stable over time. On average (again with the exception of Japan after 1950) the coefficients are above 1. As we excluded the growth of physical capital, the coefficient should indicate the effect of capital on growth plus a possible positive external effect (see section 2 in this chapter). This means that in most cases we come close to constant returns to scale.

Finally, the effect of the long-run coefficient of the growth of human capital, $\Delta \ln y_{t-1}$, is in somewhat more than half of the cases insignificant, which means that we have come close to identifying the equilibrium growth path of $\Delta ln\, h_{t-1}$ after filtering out the imbalance effects of the level of the per capita stock of human capital. In other words, because the coefficient of $\Delta ln\, h_{t-1}$ indicates the equilibrium growth path, we expect the short and long-run coefficients to be equal. In over 60% of the cases this is indeed the case. However, even in those cases where a long run effect exists, 90% of the effect has taken place within 2 years.

3.3 An interpretation of the results

The analysis of the breakpoints and the regression results can be used to evaluate the two hypotheses on the effect of the historical development of human capital forming institutions on economic growth, i.e. that a changing relation between human capital and economic growth exists over time, and that the relation between human capital and economic growth is more efficient in Japan than it is in India and Indonesia.

First, institutional changes cause breakpoints in the relation between human capital and growth. Hence, the breaks found in chapter 4 must correspond to the breaks found in section 3.1 of this chapter. Indeed, we already mentioned that this seems to be the case. Although this provides strong evidence in favour of this hypothesis, it still does not give definitive proof. For this to be the case each phase must have a unique

[153] The same goes for the coefficient of the growth of physical capital when we inserted it.

human capital coefficient. This also means that, as we found in chapter 4 that the education development in India was the reverse of that in Indonesia, the changes in the human capital coefficient over time are also reversed. We can determine this by looking at the results of the regressions in tables 7.3-7.5. However, before doing so, it is important to be aware that we estimated a dynamic model as we included lags of the independent variables in order to avoid a simultaneity bias. Yet, the original production function (equation (7.2)) is a static model. Fortunately, we can transform the coefficients of $\Delta ln h_{t-1}$ in such a way that we can interpret them as a static model. The results, based on a method described in appendix A.14, are presented in table 7.6.

The modified coefficients of $\Delta ln h_{t-1}$ in table 7.6 do not significantly differ from those in tables 7.3-7.5. We thus find, as expected, that the pattern in India and Indonesia is exactly the reverse. Whereas in Indonesia the coefficient of $\Delta ln h_t$ increases in the mid-twentieth century and declines in the final decades of the century, in India we witnessed a decline and later an increase. As their educational structure is also the reverse, this means that for both countries the phase with a relatively large increase in primary enrolments had the lowest human capital coefficient. Unfortunately,

Table 7.6: Conversion of the coefficients of the growth ($\Delta ln h_{t-1}$) of human capital (dynamic model) to the coefficients of $\Delta ln h_t$ (static model)

	$\Delta ln h_{t-1}$	
	Uncorrected β_4	Corrected $\beta_4 = 1+\gamma$
Japan		
1896-1945	4.60	4.64
1950-1990	-1.13	-1.09
Indonesia		
1892-1920	1.45	1.46
1920-1960	1.55	1.58
1960-1992	1.48	1.06
India		
1892-1920	1.96	1.85
1920-1942	1.91	1.82
1950-1990	4.29	4.12

Source: coefficients table 7.3-7.5, method: appendix A.14.

we cannot confirm this for Japan, as the phase with a large relative increase in primary enrolments ended around 1870, i.e. before the start of our data. Nevertheless, the finding of a low human capital coefficient during the phase of a relatively increasing share of primary enrolments may be explained by the situation that this period witnessed the highest increase in human capital growth. Consequently, a higher growth of human capital leads to a less firm connection with the economy and, consequently, a lower human capital coefficient.

The second hypothesis about the relation between human capital accumulation and economic growth is that the educational regimes are more firmly embedded in society and economics in Japan than in India and Indonesia. This has two consequences. First, because human capital is less well connected to society in India and Indonesia and, to a large extent, has a colonial origin, the development of mass education took place later than in most developed countries. Hence, the breakpoints in India and Indonesia should more or less coincide and they should lag behind those of Japan. Indeed, it seems that each regime has its unique effect on economic growth. This was especially prevalent in the case of the regime dominated by a relative increase of primary enrolments. This phase was still present in Indonesia around 1900. However, Japan was already in the phase dominated by a relative increase in secondary enrolments. Thus Japan was leading in educational development compared to Indonesia (and India) as the first regime had already ended before the 1890s. This seems to confirm our finding in chapter 4 that the first phase had ended in Japan already in the 1870s, at the time that the rise of mass education started in Indonesia. We attributed that partly to the efficiency of human capital accumulation in Japan. Because Japan experienced an educational development based on its own economic and social developments while India and Indonesia did not, it is logically that this development set in earlier in Japan and was only later copied by India and Indonesia.

The second consequence of the hypothesis of a higher efficiency of institutions in Japan is that the human capital coefficients will also be higher for Japan. Looking at table 7.6 we note that the human capital coefficient of Japan for the pre-1950 period is higher than those for India and Indonesia (after 1950 in Japan the coefficient of $\Delta ln\, h_t$ declines and that of $ln\, h_t$ rises, which we attributed to a shift from Lucasian to Romerian growth). In addition, we find that the human capital coefficients for India are higher than those for Indonesia. This suggests that in Japan human capital is better connected to the economy than in India and Indonesia, while India in turn outperforms Indonesia. This finding is partly confirmed by our back of the envelope estimates in section 4 in chapter 5 which indicated that the quality of human capital is highest in Japan, followed by India and Indonesia respectively.

The acceptance of these two hypotheses and their consequences for breaks in the relationship between human capital and growth and for the height of the human capital coefficient, straightforward as they are, is important for any study on the relation between human capital and growth. As we have seen, keeping account of breakpoints strongly increases the coefficients. However, the height of the coefficient is also dependent on the efficiency of human capital accumulation, the type of growth (Romerian or Lucasian), and the educational phase a country is in. Although these factors are all interdependent, it is still difficult to correct for them using either dummy variables or fixed effect panel regressions.

4. IMBALANCE EFFECTS

4.1 The imbalance effect

The results from the previous section are also interesting in another respect: they give information with respect to the imbalance effect. As we already pointed out, cycles in the imbalance effect take around 100 years. This means that, as our samples only stretch over about 30 to 50 years, mostly only at maximum a first degree polynomial has to be inserted to capture either the positive or negative effect on per capita GDP growth. This is indeed the case in tables 7.3-7.5. Although a very interesting topic, here we will use the imbalance effect solely to introduce two other important topics which we neglected so far and which relate closely to the imbalance effect, namely the inclusion of physical capital in the regressions as a separate factor of production and the correction of the dependent variable, $\Delta ln\, y_t$, for the inclusion of human capital. In addition, as the imbalance effect is often considered to be present during Lucasian growth, we might consider the presence of such an imbalance effect an extra test for the existence of Lucasian growth.[154]

4.2 A test for the presence of imbalance effects

The presence of an imbalance effect might be indicative of Lucasian growth. Of course, the cyclical fluctuations of the coefficient of the human- to physical capital ratio, and the polynomial which switches signs for every degree, are strong indications of the

[154] Please note that the main reason why in the Romer (1990) theory there is no imbalance effect is that human capital formation seems to come at no cost. However, such an assumption is doubtful.

presence of such an effect. In addition, some preliminary evidence on the presence of an imbalance effect was offered in section 2.2 of this chapter. However, in this section, we propose an alternative test by inserting the growth of physical capital in the equation.

Inserting the growth of per capita physical capital, $\Delta \ln k_{t-1}$, into equation (7.7) also has an additional advantage. In the literature, there is a debate on the effect the inserting of per capita physical capital growth in the growth regression has on the human capital coefficient. Many studies have argued that physical capital has a strong impact on growth. One demanding reason not to include physical capital is that we only have a limited number of observations in our time series. Consequently, including an extra variable reduces the degrees of freedom. However, on a more theoretical basis we can also argue that physical capital can be left out from the regression. In general, following Krueger and Lindahl (2001, 1126), the conclusion seems to be that 'unless measurement error problems in schooling are overcome […] cross-country growth equations that control for capital growth will [not] be very informative insofar the benefit of education is concerned.' Yet, excluding the growth of physical capital from this equation may result in an omitted variable bias because the standard production function, equation (7.2), requires the presence of physical capital in the empirical model.[155]

Indeed, the only case when physical capital may be left out of the equation is when the growth of human and physical capital is equal, i.e. $\Delta \ln y = \Delta \ln k = \Delta \ln hc$. For this restriction to hold, and therefore to legitimize omitting physical capital from the equation, two assumptions have to be satisfied:

[155] An alternative to including physical and human side by side in an equation might be necessary because of correlation between these two variables. Therefore, when we start with the assumption that the coefficients of the growth of human-and physical capital together are the same of the coefficient of the growth human capital when inserted alone in an equation:

$$(1-\beta+\gamma)\Delta \ln hc_{t-1} + \beta \Delta \ln k_{t-1}$$

We can also write:

$$(1+\gamma)\Delta \ln hc_{t-1} - \beta \Delta \ln hc_{t-1} + \beta \Delta \ln k_{t-1}$$

Rearranging, we get:

$$(1+\gamma)\Delta \ln hc_{t-1} + \beta(\Delta \ln k_{t-1} - \Delta \ln hc_{t-1})$$

As a consequence, it is no longer necessary to insert physical capital side by side with human capital in one regression. However, in general, we find that this modification is not necessary because the correlation between the growth of physical and human capital is relatively low.

1) The stocks of human and physical capital have a constant ratio. This is only the case if an imbalance effect is present. If there is no constant ratio, the imbalance effects will cause faster growth of either $\Delta \ln k_{t-1}$ or $\Delta ln\, h_{t-1}$.[156]
2) In the long run the positive external effect, γ, equals zero and there is no problem with the productive efficiency (the efficiency of human capital in creating per capita GDP growth).

Under these two assumptions it is possible to say that, given our basic regression ($\Delta ln\, y_t = \alpha + trend + \beta_4 \Delta ln\, h_{t-1}$), β_4 is in principle 1 and we can therefore omit $\Delta \ln k_{t-1}$. This has the interesting property that, whereas in the basic production function (equation 7.2), the standard equilibrium growth was:

$$g = g_k = (1-\beta+\gamma)g_h / (1-\beta) = B(1-\beta+\gamma)(1-u)/(1-\beta) \tag{7.13}$$

It now becomes (assuming that β is in principle 0, which means that $1-\beta=1$):

$$g = g_k = (1+\gamma)\, g_h = B(1+\gamma)(1-u) \tag{7.14}$$

This means that the human capital coefficient equals $1+\gamma$ (or, when assuming no positive external effects ($\gamma = 0$), that $g = g_k = g_h$). This means that there is no need to include physical capital in the equation.[157]

However, it is hardly likely that these two assumptions will be satisfied. One may argue that in the long-run positive external effects are incorporated in the stock of human capital. For example, if a labourer increases his productivity because he profits from the higher skill level of his co-worker, he will be inclined to offer his children the chance to also increase their skills and thus increase their productivity and earnings even further. However, it is unlikely that the productive efficiency of human capital is equal in all three countries as we have seen under hypothesis 2 in section 3.3.

But what happens if we look at the first assumption? We start by re-estimating the regressions from tables (7.3-7.5) with the per capita growth of physical capital as an extra independent variable. The results are presented in table 7.7.[158] Comparing the sum of column 1 and 2 in table 7.7 with column 2 in table 7.6, we find that the coefficients of the growth of human and physical capital together sum to about the same values as

[156] This condition can of course also be met if technical and institutional factors keep the ratio permanently out of equilibrium.
[157] The growth of per capita GDP equals $B(1+\gamma)(1-u)$ (or $B(1-u)$ when there is no positive external effect).
[158] The results are (as far as the human capital coefficients are concerned) converted into a static model. We also included the physical capital coefficients that were not significant.

the coefficients in the situation where we only included $\Delta ln\, h_{t-1}$ (table 7.6). This means that, if there are no breaks in the data, or a correction for breaks is applied as we did in section 3, the ratio of human to physical capital must be constant. This is easy to see.

Table 7.7: Coefficients of the growth of per capita stock of human capital, converted to a static model, and the coefficients of the growth of per capita physical capital. Both are presented in a regression with the standard GDP and with GDP corrected for total human capital accumulation for India, Indonesia, and Japan.

	Normal GDP		Human capital corrected GDP	
	$\Delta ln\, h$	$\Delta ln\, k_{t-1}$	$\Delta ln\, h$	$\Delta ln\, k_{t-1}$
	(1)	(2)	(3)	(4)
		Japan		
1896-1945	3.27	0.52	4.18	0.60
1950-1990	-1.15	-0.01	-1.46	-0.004
		Indonesia		
1892-1914	1.39*	0.06	1.28*	0.07
1920-1960	1.86*	0.10*	1.79*	0.10*
1960-1992	1.06	0.00	1.16	0.00
		India		
1892-1920	1.83*	0.23*	1.69*	0.22*
1920-1942	1.81*	-0.01	1.43*	-0.08
1950-1990	4.19*	0.04	5.46*	0.01

* Significant at 10% (because of the small sample the t-values must be bigger than 1.645 in order to be significant)

The basic equation, excluding imbalance effects, is:

$$\Delta Lny = \alpha + \beta_4 \Delta ln\, h + \gamma \Delta ln\, k \tag{7.15}$$

, where *k* is the per capita gross fixed non-residential stock of physical capital. Now, as we have seen, the coefficients of human and physical capital taken together are equal to the coefficient of the growth of human capital if the latter is inserted in the equation without the growth of per capita physical capital. Therefore, we can rewrite equation (7.15) as:

$$\Delta Lny = \xi + \left(\beta_4 + \gamma\right) \Delta ln\, h \tag{7.16}$$

Combining equation (7.15) and (7.16):

$$\xi + \left(\beta_4 + \gamma\right) \Delta Lnh = \alpha + \beta_4 \Delta \ln h + \gamma \Delta \ln k \tag{7.17}$$

Simplifying:

$$\gamma \Delta Lnh = \left(\alpha - \xi\right) + \gamma \Delta \ln k \tag{7.18}$$

Rewriting:

$$\Delta Lnh = \frac{\left(\alpha - \xi\right)}{\gamma} + \Delta \ln k \tag{7.19}$$

Now, assuming there are no structural changes in the first right-hand term of equation (7.19) (there are no technological or institutional changes [the parameters do not change]), this means that the growth of per capita human capital equals the growth of per capita physical capital. **This seems to prove that there is a constant ratio of human to physical capital** which in turn makes the existence of imbalance effects, as argued in section 2, plausible.[159]

This finding has two consequences. First, because an imbalance effect seems to be present, assumption 1 is satisfied. If this imbalance effect is present, if it has a U-curve, and if the economy is at the left hand side of the equilibrium ratio (see figure 7.1), the coefficient of the growth of human capital will be negative and that of physical capital positive (Pritchett 2001).[160] This might explain some of the negative human capital coefficients found in the literature.[161] Second, even though assumption 1 seems to be satisfied, this is only partly the case for assumption 2. This means that only under exceptional circumstances, if you are looking at the extremely long-run so that no positive external effects are present or if you are looking at a homogenous group of countries with an equal efficiency of human capital, $\Delta \ln k_{t-1}$ may be excluded from the regression.

4.3 Correcting GDP for human capital accumulation: a final extension

A final problem, which may influence both the inclusion of the growth of per capita physical capital and the presence of the imbalance effect is the inclusion of the total estimated human capital accumulation in GDP. The reason is that in current GDP estimates, based on the system of national accounts (SNA), only part of human capital formation is included (most notably foregone wages, experience, and home education are not included). Inclusion of these omitted factors in GDP may distort the estimates as the dependent variable, the growth of per capita GDP, changes. Therefore, we start by

[159] In addition, it might even be possible that in the long-run the ratio tends to 1. However, the only thing we can say is that figure 5.5 gives some evidence that the ratio moves to a value close to 1. However, this is only meager proof as this may also indicate that there is no steady state ratio because the ratio clearly changes over time. On the other hand, this changing ratio may be attributed to changes in educational phases.

[160] Pritchett (2001) argues that human capital is applied to activities that, although increasing wages, do reduce growth. Obvious examples are wasteful government bureaucracies. Although not explicitly stated, this may correspond to the left side of the imbalance effect from figure 7.1.

[161] However, if the economy is on the left side of the equilibrium ratio and the imbalance effect is downward sloping, the coefficient of $\Delta \ln hc_{t-1}$ is positive and that of $\Delta \ln k_{t-1}$ is negative (or insignificant in case no disinvestment of physical capital takes place).

looking how GDP changes and then move on to look at the effect on the human capital coefficients.

The inclusion of human capital formation in GDP especially increases GDP in the mid-twentieth century (see table 7.8). Here we see that in Japan the peak lies around

Table 7.8: Increase in GDP when corrected for human capital formation in Indonesia, India, and Japan, 1890-2000 using the expenditure approach

	Japan	India	Indonesia
1890-1900	*10.20%	1.50%	0.20%
1900-1910	14.02%	1.48%	1.30%
1910-1920	15.30%	1.68%	1.41%
1920-1930	16.17%	3.15%	1.34%
1930-1940	13.61%	5.28%	1.30%
1940-1950	13.06%	4.70%	2.60%
1950-1960	9.04%	5.87%	2.08%
1960-1970	4.42%	5.91%	3.31%
1970-1980	2.24%	5.96%	2.11%
1980-1990	2.82%	7.24%	1.04%
1990-2000	2.92%	6.14%	2.17%

* 1895-1900
Source: Appendix A.2 and A.13

1920-30, while in Indonesia it is around 1930-40 (and at the end of the century) and in India around 1970-80. This corresponds with the lagged development of these two countries. In other words, for all three countries we see that the increase in GDP, when corrected for human capital formation, increases most strongly in the period when the growth of secondary education was strongest. This period was also the height of the substitution of private (including home education) for public expenditure on education. In other words, the share of human capital formation not in GDP decreased as it was replaced by formal (state or private financed) education.[162]

The question is now how this change in GDP influences the coefficients of the growth of physical and human capital. The results of this exercise are presented in table 7.7 in columns 3 and 4. In general the effect of $\Delta \ln k_{t-1}$ on GDP remains about the same: it declines somewhat for India, remains the same for Indonesia, and increases slightly for Japan before 1950 and decreases after 1950. This effect might partly be caused by the increased growth rates of per capita GDP after the inclusion of total

[162] Obviously, the introduction of compulsory education was an important factor. Remember that in chapter 5 we pointed out that we included only ‘foregone wages’ as from the end of compulsory education. The introduction of compulsory education thus strongly reduces foregone wages, and thus reduces the share of human capital formation not included in GDP.

human capital formation for India, while the introduction of all forms of human capital formation in GDP caused a decline in growth rates in Japan. In Indonesia the growth rate of per capita GDP remained about the same. In other words, if the growth rate of per capita GDP increases, the coefficient of $\Delta \ln k_{t-1}$ decreases (India) and *vice versa* (Japan).

The effect of the change in GDP growth rates on the human capital coefficient is less clear. In some cases it increases the human capital coefficient (or remains about constant) and in other cases it decreases it. No clear pattern can thus be discerned and it will require a much larger database to give some definitive answers on this matter. However, our impression is that this has something to do with the imbalance effect. Inserting human capital in GDP will sometimes move the U-curve of the imbalance effects upwards (India) and sometimes downwards (Japan). Consequently, in the case of India, if the economy is on the left side of equilibrium ratio, the coefficient of $\Delta \ln k_{t-1}$ will increase and the coefficient of $\Delta \ln hc_{t-1}$ will decrease.[163] However, if the economy is relatively human capital abundant (right of the equilibrium ratio), the coefficient of $\Delta \ln hc_{t-1}$ will increase and that of $\Delta \ln k_{t-1}$ will decrease. In Japan, the situation is of course directly the reverse while Indonesia is between Japan and India.

5. SOME INTERPRETATIONS OF THE REASONS BEHIND ECONOMIC DEVELOPMENT IN JAPAN, INDIA, AND INDONESIA

5.1 Introduction

In chapter 6 and in the present chapter we have stressed that Japan, India, and Indonesia started from Lucasian growth at the start of the twentieth century. However, where India and Indonesia remained confined to Lucasian growth, Japan moved to Romerian in growth after World War II. Given that the institutional developments in these three countries mirrors the breakpoints in the relationship between human capital and growth, this suggests that the institutional development and its practical consequences such as the later human capital development in India and Indonesia, and the lower effect of human capital on economic growth, may offer important explanations for why these three countries economically diverged.

[163] This story changes if the left side has a downward sloping curve. In that case if Japan and India are both on the left side of the equilibrium ratio (physical capital abundant), in Japan the curve moves downward causing a lower human capital coefficient and in India upward causing a higher human capital coefficient.

5.2 A successful developer: Japan

Why did Japan develop faster than India and Indonesia, a situation that was emphasized because it was the only country that moved to Romerian growth in the mid-twentieth century? We distinguish four points. A first point is that the efficiency of the education system was higher in Japan than it was in India and Indonesia. In Japan, education was better connected to society and economy than was the case in India and Indonesia which was partly due to, besides the ideal of creating a strong state, economic and social developments that led to educational development in Japan after the Meiji restoration in 1868. In India and Indonesia, as in most developing economies, it were largely ideas of 'creating an indigenous class of literati', a 'moral duty of the colonizer country', nationalism, and, after World War II, the 'idea of progress by education', 'lack of finances', and 'policies of international organisations' that drove their educational development. In other words, it were often global, or at least external, factors that influenced the education systems of India and Indonesia (Ramirez and Boli 1987, 10; Stewart 1996).

The differences in the efficiency of the education systems have three implications for economic development. First, being a technical problem, in section 3 in chapter 6 we noted inefficiency (in *B*) in the second sector to be present in India and Indonesia in the mid-twentieth century. Given the test used, this caused diminishing marginal returns to human capital accumulation. Yet, after correcting for inefficiency in *B*, we found increasing marginal returns. But no such inefficiency seems to be present in Japan. Thus we cannot argue, as we did for India and Indonesia, that other factors caused the diminishing returns and that Lucasian growth remained present. Second, because Japan experienced a more economy centred development, its education system started to develop earlier than was the case in India and Indonesia. This we also saw in chapter 5 where we noted that the per capita stock of human capital of Japan around 1900 far exceeds that of India and Indonesia. Because Japan already had a far higher education level around 1950, further educational growth was unlikely to be accompanied by constant marginal returns. For example, if there are already 10 teachers for each student, to add an eleventh teacher will not add much to human capital accumulation. Third, a better educational development also raises incomes, especially because there was a closer connection between human capital and the labour market. A higher income per head in turn created the opportunity to keep expanding educational spending even in the 1950s and 1960s. So, whereas India and Indonesia were trapped in vicious cycles of low per student spending and fairly low growth, Japan was in a virtuous cycle with high growth and fast rising educational spending. Therefore, Japan did not only develop earlier but also faster in education.

This brings us to the second point why Japan experienced a shift from Lucasian to Romerian growth. It is likely that, because Japan developed earlier and faster, it did not have to face constraints that were present for later developers. As pointed out in section 2 of chapter 6, Lucasian growth implies human capital accumulation. But this can also affect economic growth through adopting (foreign) technologies. As has been argued by O'Neill (1995, 26), the rise in the level of education causes convergence among countries. However, this convergence is reversed for developing countries by human capital biased technological growth, which increases the rate of return for higher education and thus favours the developed world. In other words, because technological development nowadays requires secondary and higher education, in which the developed countries have a relative advantage, developed countries profit more from new technologies than do developing countries. As Japan is clearly ahead in education development compared with India and Indonesia, the adoption and creation of new technologies will also likely be faster. Indeed, in 1950 the average years of schooling in Japan was 6.9 years against 1.8 in India and 1.5 in Indonesia.

Third, unlike India and Indonesia, Japan had an educational development large enough to create an extensive manufacturing sector. Initially Japan witnessed a dual economy where artisan industries coexisted with modern industries. This caused an equal division of wages and thus of educational development. This combination of artisan with modern industries was special for Japan compared to India and Indonesia. This is combined with the situation that Japanese agriculture is labour intensive because of the small plots of land (Buchanana 1923, 550). Many professions, which did not require access to land such as blacksmiths, day workers, or cotton mill workers, were filled as agricultural by-employment. In effect, wages in these professions remained almost equal to farm wages. Therefore, the growth of manufacturing was possible by low wages and a high availability of skills, which in turn created the opportunity to acquire more technology (Mayer 2001, 19).

Because of the technological and human capital development, as a fourth point Japan came increasingly closer to the technological frontier. The government sponsored industrialisation and rising skill levels caused a separation of not only factory industry but also artisan industries from agriculture. As a result, wages diverged and the demand for higher skills became more pronounced. For example, in the 1920s and 1930s as a rule only those who had finished the six year elementary course were employed at the mills (National Confederation of Industrial Associations of Japan 1937, 7). This made it preferred to create new technologies to reduce the wage bill and increase productivity. This approach of a threshold level is also acknowledged by Kim and Oh (1999, 13) when they argue that "[f]or economies in which government take initiatives for industrial development, their lion share of resources is usually allocated to strengthen the supply side of technology, such as training manpower, supporting basic science, and establishing public R&D institution. (…) Once their accumulated level of capability reaches a certain level of supply, (…) then the demand for technology will be motivated indigenously." They find that Japan had passed this threshold level in the second half of the twentieth century.

5.3 Late-comers in economic development: India and Indonesia

In India and Indonesia Lucasian growth seems to be present over the entire twentieth century. Figures 6.2 and 6.3 show for both countries extended periods of increasing and diminishing marginal returns. But table 6.2 shows a positive effect of the growth of human capital, suggesting Lucasian growth. Also, regression 2 in table 6.1 showed that in a primitive way correcting for inefficiency in human capital development results in the removal of diminishing marginal returns. This suggests that either there were no periods with diminishing marginal returns or the periods that were present did not mark an end to Lucasian growth as was the case in Japan.

But why was this the case? First, in chapter 6 we argued that, using the Monteils (2002) model, just as in Japan there are troughs in the marginal returns. But unlike Japan, this can be explained by increasing inefficiency in human capital formation (*B*).

Second, as we argued in chapter 4, in Indonesia and India human capital is only loosely connected to the labour market. For example, in Indonesia before independence, there was a dual educational structure for Indonesians and Europeans. Yet, it was difficult for educated Indonesians to enter the labour market. Indonesian enterprises were largely artisan and, as a result, generated not much demand for formally educated Indonesians. As a consequence, educated Indonesians were almost entirely working in the Government sector and the remainder in the European industries. Only a few were self-employed or had jobs in Indonesian enterprises. This vision is confirmed in a report about the metal industry at Surabaya in 1926. This industry was largely European, but employed many Indonesians. Of these Indonesians there are data about their education level, not only of western but also of Indonesian education (see table 7.9). Interestingly, we see that a low level of only 7% of the Indonesian employees had any formal

Table 7.9: Education level of indigenous employees in the metal industry in Soerabaja in 1926*

Education level	% employees
No education	92,6%
Indonesian primary school	5,4%
European primary school	0,7%
Dutch-Indies school	0,6%
K.E.S. Secondary technical school	0,0%
Indonesian vocational school	0,1%
Burgeravondschool	0,2%
Other schools	0,3%

* 28 enterprises
Source: A.G. Vreede (1926, 10)

education. We also see that from this 7% by far the largest share had been enrolled in Indonesian education. Because the metal industry demanded a relatively high level of education, this figure is higher than it would be for most other industries. Therefore, it is not likely that Western, or Indonesian education for that matter, for Indonesians was a way to develop the indigenous economy (Hollandsch-Inlandsch onderwijs-commissie 1930, 26).

Third, Lucasian growth means that productivity per employee grows if human capital grows. This can be reached by adopting new technologies. But, clearly, India and Indonesia lagged behind the western countries and Japan. This makes it difficult to adopt new technologies, not only because technology is often biased toward higher education in which developed countries often have a comparative advantage (see O'Neill 1995), but also because it is often politically difficult to modernize as this will cause social unrest.[164] An interesting example can be found in textiles in India and Indonesia. In India, caused by high wages, labour unrest, taxation policy, and bureaucratic control, it were the wages of handloom weavers and the small powerloom operators that experienced rapid growth during the 1960s while the larger-scale sector (textile mills, mainly found in the metropolitan areas) declined. Wages in mills, for example, could be up to three times as high compared with more modern small scale

[164] For example, Clark (1987, 168-169) argues that the local environment has a strong influence on whether workers are willing to adopt more or different machines.

powerloom operators (RoyChowdhury 1995, 233). In the mid 1980s more market forces were let in but this did not reverse the trend. The same was true in Indonesia where the textile industry, which had known already a large growth after the 1930s partly because of a protective policy of the colonial government, continued to grow under the same policy after independence. Because of the lack of competition, however, the number of powerlooms, even after independence, remained small compared with handlooms. At the end of the 1950s and the start of the 1960s this industry was using only some of its capacity. Problems were the shortage of spare parts, lack of skilled labour, and especially the shortage of raw material (raw cotton and yarn) (Palmer and Castles 1965, 41). This was because the spinning industry could not supply enough yarn. And, much yarn, imported by the State Trading Corporations, was sold on the free market, reducing its availability. Also, the yarn that did enter the producers' hands directly through quota had to be paid for in advance. Many smaller producers could not pay the quota and worked for intermediaries who paid the quota, or sold their quota to larger and more efficient producers. In this way the larger producers got more raw materials (Palmer and Castles 1965, 43). Under Sukarno's licensing system it was thus profitable to have a license for a loom even though it was a handloom. Then one could obtain a quotum of yarn, which could be sold to larger and more efficient producers (Boucherie 1969, 55). This allocation system was abolished in 1967 and the channelling of yarn was left to market forces. Nevertheless, productivity rose only slowly, even in the modern (powerloom) sector. In the larger factories that could have had economies of scale there were old looms, often from the 1930s and 1940s, while the smaller factories used more modern looms but had no economies of scale (Boucherie 1969, 58). These two examples suggest that political and technological barriers for later developers could be an important reason of lower efficiency and growth in these countries.

But there is also a fourth reason why these countries suffer from lower growth. Barro and Sala-i-Martin (2004) intuitively developed an imbalance effect of the stocks of human and physical capital in the Lucas model which we discussed in section 2 of this chapter. When the ratio of physical to human capital exceeds the equilibrium ratio (there is too much physical relative to human capital), the rate of economic growth declines. When the ratio of physical to human capital rises (there is too much human relative to physical capital), economic growth accelerates (this means assuming a downward sloping line as indicated in figure 7.1).[165] If one wants to increase economic growth, it is thus preferable to have an excess of human capital. But an excess of either human- or physical capital reduces the returns on the abundant factor and therefore more will be invested in the scarce factor. Yet, whether countries can get a growth bonus in this way is also dependent on technology. If technology is labour biased, which it usually is, then in countries where the elasticity of substitution between skilled and unskilled labour is small, the price effect dominates and technology is directed at the scarce factor of production. That is, if human capital is abundant relative to physical capital, technology is directed at unskilled labour and *vice versa*. But in countries with a high elasticity of substitution, the market effect dominates and technology is directed toward the abundant factor (Acemoglu 2002).

As pointed out, countries with a higher educational development (and a higher economic development) show Romerian growth which does not know an imbalance effect.[166] Indeed, if we, like Grandville (1989, 479), see the elasticity of substitution as 'a measure of the efficiency of the productive system', we may argue that countries with a lower efficiency of human capital (or a less strong connection between human capital and the economy) suffer from a low elasticity between skilled labour (as a measure of human capital) and unskilled labour. So, it is likely that developed countries have a higher elasticity[167], but, as we have seen for Japan, they also may be in a phase of Romerian growth where this imbalance effect is of less importance.

This has the interesting result for developing economies that, when there is an excess supply of physical capital, technology is focused at skilled labour (which is the scarce component in the relation between skilled and unskilled labour). This increases the productivity of skilled labour, increasing its returns, and thus slows down investments in human capital to arrive again at the equilibrium ratio of human to physical capital. Conversely, if there is an excess supply of human capital, technology will again be directed at the scarce factor (unskilled labour). As physical capital is not

[165] Theoretically (Barro and Sala-i-Martin 2004) it is also possible that in both cases economic growth increases. However, in empirical studies generally a positive relation is found between the human capital-physical capital ratio and economic growth (see Duszynski 2003).
[166] This is, at least in theory, the case.
[167] A low elasticity of substitution seems to be especially prevalent in developing economies. We found that the elasticity between the skill premium and the skilled wage (and as a consequence the elasticity between unskilled and skilled labour) was much higher in Japan than in India and Indonesia. However, elasticities above 1.4 between skilled and unskilled wage (between high school and college labour) were also found for the United States, Canada, and the United Kingdom by Katz and Murphy (1992: 72) and Card and Lemieux (2001: 734).

necessarily solely embodied in unskilled labour, there is no reason investments in physical capital are slowed down. Therefore, in countries with a low elasticity of substitution, adapting to the equilibrium ratio from an excess supply of human capital will be faster than from an excess of physical capital. As the former increases growth while the second reduces it, the overall long-run effect will be negative. In other words, a low elasticity of substitution between skilled and unskilled labour as is likely to be found in developing economies causes a decline of their steady state growth because the positive effects of the imbalance effect are outweighed by the negative effects.[168]

6. CONCLUSION

In this chapter we turned to some alternative methods to estimate the effect of the growth of the per capita stock of human capital on the growth of per capita GDP. We found, as outlined in the previous chapter, that the Lucas theory fits the actual relation between human capital and economic development quite well. Indeed, when estimating this model all coefficients of the growth of human capital turn out to be positive and significant. The inclusion of an imbalance effect and the use of alternative estimates of the stock of human capital also caused an increase in human capital coefficient. Where in table 2.1 (chapter 2) we saw that the coefficient fluctuated between -0.07 and 0.05, the inclusion of the newly estimated stock of human capital and an imbalance effect increased the coefficient in tables 7.1-7.2 in this chapter to between 0.03 and 2.4. In addition, also the other coefficients have the right sign. The exception is Japan in the period after 1950 when we found evidence in favour of Romerian growth. Second, we also found evidence of the presence of an imbalance effect as might be present in the model of Lucas (1988).

Using the hypotheses derived from our historical analyses in chapter 4 and using time series regression to avoid some of the problems associated with cross-section data, we arrived at several breakpoints in the relation between $\Delta ln\, h_t$ and the growth of per capita GDP. These breakpoints corresponded to a large extent to the shifts in the phases of human capital accumulation in chapter 4. This seems to indicate that the historical development of human capital is crucial when one wants to estimate the effect of human capital on economic growth. In addition, the hypotheses we derived in chapter 4

[168] Indeed, that a higher elasticity of substitution may increase steady state growth is also argued, for the Solow model, by Rainer Klump and Harald Preissler (2000). The main difference is that we argue that it works through the imbalance effect.

from the presence of these regimes were also confirmed. Each human capital phase had a unique human capital coefficient. This was especially prevalent in the phase with an increasing relative share of enrolments in primary education. This led to the lowest coefficients. Because India developed from higher to lower to higher education and Indonesia from lower to higher education, we expected that the human capital coefficient of Indonesia would increase and for India decrease from the first to the second phase, what it actually did. Also we found that the educational phases in Japan were leading in time compared to India and Indonesia. This might be caused by an educational development that was better connected to the economy. Indeed, we also found the human capital coefficients to be structurally higher in Japan than in India and Indonesia, confirming this interpretation.

These findings did not change if we included the growth of per capita physical capital in the equation nor if we corrected GDP for the shares of human capital accumulation that had not been part of the standard GDP, nor if we added an imbalance effect. Indeed, for periods with Lucasian growth, the inclusion of an imbalance effect seems important. We also tested this by inserting $\Delta \ln k_{t-1}$ in the equation. As the coefficient of the growth of human and physical capital together equalled that of the coefficient of human capital when inserted without physical capital, this led to the conclusion that a constant ratio between human and physical capital and, as a consequence, an imbalance effect, is likely to be present.

Institutional development thus seems to have an important effect on the relation between human capital and economic growth and, hence, on economic divergence. In section 5 we addressed this divergence, and, more specifically, the question why Japan moved from Lucasian to Romerian growth and India and Indonesia did not. We attributed this to three causes. First, in India and Indonesia, the education systems were less connected to the economy and thus less efficient. Second, because Japan developed earlier, obstacles in acquiring technologies were less pronounced. We referred to economic obstacles (a bias of technology to higher education in which developed countries have a comparative advantage) and political obstacles (institutions and policies that are harmful for technological modernisation). Third, in developing countries, technologies may be biased toward the scarce factor of production. In combination with an imbalance effect caused by Lucasian growth, this may in some cases result in an on average negative effect on steady state growth.

The findings in this chapter are of course very limited due to the small sample of countries. On the other hand, our findings seem to be supported by the historical development outlined in this and in the previous chapters. Nevertheless much research is still needed to confirm all the claims made here. To give an overview of our findings, we will present these briefly in the follow chapter. There, we will try to look at the consequences for between country growth patterns and try to provide some suggestions for further research.