

Education and Natural Resources in Economic Development: Thailand Compared with Japan and Korea[†]

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Abstract

In this study, we compare among Thailand, Japan and Korea in terms of their educational and economic developments. We hypothesize that Thailand's slower economic progress has been due to its slower educational development induced by abundant land resource. Our regression analysis using pooled time-series data of these countries confirms the negative effect of land endowment on educational investment. Land endowment also has a negative effect on agricultural intensification and industrialization whereas the educational stock has a positive effect. These imply that Thailand failed to effectively mobilize resource rent in the vent-for-surplus development stage for preparing conditions of modern development.

Key words: education, natural resources, vent-for-surplus growth

JEL classification codes: I28, N95, O13, O53

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1. Introduction

In this paper, we attempt a comparative analysis of educational and economic developments in Thailand, Japan and the Republic of Korea (hereafter referred to as Korea) based on aggregate time-series data we prepared in order to identify the effect of natural resource endowments on modern economic growth.

Both Thailand and Japan had based their subsistence mainly on rice cultivation until modernization was imposed by western powers. Since the middle of the 19th century, they have shared some important characteristics: (a) both were opened to trade with western nations at around the same time; Thailand signed the Bowring Treaty with Great Britain in 1855 and Japan signed the first commercial treaty with the United States in 1858, (b) both have adopted the monarchy system, (c) both faced serious threats to their sovereignty from western powers in the 19th century but were able to maintain independence and avoided colonization, and (d) both began to promote modern education in the 1870s (Ingram, 1955; Feeny, 1982, 1998; Dhiravagin, 1981).

Unlike Japan, Korea, which was also a predominantly rice-growing economy, continued to close trade with western nations and failed to modernize by its own initiative, resulting in its colonization by Japan in 1910. In spite of this geopolitical difference, Japan and Korea are similar with respect to their scarcity of natural resources. In contrast, Thailand has been regarded as a resource-abundant (particularly land-abundant) economy until recently. Therefore, the historical comparison of Thailand with Japan and Korea is expected to reveal what role natural resources might play in the long-term economic development. In particular, we are concerned

with the process in which natural resource endowment influences investment in education that is considered vital for modern economic growth.

There have been several studies demonstrating that the abundant endowment of natural resources has a negative effect on economic development (Ascher, 1999; Gylfason, 2001; Birdsall et al., 2001; Sachs and Warner, 1995). However, these studies are based on inter-country cross section data, making it difficult to identify the process of how differences in natural resource scarcity may have resulted in different patterns of economic growth involving different institutional changes.

In this study, we try to overcome this disadvantage by using the long-term historical statistics since the late nineteenth century of Thailand and Japan, and the post-World War II statistics of Korea. We limit our analysis on Korea to the period after World War II because of the difficulty in preparing comparable data for the territory of the Republic of Korea before Korea was divided between North and South. In addition, we exclude from our analysis the data after 1995 for all the three countries in order to avoid a possible irregular effect caused by the so-called Asian financial crisis.

The aim of this study is to answer the question why Thailand lagged behind Japan and Korea in entering the epoch of “modern economic growth” characterized by sustained increases in real income per capita in the sense of Simon Kuznets (1966). However, it is outside the realm of this study to ask why in recent three decades Thailand began to follow Korea in catching up with Japan in economic growth and industrialization as a part of “East Asian Miracle” as defined by World Bank (1993).

The rest of this paper is organized as follows. Section 2 postulates our basic hypotheses and explains the data used. Section 3 compares natural resource endowments and educational

and economic developments in Thailand, Japan and Korea. The time-series regression analysis is dealt with in Section 4, and Section 5 concludes the paper.

2. Approach

This section aims to specify the theoretical framework for our empirical analysis and explain the data used.

Theoretical framework

The paper is built upon the following three premises. The first is the assumption that technological progress based on human capital accumulated through education is the major source of sustainable economic growth (T.W. Schultz, 1961; Nelson and Phelps, 1966; Easterlin, 1981; Lucas, 1988; Abramovitz, 1989; Becker, 1993). The second is the induced innovation hypothesis of Hayami and Ruttan (1971). According to this hypothesis, where natural resources are abundant so that an increase in output can be met by increasing the exploitation of natural resources such as opening new lands for cultivation by traditional technologies, as was the case of Thailand in the late 19th century to the early 20th century, the incentives to develop new technologies by such means as education and research would likely be small. Meanwhile, Japan and Korea invested heavily in education under their meager endowment of natural resources, which was crucial for their high economic growth performance (McGinn et al., 1980; Godo and Hayami, 1999; Lee, 2003).

The third concept is the vent-for-surplus development theory of Hla Myint (1965, 1971). According to this theory, a resource-abundant country's participation in international trade based on the exploitation of natural resources cannot lead to sustainable economic growth unless resource rent is effectively mobilized for investment in physical and institutional infrastructure including education. In fact, such effective use of resource rent has been identified as the basis for a successful shift in the economic growth momentum in Canada and the United States from

natural resource exploitation to agricultural intensification and industrialization (Innis, 1933; North, 1955; Watkins, 1963). The governments of Thailand and Japan began to promote educational development in the 1870s. But, throughout the late 19th and the early 20th centuries, Thailand's educational and economic developments lagged behind Japan. In the post World War II period, Korea overtook Thailand in both educational and economic developments. It seems reasonable to hypothesize that Thailand's lag in educational development relative to those of Japan and Korea represents a failure of the government to effectively utilize the resource rent generated from the vent-for-surplus development process for preparing conditions necessary for achieving sustainable modern development.

Econometric approach and data used

We test our hypotheses by applying the cointegration and error correction econometric approach, developed by Engle and Granger (1987), on pooled time-series data of Thailand, Japan and Korea. Our analysis is focused on school education, which is considered a key variable in the accumulation of human capital needed to support modern economic growth. We assume that agricultural intensification and industrialization are the two major activities comprising modern economic growth, especially in its initial stage. We define "industrialization" broadly as the development of both industrial and service sectors. Our empirical findings are that the stock of education had a significant positive impact on agricultural intensification and non-agricultural sector development, whereas the endowment of natural resources had a negative impact on these activities as well as on investment in education.

We base this study on our newly prepared data set on school enrollment ratio, average schooling, labor and GDP in Thailand, which is comparable to the data in Japan and Korea prepared by Godo and Hayami (1999, 2002) and Godo (2004), respectively.

School enrollment ratio, which is considered a proxy for current investment in education, is the proportion of the school-age population (6-20 year-old population) being enrolled in school. Average schooling is defined as the average number of years of schooling per person in the working-age population (15-64 year-old population). It is estimated by accumulating school enrollments over time adjusted for deaths and migration based on the estimation procedure and assumptions proposed in Godo and Hayami (1999)¹. As such, this variable is considered a proxy for the stock of human capital accumulated from past investments in education. Labor refers to the number of employed persons in the working-age population. GDP is measured in 1990 constant US dollar in terms of purchasing power parity.

To estimate school enrollment ratio and average schooling in Thailand, we draw the school enrollment data in 1914-1995 from Ministry of Education of Thailand (various issues). The data in the late 19th century and the first two decades of the 20th century are from Wyatt (1966) and Sukornarangsi (1967). The population data are from the National Statistical Office of Thailand, NSO (various issues), Warr (1993), World Bank (2001), and Heston et al. (2002).

The labor data are prepared by comparing the data on the number of employed persons from two sources: the Statistical Yearbook of Thailand (Thailand National Social and Economic Development Board, NSEDB, various issues) and the Annual Report of Labor Force Survey (NSO, various issues). The GDP data are prepared by comparing the data from various sources (NSEDB, 1999; Warr, 1993; World Bank, 2001; Heston et al., 2002).

The other set of data used in this study pertains to natural resource endowments, agricultural intensification and industrialization in Thailand, Japan and Korea. Total territorial land and arable land areas are used as two proxies for natural resource endowments. Arable land

¹ For the formula to calculate average schooling from the data of school enrollment ratio, see Godo and Hayami (1999).

area is defined as the total cultivated land area under both annual and perennial crops. As a proxy for agricultural intensification, average rice yield per hectare planted is used, considering the dominant weight of rice in agricultural production in the three economies under study. The non-agricultural sector's share in GDP and industrial commodities' share in total merchandise exports are used as two proxies for industrialization. All these variables are admittedly very crude proxies. Yet, no better alternatives are conceivable under the paucity of long-term historical statistics.

The data for those proxies are drawn from various sources. For Thailand, arable land area and rice yield data are available in Shintani (2003) and Ingram (1955). The data on the share of non-agricultural outputs in GDP and the share of industrial commodities in total merchandise exports are available from World Bank (2001). For Japan, arable land area and rice yield data are taken from Hayami and Yamada (1991), the Food and Agriculture Organization of the United Nations, FAO (1998) and Hayami et al. (1980). The population data are from Godo and Hayami (1999). The data on the non-agricultural sector's share in GDP and industrial commodities' share in merchandise exports are from Ohkawa and Rosovsky (1973) and World Bank (2001). For Korea, the data on arable land area are taken from Hwan Ban (1979), Francks (1999) and FAO (1998), and rice yield data are from Hayami and Kikuchi (1985) and FAO (1998). World Bank (2001) provides non-agricultural outputs' share in GDP, and industrial products' share in merchandise exports. The population data are from Godo (2004).

3. Historical Overview

Based on the data thus prepared, we present in this section an overview on changes in natural resource endowments, educational investment and stock, and other economic indicators of these three countries for giving a concrete historical perspective on our hypotheses.

Natural resource endowments and economic growth

Japan has been subject to strong population pressure on limited land resource ever since the middle of the Tokugawa period (Hayami, 2001a). Korea is also well known for its land scarcity. In contrast, Thailand had been endowed with abundant land resource until about two decades ago (Siamwalla, 1991, 1997). To provide a quantitative overview on their relative land endowments, Table 1 reports (a) territorial land area per capita and (b) arable land area per capita in these three countries.

In Section (a), it can be observed that, on average, one Japanese was endowed with roughly 1 hectare of territorial land area in 1890. The population growth in the subsequent period reduced its per-capita territorial land area to 0.4 hectare in 1960 and 0.3 hectare in 1995. Korea's per-capita land endowment had been very similar to that of Japan. In 1960, Korea's territorial land area per capita was approximately 0.4 hectare, and it declined close to 0.2 hectare in 1995. In contrast, Thailand's territorial land area per capita was as much as 7 hectares in 1910. Although the rapid population expansion quickly drove down the land per capita, population density of Thailand became close to the 1890 level of Japan only in 1995.

In Section (b), the data on arable land area per capita of these three countries are compared. Arable land area per capita in Thailand was higher than those of Japan and Korea in all the years. In 1911, one Thai had as much as 0.22 hectare whereas one Japanese had only 0.11 hectare in 1910. In 1960, one Thai had 0.32 hectare while one Japanese and one Korean had 0.07 and 0.08 hectare, respectively. A striking contrast is that, while per-capita arable land area in Japan and Korea monotonically declined over time, it increased in Thailand before 1980. It was only from the late 1970s when the land frontiers for cultivation in Thailand began to be closed, resulting in the decline in the per-capita arable land area.

Under different endowments of land resource, Thailand followed an economic growth path different from Japan and Korea. The difference is illustrated in Table 2 in terms of changes in average rice yield per hectare planted, the non-agricultural outputs' share in GDP, industrial commodities' share in total merchandise exports, and per-capita GDP in these three countries. Due to its land scarcity, Japan had to invest for increasing agricultural output per hectare in order to avoid a possible food crisis while trying to promote industrial development². The government invested in training agricultural specialists, whose scientific knowledge was combined with farmers' practical experiences in selecting and promoting high-yielding rice varieties more responsive to fertilizer application (Hayami et al., 1980). The development and diffusion of high-yielding rice varieties, supported by irrigation and drainage facilities resulted in an increase in rice yield per hectare of cultivated land since the 1890s.

Unlike Japan, Thailand developed no significant research program for increasing rice yield throughout the late 19th and the early 20th centuries. The Chao Phraya river irrigation scheme proposed in 1902 had not been constructed until the late 1950s (Feeny, 1982). Thailand's response to an increasing foreign demand for its rice by increasing production area in those years was associated with a gradual decline in rice yield per hectare, because cultivation frontiers moved to less productive areas. Although Thailand experienced gradual increases in rice yield per hectare since 1940, its level in the recent two decades was not significantly higher than the level in the 1920s. In the 1990s, Thailand's rice yield per hectare reached about the same level as that of Japan in the 1890s.

In 1960, rice yield per hectare in Korea was as high as that in Japan. In 1960-1995, Korea continued to invest in agricultural research and development, resulting in rapid increases in rice

² Japan also made efforts to improve productivity of silk production, which was a major primary commodity for export.

yield per hectare. Such effort reflected Korea's desire for avoiding a food crisis in the process of industrialization under the increasing population pressure on land.

At the time of opening trade with foreign countries in the mid-19th century, the Japanese economy was dominated by the agricultural sector. But, the Meiji government promoted industrialization (Hunter, 2000). By 1910, its non-agricultural sector's share in GDP had reached 73 percent and industrial commodities' share in merchandise exports had reached approximately 61 percent, which increased to 98 and 99 percent, respectively, in 1995.

Thailand began its trade with the western nations at around the same time as Japan, but it had remained a predominantly agricultural economy until the 1970s. In 1960, the non-agricultural sector's share in GDP was only 64 percent, and industrial outputs' share in merchandise exports was merely 11 percent. However, in the subsequent two decades, the share of the non-agricultural sector in GDP and industrial outputs' share in merchandise exports increased sharply reflecting Thailand's joining in the so-called "East Asian economic miracle."

Yet, Thailand lagged behind Korea in industrialization after World War II. In 1960, non-agricultural sector's share in GDP of Korea was 65 percent, not significantly different from that of Thailand, but its industrial commodities' share in merchandise exports was 72 percent, much higher than that of Thailand. Thereafter, Korea's industrialization progressed at a faster rate than that of Thailand. In 1995, Korea's non-agricultural sector's share in GDP was 93 percent and industrial products' share in merchandise exports was as high as 96 percent as compared with 89 and 75 percent, respectively, in Thailand.

Section (d) of Table 2 compares changes in per-capita GDP in these three countries. Japan's efforts to improve agricultural land productivity and to promote industrialization in the 1890s and the early 20th century resulted in sustained increases of per-capita GDP in that period. On the contrary, Thailand experienced a decline in per-capita GDP in 1890-1955. This poorer

economic growth performance in Thailand corresponded to its poorer achievements in agricultural land productivity improvement and industrial development. In recent decades, although Thailand has been considered as a part of “East Asian Miracle” (World Bank, 1993), its economic growth performance has been less impressive than that of Korea. The average growth rate of real GDP per capita in 1960-1995 was 5.3 percent in Thailand as compared with 6.2 percent in Korea.

In sum, Thailand was much more favorably endowed with land resources than Japan and Korea. Correspondingly, Thailand specialized in the production of primary commodities, especially rice, until very recently through exploitation of hitherto unused land with traditional technology along Hla Myint’s vent-for-surplus model (Hayami, 2001b). In contrast, Japan and Korea intensified agricultural production based on the application of modern science to production in order to avoid a subsistence crisis and to support industrial development.

Educational developments

Being endowed with abundant land resource, Thailand paid less effort to improve land productivity in agriculture and to promote industrialization. Correspondingly, its educational development was also poorer. About one decade and a half after signing commercial treaties with the western powers, the governments of Japan and Thailand began to promote modern education. However, while Japan’s objective at that time was to rapidly establish educated labor force for supporting industrial development (Levine and Kawada, 1980), Thailand’s objective was to train manpower for government offices (Sukornrarangsi, 1967; Watson, 1980). In the late 1860s and the early 1870s, the Japanese government studied extensively education systems in advanced countries and introduced compulsory primary education (Levine and Kawada, 1980). By the 1890s, Japan had been able to develop the appropriate system for rapid educational development.

Though the Thai government also recognized the importance of educated labor force for economic modernization in the early 1870s, the promotion of mass education was intermittent in the subsequent four to five decades. For example, in 1879, following the suggestion of a foreign advisor, one government school (Suan Anand School) was established, aiming to enroll not only the children of the nobility but also those of the commoners (Watson, 1980). But, the school was short-lived. In 1888, the government sent an officer to study Japanese education system. In the 1890s, the government also studied public education systems in Burma, India and Europe. However, in the 1900s, it was still not clear what form of education Thailand should take and the compulsory primary education act was enacted only in 1921, almost a half century after Japan.

Korea out-performed Thailand in educational development in the post-World War II period. Such slower educational development in Thailand compared with Japan and Korea can be observed in Table 3 in terms of the data of school enrollment ratio and average schooling.

In Section (a) of Table 3, it can be observed that school enrollment ratio in the school-age population in Japan was as high as 26 percent in 1890 whereas it was only 0.1 percent in Thailand. The ratio in Japan increased steadily, exceeding 60 percent in the 1940s whereas it remained at about 25 percent in Thailand. However, Thailand's increases in school enrollment ratio in 1910-1940 were quite impressive, reflecting the Thai government's shift in its educational development objective from educating a small number of top elite for government offices to educating a large number of middle elite in support of economic production (Sukorntarangsi, 1967; Watson, 1980). The 1921 promulgation of a compulsory primary education act, requiring all children in 8-14 years of age to be enrolled in school until they completed grade 5 was an example of the Thai government's effort to promote educational development.

Nevertheless, in spite of such educational development effort of the Thai government, by 1960, school enrollment ratio in Thailand had reached only 46 percent compared with 56 percent

in Korea in which investment in education was not quite so large under Japanese colonialism. After achieving independence, the Korean government began a strong drive to upgrade school education. This drive was heightened following the successful shift to export-oriented industrialization policy in the early 1960s, resulting in a rapid growth in the school enrollment ratio (McKinn et al., 1980; Lee, 2003). The need of education for economic growth in Thailand in the 1960s and the 1970s was not as high as in Korea since Thailand was able to continue exploiting hitherto unused land for increasing output. As a result, educational development in Thailand in the early post-war period was less impressive. In 1995, school enrollment ratio in Thailand reached only 62 percent, while it reached 86 percent in Korea.

The different rates of growth in school enrollment ratio among Thailand, Japan and Korea followed the different rates of growth in average schooling, as shown in Section (b) of Table 3. Japan's high investment in education since the early Meiji era made its average schooling grow rapidly from the 1890s to the early 20th century. It increased from 1.3 years in 1890 to 8.9 years in 1960. In 1960, average schooling in Thailand was 2.8 years, which was not significantly different from Korea's 3.2 years. Thereafter, school enrollment ratio in Korea had been consistently higher than in Thailand. As a result, average schooling in Korea reached 9.7 years in 1995, while that in Thailand was only 7.0 years.

The foregoing comparison seems to be consistent with the induced innovation hypothesis. To survive intense competition in international trade under strong population pressure on land, Japan and Korea undertook institutional and technological innovations to improve productivity in both their agricultural and non-agricultural sectors. The institutional innovations included the development of education systems. Meanwhile, Thailand was able to survive by simply increasing the exploitation of the empty land based on traditional technologies from the 1850s to

the recent past. In such situation, educational development was not an urgent task (Ingram, 1955; Siamwalla, 1991)³.

4. Regression Analysis

Historical comparisons across Thailand, Japan and Korea in terms of their land endowments, and educational and economic developments in the previous section lead to three testable hypotheses, which can be summarized as follows:

Hypothesis 1: Land endowment has a negative effect on school enrollment ratio (a proxy for educational investment).

Hypothesis 2: Average schooling (the stock of education) has a positive effect on agricultural intensification, while land endowment gives a negative incentive on the provision of public supports other than education for agricultural intensification.

Hypothesis 3: Average schooling has a positive effect on industrialization, but land endowment gives a negative incentive on the provision of public supports other than education for industrialization.

These hypotheses are tested by applying the cointegration and error correction regression approach, developed by Engle and Granger (1987), on pooled time-series data of Thailand, Japan and Korea. Here, pooling the data is necessary as the number of observations from each country is not sufficiently large. The application of this regression approach to pooled time-series data is

³ However, it is noteworthy Thailand switched its policy from promoting elite education to promoting mass education in the 1910s, despite the fact that its agricultural land frontier did not close before the 1970s. In this sense, Thailand's educational policy change in the 1910s is not likely to have been induced by its resource scarcity but caused by an external shock.

based on the assumption that the speeds of adjustment toward the long-run equilibrium paths can differ across countries.

Cointegration and Error Correction Models (C-ECM)

Engle and Granger (1987) argue that the regression equation relating one variable to other variables would exhibit their long-run relationship when they are cointegrated. According to them, variables, Y_t and X_t are cointegrated, if the elements of vector b_l in regression equation (1) shown below are statistically significant and the random error term ε_t is stationary:

$$Y_t = b_0 + b_1 X_t + \gamma_j d_j + \gamma_k d_k + \varepsilon_t \quad (1)$$

where X_t is the vector of explanatory variables and b_l represents the vector of parameters representing the long-run equilibrium effects of X_t on Y_t ; d_j and d_k are dummy variables respectively for Japan and Korea; and γ_j and γ_k respectively distinguish the long-run equilibrium levels of Japan and Korea from that of Thailand.

We can test for the stationarity of ε_t by conducting the augmented Dicky-Fuller (augmented DF) test for unit root as follows⁴:

$$\Delta \varepsilon_t = \alpha_0 + \alpha_1 \varepsilon_{t-1} + \sum_{i=1}^2 \lambda_i \Delta \varepsilon_{t-i} + e_t \quad (2)$$

where $\Delta \varepsilon_t$ denotes the first difference of ε_t , ε_{t-1} is one-year lag variable of ε_t , and e_t is assumed to be a randomly distributed error. We include $\Delta \varepsilon_{t-i}$, which are i-year lag variables of $\Delta \varepsilon_t$, in order to safeguard against the possibility that $\Delta \varepsilon_t$ is serially correlated. λ_i 's are parameters representing the distributed lag effects of past changes in ε_t on its present change. We compute ε_{t-1} , $\Delta \varepsilon_t$ and $\Delta \varepsilon_{t-i}$ for each of the three countries separately before using them for pooled regression of

⁴ Due to the pooling of time-series data of different time lengths for Japan, Korea and Thailand, the time trend variable cannot be introduced in this augmented DF test.

equation (2). If we reject the null hypothesis that α_i is statistically equal to zero, then we conclude that the error term ε_t is stationary, hence, equation (1) represents a long-run relationship of Y_t and X_t .

Engle and Granger (1987) also demonstrate that once variables (e.g., Y_t and X_t) are cointegrated, there always exists a corresponding error-correction representation. This implies that changes in the dependent variable are a function of the level of disequilibrium in the cointegrating relationship (captured by the error-correction term) as well as changes in explanatory variables other than dummy variables.

If the speeds of adjustment to the long-run equilibrium are the same among Thailand, Japan and Korea, the error correction model (ECM) specifying the relationship between Y_t and X_t can be written as:

$$\Delta Y_t = \beta_0 + \sum_{i=0}^m \beta_{i1} \Delta X_{t-i} + \sum_{i=1}^m \beta_{i2} \Delta Y_{t-i} + \phi_j d_j + \phi_k d_k + \delta \varepsilon_{t-1} + \xi_t \quad (3)$$

where ΔY_t and ΔX_t represent the first differences of Y_t and X_t , respectively; β_{i1} 's are parameters representing the short-run causal effects of X_t on Y_t ; β_{i2} 's are parameters representing the distributed lag effects of past changes in Y_t on its present change; d_j and d_k represent changes in Y_t and X_t that belong to Japan and Korea, respectively; ϕ_j and ϕ_k distinguish the short-term disequilibrium levels of Japan and Korea from that of Thailand; ξ_t is a randomly distributed error; ε_{t-1} is the error correction term taken from the long-run equation (1) regression; and δ is the speed of adjustment, which should be negative and takes a value between -1 and zero so that the long-run equilibrium is achievable⁵. In other words, δ is a short-run adjustment coefficient and represents the proportion by which the long-run disequilibrium in the dependent variable is being corrected in each short period.

⁵ For a proof of ECM model, see Engle and Granger (1987) and Wooldridge (2000).

However, if δ differs across countries, ECM can be expressed as follows:

$$\Delta Y_t = \beta_0 + \sum_{i=0}^m \beta_{i1} \Delta X_{t-i} + \sum_{i=1}^m \beta_{i2} \Delta Y_{t-i} + \phi_j d_j + \phi_k d_k + \delta_j \varepsilon_{jt-1} + \delta_k \varepsilon_{kt-1} + \delta_t \varepsilon_{tt-1} + \xi_t \quad (4)$$

where δ_j , δ_k and δ_t are the adjustment speeds, and ε_{jt-1} , ε_{kt-1} and ε_{tt-1} are the error correction terms of Japan, Korea and Thailand, respectively.

Note that same as for the case of $\Delta \varepsilon_t$ in equation (2), the first differences in Y_t and X_t in equation (3) or (4) are computed by country separately, before they are used for pooled regression analysis.

All the above equations are estimated by the ordinary least squares (OLS) method in both linear and log-linear forms. But, in the test of each hypothesis, we report only the results using the functional forms in which the variables concerned are cointegrated. To estimate equation (3) or (4), we need to determine the optimal number of lags to be included. According to Akaike (1970), the optimal lag length is achieved when the final prediction error is minimum. This means that we need to experiment with different lag lengths and compare their final prediction errors, each of which is calculated as follows (Kalirajan and Sankar, 2001):

$$(\text{Mean residual sum of squares}) \times (n+k+1)/(n-k-1) \quad (5)$$

where n and k are the number of observations and the number of parameters estimated (excluding the intercept), respectively.

Annual time-series data used for the regression analysis pertain to the periods for which data are enumerated in Tables 1 through 3.

The test of Hypothesis 1 on educational investment

Following the C-ECM regression approach, variables used for equations (1) and (3) are as follows⁶:

Dependent variable (Y_t) is ER_t , which stands for the school enrollment ratio in the school-age population, as a proxy for investment in education.

Independent variables (X_t) include LE_t , GDP/N_t , d_j and d_k , where LE_t is land endowment, which is represented by four proxies – territorial land area per capita of population (ln_t); territorial land area per worker (lw_t); arable land area per capita of population ($arabn_t$); and arable land area per worker ($arabw_t$), and GDP/N_t is GDP per capita in 1990 US dollar in purchasing power parity.

It should be reasonable to expect that GDP per capita is a major determinant of school enrollment ratio since it determines both households' demand for education and the government's capacity to supply educational services. On the other hand, current investment in education measured by school enrollment ratio does not influence current GDP though it may contribute to the growth of GDP in the future as it is added to the stock of education. As such, it is legitimate to regard GDP/N_t as predetermined in its relationship with ER_t . Territorial land area in each of the three countries was fixed, thereby, is exogenous to their economic systems. On the other hand, arable land area in each country increased corresponding to opening of new land for cultivation. Since the new land opening is considered an investment activity, arable land area is considered a stock of productive land resource created from the accumulation of past investments in new land opening. Although current investment in new land opening may influence school enrollment in the future by increasing farm output and income via an increase in

⁶ We also estimated equation (4) but the coefficient of the error correction term for each country is not significant, implying that these countries adjust to their own long-run equilibrium at the same speed.

the stock of productive resource, it is unlikely to influence the present stock of arable land. Thus, it is legitimate to regard arable land area as predetermined relative to current school enrollment ratio.

The estimation results of the cointegration model based on equation (1) in the linear form are reported in Table 4. The coefficients of ln_t , lw_t , $arabn_t$ and $arabw_t$ in all the four regressions are negative and statistically significant at the 1 percent level. The coefficients of GDP/N_t are positive and highly significant at the 1 percent level in all the regressions. The dummy for Japan has negative coefficients, all of which are statistically significant at the 1 percent level in all the regressions. The dummy for Korea also has negative coefficients, but only that in regression 3 is significant.

The augmented DF t -statistics are from -3.96 to -3.28 , which are less than the 5 percent critical value (-2.90). Thus, we have sufficient evidence to reject the hypothesis that the error term in each of our four-estimated regressions follows a unit root process. Therefore, the estimation results in Table 4 represent long-run relationships between school enrollment ratio and explanatory variables used in the estimation. The coefficients of determination of these regressions range from 75 percent to 78 percent, suggesting a reasonably good fit of the cointegration model.

The estimation results of the ECM model based on equation (3) for school enrollment ratio are reported in Table 5. Like in the case of the cointegration model, each of ln_t , lw_t , $arabn_t$ and $arabw_t$ is alternatively included in regressions 1 through 4, respectively. Following Akaike's (1970) procedure for calculating the optimal lag length, we find that the final prediction error is minimum with three-year lags for all the four regressions. The short-run effects of land endowment and GDP/N_t on school enrollment ratio are consistent with their long-run effects. That is, all the coefficients of land endowment are negative and significant, and those of GDP/N_t

are positive and most of them are significant. However, the coefficients of the Japan and Korea dummies tend to be positive, except in regression 3 where they are negative.

The estimated coefficients of the error correction term are negative and their magnitudes range from -0.12 to -0.16 , implying that 12 to 16 percent of past years' deviations from the cointegrating relationship path are corrected every year.

The negative and significant coefficients of land endowment in both the cointegration and ECM models support our hypothesis that land endowment has a negative effect on educational investment. Our hypothesis that per-capita GDP has a positive effect on educational investment is supported by its significantly positive coefficients in both models. However, the coefficients of Japan and Korea dummies do not show consistent evidence with the coefficients being generally negative in the cointegration model but positive in the ECM model, making it difficult to infer whether country-specific factors of Japan and Korea are more conducive to educational development than those of Thailand.

The test of Hypothesis 2 on agricultural intensification

To test the second hypothesis following the C-ECM regression approach, the variables used are as follows:

Dependent variable (Y_t) is RY_t , which stands for rice yield per hectare as a proxy for agricultural intensification.

Independent variables (X_t) include the four proxies for LE_t as well as d_j , d_k , which are the same as used for the test of Hypothesis 1, and AS_t which stands for average schooling as a proxy for the stock of human capital accumulated through education.

Rice yield per hectare in a year may influence current investment in education in the same year through increased incomes of farm households but it will not influence the stock of

education that is the accumulation of past investments. Thus, AS_t is considered predetermined in relation to RY_t .

The estimation results of the cointegration model in the log-linear form for rice yield are presented in Table 6. The coefficients of average schooling are positive and statistically significant in all the regressions. The coefficients of land endowment proxies are also negative and significant as expected. The coefficients of the country dummies are positive and significant in most of the cases, suggesting that the country-specific factors of Japan and Korea tend to be more conducive to agricultural intensification compared with those of Thailand. These factors may include better institutions or better government policies, or better natural environments.

The augmented DF test for unit root in each of the error terms yields t -statistics with magnitudes ranging from -5.77 to -4.29 , which are less than the 1 percent critical value (-3.52). Thus, the error terms do not have unit roots, indicating that the estimated equations in Table 6 represent the long-run relationships among the variables concerned. The coefficients of determination are high, ranging from about 94 percent to 99 percent, which suggest a very strong explanatory power of our cointegration model.

Table 7 presents the estimates of the ECM model based on both equations (3) and (4) for rice yield. When $\ln ln_t$ and $\ln lw_t$ (\ln denotes the natural logarithm) are used, we find that Japan, Korea and Thailand have different adjustment speeds toward the long-run equilibrium. But, when $\ln arbn_t$ and $\ln arbw_t$ are used, the adjustment speeds are the same for all the countries. Akaike's (1970) test for the optimal lag length suggests that two-year lags are optimum for regressions 1 and 2 and three-year lags for regressions 3 and 4. Our results are basically the same as the estimates of the long-run model. The coefficients of the error correction terms are also negative and fall within the expected range.

These results are consistent with the hypothesis that average schooling has a positive impact and land endowment has a negative impact on agricultural intensification. Based on these findings, it may be inferred that abundant land endowment impedes agricultural intensification indirectly through its negative effect on educational development and directly through its negative effect on the incentive of both the government and farmers to intensify agricultural production.

The test of Hypothesis 3 on industrialization

To test our third hypothesis, the dependent variables used are NAG_t and EXP_t , which stand for the non-agricultural sector's share in GDP and industrial commodities' share in total merchandise exports, respectively. The independent variables are the same as those used for the test of Hypothesis 2.

The estimation results of the cointegration model for NAG_t in the linear form are reported in Table 8. The coefficients of average schooling are positive and statistically highly significant in all the four regressions, while those of land endowment are negative and significant in regressions 1, 2 and 4, but it is positive and statistically insignificant in regression 3. The coefficients of Japan and Korea dummies are negative and significant in most of the regressions, except that of the Korea dummy in regression (3) where it remains to be negative but insignificant. The augmented DF tests reject the unit root process of the error term for all the equations in this table (the augmented DF t -statistics range from -3.95 to -3.27).

The estimates of the ECM model of the non-agricultural sector's share in GDP shown in Table 9 are analogous to those of the cointegration model. The coefficients of the error correction term are also negative and statistically significant at the 1 percent level, validating the long-run relationship in Table 8.

Average schooling and land endowment also have the expected long-run and short-run effects on the industrial commodities' share in total merchandise exports, which are reported in Tables 10 and 11, respectively, in terms of the linear model. The coefficients of average schooling are positive and statistically significant at the 1 percent level in all of the cointegration regressions shown in Table 10. The coefficients of land endowment are negative and significant at the 1 percent level in three regressions. In regression 3, it is significant at the 5 percent level. The coefficients of dummies also tend to be negative. The augmented DF *t*-statistics range from -6.01 to -4.26 , suggesting strong evidence against the hypothesis that the error term in each of these four equations has a unit root.

The estimates of the ECM model representing the short-run effects of average schooling and land endowment on industrial outputs' share in total merchandise exports reported in Table 11 are consistent with the estimates of the cointegration model in Table 10. The coefficients of the error correction term are also significantly negative and with the magnitude of -0.01 , suggesting that the system corrects about 1 percent of its previous year's disequilibrium every year.

The negative coefficients of land endowment in Tables 8 through 11 suggest that countries tend to develop according to their comparative advantage in international trade. Since Thailand was endowed with large amounts of land relative to its population, producing and exporting primary commodities in an exchange for industrial goods could have been an appropriate choice relative to other development alternatives. For Japan and Korea, industrialization should have been the only way to survive under their meager endowment of natural resources.

It was nothing wrong for Thailand to specialize in agricultural production according to its comparative advantage. The problem is that, unlike Japan, Thailand experienced no significant

increase in real per-capita income throughout the late 19th and the early 20th centuries (Table 2). According to Hla Myint (1965, 1971) and Lewis (1970), whether economic development based on the exploitation of natural resources would lead to sustainable economic growth characterized by sustained increases in per-capita income essentially depends on the government's ability and willingness to mobilize resource rent for investment in physical and institutional infrastructure including education in support of agricultural intensification and industrialization. The results of our analysis suggest that Thailand failed in this regard during the late 19th and the early 20th centuries.

5. Conclusion

Thailand and Japan have shared four common important characteristics since the 1850s: both were opened to trade with western nations at around the same time, both have adopted the constitutional monarchy system, both have been able to avoid colonization by western powers, and both attempted to introduce modern education in the 1870s. But, educational and economic developments in Thailand lagged behind Japan. Korea became independent only after World War II, but since then it has out-performed Thailand in educational and economic developments.

We hypothesize that Thailand's slower economic development has been due to its lower incentives to invest in education and other modernization activities due to its more abundant land resources which could be readily exploited by traditional technology. The abundant land endowment impeded long-term economic growth through its negative effect not only on educational investment, but also on investments in other forms of infrastructure needed for agricultural intensification and industrialization.

We tested the above hypotheses by regression analysis using pooled time-series data of Thailand, Japan and Korea. We employed the cointegration and error correction models. The results show that the educational stock had a positive effect on agricultural intensification and

industrialization, while land endowment had a negative effect on these variables as well as on educational investment. These results seem to support the hypothesis that Thailand failed to mobilize its resource rent for investments in education and other forms of infrastructure during its vent-for-surplus development stage to the extent needed to achieve modern economic growth through agricultural intensification and industrialization. In contrast, under strong population pressure on land, Japan and Korea had to invest in education and other infrastructure to support agricultural intensification and industrialization.

A major question not answered in this study is why Thailand failed to utilize the resource rent for preparing the conditions of modern economic growth unlike the cases of Canada and the United States. Hla Myint (1965) ascribed this failure in Southeast Asia, including Myanmar and Vietnam, to policies of colonial governments, especially the policy to suppress education and training of local people for the sake of maintaining the supply of cheap unskilled labor for mines and plantations run by white settlers. Then, why was independent Thailand not able to escape from this failure? Deprivation of tariff autonomy under the unequal treaty imposed by western powers could have made it difficult for the Thai government to protect domestic industries in a way similar to the United States. Other explanations could well be possible. To obtain a comprehensive answer to this question, major research is necessary for comparing development experiences between North America and Southeast Asia. Results of this study point out the need for such a study in the future.

However, it is important to recognize that Thailand did not entirely neglect investment in education and other infrastructure for modern economic development during its vent-for-surplus development stage. Though much slower than in Japan, the level of education in Thailand had steadily risen during one hundred years since the late nineteenth century. By the 1970s, its stock of education as measured by average schooling had reached the level of Japan in the 1920s, which could well be sufficient for supporting the spurt of labor-intensive industrialization. It is

most likely that accumulated educational investments since the vent-for-surplus stage had prepared an important condition, among others, for the Thai economy's joining in East Asian Miracle in recent three decades, although the formal testing of this hypothesis is outside the realm of this paper. Yet, it is also very likely that, if Thailand had used its resource rent more efficiently during the vent-for-surplus stage, its entry to epoch of modern economic growth would have not lagged behind Japan for so long.

References

- Abramovitz, M., 1989. *Thinking about Growth*. Cambridge University Press, New York.
- Akaike, H., 1970. Statistical predictor identification. *Annals of the Institute of Statistical Mathematics* 22, 203--217.
- Ascher, W., 1999. *Why Governments Waste Natural Resources: Policy Failures in Developing Countries*. The John Hopkins University Press, Baltimore.
- Becker, G., 1993. *Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education*, 3rd Edition. The University of Chicago Press, Chicago.
- Birdsall, N., Pinckney, T., Sabot, R., 2001. Natural resources, human capital, and growth, in: Auty, R. M. (ed.), *Resource Abundance and Economic Growth*. Oxford University Press, Oxford, pp. 57--75.
- Dhiravegin, L., 1981. The Meiji Restoration (1868-1912) and the Chakkri Reformation (1968-1910): a case for a comparative study, in: Hongladarom, C., Krongkaew, M. (Eds.), *Comparative Development: Japan and Thailand*. Thammasat University Press, Bangkok, pp. 71--100.
- Easterlin, R. A., 1981. Why isn't the whole world developed? *The Journal of Economic History* 41(1), 1--19.
- Engle, R. F., Granger, C. W. J., 1987. Co-integration and error correction: representation, estimation and testing. *Econometrica* 55(2), 251--276.
- Feeny, D., 1998. Thailand versus Japan: why was Japan first?, in: Hayami, Y., Aoki, M. (Eds.), *The Institutional Foundations of East Asian Economic Development*, St. Martin's Press INC, New York, pp. 413--443.
- Feeny, D., 1982. *The Political Economy of Productivity*. University of British Columbia Press, London.
- Food and Agriculture Organization of the United Nations, 1998. FAOSTAT CD-ROM.

- Francks, P., 1999. *Agriculture and Economic Development in East Asia: from Growth to Protectionism in Japan, Korea and Taiwan*. Routledge, London.
- Godo, Y., 2004. Revised annual estimates of average years of schooling for Japan, Korea, and the United States. Mimeo.
- Godo, Y., Hayami, Y., 1999. Accumulation of education in modern economic growth: comparison of Japan with the United States. Working Paper # 4, Asian Development Bank Institute, Tokyo.
- Godo, Y., Hayami, Y., 2002. Catching up in education in the economic catch-up of Japan with the United States, 1890-1990. *Economic Development and Cultural Change* 50 (4), 961-978.
- Gylfason, T., 2001. Natural resources, education, and economic development. *European Economic Review* 45, 847--859.
- Hayami, Y., 2001(a). *Development Economics: From Poverty to the Wealth of Nations*. Oxford University Press, Oxford.
- Hayami, Y., 2001(b). Ecology, history, and development: a perspective from rural Southeast Asia. *The World Bank Research Observer* 16 (2), 169--198.
- Hayami, Y., Kikuchi, M., 1985. Agricultural growth against a land resource constraint: a comparative history of Japan, Taiwan, Korea and the Philippines. *The Journal of Economic History* 33 (4), 839--864.
- Hayami, Y., Ruttan, V. W., 1971. *Agricultural Development: International Perspectives*. Johns Hopkins Press, Baltimore.
- Hayami, Y., Akino, M., Shintani, M., Yamada, S., 1980. *A Century of Agricultural Growth in Japan: Its Relevance to Asian Development*. University of Tokyo Press, Tokyo.
- Hayami, Y., Yamada, S., 1991. *The Agricultural Development of Japan: A Century's Perspective*. Tokyo University Press, Tokyo.

- Heston, A., Summers, R., Aten, B., 2002. Penn World Table Version 6.1. Center for International Comparisons at the University of Pennsylvania.
- Hla Myint, U., 1965. *The economics of the Developing Countries*. Praeger, New York.
- Hla Myint, U., 1971. *Economic Theory and the Underdeveloped Countries*. Oxford University Press, New York.
- Hunter, J., 2000. *Japanese Economic History 1930-1960, Vol. IV*. Routledge, London.
- Hwan Ban, S., 1979. Agricultural growth in Korea 1918-1971, in: Hayami, Y., Ruttan V. W., Southeorth, H. M. (Eds.), *Agricultural Growth in Japan, Taiwan, Korea and the Philippines*. The University Press of Hawaii, Honolulu, pp. 90--116.
- Ingram, J. C., 1955. *Economic Change in Thailand since 1850*. Stanford University Press, California.
- Innis, H. A., 1933. *Problems of Stable Production in Canada*. Ryerson Press, Toronto.
- Kalirajan, K. P., Sankar, U., 2001. Agriculture in India's economic reform program. *Journal of Asian Economics* 12, 389--399.
- Kuznets, S., 1966. *Modern Economic Growth: Rate, Structure and Spread*. Yale University Press, New Heaven.
- Lee, J. W., 2003. *Economic Growth and Human Development in the Republic of Korea: 1945-1992*. http://hdr.undp.org/docs/publications/ocational_papers/oc24aa.htm.
- Levine, S. B., Kawada, H., 1980. *Human Resources in Japanese Industrial Development*. Princeton University Press, Princeton.
- Lewis, W. A., 1970. *Tropical Development, 1880-1913: Studies in Economic Progress*. Allen and Unwin, London.
- Lucas, R., 1988. On the mechanics of economic development. *Journal of Monetary Economics* 22, 3--42.

- McGinn, N. F., Snodgrass, D. R., Kim, Y. B., Kim, S. B., Kim, Q. Y., 1980. Education and the modernization of the Republic of Korea, 1945-1975. Working Paper # 7806, Korean Development Institute, Seoul.
- Nelson, R. R., Phelps, E. S., 1966. Investment in humans, technological diffusion, and economic growth. *American Economic Review* 56, 69--75.
- North, D. C., 1955. Location theory and regional economic growth. *Journal of Political Economy* 63, 243--258.
- Ohkawa, K., Rosovsky, H., 1973. *Japanese Economic Growth: Trend Acceleration in the Twentieth Century*. Stanford University Press, Stanford.
- Sachs, J. D., Warner, A. M., 1995. Natural resources abundance and economic growth. Working Paper No. 5398, National Bureau of Economic Research, Cambridge.
- Schultz, T. W., 1961. Investment in human capital. *American Economic Review* 51(1), 1--17.
- Shintani, M., 2003. *The Process of Agricultural Growth in Thailand: Analysis of Long-Term Economic Statistics, 1950-1997*. Kyushu University Press, Fukuoka.
- Siamwalla, A., 1991. *Land-abundant Agricultural Growth and Some of its Consequences: The Case of Thailand*. Thailand Development Research Institute, Bangkok.
- Siamwalla, A., 1997. The Thai economy: fifty years of expansion, in: Siamwalla, A. (Ed.), *Thailand's Boom and Bust*. Thailand Development Research Institute, Bangkok, pp. 1--20.
- Sukornrarangsi, S., 1967. *Development of Thai Educational Bureaucracy*. The National Institute of Development Administration, Bangkok.
- Thailand Ministry of Education, various issues. *Educational Statistics*, Bangkok.
- Thailand Ministry of Education, various issues. *Educational Statistics in Brief*, Bangkok.
- Thailand National Statistical Office, various volumes. *Report of the Labor Force Survey*, Bangkok.

- Thailand National Statistical Office, various volumes. Population Census, Bangkok.
- Thailand National Economic and Social Development Board, various issues. The Statistical Yearbook of Thailand, Bangkok.
- Thailand National Economic and Social Development Board, 1999. National Income of Thailand 1951-1996, Bangkok.
- Warr, P. G., 1993. The Thai economy, in: Warr, P.G. (Ed.), The Thai Economy in Transition. Cambridge University Press, Cambridge, pp. 1--80.
- Watkins, M., 1963. A stable theory of economic growth. Canadian Journal of Economics and Political Science 29, 141--158.
- Watson, K., 1980. Educational Development in Thailand. Heinemann Asia, Hong Kong.
- Wooldridge, J. M., 2000. Introductory Econometrics: A Modern Approach. South-Western College Publishing, Australia.
- World Bank, 1993. The East Asian Miracle: Economic Growth and Public Policy. Oxford University Press, Oxford.
- World Bank, 2001. World Development Indicators CD-ROM.
- Wyatt, D. K., 1966. The Beginnings of Modern Education in Thailand, 1868-1910. Cornell University, Michigan.

Table 1 Natural resource endowments of Thailand, Korea and Japan

Year	(a) Territorial land area per capita (hectare)			(b) Arable land area per capita (hectare)		
	Thailand	Korea	Japan	Thailand	Korea	Japan
1890			0.94			0.12
1900			0.85			0.12
1910	7.20		0.76			0.11
1911				0.22		
1918						
1920	5.92		0.67	0.28		0.11
1930	4.76		0.58			0.09
1940	3.83		0.51	0.27		0.08
1950	2.77		0.45	0.32		0.07
1960	2.17	0.39	0.40	0.32	0.08	0.07
1970	1.61	0.31	0.36	0.35	0.07	0.06
1980	1.24	0.26	0.32	0.37	0.06	0.05
1990	1.03	0.23	0.30	0.34	0.05	0.04
1995	0.97	0.22	0.30	0.32	0.05	0.03

Sources: (a) Territorial land areas are 57.40 million hectares for Thailand, 9.85 million hectares for Korea, and 37.47 million hectares for Japan. The population data are: Thailand from Warr (1993), World Bank (2001) and Heston et al. (2002); Korea from Godo (2004); and Japan from Godo and Hayami (1999).
(b) The arable land area data are: Thailand in 1950-1995 from Shintani (2003) and in 1911-1940 from Ingram (1955); Korea from Hwan Ban (1979), Francks (1999) and FAO (1998); and Japan from Hayami and Yamada (1991) and FAO (1998).

Table 2 Rice yield per hectare planted, non-agricultural sector's share in GDP, industrial products' share in merchandise exports and per-capita GDP in Thailand, Korea and Japan

Year	(a) Rice yield per area planted (tons/hectare)			(b) Non-agricultural sector's share in GDP (%)			(c) Industrial products' share in merchandise exports (%)			(d) Per-capita GDP (1990 US\$)		
	Thailand	Korea	Japan	Thailand	Korea	Japan	Thailand	Korea	Japan	Thailand	Korea	Japan
1890			2.2							536		951
1900			2.3						57	528		1109
1910			2.6			73			61	602		1225
1920			2.9			76			50			1594
1925	1.7		2.8			79			58			1772
1930			2.9			80			70	568		1739
1935	1.5		3.0			83						1993
1940			3.1			87				591		2701
1945	1.2		2.9									1265
1950	1.2		3.3							418		1830
1960	1.6	3.9	3.9	64	65	87	11	72	92	470	1293	3789
1970	1.8	4.6	5.6	74	74	94	23	83	95	795	2114	9230
1980	1.8	4.3	5.1	77	86	96	42	91	98	1171	3680	12759
1990	1.7	6.2	6.3	87	91	97	66	95	99	2020	7787	17851
1995	2.2	6.1	6.3	89	93	98	75	96	99	2908	10660	18911

Sources: (a) The rice yield per hectare data are: Thailand before and after 1950 from Ingram (1955) and Shintani (2003), respectively; Korea from Hayami and Kikuchi (1985) and FAO (1998); and Japan from Hayami et al. (1980) and FAO (1998).

(b) The data on non-agricultural sector's share in GDP since 1960 for all the three countries are from World Bank (2001), and Japan's data prior to 1960 are from Ohkawa and Rosovsky (1973).

(c) The data on industrial outputs' share in total merchandise exports since 1960 for all the three countries are from World Bank (2001), and Japan's data prior to 1960 are from Ohkawa and Rosovsky (1973).

(d) The per-capita GDP data are: Thailand from NSEDB (1999), Warr (1993), World Bank (2001) and Heston et al. (2002); Korea from Godo (2004); and Japan from Godo and Hayami (1999).

Table 3 School enrollment ratio and average schooling in Thailand, Korea and Japan

Year	(a) School enrollment ratio			(b) Average schooling		
	Thailand	Korea	Japan	Thailand	Korea	Japan
	-----%-----			-----year-----		
1890	0.1		26.0			1.3
1900	0.8		38.1			2.0
1910	3.5		43.0			3.0
1920	7.5		50.8			4.3
1930	17.6		57.8			5.6
1940	25.7		62.5	1.2*		6.7
1950	38.6		70.0	1.9		7.8
1960	46.1	55.9	75.4	2.8	3.2	8.9
1970	48.6	67.7	77.7	3.9	4.7	9.9
1980	55.5	77.4	87.0	5.3	6.8	10.8
1990	55.1	80.4	84.8	6.5	8.9	11.5
1995	62.2	86.0	85.9	7.0	9.7	12.0

Note: * 1943 figure

Sources: see main text

Table 4 Cointegration model regression results for school enrollment ratio^a

Regression number	School enrollment ratio (ER_t)			
	(1)	(2)	(3)	(4)
Intercept	0.65*** (25.07)	0.69*** (19.54)	0.57*** (7.43)	0.72*** (8.43)
Territorial land area per capita (ln_t)	-0.11*** (-9.36)			
Territorial land area per worker (lw_t)		-0.06*** (-7.24)		
Arable land area per capita ($arabn_t$)			-0.58*** (-4.27)	
Arable land area per worker ($arabw_t$)				-0.36*** (-3.15)
GDP per capita (GDP/N_t)	2.35e-05*** (15.08)	2.35e-05*** (14.33)	2.00e-05*** (7.88)	2.52e-06*** (12.64)
Japan dummy (d_j)	-0.08*** (-3.72)	-0.12*** (-4.52)	-0.41*** (-4.11)	-0.19*** (-2.86)
Korea dummy (d_k)	-1.00e-03 (-0.70)	-0.02 (-0.69)	-0.32*** (-2.93)	-0.04 (-0.69)
R-square	0.7649	0.7522	0.7760	0.7732
Adjusted R-square	0.7597	0.7465	0.7692	0.7665
Augmented DF t statistic ^b	-3.50	-3.29	-3.28	-3.96
Number of observations	188	181	137	140

Note: ^a All the equations are estimated using the ordinary least squares regression method. Inside parentheses are t -statistics with *, ** and *** denoting statistical significance at the 10%, 5% and 1% level, respectively.

^b The critical value for augmented DF t statistics at the 10%, 5% and 1% levels are -2.58, -2.90, and -3.52, respectively. We include two lags of $\Delta\varepsilon_t$ in this augmented DF test.

Table 5 Error correction model regression results for school enrollment ratio^a

Regression number	Change in school enrollment ratio (ΔER_t)			
	(1)	(2)	(3)	(4)
Intercept	-0.02 (-1.09)	-0.02 (-0.93)	0.09*** (2.76)	0.03 (1.08)
ε_{t-1}	-0.12** (-2.15)	-0.14 ** (-2.39)	-0.16* (-1.82)	-0.16 (-1.37)
ΔLE_t^b	-0.13*** (-5.22)	-0.07*** (-6.96)	-0.61*** (-7.58)	-0.44*** (-7.51)
ΔLE_{t-1}	-0.09*** (-4.84)	-0.06*** (-5.70)	-0.40*** (-6.03)	-0.31*** (-5.00)
ΔLE_{t-2}	-0.06*** (-3.74)	-0.03*** (-3.92)	-0.20*** (-4.44)	-0.14*** (-3.42)
$\Delta GDP/N_t$	1.22e-05*** (5.72)	1.11e-05*** (5.83)	-3.44e-07 (-0.12)	1.97e-06 (0.73)
$\Delta GDP/N_{t-1}$	1.00e-05*** (4.63)	6.63e-06*** (4.32)	2.36e-06 (0.87)	2.83e-06 (1.11)
$\Delta GDP/N_{t-2}$	6.35e-06*** (3.78)	5.16e-06*** (3.33)	3.30e-06* (1.73)	3.23* (1.76)
ΔER_{t-1}	-0.78*** (-7.07)	-0.78*** (-7.57)	-0.67*** (-5.53)	-0.74*** (-5.95)
ΔER_{t-2}	-0.53*** (-6.14)	-0.49*** (-5.75)	-0.41*** (-4.67)	-0.44*** (-4.68)
ΔER_{t-3}	-0.13*** (-3.10)	-0.11*** (-2.85)	-0.05 (-1.20)	-0.07* (-1.90)
Japan dummy (d_j)	0.04 (1.12)	0.03 (0.75)	-0.06 (-1.62)	0.20*** (2.85)
Korea dummy (d_k)	0.04 (1.00)	0.03 (1.12)	-0.18*** (-3.44)	0.01 (0.28)
R-square	0.9373	0.9454	0.9562	0.9559
Adjusted R-square	0.9303	0.9394	0.9498	0.9498
Final prediction error	0.0040	0.0035	0.0034	0.0035
Number of observations	122	122	95	99

Note: ^a All the equations are estimated using the ordinary least squares regression method. Inside parentheses are *t*-statistics with *, ** and *** denoting statistical significance at the 10%, 5% and 1% level, respectively. Δ denotes the first difference of the variable.

^b LE_t denotes land endowment, represented by ln_t , lw_t , $arabn_t$ and $arabw_t$ in regressions (1), (2), (3) and (4), respectively.

Table 6 Cointegration model regression results for rice yield per hectare^a

Regression number	Log of rice yield per hectare ($\ln yield_t$)			
	(1)	(2)	(3)	(4)
Intercept	0.31 (1.49)	0.69*** (2.95)	-0.31*** (-6.76)	-0.01 (-0.35)
Log of average schooling ($\ln AS_t$)	0.29*** (2.86)	0.22** (2.53)	0.37*** (11.61)	0.36*** (12.00)
Log of territorial land area per capita ($\ln ln_t$)	-0.31** (-2.05)			
Log of territorial land area per worker ($\ln lw_t$)		-0.35*** (-3.40)		
Log of arable land area per capita ($\ln arn_t$)			-0.36*** (-6.85)	
Log of arable land area per worker ($\ln arw_t$)				-0.29*** (-7.09)
Japan dummy (d_j)	0.33** (2.38)	0.23** (1.98)	0.05 (0.62)	0.08 (1.10)
Korea dummy (d_k)	0.43* (1.94)	0.46*** (3.61)	0.33*** (3.91)	0.51*** (8.88)
R-square	0.9514	0.9592	0.9618	0.9676
Adjusted R-square	0.9498	0.9579	0.9604	0.9665
Augmented DF t statistic ^b	-5.77	-4.90	-4.41	-4.29
Number of observations	128	129	120	123

Note: ^a All the equations are estimated using the ordinary least squares regression method. Inside parentheses are t -statistics with *, ** and *** denoting statistical significance at the 10%, 5% and 1% level, respectively.

^b The critical value for augmented DF t statistics at the 10%, 5% and 1% levels are -2.58, -2.90, and -3.52, respectively. We include two lags of $\Delta \varepsilon_t$ in this augmented DF test.

Table 7 Error correction model regression results for rice yield per hectare^a

Regression number	Change in log of rice yield per hectare ($\Delta \ln y_{ie_t}$)			
	(1)	(2)	(3)	(4)
Intercept	-0.12** (-2.55)	-0.22*** (-3.23)	-0.12** (-2.10)	-0.22*** (-4.36)
ε_{jt-1}	-0.39*** (-3.78)	-0.34*** (-4.03)		
ε_{kt-1}	-0.24** (-2.05)	-0.31*** (-3.51)		
ε_{it-1}	-0.22** (-2.27)	-0.22** (-2.35)		
ε_{t-1}			-0.23* (-1.90)	-0.08* (-1.82)
$\Delta \ln AS_t$	0.19*** (3.26)	0.17** (2.14)	0.32*** (4.62)	0.18** (2.27)
$\Delta \ln AS_{t-1}$	0.05 (1.07)	0.03 (0.55)	0.25*** (3.99)	0.09 (1.11)
$\Delta \ln AS_{t-2}$			0.11*** (2.71)	0.02 (0.36)
$\Delta \ln LE_t^b$	-0.51*** (-10.67)	-0.62*** (-11.87)	-0.39*** (-9.20)	-0.34*** (-8.19)
$\Delta \ln LE_{t-1}$	-0.04 (-0.68)	-0.09 (-1.26)	-0.24*** (-3.10)	-0.24*** (-4.28)
$\Delta \ln LE_{t-2}$			-0.09 (-1.58)	-0.10** (-2.21)
$\Delta \ln yield_{t-1}$	-0.40 (-0.48)	-0.24** (-2.59)	-0.63*** (-5.86)	-0.69*** (-10.78)
$\Delta \ln yield_{t-2}$	-0.02 (-1.08)	-0.02 (-1.32)	-0.25*** (-2.68)	-0.31*** (-4.81)
$\Delta \ln yield_{t-3}$			-3.00e-03 (-0.18)	-0.03 (-1.46)
Japan dummy (d_j)	0.24*** (3.54)	0.14* (1.95)	0.07 (0.70)	0.16* (1.78)
Korea dummy (d_k)	0.19** (2.20)	0.22*** (2.93)	0.31*** (3.67)	0.53*** (7.75)
R-square	0.9862	0.9868	0.9907	0.9893
Adjusted R-square	0.9848	0.9856	0.9892	0.9877
Final prediction error	0.0125	0.0117	0.0103	0.0117
Number of observations	104	106	87	91

Note: ^a All the equations are estimated using the ordinary least squares regression method. Inside parentheses are t -statistics with *, ** and *** denoting statistical significance at the 10%, 5% and 1% level, respectively. Δ denotes the first difference of the variable.

^b LE_t denotes land endowment, represented by \ln_t , lw_t , $arabn_t$ and $arabw_t$ in regressions (1), (2), (3) and (4), respectively.

Table 8 Cointegration model regression results for non-agricultural sector's share in GDP^a

Regression number	Non-agricultural sector's share in GDP (NAG_t)			
	(1)	(2)	(3)	(4)
Intercept	0.57*** (23.77)	0.60*** (25.01)	0.49*** (7.45)	0.56*** (9.62)
Average schooling (AS_t)	0.05*** (27.62)	0.05*** (24.91)	0.05*** (28.26)	0.05*** (14.14)
Territorial land area per capita (ln_t)	-0.03** (-2.50)			
Territorial land area per worker (lw_t)		-0.02*** (-3.91)		
Arable land area per capita ($arabn_t$)			0.04 (0.25)	
Arable land area per worker ($arabw_t$)				-0.07** (-2.14)
Japan dummy (d_j)	-0.13*** (-11.15)	-0.14*** (-12.34)	-0.10** (-2.21)	-0.15*** (-7.77)
Korea dummy (d_k)	-0.08*** (-6.08)	-0.09*** (-7.75)	-0.04 (-0.77)	-0.09*** (-4.71)
R-square	0.9644	0.9666	0.9617	0.9636
Adjusted R-square	0.9630	0.9653	0.9602	0.9621
Augmented DF t statistic ^b	-3.95	-3.55	-3.40	-3.27
Number of observations	107	108	102	103

Note: ^a All the equations are estimated using the ordinary least squares regression method. Inside parentheses are t -statistics with *, ** and *** denoting statistical significance at the 10%, 5% and 1% level, respectively.

^b The critical value for augmented DF t statistics at the 10%, 5% and 1% levels are -2.58, -2.90, and -3.52, respectively. We include two lags of $\Delta \varepsilon_t$ in this augmented DF test.

Table 9 Error correction model regression results for non-agricultural sector's share in GDP^a

Regression number	Change in non-agricultural sector's share in GDP (ΔNAG_t)			
	(1)	(2)	(3)	(4)
Intercept	0.04*** (4.21)	0.05*** (5.02)	0.01 (0.60)	0.01 (1.59)
ε_{t-1}	-0.01*** (-4.32)	-0.01*** (-3.64)	-0.01*** (-8.46)	-0.01*** (-7.02)
ΔAS_t	0.04*** (14.06)	0.04*** (12.38)	0.04*** (18.10)	0.04*** (14.99)
ΔAS_{t-1}	0.02*** (4.64)	0.02*** (5.18)		
ΔAS_{t-2}	0.01*** (3.32)	0.01*** (3.94)		
ΔLE_t^b	-0.01 (-0.73)	-0.01** (-2.02)	-0.15*** (-5.40)	-0.04*** (-2.91)
ΔLE_{t-1}	0.08 (-0.83)	-0.01** (-2.07)		
ΔLE_{t-2}	-6.19e-04 (-0.10)	-2.00e-03 (-0.87)		
ΔNAG_{t-1}	-0.43*** (-3.54)	-0.53*** (-4.87)	-0.04 (-1.37)	0.05 (1.39)
ΔNAG_{t-2}	-0.22** (-2.27)	-0.30*** (-3.28)		
ΔNAG_{t-3}	-0.03 (-1.08)	-0.02 (-0.87)		
Japan dummy (d_j)	-0.08*** (-4.13)	-0.09*** (-4.36)	-0.02 (-1.13)	-0.02 (-1.31)
Korea dummy (d_k)	-0.05*** (-3.33)	-0.07*** (-5.00)	0.10 (0.63)	-0.01 (-1.18)
R-square	0.9746	0.9734	0.9675	0.9583
Adjusted R-square	0.9711	0.9699	0.9653	0.9555
Final prediction error	0.0752	0.0767	0.0866	0.1114
Number of observations	102	104	95	96

Note: ^a All the equations are estimated using the ordinary least squares regression method. Inside parentheses are t -statistics with *, ** and *** denoting statistical significance at the 10%, 5% and 1% level, respectively. Δ denotes the first difference of the variable.

^b LE_t denotes land endowment, represented by ln_t , lw_t , $arabn_t$ and $arabw_t$ in regressions (1), (2), (3) and (4), respectively.

Table 10 Cointegration model regression results for industrial products' share in merchandise exports^a

Regression number	Industrial products' share in merchandise exports (EXP_t)			
	(1)	(2)	(3)	(4)
Intercept	0.82*** (11.83)	0.89*** (15.47)	0.47* (1.66)	0.52*** (4.77)
Average schooling (AS_t)	0.03*** (6.51)	0.02*** (5.31)	0.07*** (8.67)	0.06*** (9.08)
Territorial land area per capita (ln_t)	-0.45*** (-11.83)			
Territorial land area per worker (lw_t)		-0.21*** (-18.60)		
Arable land area per capita ($arabn_t$)			-0.62* (-1.71)	
Arable land area per worker ($arabw_t$)				-0.60*** (-5.17)
Japan dummy (d_j)	-0.05 (-1.52)	-0.03 (-1.59)	-0.19 (-0.96)	-0.17** (-2.43)
Korea dummy (d_k)	-0.04 (-0.94)	0.01 (0.11)	0.04 (0.20)	0.06 (0.94)
R-square	0.9672	0.9825	0.9274	0.9438
Adjusted R-square	0.9658	0.9817	0.9241	0.9412
Augmented DF t statistic ^b	-4.26	-4.62	-6.01	-4.85
Number of observations	98	99	93	94

Note: ^a All the equations are estimated using the ordinary least squares regression method. Inside parentheses are t -statistics with *, ** and *** denoting statistical significance at the 10%, 5% and 1% level, respectively.

^b The critical value for augmented DF t statistics at the 10%, 5% and 1% levels are -2.58, -2.90, and -3.52, respectively. We include two lags of $\Delta\varepsilon_t$ in this augmented DF test.

Table 11 Error correction model regression results for industrial products' share in merchandise exports^a

Regression number	Change in industrial products' share in merchandise exports (ΔEXP_t)			
	(1)	(2)	(3)	(4)
Intercept	0.02 (1.11)	0.01 (0.77)	-0.07 (-1.44)	-0.05 (-1.53)
ε_{t-1}	-0.01*** (-8.76)	-0.01*** (-8.37)	-0.01*** (-3.10)	-0.01** (-2.54)
ΔAS_t	0.03*** (9.31)	0.01*** (6.48)	0.04*** (3.46)	0.02 (1.63)
ΔAS_{t-1}			0.03*** (2.86)	0.01 (1.16)
ΔAS_{t-2}			0.02*** (3.24)	0.01 (1.31)
ΔLE_t^b	-0.45*** (-12.51)	-0.22*** (-3.04)	-0.53*** (-3.95)	-0.64*** (-6.85)
ΔLE_{t-1}			-0.40 (-1.05)	-0.39** (-2.47)
ΔLE_{t-2}			-0.30 (-1.23)	-0.29*** (-2.80)
ΔEXP_{t-1}	-0.02 (-0.98)	0.02 (1.24)	-0.46** (-2.43)	-0.61*** (-3.68)
ΔEXP_{t-2}			-0.34** (-2.56)	-0.43*** (-3.84)
ΔEXP_{t-3}			-0.03 (-0.80)	-0.02 (-0.90)
Japan dummy (d_j)	-0.02 (-0.79)	-0.02 (-1.19)	0.05 (0.77)	0.06 (1.05)
Korea dummy (d_k)	-0.03 (-1.27)	-1.00e-03 (-0.40)	0.16* (1.86)	0.12** (2.00)
R-square	0.9873	0.9932	0.9825	0.9866
Adjusted R-square	0.9865	0.9927	0.9792	0.9842
Final prediction error	0.3153	0.1601	0.6203	0.4740
Number of observations	95	96	77	80

Note: ^a All the equations are estimated using the ordinary least squares regression method. Inside parentheses are t -statistics with *, ** and *** denoting statistical significance at the 10%, 5% and 1% level, respectively. Δ denotes the first difference of the variable.

^b LE_t denotes land endowment, represented by ln_t , lw_t , $arabn_t$ and $arabw_t$ in regressions (1), (2), (3) and (4), respectively.