The Economic Value of Education in Agricultural Production:
A Switching Regression Analysis of Selected East Asian Countries

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Abstract: The emphasis of education as a driving force for the growth of agricultural productivity can be dated back to the early 1960s. However, most empirical work failed to take into account of the fact that production technology changes with time and consequently obscure the true contribution of education in agricultural production. This study presents a more efficient version to testing the hypothesis that education plays a key role in agricultural development using a switching regression model. Because farmers' ability to deal with disequilibria is allowed to change with education in the present setting, a concrete evidence of the key role of education is provided in the empirical analysis of eight East Asian countries. The results suggest that there exists a threshold for the effects of education on agricultural productivity change. For the group of countries where education constitutes a major determinant of productivity growth in both the technical progress and stagnation regimes, we found the effect of education varies from country to country and from regime to regime. Moreover, our results also suggest technological improvement can defer the starting point of the descending stage whereas advance the time for taking off.

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The Economic Value of Education in Agricultural Production: An Application of the Switching Regression Analysis

I. Introduction

The emphasis of education or public investment in the forms of human capital as a driving force for the growth of agricultural productivity can be dated back to the early 1960s (Schultz, 1963; Griliches, 1963). One of the reasons that education may affect agricultural productivity stems from the general-skill building up function of education. For instance, literacy enables farmers to follow written instructions for applying chemicals, whereas numeracy may assist in calculating correct dosages in the practices of application (Appleton and Balihuta, 1996).

In a rapidly changing technological environment, education becomes even more important because farmers' ability to deal with disequlibria induced by technological change depends largely on education. Although a couple of studies did find better educated farmers to adjust more successfully than less educated farmers (Schultz, 1975, Ali and Byerlee, 1991; Appleton and Balihuta, 1996), most empirical work on education and agricultural productivity failed to take into account of the fact that agricultural technology changes over time. For the developing countries, it is well documented that agriculture has undergone considerable technological progress following the innovation of high-yielding crop varieties and massive use of chemical fertilizers. Empirical analyses assuming homogenous technology thus may obscure the true contribution of education to agricultural productivity (Alene and Manyong, 2007).

This study presents a more efficient version to testing the hypothesis that education plays a key role in agricultural development using a switching regression model. Our empirical application involves examining the effect of education on total factor productivity (TFP) change in the agriculture sector of the eight East Asian countries – China, Indonesia, Japan, Malaysia, the Philippines, South Korea, Thailand and Taiwan. Some of the East Asian countries' growth in the agricultural sector appears to have been the result of remarkable gains in educational attainment (Jamison and Lau; 1982; Bosworth and Collins, 2007). However, without properly taking into account that farmers' ability to deal with disequlibria induced by technological change improves with education, a concrete empirical evidence of the key role of education in a rapidly changing era is still lacking.

II. The Model and Empirical Specification

Before assessing the differential effects of education on agricultural productivity for the eight economies, we calculate the Malmquist productivity-change indexes using the mathematical programming procedure outlined in Färe et al.(1994). The Malmquist index of productivity change is defined as the geometric mean of two distance-function-based Malmquist productivity indexes,

$$M_0(x^{t+1}, y^{t+1}, x^t, y^t) = \left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t\left(x^t, y^t\right)}\right)\left(\frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^{t+1}\left(x^t, y^t\right)}\right)\right]^{1/2}. \quad (1)$$

In the above equation, the first term in the bracket represents the Malmquist productivity index with technology in period t as the reference technology. The distance function in the numerator, $D_0^t(x^{t+1}, y^{t+1})$, measures the maximal proportional change in output required to make (x^{t+1}, y^{t+1}) feasible in relation to the technology at t. In the denominator, the distance function $D_0^t(x^t, y^t)$ measures the reciprocal of the maximum proportional expansion of the output vector y^t given x^t. The second term in the bracket is similarly defined as the Malmquist productivity index with technology in period $t+1$ as the reference technology.

Following Färe et al. (1989), the Malmquist productivity-change index can be calculated through the linear-programming approach. The basic idea in the nonparametric programming technique is to construct a world or best-practice frontier from the data in the sample, and then compares individual countries to the frontier. The annual percentage measures of total factor productivity change can be calculated for each country in each pair or adjacent years using this method. To delineate the pattern of growth, the smoothed measure is usually reported in the form of cumulative percentage change measures (Coelli et al., 2005). Therefore, to examine the differential productivity effects of education in different regimes, the cumulative TFP change measures is regressed on the percentage of secondary-school enrollment and one other confounding factor, the ratio of arable land to the total agriculture population, with the following specification:

Agricultural Productivity Analysis Model

$$T\dot{F}P_{it}^{*}(\text{Regime1}) = \alpha_{0i}{}^{R1} + \alpha_{HK}{}^{R1} Edu\_Ratio_{it} + \alpha_{HK2}{}^{R1} Edu\_Ratio_{it}{}^{2} + \beta_{s}{}^{R1} Scale_{it} + \beta_{s2}{}^{R1} Scale_{it}{}^{2} + \varepsilon_{it}{}^{R1}$$

$$T\dot{F}P_{it}^{*}(\text{Regime2}) = \alpha_{0i}{}^{R2} + \alpha_{HK}{}^{R2} Edu\_Ratio_{it} + \alpha_{HK2}{}^{R2} Edu\_Ratio_{it}{}^{2} + \beta_{s}{}^{R2} Scale_{it} + \beta_{s2}{}^{R2} Scale_{it}{}^{2} + \varepsilon_{it}{}^{R2}$$

The switching mechanism

$$T\dot{F}P_{it} = \begin{cases} T\dot{F}P_{it}^{*}(\text{Regime1}) & \text{if } \; TCC \geq 1 \\ T\dot{F}P_{it}^{*}(\text{Regime2}) & \text{if } \; TCC < 1 \end{cases}$$

where TCC, the regime separation index, is measured as

$$TCC = \left[\left(\frac{D_0^{t}(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1})} \right) \left(\frac{D_0^{t}(x^{t}, y^{t})}{D_0^{t+1}\left(x^{t}, y^{t}\right)} \right) \right]^{1/2}$$

In the above format, $T\dot{F}P_{it}^{*}$, represents proportional growth rate of total factor productivity. The variable Edu_Ratio_{it} is used to quantify the direct influence of education through the percentage of secondary-school enrollment. Growth coefficient α_{0i} represents disembodied technological change. The variable *SCALE* reflects one of the major country-specific agricultural farming characteristics – land/labor ratio, and is calculated as arable land per unit of agricultural labor. The separation index in the switching regression, *TCC*, can be interpreted as a technical change component, which measures the shift in the frontier over time. That is, in our empirical analysis, how much the world frontier shifts at each country's observed input mix is measured by this variable, and it is used to separate the entire time span into two separate regimes – the progress and stagnation regimes. According to Färe et al. (1994), the improvements in the technical-change component of the Malmquist productivity-change index can be interpreted as providing evidence of innovation for the countries considered.

III. Data Description

Our sample includes the agricultural production data for eight East Asian economies over the period of 1961-2001. The data of China, Indonesia, Japan, Korea, Malaysia, Philippines, and Thailand come from the Food and Agriculture Organization (FAO) of the United Nations' statistical database, which are available through the internet website: http://www.fao.org. Taiwan's data comes from the Agricultural Yearbook published by the Council of Agriculture, Executive Yuan.

The DEA model is composed of one single output and three inputs. We chose the "crop primary" from the FAO database as our output variable. The three input items are land, labor, and fertilizer. Agricultural labor is approximated by agricultural population, which by the FAO's definition is all persons depending for their livelihood on agriculture, hunting, fishing or forestry. Agricultural land is the area harvested, and therefore excludes the area from which there was no harvest due to damage, failure, etc. Fertilizer is the quantity of chemical fertilizer consumed in agriculture by the sample country. The unit for fertilizer is in metric tons.

To quantify the effect of education on agricultural productivity, we took the proportion of secondary school enrollment in total population as a proxy variable for the agriculture sector. In a neoclassical growth model, the growth of output can be easily derived as a function of changes in the stock of education (Mankiw et al., 1992), whereas, output growth is modeled as a function of the level of human capital in an endogenous growth framework (Lucas, 1988; Romer, 1990). This study follows Mankiw et al. (1992) to specify productivity growth as a function of growth of human capital, which is proxied by the secondary school enrollment rate. Except for Taiwan, our data for the number of students enrolled in the secondary level schools (including high schools and teacher training) are taken from the "Statistical Yearbook for Asia and the Pacific" published by the United Nations. The data for Taiwan are mostly taken from "Taiwan Statistical Data Book" published by the Council for

Economic Planning and Development of Republic of China. Sample means of the dependent and explanatory variables are reported in Table 1.

IV. Results and Discussion

The scatterdiagrams in Figures 1-3 demonstrate 3 different growth patterns revealed by the time trend of the cumulative percentage changes of the productivity-change index. The first group exhibiting similar growth patterns is Thailand, Philippines, Indonesia and China. Since improvements in productivity are associated with values exceeding unity, while values less than unity denote regress or deterioration of performance (Färe et al., 1994), the time trend of the productivity-change indexes suggest the productivity of these four countries experienced deterioration in the early periods and then gradually leveled off. The group contrasting to the first group includes Malaysia and Japan. For these two countries, we observe obvious improvements in productivity over time. The remaining two countries – Korea and Taiwan – exhibit a unique pattern of productivity change because the productivity-change index for these two economies does not reveal either an upper trend as Japan and Malaysia, or a downward trend as Thailand, Philippines, Indonesia and China.

Listed in Tables 2-4 are results from applying switching regression to the forty-year data. The results in Tables 2-4 suggest that, for the group of countries whose productivity experienced deterioration in the early periods and then gradually leveled off, variations in education ratio could not offer a plausible explanation for the observed pattern of growth, whereas farm size seems to be a crucial factor. For the other two groups whose productivity over time remains unchanged or exhibits obvious improvements, our results suggest the importance of education in both the technical progress and stagnation regimes. This result is in accordance with the general expectation that investment in human capital is a prerequisite for the newly developed technology to take effect (Antle and Capalbo, 1988). Furthermore, we found that on average both the cumulative TFP change and education ratio is higher for the group of countries in which education plays an important part.

A further synthesis of the effect of education for individual countries yields some interesting empirical implications. First of all, when categorizing the three groups of countries by their degree of economic development, our results suggest that there exists a threshold for the effects of education on agricultural productivity change. That is, education will not play an important part in affecting growth in the agriculture sector until the general economy has reached certain level of development. Secondly, for the group of countries where education constitutes a major determinant of productivity growth, we found the effect of education varies from country to country. Specifically, Figures 4-7 suggest a nonlinear effect of education on cumulative TFP change in either/both of the two regimes for the last two groups of countries. For Korea, Japan and Malaysia, Figures 4-6 suggest the effect of education first decreased and soon went up after reaching its lowest point. Contrast to this pattern, the effect of education in Taiwan first increased and soon gradually leveled off. Despite of this difference, however, all four countries reached their turning point in short time.

Moreover, our results suggest that for the same group of countries, the effect of education also varies from regime to regime. For Korea, the turning point of the technical progress regime (regime 1) is 0.057, which is smaller than the turning point of the stagnation regime. However, the effect of education reached its lowest point some time later in regime 1 than in regime 2 for Taiwan. These results in turn indicate technological improvement might defer the starting point of the descending stage whereas advance the time for taking off. Moreover, the marginal effect of education in the technical progress regime for Korea, Japan and Malaysia exceeds those in the stagnation regime.

V. Conclusion

Assessing the economic value of education to agricultural productivity for developing countries has been one of the main themes of agricultural development studies lately. However, most previous work on education and agricultural productivity failed to take into account of the fact that agricultural technology changes over time. By taking into account of the fact that farmers' ability to deal with disequilibria induced by technological differences over time improves with education, this study presents a more efficient version to testing the hypothesis that education plays a key role in agricultural development. It is found that variations in education ratio could not offer a plausible explanation for countries whose productivity experienced deterioration in the early periods and then gradually leveled off. However, our results do suggest that, for countries agricultural productivity exhibiting obvious improvements throughout the entire time span, education constitutes a major determinant of the change in productivity.

A synthesis of the effect of education through the switching regression leads to a couple of new insights. First of all, our results suggest that there exists a threshold for the effects of education on agricultural productivity change. For the group of countries where education constitutes a major determinant of productivity growth in both the technical progress and stagnation regimes, we found the effect of education varies from country to country and from regime to regime. Despite of those differences, most countries reached their turning point in short time. Finally, one of the important implications of the current study is our results suggest in addition to enhancing agricultural productivity, technological improvement can defer the starting point of the descending stage whereas advance the time for taking off.

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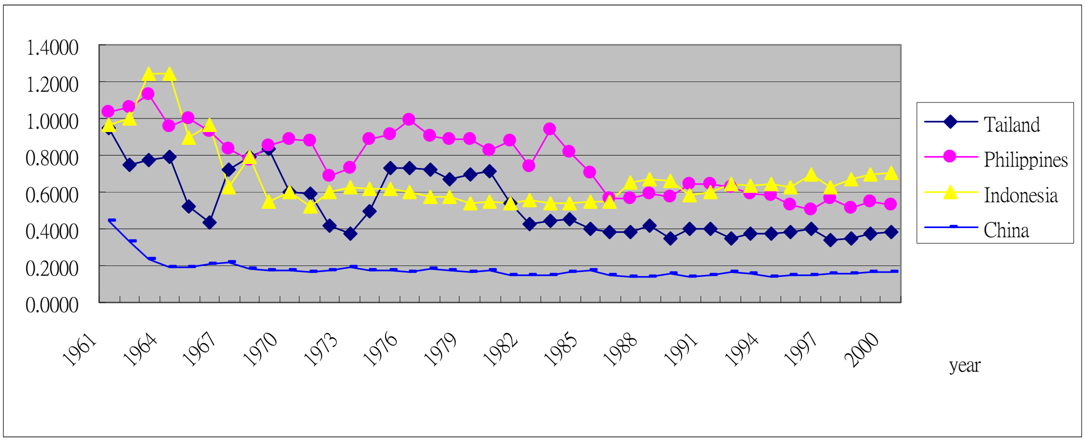

Figure 1. Growth Patterns of Thailand, Philippines, Indonesia, and China

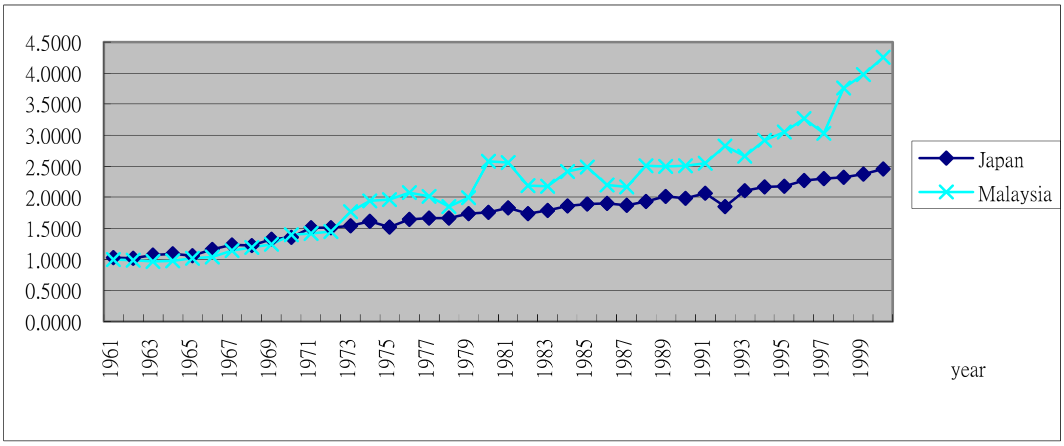

Figure 2. Growth Pattern of Malaysia and Japan

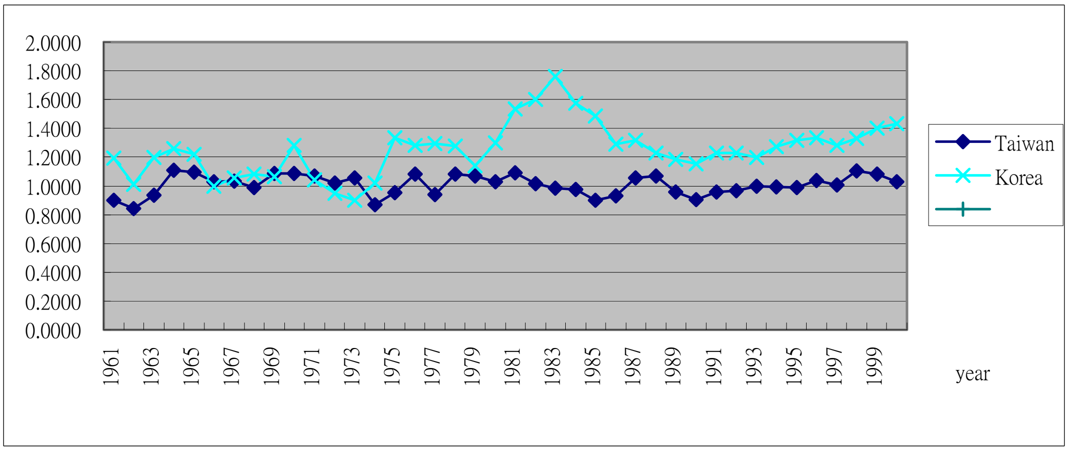

Figure 3. Growth Pattern of Korea and Taiwan

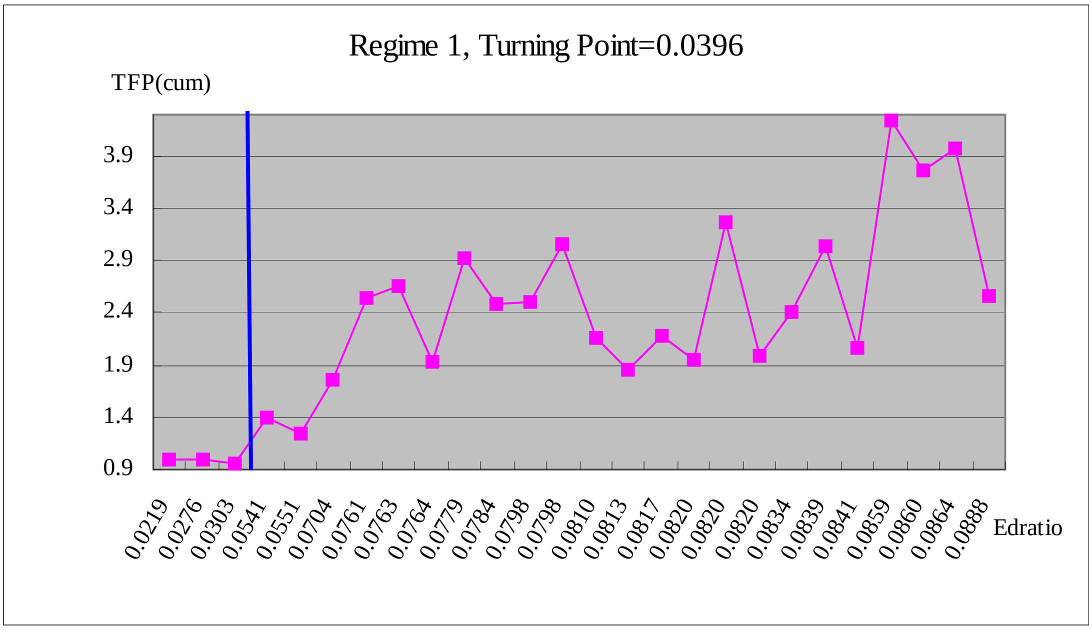

Figure 4. Effects of Education – Malaysia

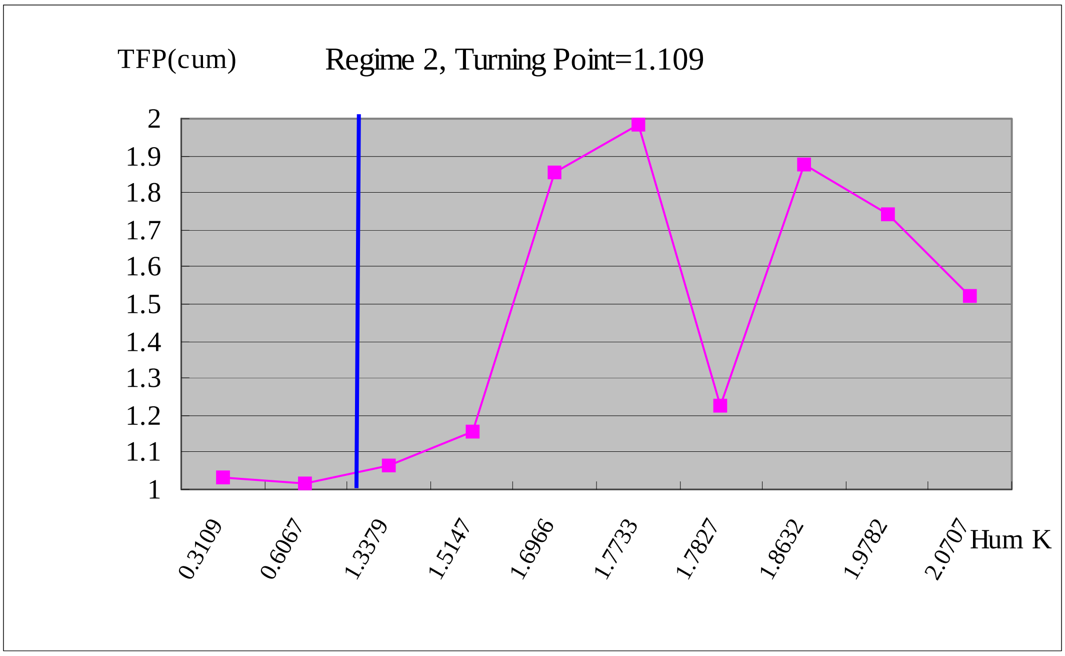

Figure 5. Effects of Education – Japan

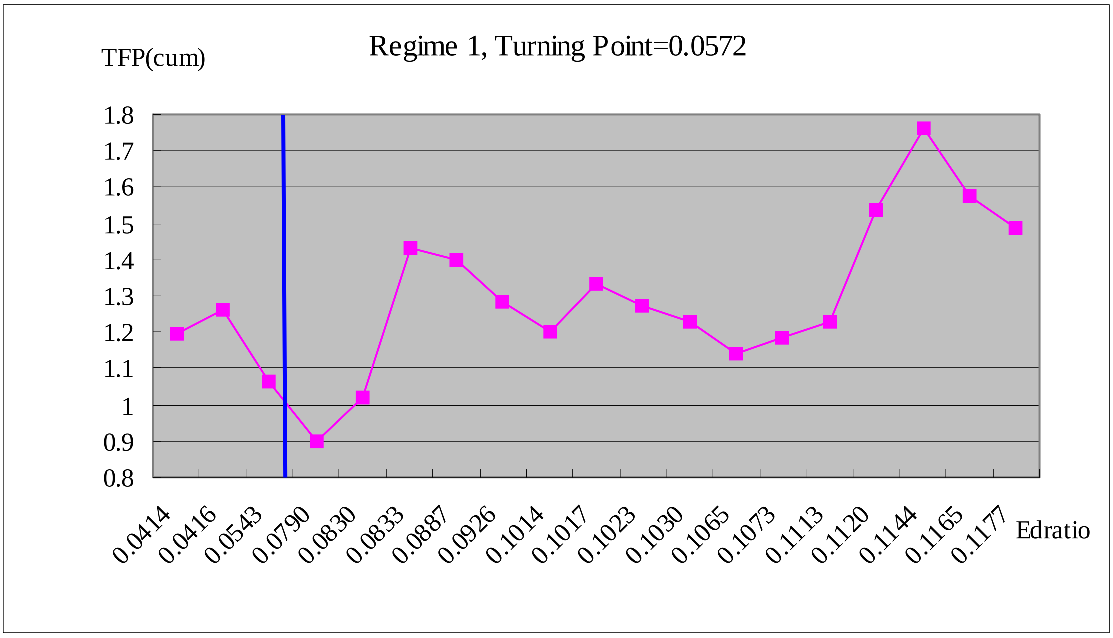

Figure 6(a). Effects of Education – Korea

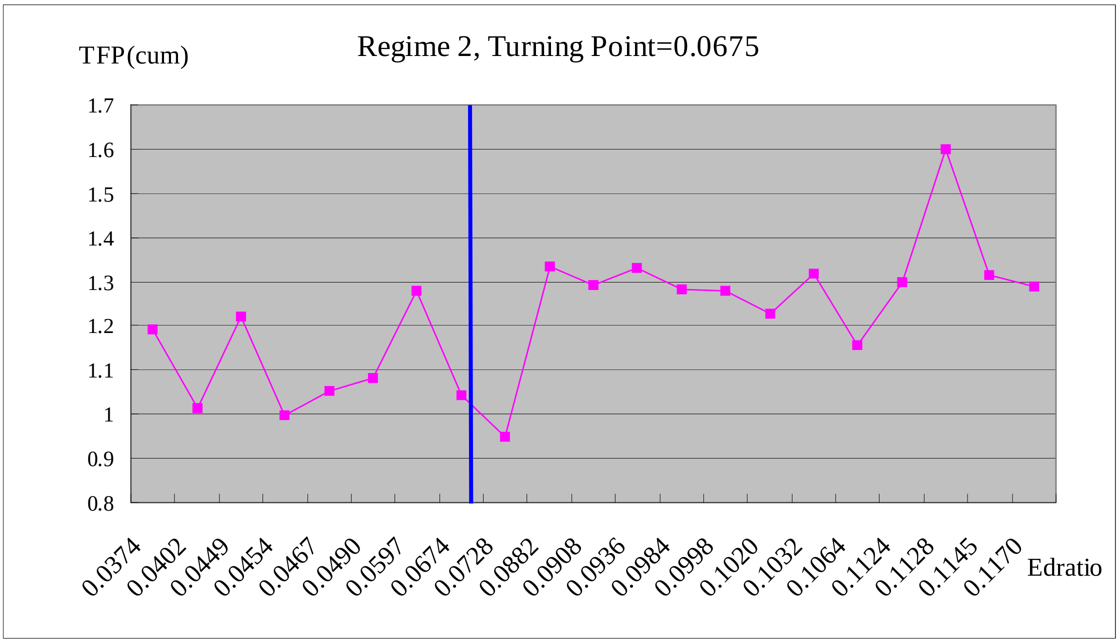

Figure 6(b). Effects of Education – Korea

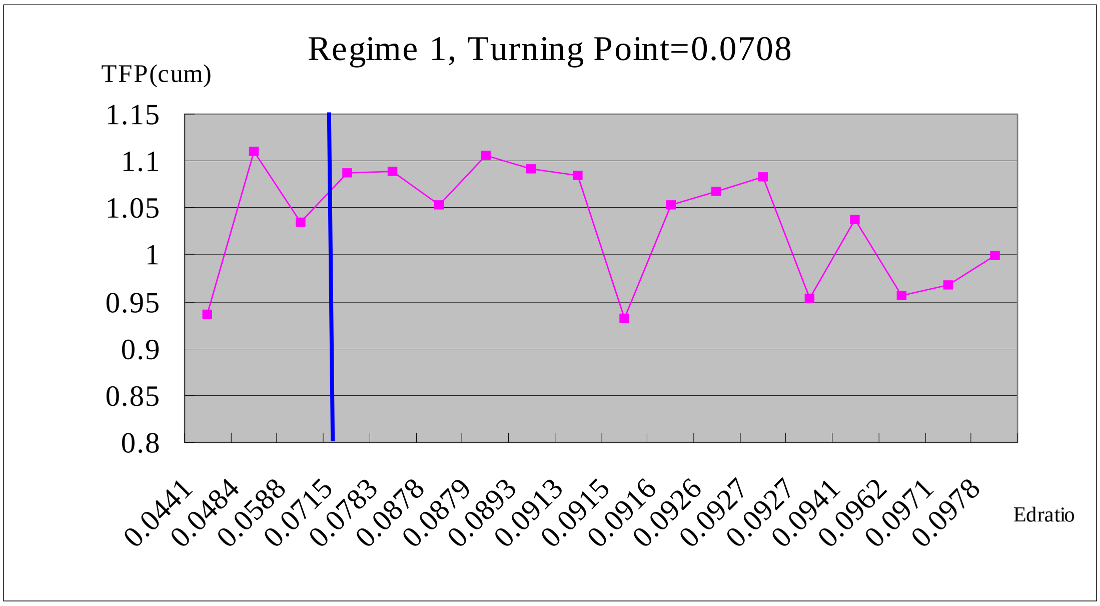

Figure 7(a). Effects of Education – Taiwan

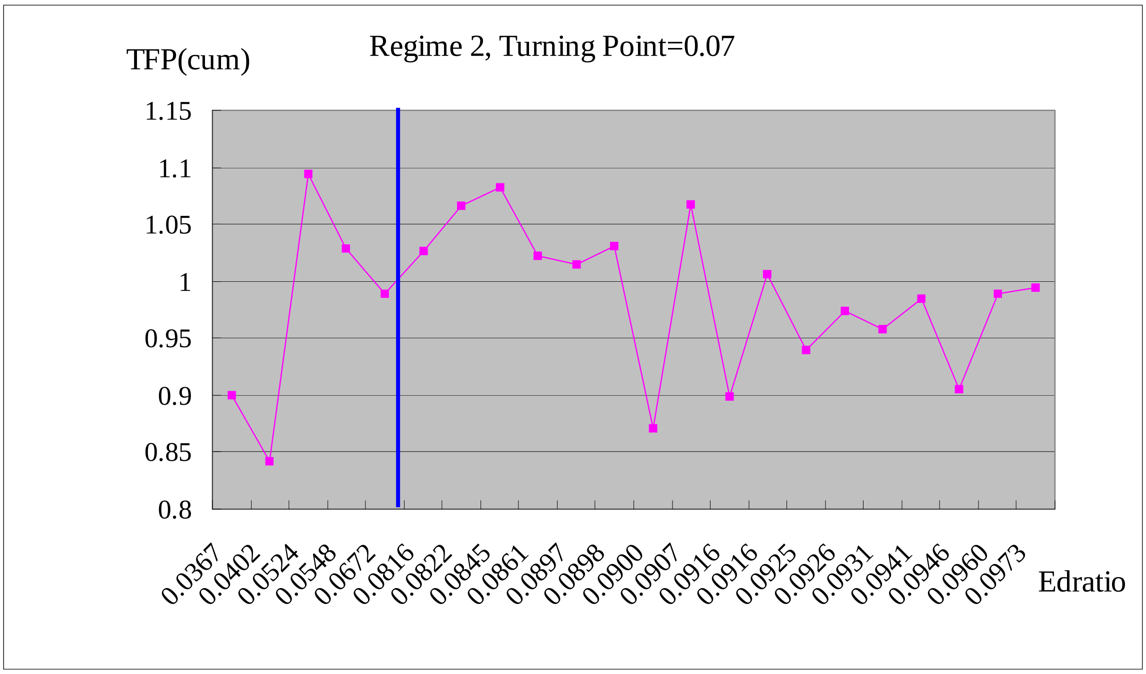

Figure 7(b). Effects of Education – Taiwan

Table 1: Sample Means of Eight East-Asian Countries

	Regime 1			Regime 2		
	cumTFP	*Edu - Ratio* [Human capital]	*Scale*	*cumTFP*	*Edu - Ratio* [Human capital]	*Scale*
		Group 1 Countries:				
China	0.164	0.050	0.149	0.195	0.054	0.153
Thailand	0.538	0.038	0.527	0.523	0.033	0.520
Philippines	0.844	0.050	0.219	0.705	0.057	0.208
Indonesia	0.663	0.037	0.226	0.692	0.036	0.226
		Group 2 Countries				
Japan	1.805	[1.761]	0.467	1.446	[1.493]	0.345
Malaysia	2.345	0.073	0.279	1.788	0.065	0.214
		Group 3 Countries				
Taiwan	1.036	0.084	0.185	0.986	0.081	0.186
Korea	1.289	0.093	0.228	1.217	0.081	0.199

Note: 1. Edu-Ratio is defined as the percentage of secondary-school enrollment, and Scale denotes the ratio of arable land to the total agriculture population.

2. In Japen, Edu-Ratio does not play significant role in explaining the cumulative TFP change, and is replaced with variable “Human capital stock”.

Table 2: Results from Switching Regression – China, Thailand, Philippines, Indonesia

Variable	Coefficient (b/St.Er.)			
	China	Thailand	Philippines	Indonesia
Regime 1				
Intercept	2.595	-8.277	12.773	7.182
	(3.241)	(-0.944)	(8.715)	(1.683)
Edu - Ratio	-0.292	-13.380	2.049	-16.671
	(-0.149)	(-0.790)	(0.837)	(-0.496)
Edu - Ratio^2	0.292	73.244	-201.065	226.628
	(0.149)	(0.377)	(-3.505)	(0.532)
Scale	-33.432	35.341	-85.140	-60.350
	(-3.253)	(1.029)	(-7.701)	(-1.368)
Scale^2	116.098	-33.521	155.381	144.475
	(3.446)	(-1.010)	(7.584)	(1.380)
Regime 2				
Intercept	2.970	-9.693	11.241	18.228
	(3.355)	(-1.752)	(0.767)	(3.491)
Edu - Ratio	0.084	-6.250	3.376	14.974
	(0.053)	(-0.632)	(0.03)	(0.798)
Edu - Ratio^2	-0.084	-24.744	-200.951	-144.177
	(-0.053)	(-.0181)	(-0.199)	(-0.608)
Scale	-38.087	41.676	-80.032	-169.808
	(-3.448)	(1.903)	(-0.533)	(-3.566)
Scale^2	128.991	-40.806	157.407	399.772
	(3.634)	(-1.894)	(0.461)	(3.705)
Sigma(1)	0.031	0.164	0.146	0.127
	(4.935)	(4.556)	(1.058)	(4.16)
Sigma(0)	0.034	0.110	0.168	0.098
	(4.220)	(5.791)	(4.377)	(5.168)
Log likelihood function	61.296	4.232	68.197	13.802

* *t* value is listed in the parenthesis.

Table 3: Results from Switching Regression – Malaysia, Japan

Variable	Coefficient (b/St.Er.)	
	Malaysia	Japan**
Regime 1		
Intercept	4.003	0.416
	(2.930)	(2.035)
Edu - Ratio [Human capital]	-64.399	[0.307]
	(-2.040)	(2.577)
$Edu\text{ - }Ratio^2$	812.625	—
	(2.954)	
Scale	-15.801	2.122
	(-2.348)	(8.014)
$Scale^2$	34.323	—
	(2.970)	
Marginal effect of education in regime 1	**54.244**	**0.307**
Regime 2		
Intercept	-0.319	0.830
	(-0.548)	(2.218)
Edu - Ratio [Human capital]	20.053	[-0.670]
	(2.583)	(-1.534)
$Edu\text{ - }Ratio^2$ [Human capital^2]	—	[0.302]
		(2.469)
Scale	4.610	3.186
	(8.110)	(15.819)
$Scale^2$	—	-1.131
		(-5.191)
Marginal effect of education in regime 2	**20.053**	**0.232**
Sigma(1)	0.165	0.514
	(2.383)	(2.796)
Sigma(0)	0.297	0.027
	(5.149)	(6.915)
Log likelihood function	-13.582	58.162

* *t* value is listed in the parenthesis. In Japen, Edu-Ratio does not play significant role in explaining the cumulative TFP change, and is replaced with variable "Human capital stock".

Table 4: Results from Switching Regression – Korea, Taiwan

Variable	Coefficient (b/St.Er.)	
	Taiwan	Korea
Regime 1		
Intercept	0.526	2.936
	(0.517)	(4.133)
Edu - Ratio	23.347	-20.137
	(2.049)	(-2.098)
Edu - Ratio^2	-164.775	176.053
	(-1.981)	(2.871)
Scale	-2.776	-12.047
	(-0.306)	(-2.179)
Scale^2	7.674	23.907
	(0.328)	(2.147)
Marginal effect of education in regime 1	**-4.335**	**12.602**
Regime 2		
Intercept	0.715	3.162
	(0.530)	(4.239)
Edu - Ratio	22.453	-31.732
	(2.642)	(-2.887)
Edu - Ratio^2	-160.393	234.927
	(-2.617)	(3.437)
Scale	-4.243	-9.212
	(-0.305)	(-1.843)
Scale^2	11.587	18.333
	(0.312)	(1.866)
Marginal effect of education in regime 2	**-3.532**	**6.326**
Sigma(1)	0.081	0.135
	(5.278)	(5.312)
Sigma(0)	0.048	0.135
	(3.658)	(5.421)
Log likelihood function	34.719	4.332

* *t* value is listed in the parenthesis.