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Accumulation of education in modern economic growth: A comparison of Japan with the United States, 1888 - 1995

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Accumulation of Education in Modern Economic Growth: A Comparison of Japan with the United States

Yoshihisa Godo and Yujiro Hayami[†]

1. Introduction

The record of ‘modern economic growth’ à la Simon Kuznets (1966) shows that sustained increases in real national income in advanced market economies depend predominantly on improved efficiency as measured by the growth of total factor productivity (TFP). Real national income is less dependent on increases in conventional inputs, i.e. physical capital and labor in person-hours. With the strong advocacy of economists such as Theodore Schultz (1961), it has been established that investment in education is a major source of growth in TFP and, hence, national income (Denison, 1962; 1967; T.W. Schultz, 1963; Blaug, 1970; Psacharopoulos and Woodhall, 1985; T. P. Schultz, 1988).

Yet estimations of the contribution of TFP to economic growth in advanced market economies have hitherto been limited to periods after these economies reached a stage of relatively high income. However, recent extensions of growth accounting analysis for earlier stages of industrialization in the United States by Moses Abramovitz and Paul David (1973) and Abramovitz (1993), as well as in Japan by Yujiro Hayami and Junichi Ogasahara (1999), show that the contribution of TFP growth to national income growth was relatively minor. These historical findings are also consistent with other studies indicating that the contribution of TFP growth to economic growth was small in comparison to the contribution of physical capital accumulation in newly-industrialized economies (NIEs) in recent decades (Kim and Lau, 1994a, 1994b, 1995; Young, 1995). Such observations suggest that the role of education may be different between the earlier and the later stages of modern economic growth. The validity of this hypothesis is critical for drawing relevant policy implications for developing economies from the historical experiences of developed economies.

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Nevertheless, a comprehensive analysis on the role of education covering the entire span of modern economic growth has been stymied by the sheer paucity of long-term statistics on the accumulation of human capital created from investments in education. In order to close this critical data gap, we attempt to estimate a consistent time-series of the average number of years of schooling per person in the working-age population. We have termed this measure ‘average schooling’. Working age is defined as between the ages of 15 and 64, inclusive, for Japan in the 1888-1995 period and for the United States in the 1870-1990 period. We estimate *average schooling* not only for the entire working-age population but also for several groups segregated by age and gender, for the periods in which data are available, in order to facilitate an assessment of the nature and process of long-term developments in education.

Japan was late to industrialize relative to nations in Western Europe and North America. Yet it was the first non-Western nation that entered the stage of modern economic growth. The basic characteristics of Japan’s economic development are reflected in its progress in education. In order to develop a clear perspective on the characteristics of educational development and its relation to economic growth, we compare the experience of Japan with that of the United States.

The starting year of our estimation for Japan is 1888, when the Japanese economy was on the eve of ‘taking off’ into modern economic growth.¹ Thus, it should be legitimate to claim that our series covers the entire period of modern economic growth in Japan from its very beginning. On the other hand, the US economy had already reached the peak of its spurt of industrialization by 1870, in the period now known as the ‘industrial revolution’.² Therefore, our data does not really cover the pre-takeoff period for the United States.

Average schooling in a given year is estimated by first accumulating the number of years of schooling received in the past by persons of working-ages in that year.³ Because the oldest person of the working-ages in any given year is 64 and he or she could conceivably have

gratefully acknowledged.

¹ It is a popular view among researchers that after the Meiji restoration of 1868 Japan needed 20-30 years to complete its ‘transition’ from a feudal to modern state. For example, see Takatoshi Ito (1992: p.16).

² While the data availability for the US economy prior to 1870 is very limited, it is commonly believed that the US economy’s industrial revolution started before 1870. For example, see Moses Abramovitz (1989: p.128).

begun schooling at age 4, estimating *average schooling* for a given year requires enrollment data going back nearly 60 years prior.⁴ Since our estimates of *average schooling* start at 1888, our school enrollment data must go back to the early 19th century, when Japan was still governed by the feudal Tokugawa Shogunate. Despite the limited availability of data in such early years, we managed to conduct an intensive search for historical data.

It must be emphasized that the major focus of this study is to identify the characteristics of educational growth in the process of modern economic development in Japan. Comparisons with the United States are attempted for the purpose of clarifying these characteristics. Although we tried to prepare comparable data series for the two economies to the extent possible, the results are much more detailed and comprehensive for Japan. While *average schooling* data for the entire working-age population as well as by age and gender groups are prepared for both Japan and the United States, the breakdown for levels and types of education are prepared for Japan only.

In this first report of our work, we attempt to advance a broad outline of educational development in terms of major trends in the growth of *average schooling*. Using simple tabulation and charting of time-series data, we present our findings supported by data compiled according to the procedures described in Appendix A. The simple analysis conducted in this paper is intended to generate hypotheses upon which more detailed study may be conducted with the possible use of our data sets.

2. Measuring the Average Level of Education

Various indexes may be selected to measure the levels of education across nations and over time. One's choice depends on the availability of data as well as the purpose of analysis. We adopted

³ It should be noted that our measure of *average schooling* is different from the average level of education in school years attained. For example, *average schooling* includes years for repeating the same grade, while the average level of education does not. Although the level of educational attainment is surveyed in some censuses, availability, accuracy and comparability are so limited that we decided not to rely on such data.

⁴ As described in the next section and in greater detail in Appendix A, *average schooling* assumes that schooling is provided for persons of age 6 and over.

the ‘*average schooling*’ index that measures the average number of years of schooling per person in the working-age population (15-64 years, inclusive) prior to a given year. We select this index because we consider it the best indicator for representing the stock of human capital produced from formal education, which can be consistently constructed from available data sources over the period of our estimation. Our data sources and estimation procedures are explained in detail in Appendix A. This section will outline the basic approach to the construction of the *average schooling* series.

Since *average schooling* itself was not surveyed in national censuses, we estimate it from data on school enrollment and the total population by age. Specifically, let:

$N_{w,t}$ = Total school enrollment of persons of age w years in year t ;

$G_{v,t}$ = Total number of persons of age v years in year t ; and

$E_{u,t}$ = Total number of years of schooling of persons of age u years in year t .

Then, assuming schooling starts at age 6 years, the total number of years of schooling of persons of age u years in year t ($E_{u,t}$) is given by:

$$(1) \quad E_{u,t} = \sum_{w=6}^u \left(\frac{G_{u,t}}{G_{w,t+w-u}} \right) N_{w,t+w-u}$$

Accumulating $E_{u,t}$ for the entire working-ages and dividing it by the total working-age population, we can find *average schooling*. Let:

AS = *Average schooling* (i.e., the average numbers of years of schooling per person in the working-age population) in year t .

Then, *average schooling* is described as follows:

$$(2) \quad AS_t = \frac{\sum_{u=15}^{64} E_{u,t}}{\sum_{u=15}^{64} G_{u,t}}$$

This equation (2) sums the number of students for each age group enrolled in schools in previous years, after adjusting for their survival rates, to form an estimate of the stock of school education received by the current population of the age group ($E_{u,t}$). For the sake of simplicity, we assume no difference in *average schooling* between immigrants and domestic citizens, and no correlation between school career and mortality in each cohort.

In this calculation, any single year that a surviving person was enrolled in school is counted as one irrespective of the quality or the level of education; for example, one year in primary school is assigned the same weight as one year in university. Repetition of the same grade counts as two years. Also, education received early in one's life is assumed to have the same weight as education received in later years; i.e., we assume no depreciation in human capital created by education. Our series includes only education received in formal schools (not including kindergartens) according to the definitions of the Japanese Ministry of Education and the US Office of Education. Other forms of education, such as on-the-job training, are excluded.⁵

Japan is endowed with an exceptionally rich accumulation of official statistics on education from the very beginning of modern economic growth, compiled by the Japan Ministry of Education (1967, 1969, and 1972). While the original data is fairly reliable and surprisingly comprehensive, comparability of data series over time is not so simple due to almost constant changes in definitions, data collection procedures, and education systems. A major part of this project was to adjust different series for different periods through splicing, interpolation, extrapolation, etc. so as to form a single comparable series. Another major effort was made to search for data in the late Tokugawa and the early Meiji periods before the establishment of the modern education system under the auspices of the Ministry of Education. Despite our best efforts, it was inevitable that the reliability of our data series declines progressively as we go

⁵ However, enrollment in informal private schools (*Terakoya*) in the pre-modern period, as discussed in the next section, are included.

back to earlier years. We rely on Umehara et al. (1988) for population data for years prior to 1920. The data from 1920 onward is mainly based on national censuses.

The US census began to enumerate school enrollments as early as 1840. Moreover, enrollment data for 1830 was estimated by Cremin (1980). Significant inconsistencies are known to exist, however, throughout this enrollment data. We try to adjust for obvious inconsistencies among census years based on the analysis of Folger and Nam (1967). School enrollments in inter-census years are derived by interpolation. Our population data is also based on censuses, which were accumulated by the US Bureau of the Census (1965, 1974, 1975, 1982, and 1993), which comprise the basis of our estimation of *average schooling* for 1890-1990. In order to extend our estimation back to 1870, however, the school enrollment ratio in 1810 and 1820, as well as populations by single years of age for 1870-89 were also necessary. The school enrollment ratio was extrapolated from 1830 data by means of the growth rate between 1830 and 90. The population by single years of age is estimated from population census data. While estimates of *average schooling* for 1870-89 stemming from these ad hoc procedures are admittedly crude and less reliable than those for 1890 and after, we conducted this immense task for the entire working-age population on our own and did not dare do so for other age or gender groups.

3. Changes in the Japanese Education System

Before proceeding to a quantitative assessment of the rise of educational levels in modern Japan, it would be useful to provide a short summary of changes in the education system. While this outline focuses on modern developments after the Meiji Restoration of 1868, it must not be forgotten that education was fairly widely diffused in Japan among ordinary people below the warrior (*samurai*) class before this time. Their children commonly attended *Terakoya* (informal private schools) to receive basic education. Umihara (1988, pp. 317-31) estimated that, as of the late 1860s, 15.2 percent of the population between the ages of 6 and 13 years (24.5 percent for male and 5.8 percent for female) attended *Terakoya*. His estimates were used as a benchmark for constructing our series (Appendix A-2).

The Meiji Restoration eclipsed the feudal system of the Tokugawa Shogunate and established a centralized nation-state under the Emperor. As this reform was induced by the threat of invasion and colonization by Western powers, national leaders sought to ‘enrich the nation and strengthen the army’ (*Fukoku Kyohei*). To achieve this goal, it was considered necessary to ‘promote industries’ (*Shokusan Kogyo*) by means of borrowing modern technologies from the West.

Leaders in the Meiji government recognized that effective borrowing of Western technologies could not be achieved without developing a modern education system that were able to produce high-quality manpower. As early as 1872, only four years after the Meiji Restoration, the government promulgated the School System Rule (*Gakusei*), which specified the design of a modern educational system (Figure 1a). This design was rather idealistic, targeting the full enrollment of all children for eight years of primary education. This target was difficult to achieve despite the government’s encouragement and persuasion, which even extended to intimidation by the police force.

Insert Figures 1–a , 1-b, 1-c, and 1-d

The Primary School Order (*Shogakko Rei*) of 1886 later introduced compulsory education and established two types of primary schools: ordinary primary schools and higher primary schools. The former provided four-year-long compulsory education. The latter provided an additional two to four years of schooling for those who completed compulsory education. The municipal authority in each district was mandated to support an ordinary primary school so that all children could attend.⁶ After many modifications through trial and error, the system was consolidated by 1900 into the illustrated structure (Figure 1b). In 1908 the period of compulsory education was expanded to six years, and by 1919 the system had evolved into a structure that probably most represented the Japanese school system before the Pacific War, as illustrated in Figure 1c.

⁶ Some municipal authorities that could not afford to support 4-year-long ordinary primary school were permitted to simplify compulsory education into 3-year-long schooling. This shortened course is called ‘Kan-i-ka’ (see further Note 10 of Appendix A).

The major characteristics of the prewar educational system, as illustrated by the structures of 1900 and 1919, were: (a) homogeneous general education at ordinary primary schools, which was compulsorily applied to nearly all children; and (b) multiple paths of higher-level education separated by profession and gender. Only a small fraction of children who completed primary education advanced to universities through ordinary middle schools and high schools. A larger number ended their education at either higher primary school or vocational school. A relatively few -- together with some graduates from ordinary middle schools who were neither sufficiently capable nor rich enough to study in universities -- advanced to vocational colleges along the German model of *Technische Hochschulen*. Once a child entered a vocational school, it was difficult, if not impossible, for him to advance to a university. The separate paths of school education were quite pronounced between males and females. While boys and girls received the same education at primary school, middle schools were segregated according to gender. The only tertiary education in the public school system open to females were girls high-school graduate courses, girls higher normal schools, and medical schools; universities were literally closed for them. Private women's colleges operated by Christian missionaries and others were not allowed to attain the status of universities (*Daigaku*).

The educational system underwent major change with the Japanese defeat in the Pacific War. Under the direction of the General Headquarters of the Allied Occupation Forces (GHQ), the educational system in Japan was drastically reformed after the US model. The new system was restructured by the School Fundamental Law (*Gakko Kihon Ho*) of 1947 and is illustrated in Figure 1d. Three years at junior high schools were added to the six years of education at primary schools to form the new compulsory education system. Moreover, the higher level of secondary education was unified into senior high schools. Within these senior high schools, vocational education courses were offered alongside general education courses. Unlike the prewar system, however, graduates from the vocational courses did not face discrimination in advancing to universities. Gender discrimination against such opportunities was also eliminated. This system, as illustrated in Figure 1d, has remained essentially unchanged until today.

4. Japan's Catch-Up in Education

We will now summarize our quantitative findings so as to describe the characteristics of education growth in Japan in comparison with the United States.

The process of human capital accumulation in the modern economic growth of Japan is summarized in Table 1. From 1888 to 1995, total population grew about threefold at the average rate of 1.1 percent per year. The working-age population grew faster at 1.2 percent per year, resulting in an increase in the share of the working-age population from 60 percent in 1888 to 69 percent in 1995. Note that this relative increase occurred mainly during the so-called ‘high-growth era’ from 1955 to 1970, suggesting that a significant portion of economic growth in this period may be attributed to the increased percentage in the working-age population.

Insert Table 1

This rapid increase was mainly a result of the entrance of an unusually large number of children born immediately after the Pacific War (the so-called ‘postwar baby boom’) into the working-age bracket.⁷ It was further accelerated by a reduction in the incidence of tuberculosis among the young as a result of improvements in nutrition as well as advances in medical technology.

Meanwhile, the level of education as measured by *average schooling* increased at nearly twice the rate of population growth. The growth of *average schooling* was much faster in the period before the Pacific War (3.4 percent per year) than the postwar period (1.0 percent per year). This rate was especially high during the initial two decades from 1888 to 1910 (as much as 4.6 percent per year). The rate of increase in the level of education (or the stock of education) as measured by *average schooling* was associated with the rise in the school-enrollment ratio for the population between the ages of 6 and 20 years, which may be considered a proxy for current investment in education. This ratio increased from 25 percent in 1888 to 86 percent in 1995. The increase in this ratio also occurred mainly before the Pacific War.⁸

⁷During 1947-51, the birth rate in Japan reached historical highs of between 2.4 and 3.4 %. These figures are extremely high compared with 1.6 % for the average birth rate in 1952-1990. In 1995, the population of ages 44-48 years (i.e. those who were born in 1947-1951) accounted for nearly one-tenth of the total Japanese population.

⁸In Japan, the enrollment ratio of the compulsory-education aged population has been over 98 % since 1908. Thus, the increases of figures in the last column of Table 1 after 1910 are attributed to the increases in the enrollment ratios of post-compulsory education. After 1980, the composition ratio of persons of age 15-20 years (i.e. post-compulsory-education ages) in the school-age population (from age 6 to 20) is increasing because of a downward

The characteristics of the growth in Japanese education levels can be best understood through comparison with the experiences of the United States. We compare the growth of *average schooling* for the total population from 1888 to 1990, and for age group and gender from 1890-1990, and for which comparable data were compiled (Tables 2a, 2b, and 2c). Our first observation is that Japan lagged well behind the United States in average schooling during the early period. In 1888, *average schooling* for the total population of Japan was only 18 percent of the US level and only 23 percent when compared with the 1870 US level (Table 2a). This initial lag in Japan is associated with a much faster growth rate in *average schooling* in later years. Indeed during the period of 1890-1990, *average schooling* for Japanese males and females between the ages of 15-64 years, in Japan increased at the rate of 2.2 percent per year compared with only 0.7 percent in the United States. As a result, the ratio of *average schooling* in Japan to that of the United States rose from only 20 percent in 1890 to 85 percent in 1990. Japan reduced this educational gap with the United States mainly before the Pacific War. Such reduction first occurred in the younger age group (15-39 years) and then followed at an even faster pace in the older age group (40-64 years) as the younger cohorts aged.

Insert Tables 2-a, 2-b, and 2-c

These observations clearly reflect the fact that Japan, as a late-comer to industrialization and modern economic growth, invested heavily in education, especially in its early development stage, in order to catch up to advanced economies in the West. Such a disproportionately high investment in education demonstrates the strong belief held among leaders in Meiji Japan that the elevation of human capital to the Western level was a precondition to match the West's economic (and military) power.

The strong intention of Meiji leaders to use school education as a means of economic catch-up can be seen in the heavy emphasis on vocational education. The average number of years of vocational schooling, as shown in Table 3, increased more than three times faster than the average of all schools before the Pacific War. As a result, the share of vocational education in total schooling years at the post-primary (i.e., secondary and tertiary) level rose from 3 percent in

trend in the birthrate. This is the reason the enrollment ratio in the last column of Table 1 remains almost constant

1900 to 54 percent in 1940. This disproportionate growth in vocational education was due to the high demand for mid-level engineers, technicians, managers and clerks who were needed to transfer technology from the West.

Insert Table 3

5. Differences According to Gender

The same comparison conducted in terms of males and females (Table 2b and 2c) shows another major characteristic in the progress of education in Japan. The growth of *average schooling* in Japan for each gender separately was faster than in the United States. In Japan, however, the speed was nearly 50 percent faster among women than men, while no such inter-gender difference is observed in the United States. Such a difference in Japan stemmed from the very low initial level of female education at the start of its modern development. Indeed, *average schooling* for Japanese females in 1890 was only 0.6 years, or one-third of male's 1.9 years, while there was only a small difference in the United States in the same year (6.7 years for men and 6.3 years for women).

From this low initial level, the *average schooling* of women in Japan increased faster than that of men. Yet a major gap between men and women persisted until the Pacific War that was only fully closed with the introduction of the US school system after the war. As seen in Table 4 and Figure 2, the large gap in education between males and females, as measured by either *average schooling* or the school-enrollment ratio, rapidly closed in Japan over a century of modern economic growth. No such gap ever existed in the United States, however, at least for the period of our analysis.

Insert Table 4

Insert Figure 2

A relevant question to ask is whether the low level of education among women in the

after 1980 in spite of upward trends in enrollment ratios for persons of age 15-20 years.

initial period and their subsequent catch-up was unique to Japan? Was it rooted in Japan's cultural and religious traditions, like Confucianism and Buddhism, or was it a process common to all early stages of industrialization? In order to resolve this question, it would be necessary to examine educational statistics, such as *average schooling* and school-enrollment ratio, in the period before modern economic growth, such as the early 19th century in the case of the United States. Unfortunately, we had neither the time nor resources to answer this question in our paper.

It is likely, however, that cultural tradition played a significant role in the pattern of educational growth in Japan, although it may be difficult to ascertain the extent. Evidence for such conjecture may be provided by a comparison of *average schooling* across different levels of education. As Table 5 shows, the ratio of *average schooling* for women as opposed to men already exceeded 80 percent prior to the Pacific War in the case of primary education. There was a significant improvement in this ratio for secondary education, though women's *average schooling* was still half that of men's in 1940. In contrast, the gap in tertiary education had not only been extremely large initially, but did not close at all until the end of the Pacific War. It was only in the postwar period that the gap began to close rapidly.

Insert Table 5

This quantitative data is consistent with the fact that universities were virtually closed to women and only opened after Japan's defeat. It seems reasonable to hypothesize that certain Confucian ideologies and traditions may have confined women to a subordinate role, which deprived them of the opportunity to receive higher education in the prewar period. GHQ policy helped open the door of higher education to women. Yet it should be recalled that the Japanese people themselves re-evaluated such traditional ideology and supported democratization and liberalism, which enabled Japanese women to study at universities. In fact, the speed of postwar growth in women's enrollment in the tertiary level of education was high, enough to sharply increase the ratio of female versus male schooling in tertiary education from 5 percent in 1950 to 43 percent in 1990. It is expected that the rise in women's education at the tertiary level will continue for the next few decades and that women's *average schooling* will become par with men's in all levels of education.

6. Education and Economic Growth

What was the role of education in Japan's modern economic growth? We try to make some inferences on this question by comparing broad trends in the level of *average schooling* with trends in real GDP per capita and the capital-labor ratio (Unless it is otherwise expressed, 'capital' in this paper means 'physical capital'). Further, we compare the relationships between *average schooling* and economic indicators in Japan with those in the United States, so that the characteristics of Japan's catch-up growth can be clearly observed. Such broad comparisons are intended to generate hypotheses for further rigorous testing in the future by means of aggregate production function analysis or some other analytical method.

Table 6 makes this comparison of long-term changes in real GDP per capita, capital-labor ratio and *average schooling* between Japan and the United States from 1890 to 1990. In preparing this table, we pay due attention to the comparability of data between the two nations. There are several popular data sources for capital stock and GDP for both nations, as described by Angus Maddison (1995). As far as GDP is concerned, the long-term international panel data that Maddison prepared seems suitable for our purpose because of their cross-country comparability. His capital stock data, however, appears to be both inconsistent and ambiguous in methods of estimation. Hence, we re-estimated the series of gross capital stock (excluding residential structure and military use) by extending the perpetual inventory method as used by Boskin and Lau (1992). The population figures are also from Maddison (1995). As for labor, we use our own series for the working-age population compiled from various sources. For more detail of the estimation methodologies for capital stock and labor, see Appendix B.

Insert Table 6

Over the one-hundred year span between 1890 to 1990, real per-capita GDP in Japan increased at an annual compound rate of 3.0 percent, the capital-labor ratio at 4.9 percent and *average schooling* at 2.2 percent. This speed of per-capita GDP growth in Japan was 60 percent higher than in the United States, while the growth of the capital-labor ratio was 150 percent

higher and that of *average schooling* was 200 percent higher than in the United States. Such comparisons seem to be consistent with the general hypothesis that economic growth for late-comers to industrialization may need faster accumulation of physical and human capital relative to improvements in efficiency than for the early starters (Hayami and Ogasahara, 1999).

It also appears that the reliance of Japan's GDP growth on physical capital relative to human capital changed greatly over time. Before the Pacific War, the growth of *average schooling* was faster than that of the capital-labor ratio, while the reverse was the case in the postwar period. A more dramatic comparison exists between the initial period (1890-1910) and the high-growth era (1955-1970). In the former, Japan's per-capita GDP growth was only 1.3 percent per year, which was slower than that of the United States by approximately 40 percent. This slow growth in GDP per capita was accompanied by a very rapid growth in the capital-labor ratio at 5.5 percent per year, which was faster than that of the United States by approximately 50 percent. Meanwhile, the growth rate of *average schooling* in Japan was five-times higher than in the United States. The pattern in the postwar high-growth era, however, represented a sharp contrast to the prewar pattern. From 1955 to 1970, both per-capita GDP and the capital-labor ratio in Japan increased about four-times faster than in the United States, while the growth of *average schooling* was only twice as fast.

Such changes in the rate of growth in physical capital relative to human capital as well as their relationship with GDP growth in Japan are more clearly visible in Figure 3, which plots per-capita GDP, the capital-labor ratio and *average schooling* in Japan as percentages of the respective variables in the United States. From 1890 to 1930, Japan's GDP per capita was approximately 30 percent of that of the United States, despite having closed the gap in *average schooling* from 20 to 67 percent. Meanwhile, there was a significant reduction in the gap in the capital-labor ratio, but Japan's capital-labor ratio remained low at only 16 percent of the United States' level in 1930.

Insert Figure 3

Indeed, the pattern of Japan's catch-up changed sharply between the pre- and post-war periods. Japan's capital-labor ratio rose very fast from only 18 percent of that of the United

States in 1955 to 102 percent in 1990. This was paralleled with a reduction in the income gap from 25 percent to 85 percent. Meanwhile, the gap in the level of education continued to close, albeit rather slowly, from 75 to 85 percent.

The major anomalies are: (i) Why was the gap in per capita GDP not reduced significantly before the Pacific War, especially before 1930, despite the very rapid closing of the educational gap, which was almost double the catch-up speed of the capital-labor ratio?; and (ii) Why did the income gap begin to close rapidly in the postwar period with the major investment spurt of the high-growth era despite slow growth in *average schooling*? The first hypothesis to answer these questions is to assume complementarity between physical and human capital, especially in the early stages of development. Improved skills and knowledge created from education may not contribute much to productivity growth, unless appropriately combined with physical capital. For example, education would not raise productivity in simple manual work, such as digging a ditch with a shovel, but it would significantly increase efficiency in the operation of modern sophisticated earth-moving machinery (Hayami, 1997, p.45). It appears that the speed of educational growth in Japan before the Pacific War was too fast to maintain the appropriate combination between physical and human capital. The second hypothesis postulates that the level of education, instead of its growth rate, is the major determinant of a country's capability for borrowing external technology and, hence, its economic growth rate, as attested by Robert Barro (1991) in his cross-country regression analysis.

These two hypotheses are not mutually exclusive but complementary. In our perspective, human capital in Japan did not yet reach the threshold at which frontier technology practiced in the United States could be effectively borrowed before the Pacific War, despite the rapid accumulation of investments in education.⁹ As a result, the immediate economic return to education was not very high in the prewar period. It appears that the accumulation of educational investments in the first half-century brought Japan to such a threshold, but the opportunity of importing foreign technology was stopped by the war. The opportunity, however, to profitably employ premier frontier technology with sufficiently elevated human capital was open for exploitation in the postwar period. It appears that this profit opportunity for physical capital

investment based on previously accumulated human capital brought about the major investment spurt in the high-growth era.

This hypothesis is tested in terms of a simple growth accounting analysis, in the style of Robert Solow (1957), under the assumptions of neutral technical change, and constant returns in production with respect to labor (in man-hours) and physical capital (gross non-residential capital). In this analysis, as shown in Table 7, the growth of labor productivity ($G(Y/L)$) is separated into the contribution of growth in the capital-labor ratio and the residual that is defined as total factor productivity (TFP). As a standard practice, the former is obtained by multiplying the share of capital (b) by the growth rate of the capital-labor ratio ($G(K/L)$). $G(A)$, which is obtained by subtracting $b(K/L)$ from $G(Y/L)$, is the estimate of TFP in simplest form. Taking the ratio of the growth rate of TFP and *average schooling*, we get a rough proxy of the output elasticity of human capital.¹⁰

Insert Table 7

Data used for growth accounting is the same as in Figure 3, except that labor is measured in working hours instead of working-age population. Work hours are calculated by multiplying ‘numbers of employed persons’ and ‘average working hours per worker’, which are derived by splicing several date series from Umemura (1988), the Japan Economic Planning Agency (1991, 1996a), Kendrick (1965), Maddison (1991), and the *Economic Report of the President* (1991). ‘Capital’s share in the total cost’, which is based on Abramovitz (1993) for the United States and estimated for Japan from Hayami and Ogasahara (1999) and Yamada and Hayami (1991), is used as a proxy of output elasticity of capital. For more detail on data preparation, see Appendix B.

The results of this growth accounting analysis are summarized in Table 7. In Japan, the relatively modest rates of growth in labor productivity were outpaced by very rapid increases in

⁹ For empirical evidence on the threshold effect of education, see Jamison and Lau (1982) and Lau, Jamison, Liu and Rivkin (1993).

¹⁰ It is desirable to estimate the contribution of human capital as measured by comparing *average schooling* to TFP growth. However, in the absence of information on output elasticity with respect to human capital, we simply take the ratio between growth rates of TFP and *average schooling*. This is considered a rough proxy of the elasticity of TFP with respect to human capital.

the capital-labor ratio to result in negative growth of TFP for 1890-1900 and almost zero growth for 1900-20. Correspondingly, the elasticity of TFP with respect to human capital was negative or negligible in magnitude in the face of very rapid increases in *average schooling*. The TFP growth became significant at the rate of 1.5 percent per year for 1920-40 but the estimate of human capital elasticity was much less than one because *average schooling* increased twice as fast as TFP.

The situation after the Pacific War represents a sharp contrast to the prewar scene. TFP increased at a very rapid rate partly because of acceleration in labor productivity growth relative to the growth of the capital-labor ratio and partly because of the decreased share of capital. The acceleration of TFP growth, when combined with deceleration in the growth of *average schooling*, resulted in the elasticity of TFP with respect to human capital as high as 4.5 for the high-growth era in 1955-70 and above 2 even in 1970-90 when Japan's growth miracle ended.

In the United States also, both the role of TFP in economic growth and the role of human capital in TFP growth increased as the economy moved into advanced stages. However, the changes in the roles of TFP and human capital in the course of development were much more pronounced in Japan than in the United States.

It appears to be a common pattern that the role of human capital relative to physical capital increases as an economy advances to higher income stages. These stages are characterized by a shift in the center of economic activity from those based on low-skilled labor combined with large physical capital to activities based on highly educated manpower for the production of non-physical products, such as knowledge and design (Hayami 1997, pp.139-43). The data in Table 7, as well as in Figure 3, suggests that this transition is difficult to achieve before the accumulation of both human and physical capital reaches a certain threshold level.

Such a hypothesis, based on the experiences of Japan in one hundred years of modern economic growth as compared with that of the United States, does not deny the consensus view that investment in education is the critical condition for developing economies to catch up with advanced economies. It does imply, however, that developing economies cannot expect to harvest the fruits of education immediately. They must be prepared to endure the heavy burden of investment in education relative to their income level for many years before the stock of

human capital together with physical capital reaches a sufficiently high level to enable rapid economic catch-up. It is still possible that education will prove to have the highest economic return for investment in the long run, although its short-run return might not be quite so attractive for political leaders in developing economies relative to their high discount rates.

7. Summary and Conclusion

In this paper, we have tried to outline the development of education in the context of modern economic growth in Japan since the Meiji Restoration. We based our estimates on the average number of years of schooling per person in the working-age population, termed as *average schooling*, from 1888 to 1995. Japan was compared with the United States in order to single out its characteristics of as a late-comer to industrialization and as the first non-Western nation that entered the era of modern economic growth.

It was found that the growth of *average schooling* in Japan was much faster than in the United States throughout the period of analysis. As a result, the major gap in the level of school education existing between Japan and the United States in the early Meiji period was largely closed by 1990. The rate of reduction of this gap was especially fast in earlier years, reflecting the Meiji government's determination to shoulder the extraordinarily heavy cost of education. Such a high priority on education is seen to have reflected a consensus among leaders in the Meiji period that catching-up in education was the efficient means to catch up with Western economic and military power. Their intention of using education as an instrument of economic pursuit also demonstrates the disproportionate growth in vocational education before the Pacific War.

A major gap in the initial level of education between men and women mirrors the unique nature of Japan as a non-Western nation entering the epoch of modern economic growth. The male-female gap in primary education rapidly closed before the Pacific War. The reduction of differences in higher levels of education, especially at the tertiary level, however, was largely achieved in the postwar period. Underlying the faster progress in women's education after the war was educational-system reform under the Occupation as well a shift toward beliefs in

liberalism and democracy.

A major change is observed in the pattern of economic growth vis-a-vis education growth between pre- and post-war periods in Japan and the United States with respect to *average schooling*, real GDP per capita and tangible capital stock per worker, together with a simple growth accounting analysis. In the prewar period, despite rapid catching up in the level of education, the major gap in GDP per capita as well as the gap in the capital-labor ratio between Japan and the United States was not significantly reduced. In the postwar period, however, a rapid catch-up in GDP per capita was paralleled with that of the capital-labor ratio, while further growth in educational levels was rather modest.

Such observations suggest high complementarity between tangible and human capital. They also suggest social capital's dependency to borrow frontier technologies on a certain threshold of human capital accumulation. A hypothesis is established that cumulative investments in school education in the first half-century of modern economic growth brought Japan to such a threshold of human capital accumulation. With respect to this past accumulation of educational investments, Japan profited from the importation of world frontier technologies coupled with a boom in physical capital investment since the end of the Pacific War. Our conclusion, however, remains a hypothesis until rigorous testing can further examine its merits.