Human capital and economic growth in Asia 1890–2000: a time-series analysis

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Abstract

There is a general consensus that human capital is a major factor behind long-run economic growth. Yet, on a macro level, the empirical results do not always seem to concur with this view. To explain this gap between theory and empirics, more focus has been laid on measurement error and data quality. Using an alternative estimate of the stock of human capital, based on Judson (2002), we find evidence that the two major views on the role of human capital in economic development by Lucas (1988) and Romer (1990) coexist and are by no means mutually exclusive. Using a Johansen cointegration test, we find that in India and Indonesia the level of human capital is cointegrated with the level of aggregate income during the whole 20th century, which confirms the theory of Lucas (1988). In Japan, however, the Lucasian approach can be verified only for the first half of the century, while after 1950 there is a cointegration between the growth rate of aggregate income and the level of human capital, which is in line with Romer's view.

Keywords: Human capital, education, economic growth, time-series analysis, cointegration

JEL classification: J24, N15, N35, O47

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I. Introduction

After World War II at the height of decolonization, the analysis of the underlying process of economic growth became a topic of high priority. The neo-classical, Solowian, growth theory (Solow, 1956, 1957; Swan, 1956), with all its limitations, was embraced by economists and economic historians alike, resulting in countless growth accounting studies and further research into country-specific institutional developments. Yet, Solow's theory has its limitations: it can explain economic growth in the long-run only by assuming an exogenous technological development, and initially it focused too much on physical capital accumulation. The neoclassical model of growth has been extended since the 1960s to include several indicators of social development such as health, life expectancy and literacy.

It was in the 1980s that the second step was taken: human capital was introduced in growth theory in a way that decreasing returns to physical capital were overcome. Human capital accumulation, determined within the model, offered a way to explain differences in the economic performance in the long-run. Even though human capital is of crucial importance for economic growth, the empirical results have more often than not been disappointing. As Judson (2002, 210) states: '[d]espite the conventional wisdom that output growth and human capital should be positively correlated, statistically significant results have been mixed, and strong and positive correlations between growth and human capital accumulation have been the exception rather than the rule'.

Generally, this has been attributed this to measurement error (De la Fuente and Doménech, 2000; Krueger and Lindahl, 2001; Cohen and Soto, 2001; Portela, Alessie and Teulings, 2004). However, in recent studies the construction of the human capital proxies has been questioned as well (Judson, 2002; Wöβmann, 2003). Popular variables like the *average years of education* or the *educational attainment* cannot capture the differences in the quality of schooling, and variables like literacy rates or the Whipple-index have an upper limit which is reached at a relatively low development level making these variables poor proxies of human capital endowment when modern economic growth sets off in a region. If we seek to test different growth theories, a direct measure of human capital is needed, preferably expressed in monetary units.

In this paper, we focus on three Asian countries, a successful early developer (Japan) and two late-comers (India and Indonesia) to test whether the same growth theory can be applied to them, or the different path of development leads to a different role of human capital in the growth process. We start by discussing some problems related to estimating human capital and briefly describe the construction of the alternative measure in Section 2. This human capital measure may be used to distinguish among the growth theories discussed in Section 3. Section 4 presents the unit-root tests, followed by the tests of cointegration in Section 5. We conclude the paper in Section 6 by summarizing the main findings.

II. Measuring human capital: method and sources

II.1 Method

Following Judson's (2002) cost-based method, we use expenditure on education to capture the quality of education. This allows us to estimate the human capital stock expressed in 1990 international USD, which makes it directly comparable to physical capital and GDP. Judson calculates the stock of human capital stock based on replacement costs with the following formula:

$$h_{it} = \sum_j d_{ijt} a_{ijt} \tag{1}$$

, where d_{ijt} is the public expenditure on education per level of education *j* in country *i* in year *t*, and a_{ijt} denotes the share of the labour force in year *t* with a certain level of education. h_{it} is the average per worker human capital stock. If one wishes to arrive at the total human capital stock, h_{it} must be multiplied with the labour force (L_{it}):

$$H_{it} = h_{it}L_{it} \tag{2}$$

Judson (2002, 216) identifies four problems concerning this method. First, current production costs may not be a good indicator of the value of human capital that has been produced earlier. Second, she does not use private expenditure on education since these data are usually difficult to obtain. Third, foregone income during the time of study is not taken into account. Fourth, while private expenditure is generally neglected, the available figures on students enrolled often include students entering private education. Consequently, if the private expenditures are differently distributed per level of education than public expenditures, the estimates may be biased. We may mention a fifth problem regarding this method. Judson's method uses d_{ijt}, the expenditure per level of education for year *t* and weighs this with the shares of primary, secondary, and higher educated in the working population. Hence, even after multiplying with the total working population she arrives at the replacement value of *a single year of education* instead of the total accumulated stock of human capital. As such, the human capital stock by the original method of Judson is very likely to underestimate the value of the stock of human capital.

The above-mentioned weaknesses of the Judson method are serious but can be solved. We can address the second and third problem by adding private expenditure and foregone wages to the HC stock. Since foregone wages are likely to increase over time, including it will lead to a faster appreciation of human capital. As for the fourth problem, similarly to Judson, we assume that private expenditures are identically distributed to public expenditures. The fifth problem is corrected for by multiplying equation (2) with *average years of education*. The corrected stock of human capital is denoted by H^*:

$$H_{it}^* = H_{it} * Educ_{it} \tag{3}$$

II.2 Sources

In this sub-section we offer a brief overview of the sources and construction of the dataset. A more extensive description of the sources and calculations can be found in Van Leeuwen (2007).

For Japan we obtain the data on skilled and unskilled wages and CPI from Ohkawa (1967a), Bank of Japan (1966), Japan Statistical Association (1987a), Bureau of Statistics (various issues), and the ILO (various issues). As far as it is possible, we take the wages of unskilled construction workers and construction masons or carpenters. These wages are used to estimate foregone wages. The data on public and private expenditure on education and the number of students are available from the Bureau of Statistics (various issues), Japan Statistical Association (1987b), and Ohkawa (1967b). For private expenditure on education we use school fees and stationary. Enrolment rates per level of education, just as population per age class, were obtained from Japan Statistical Association (1987b; 1987c) and Bureau of Statistics (various issues).

For India the wages and CPI are obtained from Brahmananda (2001, p. 119, 123), for 1951-2001 the ILO (various issues), Mukerji (1960), Roy (1996, 352), Sivasubramonian (1977; 2000), and Williamson (1998). For 1873-1912 the unskilled and skilled wages are available in the, *Statistical Abstract of British India*. Public and private expenditure on education, the number of students, the population per age class can be found in *Statistical Abstract of (British) India* (various issues) and Roy (2003). For the period prior to 1947, we calculate the variables for the Indian Territory only.

For Indonesia the data sources are quite fragmented. We use the CPI from Van der Eng (2002) for 1900-1941; 1949-1983. For the 1984-2000 period we use the CPI series of the ILO (LABORSTA).

The skilled and unskilled wage series are constructed using an array of scattered sources. For the period between 1875 and 1915 we use wage data for craftsmen and coolies on Java (Dros, 1992, table 5.4). As these are given per residency per year, we take the logarithmic average of all residencies as in general wages have a logarithmic distribution. From 1921 to 1940 we use the logarithmic average of workers at a sugar plantation (Dros, 1992, table 9.1, regular workers) as unskilled wages. As skilled wages we take the logarithmic average of the wages of factory foremen, canefield overseers, and fieldguards (Dros, 1992, table 9.1). For the years 1916-1920 the wages were interpolated by using the logarithmic average of the wages of male and female labourers in the sugar industry (Dros 1992, table 9.2).

After World War II, we use plantation wages supplied by Van der Eng (personal correspondance) as unskilled wages. The data on skilled wages from 1952-1957 and 1959 are wages in mining while in 1958 we took the wages in the metallurgical industry (Bank Indonesia, 1954-1960). For 1960 and 1961 the wages came from metal manufacturing (*BPS Statistical pocketbook*). For 1963 the skilled wage is that of bricklayers (ILO, 1964). For 1969, 1970, 1972, 1981-1984 the data are derived from the ILO (various issues). For the years 1985-1989 we use the wages of farm supervisors and for the years 1991 and 1992 we take wages of gas supervisors (ILO, various issues). For 1995-2000, we obtained manufacturing wages from the ILO (LABORSTA). For the remaining years with missing data on skilled wages (1964-1968, 1970-1971, and 1973-1978) we interpolated the skill premium (ratio of skilled and unskilled wages) and used these values to arrive at the skilled wages.

Population per age class, educational enrolments, and public expenditure on education in Indonesia are taken from Boomgaard and Gooszen (1991), *Colonial Report* (various issues), *Indies Report* (various issues), *BPS Statistical Yearbook/Pocketbook* (various issues), and the *Budget of the Netherlands Indies* (various issues). Unfortunately, no direct observations are available for private expenditure on education. For the period before 1970 there are household surveys available for some years and after 1970 we can rely on a number of input-output tables. We use these sources to distil information on private expenditure on education (see references). The missing observations are interpolated using data on total consumption, public expenditure on education and wages.

Figure 1-3 plot the estimated human capital stock (not multiplied by the average years of schooling yet) in three steps: first using public expenditure only (the original Judson method), and latter adding private expenditure and foregone wages.

Figure 1-3

The data on public expenditure on education are by far the most reliable, so we can use these graphs to cross check whether including new data sources significantly alter the pattern found. In all countries we find that including private expenditure and forgone wages may cause an upward shift in the human capital stock, but does not change the patterns fundamentally. This is not surprising given that when the time devoted to education increases, both public expenditure and foregone wages increase. Hence, as is also assumed by Judson (2002), it is unlikely that the increase in foregone wages is substantially higher than that of public expenditure on education.

III. New growth theories

Even though several growth model specifications exist that can be labeled as New or Endogenous Growth Theory, with some simplification one may argue that there are two ways in which human capital is expected to affect economic growth in the long-run. The first technique is to incorporate human capital into growth models as a factor of production. This approach we call 'Lucasian' after the probably most influential article on this field by Lucas (1988). In such model the growth rate of human capital affects the growth rate of aggregate income:

$$Y_t = K_t^{\alpha} H_t^{1-\alpha} h_t = K_t^{\alpha} (L_t h_t)^{1-\alpha} h_t^{\gamma} \tag{4}$$

where Y, K, H, h and L denote aggregate income, physical capital stock, aggregate and per capita human capital stock and labour respectively. The coefficient γ is introduced to capture the possible social (external) effect of human capital that may lead to increasing returns to scale. Along a balanced growth path[1] the relationship between the stock of human capital and economic growth is:

$$\left(\frac{\dot{y}}{y}\right)^{*} = \frac{(1-\alpha+\gamma)}{1-\alpha}\frac{\dot{h}}{h} \tag{5}$$

where lowercase letters denote per capita values. If we neglect the possibility of increasing returns to scale, the above-expression simplifies into:

$$\left(\frac{\dot{y}}{y}\right)^{*} = \frac{\dot{h}}{h} \tag{6}$$

The second stream in growth literature that we will refer to as Romerian (Romer, 1990), is based on the idea that human capital facilitates technological development. In this specification, a higher level of human capital leads to more innovations and higher efficiency, which finally causes a higher growth rate of the aggregate income. In short, the level of the human capital stock affects the growth rate of the economy. There are basically two ways to incorporate this idea into a growth regression. Romer (1990) assumes that human capital is used to improve technology which translates into a physical capital accumulation. We take a

[1] We assume that along a balanced growth path aggregate income and physical capital stock grow at the same rate.

simpler, and somewhat oversimplifying, approach by assuming that the level of human capital affects the growth rate through the neutral technology or TFP parameter *A*. This leads to a very simple model:

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha} = A_t k_t^{\alpha} \tag{7}$$

where the following equation establishes a relationship between human capital and technological development (another simplification is that human capital does not enter the production process directly):

$$\dot{A}_t = \phi_0 h_t A_t \tag{8}$$

We obtain the following for the growth-rate along a balanced growth path:

$$\left(\frac{\dot{y}}{y}\right)^{*} = \frac{\phi_0}{1-\alpha} h_t \tag{9}$$

From a practical point of view, we have no reason to believe that these assumptions regarding the relationship between human capital and economic growth are mutually exclusive. Instead one may argue that they capture two different aspects of human capital.

The Lucasian approach considers human capital as a qualitative aspect of labor that is required, for example, to operate existing and new technologies. When a country is close to the technological frontier and cannot import technology, the importance of the Romerian aspect of human capital should become dominant. More and more labor is employed to extend the technological frontier.

This is the hypothesis we wish to test in this paper. We expect that in developing countries the dominant relationship between economic growth and human capital is the Lucasian, which is replaced by the Romerian type of growth only when the economy gets close to the technological frontier and becomes a leader itself.

We apply a cointegration test to find out whether this hypothesis can be confirmed. If the Lucasian growth is dominant, the aggregate income and the human capital stock should be at least I(1) and integrated of the same order. Additionally, they should be cointegrated. The Romerian hypothesis can be confirmed, however, if the aggregated income is at least I(2), with the stock of human capital being I(1), and the growth rate of the aggregate income is cointegrated with the stock of human capital.

IV. The unit-root tests

When unit-root tests are used to validate or falsify a theoretically important hypothesis, one needs to pay extra attention to the fallacies of these tests. There is a general consensus that the available unit-root tests have low power and they are especially sensitive to trend breaks and

Table 1.
ADF unit root tests1890-1940, we report the respective test statistics, the p-values are reported in parentheses.

	Japan		Indonesia (1893-1940)		India	
Variable	Drift	Trend	Drift	Trend	Drift	Trend
lny	0.318 (0.977)	-3.131 (0.111)	-0.364 (0.907)	-2.231 (0.463)	-1.900 (0.329)	0.585 (0.999)
Δlny	-8.694*** (0.000)	-8.708*** (0.000)	-4.909*** (0.000)	-4.868*** (0.001)	-0.194 (0.931)	-4.175*** (0.001)
Δ^2lny	-11.830*** (0.000)	-11.706*** (0.000)	-8.773*** (0.000)	-8.686*** (0.000)	-13.120*** (0.000)	-12.977*** (0.000)
lnh	-2.196 (0.210)	-1.635 (0.765)	-1.440 (0.555)	-2.198 (0.480)	-0.168 (0.936)	-2.676 (0.251)
Δlnh	-3.707*** (0.007)	-3.958** (0.017)	-3.718*** (0.007)	-3.624** (0.040)	-7.106*** (0.000)	-7.069*** (0.000)
Δ^2lnh	-14.311*** (0.000)	-14.157*** (0.000)	-13.114*** (0.000)	-13.010*** (0.000)	-10.877*** (0.000)	-10.778*** (0.000)
lnh2	-2.147 (0.228)	-1.483 (0.822)	-1.035 (0.733)	-2.171 (0.494)	0.027 (0.956)	-2.806 (0.202)
Δlnh2	-3.730*** (0.007)	-4.025** (0.014)	-3.815*** (0.005)	-3.736** (0.030)	-7.175*** (0.000)	-7.138*** (0.000)
Δ^2lnh2	-14.112*** (0.000)	-13.962*** (0.000)	-12.616*** (0.000)	-12.509*** (0.000)	-11.105*** (0.000)	-11.007*** (0.000)
lnedu	-0.659 (0.847)	-0.356 (0.987)	-1.875 (0.341)	-1.611 (0.773)	-3.892*** (0.004)	-0.213 (0.991)
Δlnedu	-1.881 (0.338)	-5.374*** (0.000)	-5.292*** (0.000)	-9.981*** (0.000)	-2.771* (0.071)	-3.665** (0.035)
Δ^2lnedu	-7.593*** (0.000)	-7.476*** (0.000)	-13.100*** (0.000)	-12.946*** (0.000)	-13.309*** (0.000)	-13.219*** (0.000)

Note: the lag-length used for the ADF test is chosen based on a Modified Akaike Information Criterion by Ng and Perron (2001). *,**,*** denote that we can reject the null-hypothesis of non-stationarity at 10%, 5%, and 1 % respectively.
Source: h denotes the human capital stock according to the original Judson method, that is, without multiplying it by *average years of education*; h2 equals h multiplied by *average year of education*; edu is *average years of education.* GDP: Maddison (2003); Roy (1996); Van der Eng (1992)

Table 2.
ADF unit root tests, 1950-2000, we report the respective test statistics, the p-values are reported in parentheses.

	Japan		Indonesia		India	
Variable	Drift	Trend	Drift	Trend	Drift	Trend
lny	-2.739* (0.074)	-0.204 (0.991)	-0.244 (0.926)	-1.610 (0.776)	1.286 (0.998)	-0.316 (0.988)
Δlny	-1.005 (0.745)	-2.740 (0.226)	-2.785* (0.067)	-2.748 (0.223)	-0.821 (0.805)	-1.227 (0.894)
Δ^2lny	-8.546*** (0.000)	-8.499*** (0.000)	9.679*** (0.000)	9.587*** (0.000)	-13.178*** (0.000)	-13.048*** (0.000)
lnh	-1.719 (0.416)	0.287 (0.989)	1.656 (0.999)	-1.170 (0.906)	-0.818 (0.805)	-1.665 (0.752)
Δlnh	-0.759 (0.822)	-9.866*** (0.000)	0.887 (0.785)	3.016 (0.138)	-2.237 (0.196)	-2.156 (0.503)
Δ^2lnh	-8.159*** (0.000)	-8.338*** (0.000)	-3.996*** (0.003)	-3.954** (0.017)	-11.085*** (0.000)	-10.985*** (0.000)
lnh2	-1.754 (0.399)	0.110 (0.993)	-0.027 (0.951)	-2.382 (0.384)	-0.301 (0.917)	-1.614 (0.773)
Δlnh2	0.574 (0.867)	-10.054*** (0.000)	2.598 (0.100)	1.616 (0.773)	-2.004 (0.284)	-1.911 (0.634)
Δ^2lnh2	-8.171*** (0.000)	-8.328*** (0.000)	-10.357*** (0.000)	-10.297*** (0.000)	-10.570*** (0.000)	-10.478*** (0.000)
lnedu	-3.606*** (0.009)	-1.625 (0.769)	-1.496 (0.527)	-1.089 (0.921)	-1.163 (0.998)	-2.026 (0.574)
Δlnedu	-0.474 (0.888)	-6.427*** (0.000)	-1.875 (0.341)	-2.302 (0.426)	-1.432 (0.560)	-1.788 (0.696)
Δ^2lnedu	-9.233*** (0.000)	-9.146*** (0.000)	-6.274*** (0.000)	-6.211*** (0.000)	-11.147*** (0.000)	-11.022*** (0.000)

Note: the lag-length used for the ADF test is chosen based on a Modified Akaike Information Criterion by Ng and Perron (2001). *,**,*** denote that we can reject the null-hypothesis of non-stationarity at 10%, 5%, and 1 % respectively.
Source: see table 1

the choice of lag-length to take care of autocorrelation (traditional model selection criteria may underestimate the optimal lag-length). For this reason, we divide our sample into two sub-periods: 1890-1940 and 1950-2000, and we follow Ng and Perron's (2001) advice and use their Modified Akaike Information Criterion to choose the lag-length for the Augmented Dickey Fuller test. The results are reported in Table 1 and 2.

Table 1 suggests that between 1890 and 1940 all series were I(1), which is in accordance with the expectations, and indicative of the dominance of the Lucasian level-level (or growth-growth) relationship between human capital and economic growth. The results form Table 2 indicate that all series are I(2), with the sole exception of the Japanese human capital stock which is found to be I(1).[2]

Even though the majority of studies find that the main macroeconomic variables, and especially GDP, tend to be I(1), one should bear in mind that most studies focus on developed countries, and not on Newly Industrialized Economies. Barossi-Filho, Silva, and Diniz (2005) on the other hand found that the GDP was I(2) for 20% of the countries in their sample. Also, different unit-root testing techniques may lead to different conclusions: Cheng and Hsu (1997), for example, apply a Philips-Perron unit root test for the Japanese GDP in the period 1952-1993 and find it being I(1). Their conclusion regarding the relationship between human capital and economic growth is, however, the same as ours: the level of human capital affects the growth rate of income.

V. Cointegration tests

To determine whether a long-run relationship exists between human capital and growth we must not only test whether both variables are integrated of the same order, but we need to find evidence for a cointegration. Here we apply the Johansen (1991, 1995) procedure to test for the presence of a cointegration. Since only variables integrated of the same order may be cointegrated, we test whether the log of GDP per capita is cointegrated with the log of the h2 variable. The only exception is Japan, where we test whether the growth rate of the income is cointegrated with the log of the h2 variable.

As a first step we estimate a VAR system for each country and each period. We use the Akaike Information Criteria statistics to choose the lag-length, and capture the outliers by dummies. As a general check of our specification we always checked whether the residuals

[2] We carried out the unit-root tests on a human capital stock estimates based on public expenditures only. We find very similar results (not reported). The only difference is that depending on the level of significance chosen, one may find that Japan's human capital stock was I(2) in the period 1890-1940, which would be very difficult to explain and place into any of the growth theories. Consequently, we prefer the augmented version of the Judson method with all available information incorporated and choose to trust the results in Table 1 and 2.

follow a normal distribution, and whether there is any heteroscedasticity or serial correlation. We moved to the cointegration test only after the residuals were homoscedastic and normally distributed. As for the form of the cointegration vector, we preferred to assume that our data is difference stationary and there is no linear deterministic trend in our data.

The results form the trace and max-eigenvalue test are reported in the tables below together with the normalized cointegration vector:

Table 3

Trace test (Japan)				
	1890-1940		1950-2000	
No. of hypothesized Cointegration Equations	Trace statistics	p-value	Trace statistics	p-value
0	27.240	0.005	39.416	0.000
At most 1	3.806	0.442	5.309	0.251
Max. eigenvalue test (Japan)				
No. of hypothesized Cointegration Equations	Max eigenvalue statistics	p-value	Max. eigenvalue statistics	p-value
0	23.434	0.003	34.107	0.000
At most 1	3.806	0.442	5.309	0.251
Normalized cointegration vector	$\ln y_t = 5.039 + 0.2897 \ln h2_t$ s.e. (0.205) (0.028)		$\Delta \ln y_t = 0.114 + 0.0107 \ln h2_t$ s.e. (0.071) (0.006)	

Table 4

Trace test (Indonesia)				
	1893-1940		1950-2000	
No. of hypothesized Cointegration Equations	Trace statistics	p-value	Trace statistics	p-value
0	20.262	0.002	19.531	0.063
At most 1	9.165	0.137	2.063	0.765
Max. eigenvalue test (Indonesia)				
No. of hypothesized Cointegration Equations	Max eigenvalue statistics	p-value	Max. eigenvalue statistics	p-value
0	15.892	0.004	17.467	0.028
At most 1	9.165	0.137	2.063	0.765
Normalized cointegration vector	$\ln y_t = 5.945 + 0.209 \ln h2_t$ s.e. (0.050) (0.011)		$\ln y_t = 5.833 + 0.299 \ln h2_t$ s.e. (0.142) (0.025)	

Table 5

Trace test (India)				
	1890-1940		1950-2000	
No. of hypothesized Cointegration Equations	Trace statistics	p-value	Trace statistics	p-value
0	32.370	0.001	26.853	0.005
At most 1	5.950	0.195	2.272	0.723
Max. eigenvalue test (India)				
No. of hypothesized Cointegration Equations	Max eigenvalue statistics	p-value	Max. eigenvalue statistics	p-value
0	26.780	0.001	24.581	0.002
At most 1	5.950	0.195	2.272	0.723
Normalized cointegration vector	$\ln y_t = 5.243 + 0.266 \ln h2_t$ s.e. (0.113) (0.035)		$\ln y_t = -4.742 + 0.618 \ln h2_t$ s.e. (1.403) (0.229)	

VI. Conclusion

The cointegration tests confirm our initial hypothesis regarding the long-run relationship between human capital and economic growth. In less developed countries such as

India and Indonesia the dominant relationship is according to the Lucas model (Lucas 1988), and it is the accumulation of human capital that affects economic growth. Human capital is better modeled, therefore, as a factor of production.

After a country nears the technological frontier, as was the case with Japan during the economic miracle in the second half of the 20th century, technology will be increasingly self-developed, and a larger share of human capital will be employed to expand technological frontier. In such case the Romerian approach seems to be a better way to model long-run growth: the level of human capital is cointegrated with the growth rate of the aggregate income.

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Figure 1
Per capita human capital stock in Japan, 1890-2000

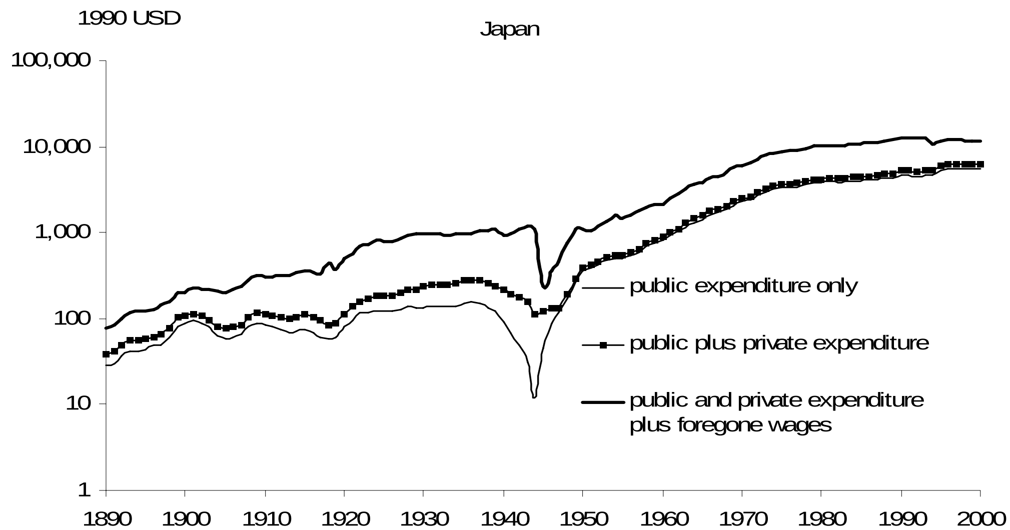

Figure 2
Per capita human capital stock in India, 1890-1996

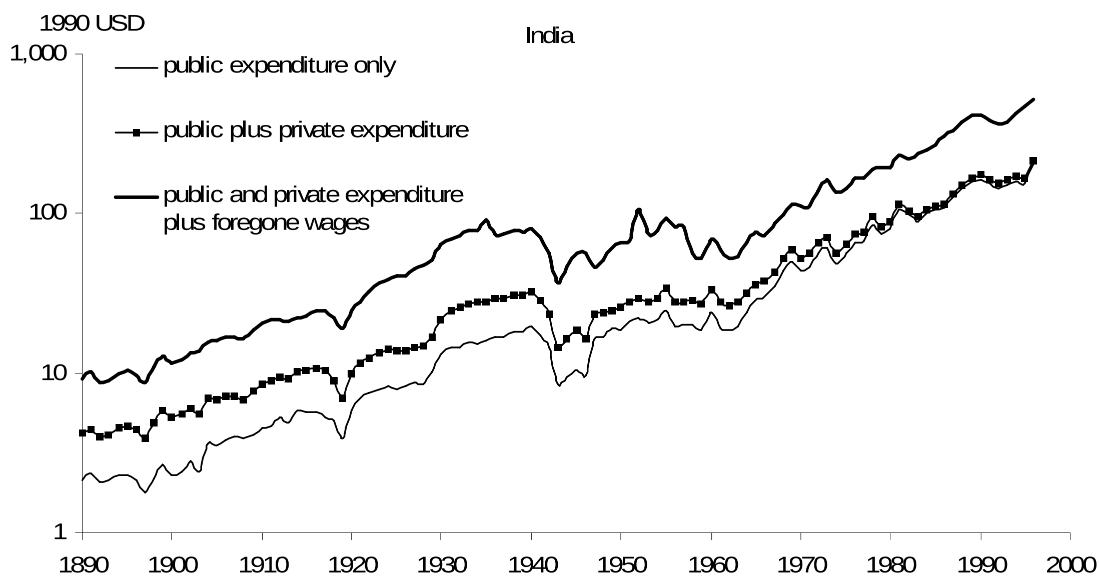

Figure 3
Per capita human capital stock in Indonesia, 1893-1999