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Productivity Lessons for Asian Region*

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Abstract

This study investigates how the patterns of productivity growth have changed over the past few decades for the Asian economies in comparison with the advanced economies. The findings indicate that the Asian economies are in the process of transition in terms of pattern of growth. It seems that the 4 NIEs have already transitioned from input-based growth to productivity-based growth, and the remaining Asian economies are starting to show signs of transition in the past decade. Scrutinizing the recent trends in human capital, R&D, patent statistics, and inward FDIs, they all indicate that the productivity growth will be stronger in the Asian region than before and will constitute the major basis for growth.

JEL Classification: O47, O57
Keywords: Total factor productivity, Asian economies, economic growth, human capital, R&D

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1. Introduction

High and persistent growths of the 4 Newly Industrialized Economies (NIEs) – Hong Kong, Korea, Singapore, and Taiwan during the period of 1970 – 1990 prompted a considerable debate regarding the contributing factors of growth in these Asian economies. There have been numerous studies looking into this issue, but they were unable to reach a common conclusion. Some studies supported an assimilationist view, which is a claim that high rate of technological change—a result of an infusion of high technology from more advanced economies—is the main driver of growth in the Asian economies (e.g., Easterly and Levine, 2001; Iwata et al. 2002; Klenow and Rodriguez-Clare, 1997; Pack, 1993; Pack and Page, 1994; Sarel, 1997; World Bank, 1993; Young, 1992). Globalization have helped these economies to adopt advanced foreign technologies at a low cost and to develop new skills based on the absorbed technologies. This attributes the success of the Asian economies to government interventions that facilitate assimilation and to government policies promoting exports. The growth pattern consistent with this view is denoted as 'productivity-based growth'.

Other studies supported an accumulationist view, which is a claim that the main source of Asian economic growth is the rapid accumulation of capital (e.g., Collins and Bosworth, 1997; Kim and Lau, 1994; Lau and Park, 2015 for the pre-1986 period; Senhadji, 1999; Tsao, 1985; Young, 1992, 1994, 1995). These studies calculate total factor productivity (TFP) estimates, or estimate the technical progress, using a regression-based approach and find the measured TFP growth to be relatively small. This branch of the literature, therefore, disputes the conventional belief about the role of TFP in the growth of East Asian economies. The growth pattern consistent with this view is denoted as 'input-based growth'.

More than twenty years have passed since then and a new group of Asian economies – China, India, Indonesia, Malaysia, Philippines, and Thailand – have emerged with high and prominent growth starting from the 1990s. Meanwhile, there was a growth slowdown in the economic growth for the 4 NIEs in the recent decade. Given these new observations and extended series of data set, this study is devoted to disentangle and find out the origins of growth, and assess the potentials for the future productivity growth for these Asian economies.

Sections 2 and 3 provide two alternative approaches in measuring technical progress: growth accounting approach and estimation approach. Given the estimates based on two methods, growth decompositions are provided in ten-year intervals for the Asian economies. Section 4 devotes to identify the determining factors influencing the TFP growth. Section 5 looks into examine the trends in the relevant variables affecting TFP growth and attempts to assess the potentials for future productivity growth. Section 6 concludes.

2. Pattern of productivity growth: Growth accounting method

To understand the challenges that the Asian economies are facing, it would be helpful to measure how much the productivity growth contributed to economic growth in these economies. By decomposing growth into a part attributable to productivity-growth and a part due to input-growth, we may be able to visualize how the relative importance of productivity growth has changed over time as these economies transform in their developmental process. In this section, we first introduce 'the growth accounting method' to derive TFP growth rates of these economies in comparison with advanced economies – G5 – over different periods of time.

2.1 Calculation of TFP growth

Calculation of TFP growth depends on specific model assumptions of the production function as well as on the data necessary for the calculation. To check the sensitivity of TFP estimates to specific assumptions in derivation, we present three alternative measures and compare. The first measure is calculated as follows. We assume a two-input neoclassical production function with constant returns to scale. TFP growths are calculated as

$$\Delta\, ln(TFP) = \Delta\, ln(Y) - (1 - a_L)\Delta\, ln(K) - \, a_L \Delta\, ln(L), \tag{1}$$

where Y is gross domestic product (GDP) , K is the capital stock, and L is the labor. This basic formula uses a labor input without quality adjustment for human capital differences. The parameter a_L is the output elasticity with respect to labor. Penn World Tables 8.0 (PWT) provides all these values for the calculation. We use real GDP and real physical capital stock at 2005 constant US dollars for Y and K. Total number of annual hours worked by persons engaged is used for L.[1] We use the labor shares in PWT to proxy output elasticity with respect to labor under the assumption that labor shares are commensurate to the output elasticities.

As for the second measure of TFP, we adjust the TFP growth formula for labor quality, which, according to the literature, is augmented by enhancements in human capital. Since micro labor literature on the returns to schooling suggests that the labor quality is enhanced by approximately 8% per an additional year of schooling, we exponentially adjust labor by human capital (h) as exp$(0.08*h)L$.[2] This adjustment method is borrowed from Barro and Lee (2010). PWT 8.0 calculates and constructs their own human capital index based on the Barro-Lee education statistics and returns to education. Thus, we calculate TFP growth estimates as

$$\Delta\, ln(TFP) = \Delta\, ln(Y) - (1 - a_L)\Delta\, ln(K) - \; a_L[\Delta\, ln(L) + (0.08)\Delta h] \quad (2)$$

The third measure of TFP is the TFP measure provided by the PWT which is assuming that labor is enhanced in proportion to the level of human capital, $h*L$. The formula is as follows.

$$\Delta\, ln(TFP) = \Delta\, ln(Y) - (1 - a_L)\Delta\, ln(K) - \; a_L[\Delta\, ln(L) + \Delta \ln(h)] \quad (3)$$

2.2 Relative Contributions to Growth

We provide three alternative TFP growth estimates of Asian economies for the period of 1970 to 2011based on the growth accounting in comparison with the estimates for the G5 economies. We categorize the countries into the following subgroups: non-Asian G5 (France, Germany, United Kingdom, and United States), Japan, 4 NIEs (Hong Kong, Korea, Singapore, and Taiwan), China, and four ASEANs (Indonesia, Malaysia, Philippines, and Thailand).

Figure 1 provides relative contributions of physical capital, labor, and TFP growths based on the basic model without labor-quality adjustment and using actual labor shares (TFP1). The panel

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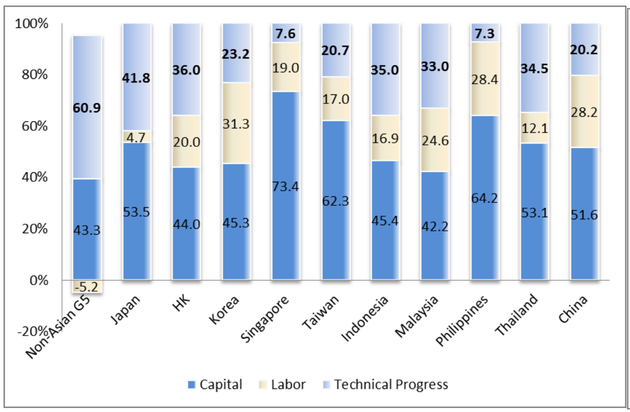
[1] As work hours are missing for some Asian economies such as Indonesia, Malaysia, Philippines, and Thailand in PWT, we use work hours collected from ILO *Database of Labour Statistics*.

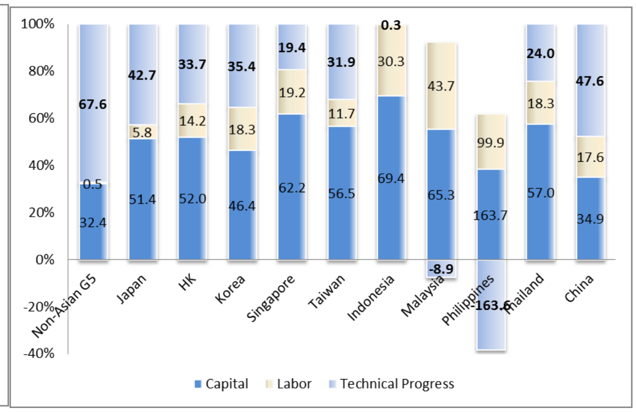
[2] Although it is plausible to argue that the returns to schooling may widely differ across developed and developing economies, generally accepted measures specific to the developing economies do not exist. We acknowledge that we use the estimates from the micro-labor studies despite these limitation and imperfection in measurement.

results show that the contributions of TFP growth to GDP for the four NIEs are less than that of the non-Asian G5 during the period of 1970 to 2000. The contribution of TFP growth to GDP for the four ASEANS is minimal when compared to those of the 4 NIEs and the non-Asian G5 between 1980 and 2000. However, the contributions of TFP growth for the 4 NIEs and four ASEANSs increase significantly in the period of 2000 to 2011. Interestingly, the estimates and contribution of China's TFP growth are strongly positive beginning 1980s, thus exhibiting a very different pattern relative to the Asian economies in a comparable developmental stage.

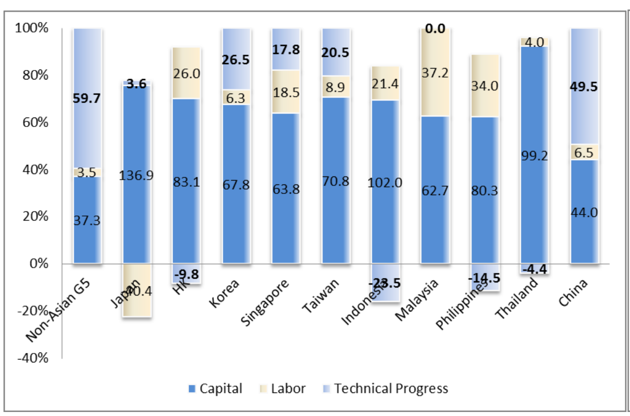
Figure 1. Sources of Growth by Sub-Periods: TFP Estimates without Labor Quality Adjustments, Growth Accounting Approach



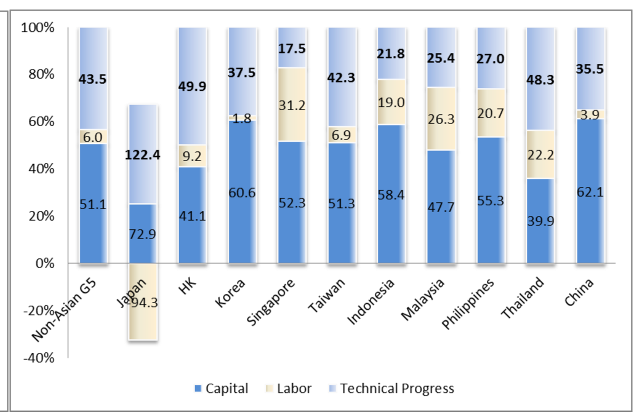
1971-1980



1980-1990



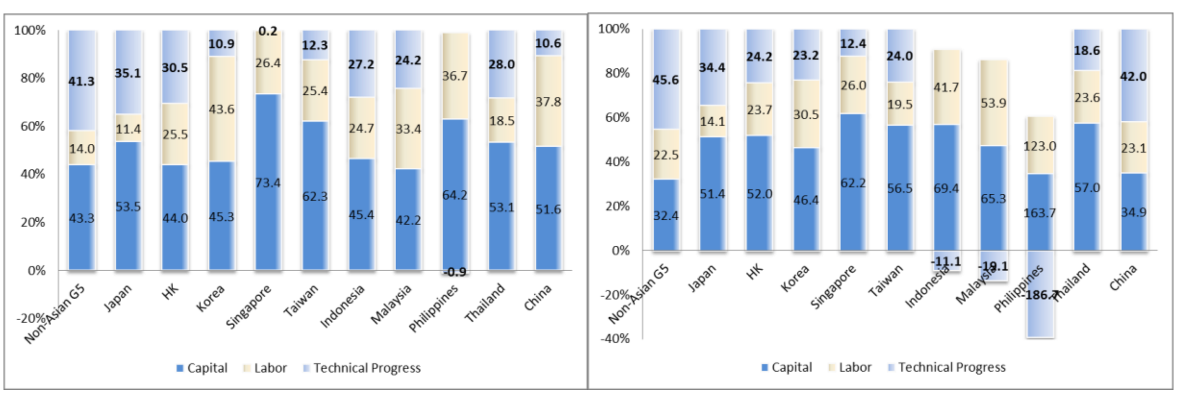
1990-2000



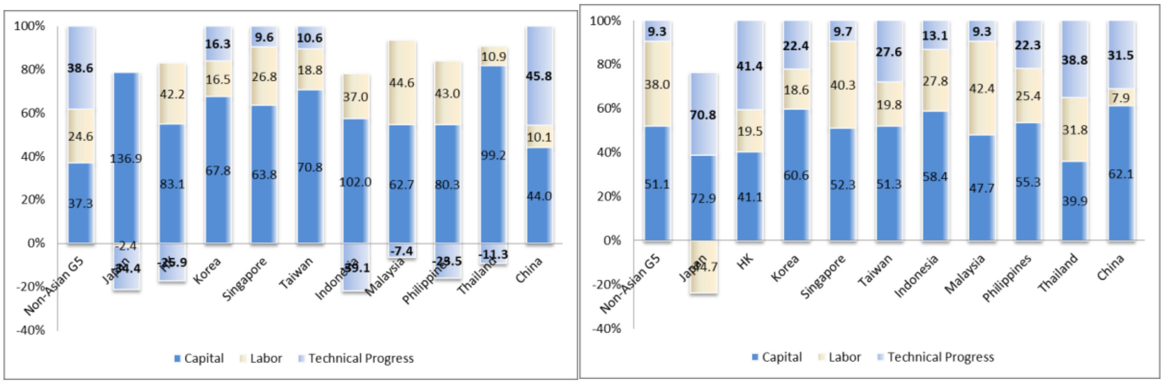
2000-2011

Figure 2 provides of physical capital, labor, and TFP growths based on the model with exponential labor-quality adjustments (TFP2) as described in Eq. (2) with actual labor shares. Because the human capital contribution is incorporated into the TFP growth calculation, the TFP growth estimates are lower than the estimates in Figure 1, and the patterns across groups of countries look somewhat different. Specifically, the contributions of TFP growth for the four NIEs are very much stable across sub-periods, except for the 1990-2000 subperiod. However, the patterns of TFP growth across time for the 4 ASEANs are very much the same as seen in Figure 1. TFP growth contributions for the G5 are very similar to those in Figure 1 since the schooling years have mildly increased in these economies as the levels of educational attainment are already high. Thus the TFP growths have been the main drivers of growth in the G5 up to 2000. The TFP growths shrink to a small portion in the 2000-2011 sub-period, probably because these countries have been exposed to severe negative aggregate shocks disproportionately during the global financial crisis. Once again, the estimates and contribution of China's TFP growth are strongly positive and increasing throughout the whole period.

Figure 2. Sources of Growth by Sub-Periods: TFP Estimates with Exponential Labor Quality Adjustments, Growth Accounting Approach



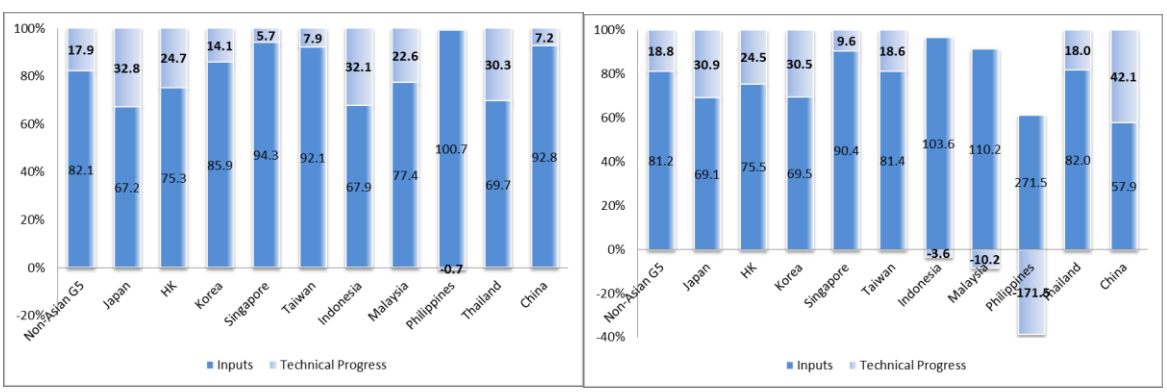
1971-1980 1980-1990



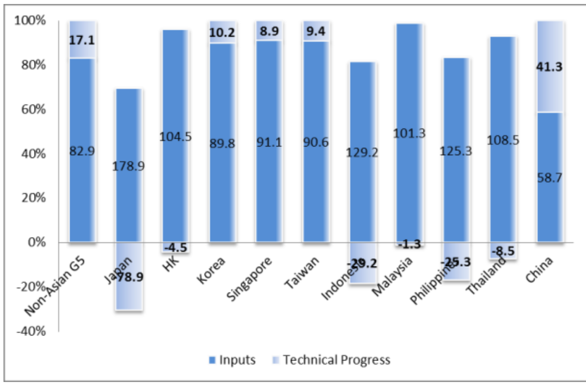
1990-2000 2000-2011

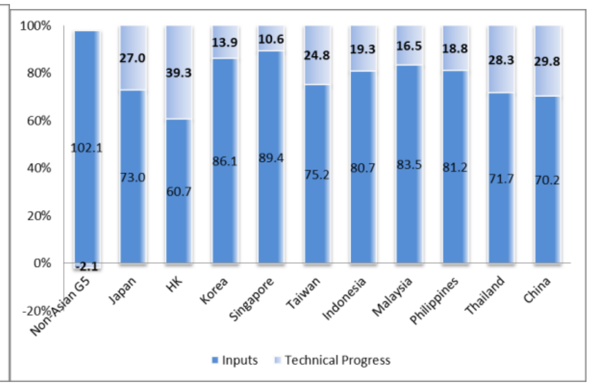
Figure 3 provides of input and TFP growths based on the TFP data listed in PWT8.0, which is calculated with linear labor-quality adjustments (TFP3) as described in Eq. (3). TFP indices are derived using this human capital index. The pattern of TFP growths for the 4 NIEs, 4 ASEANs, and China are qualitatively the same as those in Table 2 (TFP2). However, the TFP growths for the G5s are relatively smaller in this version of TFP estimate.

Figure 3. Sources of Growth by Sub-Periods: TFP Estimates with Linear Labor Quality Adjustments (TFP index in PWT8.0), Growth Accounting Approach



1971-1980 1980-1990





1990-2000 2000-2011

In sum, for the pre-2000 period, the results are in general consistent with the previous studies supporting accumulationist's view regarding Asian economic growth (e.g., Collins and Bosworth, 1997; Young, 1995). However, the TFP growth contributions for the more recent period – 2000 to 2011 – show that the pattern changes from 'input-based' to 'productivity-based' growth for the Asian economies. A number of plausible reasons can explain this transition in these economies which include increases in R&D investments, greater trade flows, assimilation of technology from intensified globalization of production processes, greater human capital, and changes in government policies raising absorptive capacity.

3. Pattern of Productivity Growth: Production Function Estimation Method

There is an alternative approach to decompose the sources of growth and to evaluate the importance of productivity growth (or technical progress). Kim and Lau (1994, 1995) introduced meta-production function approach to decompose sources of Asian economic growth. Their meta-production function is specified to be the transcendental logarithmic (translog) functional form introduced by Christensen, Jorgenson and Lau (1973). With two inputs, tangible capital and labor, the translog production function takes the following form.

$$lnY_{it}^* = lnY_0 + a_k\, lnK_{it}^* + a_l\, lnL_{it}^* + b_{kk}(lnK_{it}^*)^2/2 + b_{ll}\,(lnL_{it}^*)^2/2 + b_{kl}(lnK_{it}^*)(lnL_{it}^*) \quad (4)$$

$Y_{it}^*, K_{it}^*,$ and L_{it}^* are efficiency-equivalent units of output, tangible capital, and labor, respectively. Using a panel data set of G5 economies and 4 NIEs, they performed a series of hypotheses tests to identify the nature of technical progress: tangible-capital-augmenting, labor-augmenting, or output-augmenting. Their results indicated that the technical progress is purely tangible capital augmenting which allows us to simplify the equation consisting entirely of observable variables:[3]

$$lnY_{it} = lnY_0 + lnA_0^* + a_{ik}lnK_{it} + a_{il}\,lnL_{it} + b_{kk}(lnK_{it})^2/2 + b_{ll}\,(lnL_{it})^2/2 + b_{kl}(lnK_{it})(lnL_{it}) + b_{kk}c_{ik}lnK_{it}\,\mathrm{t} + b_{kk}c_{ik}^2t^2/2 \quad (5)$$

where the c_{ik}, a_{iK} and a_{iL}'s are economy-specific constants. b_{KK}, b_{LL} and b_{KL} are the only common parameters across economies under the maintained hypothesis of a single identical meta-production function for all economies. Due to the non-stationarity of the dependent and independent variables, the model is estimated in a first-differenced form. In this study, we adopt this estimation approach on an unbalanced panel data set of G5, 4NIEs, 4 ASEAN, and China for the period of 1960-2010. Data used in this study is from Lau and Park (2014) where the sources of the variables are explained in detail. Since the time dimension is long and the rates of technical progress may change over time, we allow the augmentation rate to change in two separate sub-periods with the break being in the year 1985.[4] Thus, c_{ik1} and c_{ik2} are the augmentation rates for each economy *i* for the pre-1985 and post-1985 periods, respectively.

Table 1. Estimated Parameters for the Final Specification a Break in the Rates of Capital-Augmentation: 4 NIEs, 4 ASEAN, China and G-5

Parameter	Estimate	t-statistic	Parameter	Estimate	t-statistic
a_K	0.195	4.305			
a_L	0.368	1.283			
B_{KK}	-0.046	-3.733			
B_{LL}	0.080	1.171			
B_{KL}	0.036	1.982			
c_{iK1}			c_{iK2}		
US	0.063	4.769	US	0.067	2.500

[3] Technical progress is purely tangible-capital-augmenting, first found and reported by Boskin and Lau (1990) for the G-5 countries

[4] We have identified that trends in many of the intangible variables for the Asian economies have significantly changed in the early 80s. Empirical analyses with break points in 1981, 1982, 1983, or 1984 are qualitatively the same. We acknowledge that we need to present a systematic test to accurately identify the break point for individual economies.

Japan	0.068	2.916	Japan	0.153	3.796
Germany	0.082	4.350	Germany	0.131	2.736
UK	0.025	2.065	UK	0.073	3.092
France	0.073	4.309	France	0.073	3.019
HK	0.048	1.560	HK	0.102	1.643
Korea	0.021	0.796	Korea	0.117	1.502
Singapore	0.070	1.670	Singapore	0.169	1.689
Taiwan	0.022	1.090	Taiwan	0.159	3.201
Indonesia	0.001	0.029	Indonesia	0.010	0.389
Malaysia	-0.005	-0.203	Malaysia	0.044	1.312
Philippines	-0.018	-0.623	Philippines	0.025	0.873
Thailand	0.012	0.445	Thailand	0.078	1.713
China	0.006	0.131	China	0.098	1.008
Adjusted R^2		0.655			
D.W.		1.709			
Number of Observations		692			

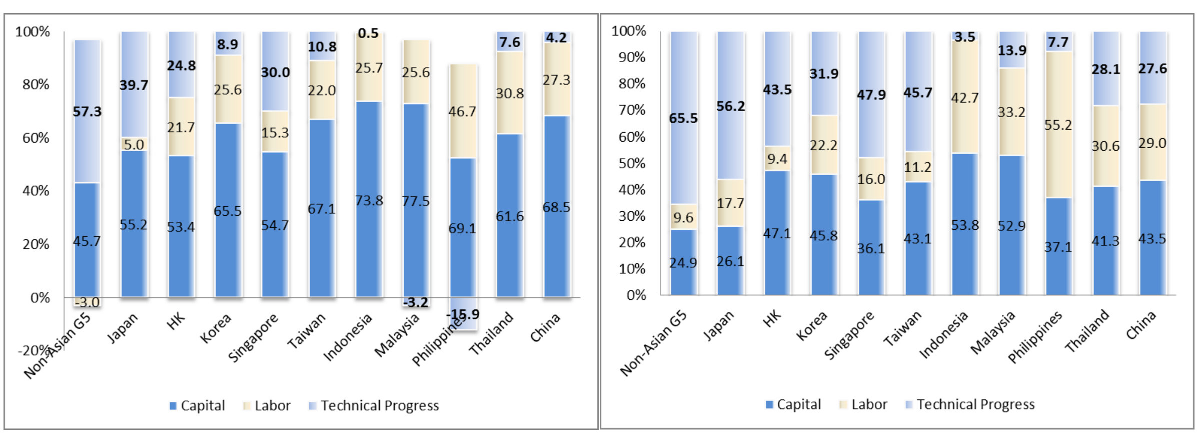
Note) There are unreported 1997-crisis dummies for the 9 Asian economies.

Estimation results in Table 1 indicate that the augmentation rates for Asian economies are in general low or insignificant for the pre-1985 period. They become positive and significant for most of 4 NIEs in the post-1985 period, but still they are insignificant for the 4 ASEAN and China, except for the case of Thailand. This finding is in contrast with the case of G5 where the augmentation rates are all positive and significant in both periods and rise further in the post-1985 period.

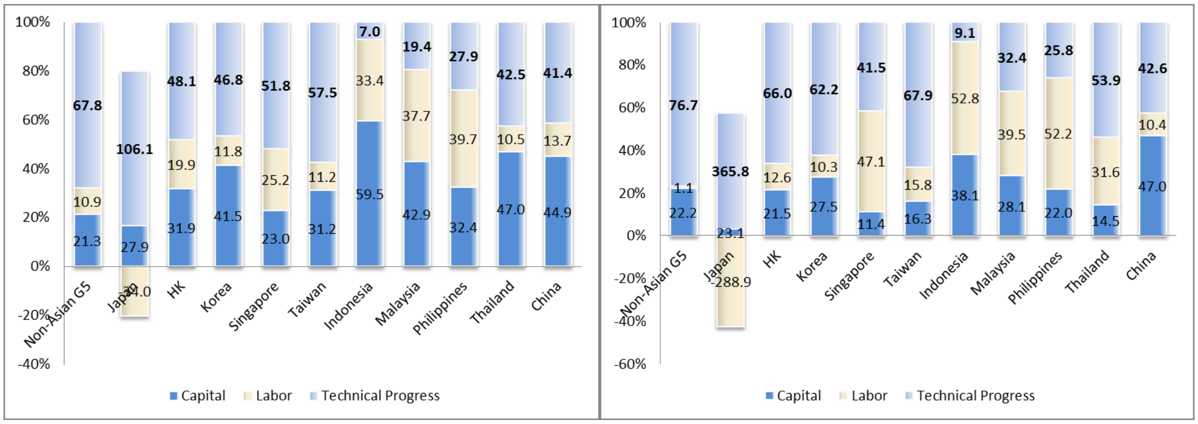
Based on the estimated parameters of the empirical model reported in Table 1, the relative contributions of tangible capital, labor, and technical progress are estimated and reported in Figure 4. Tangible capital is the most important source of economic growth for the Asian economies in the 1970-1980 sub-period, accounting for between 53 percent and over 74 percent, followed by labor. In contrast, technical progress remains the most important source of economic growth for the non-Asian G-5 countries, accounting for almost 57 percent on average, followed by tangible capital. Japan occupies an intermediate position. It has, like the other G-5 countries, significant technical progress, which accounts for between 43 and 49 percent of its economic growth, but, like the East Asian NIEs, tangible capital remains a much more important source of growth for Japan than it is for the non-Asian G-5 countries.

However, the growth accounts for the second sub-period of 1980-1990 show that technical progress has begun to make a significant contribution to economic growth of the East Asian developing economies. The contributions of technical progress to the economic growth of the 4 East Asian NIEs in this second sub-period average 42 percent, comparable in order of magnitude to the contributions of tangible capital. The contributions of technical progress to the economic growth of the other four ASEAN economies are significantly lower, averaging 13 percent. It is also interesting to note that the relative contribution of technical progress to Japanese economic growth for the second sub-period has become the most important, accounting for approximately 65 percent, with the contribution of tangible capital falling to 26 percent. It is notable that the relative contribution of technical progress is expanding in the third and fourth sub-periods for both 4 NIEs and 4 ASEAN economies. Thus, for the most recent sub-period, the relative contributions of the different sources of growth for 4 NIEs have become quite similar to those of the non-Asian G-5 countries. On the whole, the picture is one in which Japan is becoming more like the non-Asian G-5 countries, the East Asian NIEs are becoming more like Japan, and the other four ASEAN economies are also becoming more like Japan, but at a slower pace.

Figure 4. Relative Contribution to Growth by Sub-Periods: Production Function Estimation Approach



1971-1980 1980-1990



1990-2000 2000-2010

4. Drivers of TFP growth

4.1 Estimation of TFP growth model

The findings in Sections 2 and 3 suggest that TFP growth (or technical progress) has become an integral part of economic growth for the Asian economies. In order to assess future economic potentials of the Asian countries, it would be helpful to understand what are the factors driving the TFP growth. Bosworth and Collins (2003) provide empirical results that identify sources of labor productivity growth and TFP growth based on international country-level panel data. Their empirical results suggest that the catch-up effect, openness, geographical factors, and institutional quality are influential in TFP growth equation estimations. In addition to these factors, human capital has been a focus of study in a large body of literature. Benhabib and Spiegel (1994) and Pritchett (2001) considered human capital as a factor of input in a production function, while Benhabib and Spiegel (1994), Bils and Klenow (2000), and Dinopoulos and Thompson (2000) assume that level of human capital is a factor that influences productivity growth, as suggested in endogenous growth literature. Park incorporates both aspects of human capital in his regression analysis. Second, R&D-based growth studies such as Jones (1995) and Coe and Helpman (1995) show that R&D stock, R&D per scientists, or R&D per population governs dynamics of TFP growth.

Park (2012) conducted regression analysis to identify the drivers of TFP growth based on a comprehensive international data set. He adopted TFP growth regression models of Bosworth and Collins (2003) as a benchmark model and further modifies to include human capital and R&D as additional determinants of TFP growth, to incorporate the importance of intangible factors influencing TFP growth in the recent years. His model equation includes the initial conditions such as initial income per capita(–) relative to the U.S. level ($\frac{Y_{i0}}{Y_{us,0}}$), educational attainment level (*human*) as the level of human capital, and other potential determinants such as initial life expectancy relative to the United States (initial health condition) and initial population, an openness variable from PWT, and a geographical factor (composite average of the number of frost days and tropical area). The model is as follows:

$$\Delta\, ln(TFP)_{it} = \beta_0 + \beta_1\, ln\left(\frac{Y_{i0}}{Y_{us,0}}\right) + \beta_2 human + \gamma' Z + dum\_yr_t + \varepsilon_{it}. \quad (7)$$

He also considered an alternative model additionally augmented with R&D variable to incorporate the innovative activities which intensified in the recent years. The growth of R&D capital stock per worker entered as an additional determinant in the TFP growth regression.[5] The sample is an unbalanced international country-level panel data set from PWT covering the period from 1970 to 2007 in 10-year non-overlapping intervals.[6]

Table 4 is from Park (2012) which shows that catch-up effect (coefficient of *lny_us* is strongly negative) and human capital are significant sources of TFP growth in all models. Among other potential determinants, initial life expectancy relative to the United States and openness both consistently influence the TFP growth.[7] Models (5) and (6) show the results of the R&D augmented empirical model where the growth of R&D capital per worker is an additional

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[5] He considered various versions of TFP growth models where R&D enters in different forms: R&D intensity, the level of R&D capital, the level of R&D capital stock per worker, or growth of R&D capital stock per worker. The only positive relationship was found in a model where the R&D variable enters as the growth of R&D capital stock per worker.

[6] The ending year is set at 2007, which is the terminal year in the PWT 6.3 data set. He used a 10-year interval data set, which consists of average values or initial values of variables from each non-overlapping 10-year interval within the full sample. Initial values of each respective interval are considered for the variables representing initial conditions such as initial income per capita relative to the U.S. level, initial life expectancy relative to the United States, and initial population.

[7] Fixed effects panel regression also result in the qualitatively same results. These results are available from the author on request.

determinant.[8] As in other models, both the catch-up effect and human capital are robustly significant as sources of TFP growth in all models. In addition, the R&D variable is significantly positive in all models.

Table 2. Determinants of TFP Growth, Non-Overlapping 10-year Average Growth: Dependent Variable = dln(TFP)

	(1)	(2)	(3)	(4)	(5)	(6)
lny_us	–0.012***	–0.011***	–0.013***	–0.012***	–0.009***	–0.008***
	(–7.479)	(–6.869)	(–6.902)	(–6.304)	(–3.565)	(–3.059)
lnlife	0.052***	0.045***	0.041***	0.039***	0.030*	0.031*
	(4.674)	(4.033)	(3.630)	(3.460)	(1.845)	(1.915)
mhuman	0.022***	0.023***	0.022***	0.021***	0.014***	0.014***
	(4.594)	(4.796)	(4.065)	(3.880)	(2.752)	(2.670)
asia12		0.011***		0.011**		0.009*
		(2.869)		(2.198)		(1.910)
lnpop			0.002**	0.000	0.001	–0.000
			(2.158)	(0.283)	(1.530)	(–0.137)
mfrost			0.000	0.000	0.001**	0.000**
			(1.246)	(1.393)	(2.527)	(2.461)
mtropic			–0.000	–0.001	0.007	0.006
			(–0.0981)	(–0.295)	(1.550)	(1.275)
mopenc			0.000**	0.000	0.000*	0.000
			(2.516)	(0.840)	(1.872)	(0.329)
mdrk_l					0.052*	0.049*
					(1.870)	(1.796)
Constant	–0.046***	–0.047***	–0.075***	–0.054***	–0.055***	–0.034*
	(–4.339)	(–4.540)	(–4.735)	(–2.906)	(–3.208)	(–1.696)
Period dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	505	505	447	447	141	141
Adj R^2	0.167	0.179	0.198	0.205	0.238	0.253

Source: Tables 4 and 5 of Park (2012)

Notes: The dependent variable (*dlnTFP)* is the 10–year average growth rate of TFP. *lny_us, lnlife,* and *lnpop* are the log of the per capita GDP relative to that of the United States in the initial year of each respective 10–year interval, initial life expectancy relative to the United States, initial population. *mhuman* is exp(0.08**h*) where *h* is the 10–year averages of educational attainment level from Barro–Lee (2010) data set. *mdrk_l* and *mopenc* are growth rate of R&D capital stock per worker and openness variable from Penn World Tables. *mtropic* and *mfrost* are the tropical area and the number of frost days, respectively. *asia12 is* an Asian economy dummy that equals 1 for one of the 12 Asian economies, and zero otherwise. *mh_y* is an interaction term between human capital and catch–up variable. Models include unreported period dummies. *t*–statistics are in parentheses. *** p<0.01, ** p<0.05. * p<0.1.

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[8] Due to data limitations, the sample size is much smaller and all values are post-1980.

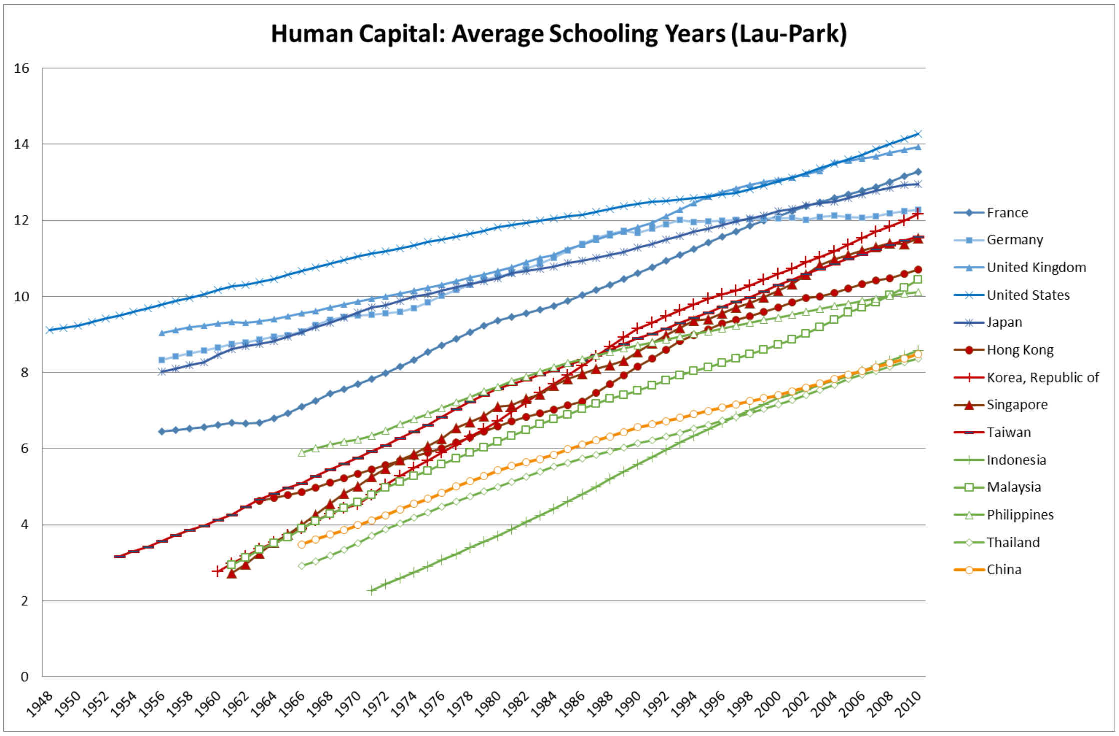
5. Future prospects of TFP growth in Asian region

Section 4 identified several important factors influencing the TFP growth of economies based on the estimation of TFP growth model. This section is devoted to examine how these factors in the Asian region have changed over time in order to evaluate the future productivity growth potentials of Asian economies. We extend our discussion to other factors that may influence the productivity growth.

Human capital has been cited as one of the main component to increase productivity growth (Bosworth and Collins, 2003; Park, 2012). Figure 5 shows the average schooling years of the Asian economies in comparison with those of the G5 economies from 1948 – 2010. We have estimated average schooling years by accumulating the enrollments at each level of education taking into account of the survival rates of respective educated cohorts and how much they are contributing to the schooling years of the working age population at each point of time.[9] This method allows us to obtain annual estimates of the human capital. It is worthwhile to note that average schooling years for the all Asian economies started at the very low levels in the 60s, but have risen at a fast pace to close the gap with the levels for the G5. Clearly, 4 NIE group stands out in this human capital catch-up process and their education attainment levels are only slightly lower than those of G5 in 2010. It is true that educational attainments have risen for the four ASEAN economies and China. However, their levels are still far lower than the levels of the G5.

Figure 5. Average Schooling Years of the Working Age Population

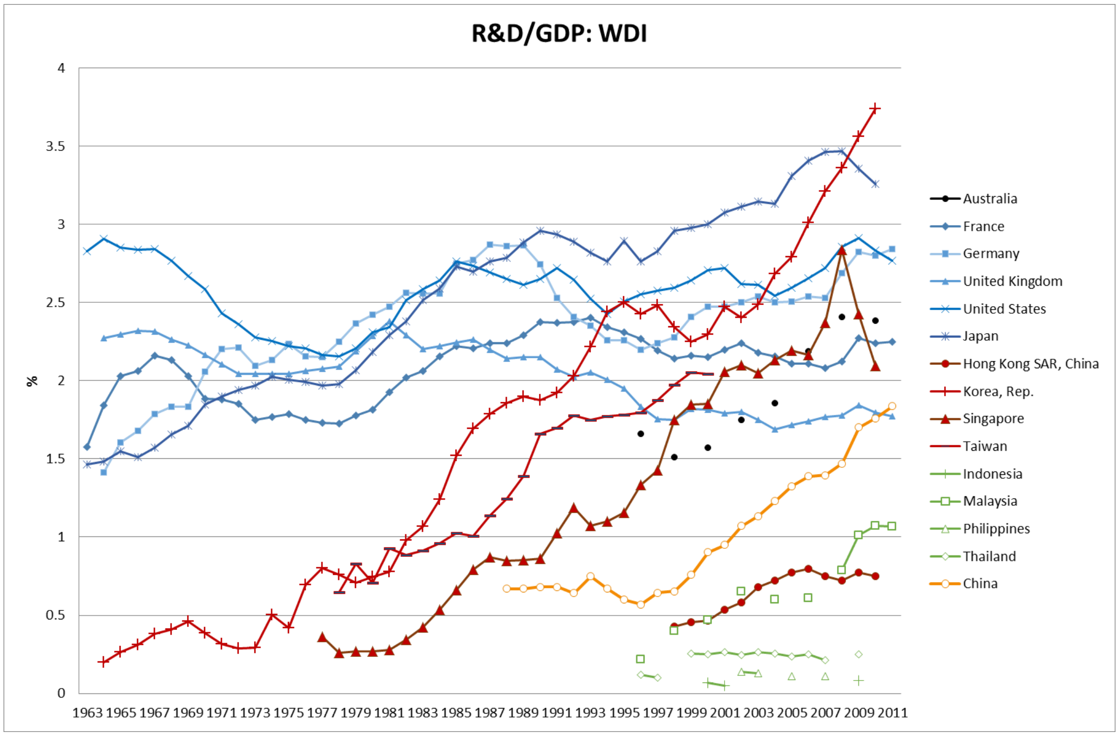
[9] Refer to Lau and Park (2014) for detailed explanation.



Source: Authors' calculation

Innovative activity such as R&D investments is also an important factor influencing productivity growth (Jones, 1995). In Figure 6, R&D to GDP ratios for the G5 have fluctuated over the given period, but shows a slight upward trend in recent years. Although Korea, Singapore, and Taiwan started at the very low levels of R&D, they have significantly increased their efforts to devote their resources in R&D investment since the 1980s. By 2011, we note that their R&D to GDP ratios have certainly reached the levels comparable to G5 and still seem to hold a persistent rising trend. The R&D ratios of the 4 ASEANs are relatively low and do not seem to exhibit any strong upward trend. China's R&D investments have started to show a strong upward movement since 1999 and has now caught up with the U.K. level.

Figure 6. R&D-to-GDP Ratio (WDI)

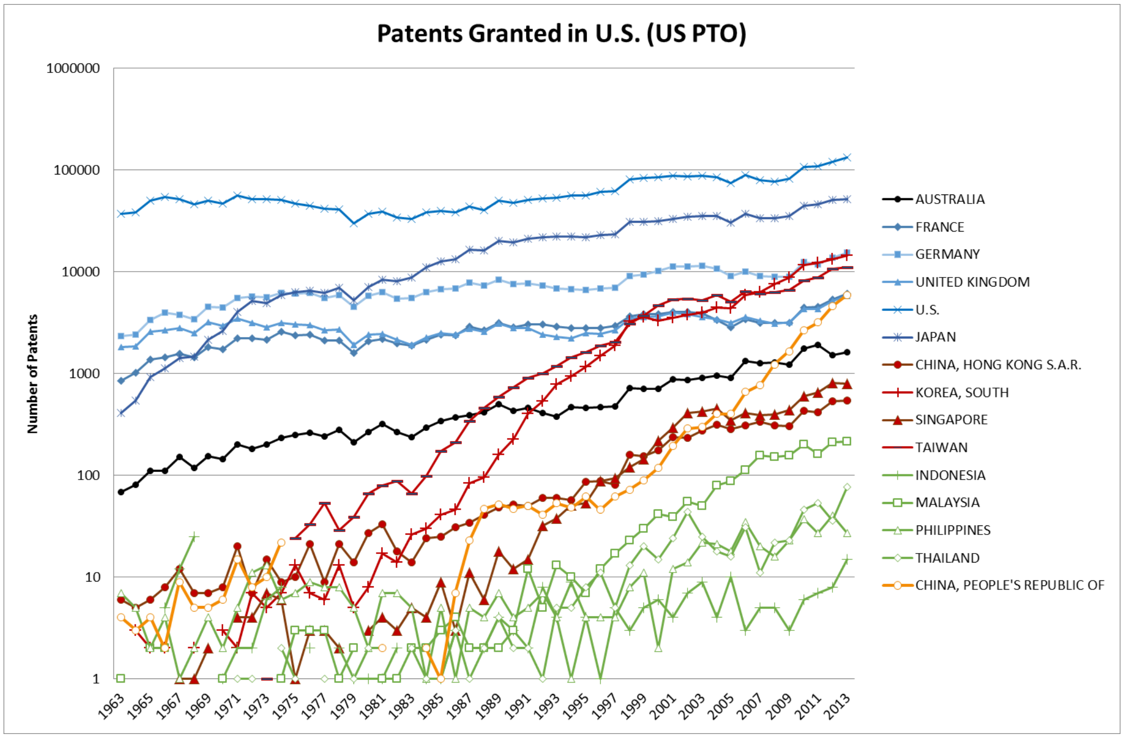


Source: *World Development Indicators*, World Bank

R&D investments lead to innovation outputs which can be measured in various ways such as patents. Application for patents can be submitted domestically or also in other foreign countries. To count only the international competitive patents, we collected patent data from the U.S. Patent and Trademark Office which lists statistics regarding patents granted to domestic and foreign residents. In Figure 7, for G5, we again see fluctuation in patent series, but shows a slight upward trend in recent years. Korea and Taiwan started at the very low levels, but their patents started to take off in the early the 1980s. By 2011, we note that their number of patents granted reached the levels comparable to G5 and still seem to show a persistent rising trend. The patents for the 4 ASEANs are still low, but started to show a significant rising trend since the late 90s. The patents for China also show a steep rise from the late 90s and have now caught up with the levels of the U.K.

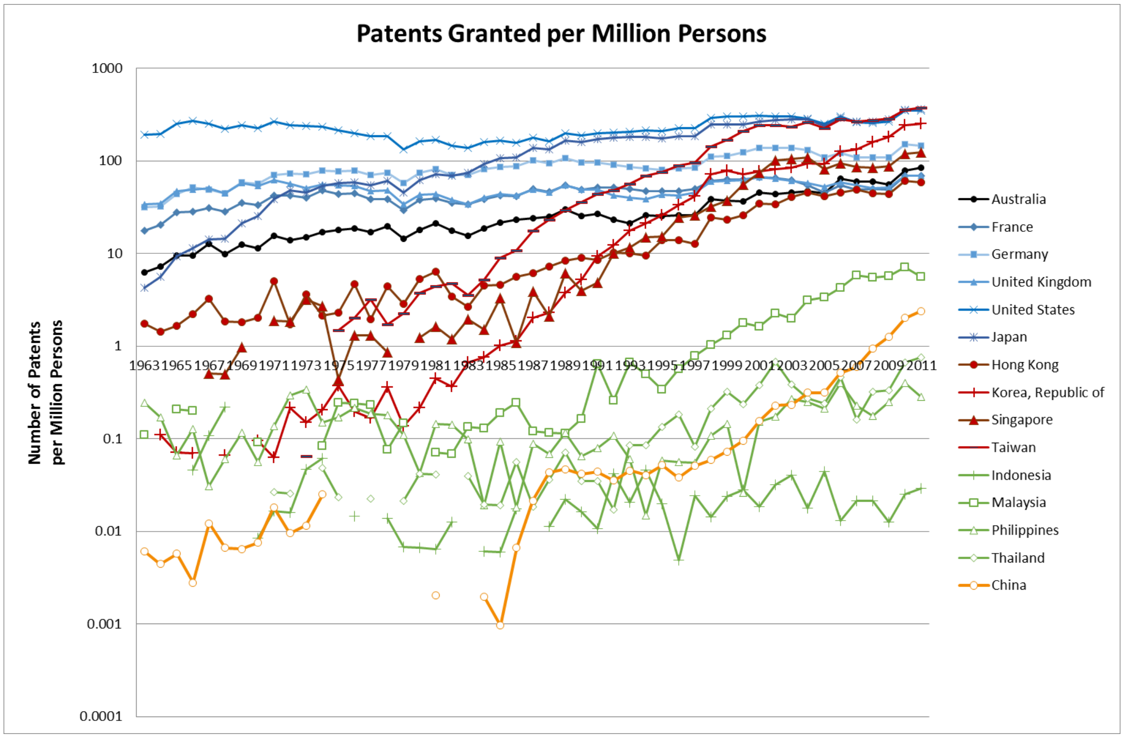
To take into account of the size of the economy, Figure 8 shows the number of patents granted per million persons by countries. The figure illustrates that there was a clear transition in the innovation performance for the all 4 NIEs during the 80s and 90s. Their levels have risen up to the levels of G5 by the late 90s and the series are showing a clear comovement with those of G5. Although the levels of other Asian economies are rising, they are still far behind the advanced economies.

Figure 7. Number of Patents Granted in the U.S., by Country Origin.



Source: U.S. Patent and Trademark Office

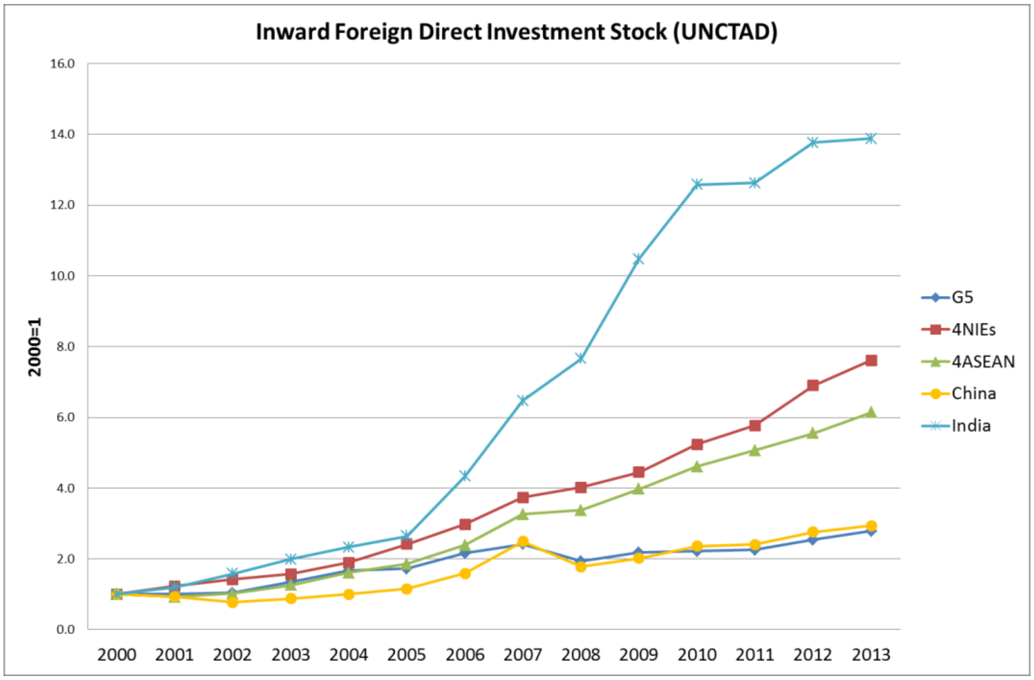
Figure 8. Number of Patents Granted (in the U.S.) per Millions of Persons by Country Origin.



Source: U.S. Patent and Trademark Office

Trade and foreign direct investments have been identified as channels of technology spillovers in the recent international economics literature. Coe and Helpman (1995) and Park (2004) show evidence of positive R&D spillover from through trade, while Javorcik (2004), Haskel et al. (2002), Keller and Yeaple (2009) provides empirical evidence of positive productivity spillovers from inward FDI. It is notable that global trade and capital flows have intensified especially in these Asian regions, according to UNCTADSTAT. For instance, Figure 9 shows that inward foreign direct investment stock have increased by 7.6 times in 4 NIEs, 6.1 times in 4 ASEANs, 13.9 times in India, and 2.9 times in China, while the inward FDI stocks increased by only 2.8 times in the G5 region and 3.4 times for the world.

Figure 9. Inward Foreign Direct Investment Stock (2000=1, UNCTAD)



Source: UNCTAD

6. Conclusion

In this study, we have investigated how the patterns of productivity growth have changed over the past few decades for the Asian economies in comparison with the advanced economies. Although we observe some meaningful differences according to different method of analyses, they all indicate that the Asian economies are in the process of transition in terms of pattern of growth. It seems that the 4 NIEs have already transitioned from input-based growth to productivity-based growth, and the remaining Asian economies are starting to show signs of transition in the past decade. In recent studies, intangibles such as human capital and R&D capitals are identified as main determinants of TFP growth. Scrutinizing the recent trends in human capital, R&D, patent statistics, and inward FDIs, they all indicate that the productivity growth will be stronger in the Asian region than before and will constitute the major basis for growth.

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