Efficiency Change and Productivity Growth in East Asian Agriculture

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This study focuses on identifying the sources of agricultural growth for eight East Asian economies – with special emphasis on international knowledge spillovers. The Malmquist productivity growth index and its two components are calculated and regressed on variables including domestic R&D and international spillovers to characterize the differential patterns of growth.

I. INTRODUCTION

In literature of development, the difference in agricultural productivity across countries, or the continued growth of the agriculture sector in one country, is constantly attributed to three general characteristics of supply: the advancement of production technology, the exploitation of scale economies, and the inducement of biased technical change. Recent developments of the endogenous growth models stress the importance of human capital and knowledge acquisition (Romer, 1990). However, despite of the long and rich history of agricultural productivity analysis, there has not been much work on identifying the endogenous sources of growth for East Asian agriculture.

Among the many, the group of endogenous growth models that have succeeded in explaining the growth of the newly industrializing Asian countries (Grossman and Helpman, 1991; Rivera-Batiz and Romer, 1991; Romer, 1990a) emphasized the role of international trade. Although those models posit the potentials international trade has in increasing specialized inputs, most empirical evidences point to the exchange of intangible ideas through different modes of transfer facilitated by bilateral trade. Along with this line of conjecture, the benefits of innovation or R&D can spill across countries and can be done so through foreign direct investment, patenting, or international alliances such as

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joint ventures, and even freely available spillovers that go beyond the geographic boundaries.

By linking foreign direct investment to international spillovers, for instance, Lichtenberg (1992) found that although the impacts are not instantaneous, spillovers that go beyond the geographic boundaries have significant impacts on growth. Nevertheless, those of Aitken and Harrison(1999), Damijan et al. (2001), Djankov and Hoekman (2000), Konings (2001) and Zukowska-Gagelmann (2001) suggest the negative spillover effects of the presence of multinationals on domestic firms' productivity. Coe and Helpman (1993), on the other hand, used trade flows as carriers of international spillovers to find that both domestic and foreign R&D capital stocks have important effects on total factor productivity. Because foreign R&D capital stocks are likely to have stronger effects when import flows take a larger share in GDP, Coe and Helpman'¦s results also suggested a more open economy will extract larger productivity benefits. Hypothesizing foreign patenting as the channel to transmit, Eaton and Kortum (1996) and Branster (1996) found that foreign research stimulates domestic private research, providing empirical support for arguments in favor of international science and technological coordination.

As in any other sectors of the economy, research and extension investments are closely linked to the growth of the agriculture sector. This can be clearly seen by much work devoted to measuring the rate of returns of agricultural R&D. However, the findings in a couple of recent studies suggest the existence of international spillovers as well as its contribution in the agriculture sector (Jonston and Evenson, 1999; Schimmelpfennig and Thirtle, 1999; Gutierrez and Gutierrez, 2003). Therefore, without properly taking into account the effect of international spillovers, those estimates may end up overstating the effects of domestic R&D on agricultural growth. Accordingly, identifying the linkages between international spillovers and the growth of agriculture is important in the sense that it may help explain agricultural growth, and what is more important, it will help characterizing the differential patterns of growth in multilateral comparison.

This study focuses on identifying the sources of agricultural growth for eight East Asian economies – China, Indonesia, Japan, Malaysia, the Philippines, South Korea, Thailand and Taiwan – with special emphasis on international knowledge spillovers. To emphasize the effects of R&D spillovers that go beyond the geographical boundaries, Coe and Helpman (1995) construct a foreign stock of knowledge that is based partly upon its trade partners' R&D spending. Our spillover index thus defined is calculated as an import-weighted sum of trade partners' R&D stock to reflect the possibility that a country receives relatively more knowledge spillovers from countries relatively more goods and services is imported from.

The remainder of the paper is organized as follows. In the next section, we give a brief introduction of the model and the empirical specifications. Description of the data is described in the third section. This is followed by presenting empirical estimates and discussion of the results, while the final section presents our conclusions.

II. IDENTIFYING AND EXPLAINING AGRICULTURAL GROWTH

The Malmquist index has gained considerable popularity in recent years due to the appealing feature for allowing further decomposition of productivity variation. Therefore, to examine the sources of agricultural growth for the eight East Asian economies, we calculate the Malmquist productivity-change indexes as well as the technical-change and efficiency-change components using the mathematical programming procedure outlined in Fare et al.(1994) The linkages between the growth of total factor productivity and domestic R&D as well as international spillovers are identified by regressing the productivity-change indexes and the two components on cumulative R&D spending.

II.1 Decomposition of the Malmquist Index

Following Fare et al. (1994), the Malmquist productivity-change index is defined as the geometric mean of two distance-function-based Malmquist productivity indexes and is of the following form,

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

In the above equation, the Malmquist productivity index with technology in period t as the reference technology is defined as

$$M_{CCD}^{t} = \frac{D_0^t\left(x^{t+1}, y^{t+1}\right)}{D_0^t\left(x^t, y^t\right)},$$

(2)

where the distance function in the numerator, $D_0^t\left(x^{t+1}, y^{t+1}\right)$, measures the maximal proportional change in output required to make $\left(x^{t+1}, y^{t+1}\right)$ feasible in relation to the technology at t, whereas the distance function in the denominator, $D_0^t\left(x^t, y^t\right)$, measures the reciprocal of the maximum proportional expansion of the output vector y^t given x^t. Similarly, the Malmquist productivity index with technology in period $t+1$ as the reference technology is defined as

$$M_{CCD}^{t+1} = \frac{D_0^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_0^{t+1}\left(x^t, y^t\right)}.$$

(3)

In equation (3), the distance function in the denominator, $D_0^{t+1}\left(x^t, y^t\right)$, measures the maximal proportional change in output required to make $\left(x^t, y^t\right)$ feasible in relation to the technology at $t+1$, whereas the distance function in the numerator, $D_0^{t+1}\left(x^{t+1}, y^{t+1}\right)$, measures the reciprocal of the maximum proportional expansion of the output vector y^{t+1} given x^{t+1}.

The Malmquist productivity change index in equation (1) can be decomposed into the change in relative efficiency and shift in technology over time by rewriting as (Fare et al., 1989, 1992)

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

(4)

The expression outside the brackets illustrate the change in relative efficiency and thus measures the extent to which observed production is getting closer (or farther) from the frontier. For a multilateral analysis, the frontier is a "grand" or "world" frontier, which is constructed by the best practice countries in the sample. The efficiency change component, therefore, captures the performance relative to the best practice in the sample and can be interpreted as the catching-up effect.

The geometric mean of the two ratios inside the brackets in equation (4) can be interpreted as the technical change component, which measures the shift in the frontier over time. Therefore, in our empirical analysis, how much the world frontier shifts at each country's observed input mix is measured by this component. The improvements in this technical-change component can be interpreted as providing evidence of innovation (Fare et al., 1994) for the country considered. A further examination of this component thus allows for identifying the innovators.

The Malmquist index can be calculated through the linear-programming approach outlined in Fare et al. (1989). Fare et al. (1994) indicate that since for each sample country there is only one aggregate output, the output distance function is equivalent to a frontier production function in the sense that the frontier gives the maximum output given input. Therefore, the nonparametric programming technique involves constructing a world or best-practice frontier from the data in the sample, and then compares individual countries to the frontier.

To calculate the Malmquist index of productivity change for country k', the liner- programming approach solves for four different distance functions that make up the index, that is, $D_0^t\left(x^{k',t}, y^{k',t}\right)$, $D_0^{t+1}\left(x^{k',t+1}, y^{k',t+1}\right)$, $D_0^t\left(x^{k',t+1}, y^{k',t+1}\right)$ and $D_0^{t+1}\left(x^{k',t}, y^{k',t}\right)$. The output distance functions are reciprocal to the output-based Farrell measure of technical efficiency. Calculating the Malmquist index relative to the constant-returns-to-scale technology, the four different linear programming problems can be expressed as

$$\left(D_0^{t+i}\left(x^{k',t+j}, y^{k',t+j}\right)\right)^{-1} = \max \theta^{k'}$$

subject to

$$\theta^{k'} y_m^{k',t+j} \leq \sum_{k=1}^{K} z^{k,t+i} y_m^{k'.t+i} \qquad m = 1, \ldots, M$$

$$\sum_{k=1}^{K} z^{k,t+i} x_n^{k,t+i} \leq x_n^{k',t+j} \qquad n = 1, \ldots, N$$

$$z^{k,t+i} \geq 0 \qquad k = 1, \ldots, K,$$

where $(i,j)=(0,0)$ for solving for $\left(D_0^t\left(x^{k',t},y^{k',t}\right)\right)^{-1}$

$(i,j)=(1,1)$ for solving for $\left(D_0^{t+1}\left(x^{k',t+1},y^{k',t+1}\right)\right)^{-1}$

$(i,j)=(0,1)$ for solving for $\left(D_0^t\left(x^{k',t+1},y^{k',t+1}\right)\right)^{-1}$

$(i,j)=(1,0)$ for solving for $\left(D_0^{t+1}\left(x^{k',t},y^{k',t}\right)\right)^{-1}$

It is important to note that when solving for either $D_0^t\left(x^{k',t+1},y^{k',t+1}\right)$ or $D_0^{t+1}\left(x^{k',t},y^{k',t}\right)$, the linear-programming problem involves observations from both period t and period $t+1$ because the reference technology relative to which the given input-output mix is evaluated is constructed from observations at the other period.

II.2 Explaining the Growth of the Agriculture Sector

Our model is similar to that of Coe and Helpman (1993) and Park (1995) and others, assuming that not only traditional labor and capital inputs affect the output level, domestic R&D capital as well as international spillovers also have significant impact. The general specification of the aggregate production, along with the expected signs, is as follows,

$$Output = f\,(\underset{+}{Capital},\ \underset{+}{Labor}, \underset{+}{domesticR\,\&\,D},\ \underset{?}{International\ Spillovers})\,.$$

The growth equation frequently used in empirical studies is thus specified as

$$\log \dot{TFP}_i = \alpha_{0i} + \alpha_d \log \dot{SRD}_{i(t-1)} + \alpha_f\,(\log \dot{IS}_{i(t-1)})\,.$$

In the above format, $T\dot{F}P$ represents the growth rate of total factor productivity. The growth rate of domestic R&D stock and international spillovers are denoted by $S\dot{R}D$ and $\dot{I}S$. Growth coefficient a represents disembodied technological change.

To make cross-country comparison, multiplicative dummies are added to our model. The dummy variables associated with domestic R&D are used to group sample economies according to their income and size following the classification rule provided by Pardy, et al. (1998) and Pray and Fugli (1998). Specifically, $D_1 = 1$ for China, which is classified as large-size and low-income in Pray and Fugli (1998). $D_2 = 1$ for Malaysia and Thailand, which are classified as middle-income countries in both studies. $D_3 = 1$ for Indonesia and Philippines, which are classified as mid-size and low-income in both studies. Finally, $D_4 = 1$ for Korea and Taiwan, which are classified as middle-income in Pardy et al. (1998). We separate these two countries from the other middle-income group due to geographic consideration. The base group for these four dummy variables is Japan. The dummy variables $Y_1 - Y_2$ are used to differentiate the country-specific effects of international spillovers. The base group for these eight variables is also Japan.

To infer the existence of international spillovers, a proxy index is constructed in our empirical analysis. The general form of the spillover index can be described as

$$IS_i = \sum_{j \neq i}^{N} \theta_{ij} R_j ,$$

where IS_i denotes the index of international spillovers for the *ith* country, and N is the number of its major trade partners. The absorption rate, denoted by θ_{ij}, ranges from zero to one. The absorption rate is the fixed proportion that foreign R&D is spilled over to the country.

Coe and Helpman (1995) constructed a foreign stock of spillovers that is based on the trade flows and the trade partners’¦ R& to examine the extent to which a country’¦s productivity level depending on foreign R&D capital stocks. The foreign R&D capital stock was calculated as an import-weighted sum of trade partners’¦ R&Dstock to reflect the possibility that a country receives relatively more knowledge spillovers from countries which relatively more goods and services are imported from. Our spillover index thus defined is calculated as

$$IS_i = \sum_{j \neq i}^{N} s_{ij} SRD_j ,$$

where s_{ij} is the *jth* country’¦s import share in *ith* country’¦s total imports.

Ⅲ. DATA DESCRIPTION

Our sample includes the agricultural production data for eight East Asian economies: China, Indonesia, Japan, Korea, Malaysia, Philippines, Taiwan, and Thailand, 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 choose the "crop primary" from the FAO database as our output variable. The crop production data reported in the FAO database refer to the actual harvested production from the field or orchard and gardens, excluding harvesting and threshing losses and that part of crop not harvested for any reason. The unit of crop production data is in metric tons (MT).

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 also in metric tons.

Our data for agricultural R&D expenditures is taken from Agriculture Science and Technology Indicators database. Because the data set does not include Taiwan and the Philippines, R&D expenditure for these two countries are calculated from average annual agricultural research expenditure provided in Pardy et al. (1998) and agricultural R&D intensity in Pray and Fugli (1998). Except for Taiwan, import shares for individual economies are taken from the statistical yearbook for Asia and the Pacific. External trade data for Taiwan are mainly taken from the statistical yearbook of the Republic of China.

Assuming an obsolescence rate of 0.10, the stock of agricultural R&D is calculated using the perpetual inventory method suggested in the R&D Master File, that is,

$$SRD_t = (1-\delta)SRD_{t-1} + RD_{t-1},$$

where RD_t denotes domestic R&D expenditures at time t and δ is the obsolescence rate. The initial level of R&D capital stock is calculated by dividing constant dollar R&D expenditure by the sum of the rate of obsolescence and the average rate of growth of R&D expenditure.

To take into account possible structural changes, our discussion is based on four separate periods, that is, 1961-1970, 1971-1980, 1981-1990 and 1990-2001. The summary statistics in Table 1 indicate that agricultural production in China, Japan, Indonesia, Philippines and Thailand increase over the entire time span. However, production in Taiwan, Malaysia, and South Korea experience a downward trend during the fourth period.

Tables 2, 3, and 4 present the trend of land, labor, and fertilizer use over time. The figures suggest that area harvested in Taiwan, Japan, and Korea is decreasing over time while an opposite trend is observed for the other five countries. As for agriculture labor, the tables indicate that labor use in China, Indonesia, Philippine, and Thailand all increase over time, a significant change is observed especially in China. Based on the figures in Table 4, we find that almost all countries increase their fertilizer use over the entire time span.

IV. RESULTS AND DISCUSSION

Geometric means of the Malmquist productivity-change indexes and the two components of growth for each sample economy are listed in Table 5. As noted by Fare et al. (1994), improvements in either productivity or any of the two components are associated with values exceeding unity, while values less than unity denote regress or deterioration of performance. Therefore, it is clear from Table 5 that the average performance of each economy, over the second period, is better than in the first period. However, although the productivity-change indexes suggest each of the economy made improvement over time, especially in the forth period, most of the East Asian agriculture experience either technical regress or efficiency loss, and thus deterioration in productivity during the 1980'¦s The only exceptions are Japan, Malaysia and Indonesia.

As for a country-to-country comparison, the first two economies of the previous exception – Japan and Malysia – show consistent technical progress or efficiency improvement over the entire time span. Agricultural productivity in the Philippines deteriorates because technical regress dominates efficiency improvement. Results in Table 5 also suggest that most economies experiencing deterioration in productivity show technological regress at the same time, which is especially true for the South East economies such as the Philippines and Thailand. We also observe similar patter of change in China and Indonesia during the 60's and Taiwan during the 80's. However, during 1981-2000, economies such as China, Korea and Taiwan experience efficiency loss, and thus deterioration in agricultural productivity.

In order to characterize the differences and similarities in growth patterns for the sample economies, further decomposition results of efficiency change and technical change are reported in Tables 6 and 7. In comparison, Korea has the lowest scale efficiency among all sample economies. Since the deterioration of productivity in Korea is mainly due to efficiency loss, it is a reasonable conjecture that the source of efficiency loss come from the scale component. Similar argument can be made for China during the 80's and Taiwan during the later decade. Our results also suggest that, with only very few exceptions, almost all East Asian economies achieve pure efficiency improvements over the entire time span.

According to Fare et al. (1997), input bias makes no contribution to productivity change under conditions such as constant-returns-to-scale technology and implicit Hicksian input-neutral technical change. Results in Table 6 further imply that for most East Asian economies, input bias contribute positively to the performance of the agriculture sector in the form of technical progress. However, constant returns to scale and Hicksian neutral technical change seem to characterize Korean agriculture.

Based on our previous argument, most economies experiencing deterioration in agricultural productivity show technical regress at the same time. Following Fare and Grosskopf (1996) and Fare et al. (1997b), for the one-out case as is ours, the technical-change index can be decomposed into the product of a magnitude index and an input-bias index. From Table 7, we can find the major source of technical regress for most economies is the deterioration in magnitude. This magnitude technical regress may provide a reasonable explanation to the deterioration of agricultural productivity experienced by the Philippines and Thailand, and especially Taiwan, over the entire time span. The case of Taiwan is slightly different in that, despite its input efficiency is the highest among all sample economies, its magnitude efficiency is also the lowest. Therefore, the first priority for the economy would be to expand the production scale to improve the productivity loss associated with magnitude technical regress.

In addition to investigating whether it is change in efficiency or technology that contributes to the growth in productivity, decomposition of productivity change allows identifying the innovators who actually cause the best-practice frontier to shift. Following Fare et al. (1994), the following conditions are used to identify the innovators under two alternative benchmark assumptions:

$$TC^{k} > 1,$$
$$D^{t}\left(x^{k,t+1}, y^{k,t+1}\right) > 1,$$
$$D^{t+1}\left(x^{k,t+1}, y^{k,t+1}\right) = 1.$$

Economies satisfying the three conditions outlined above can be regarded as having contributed to a shift in the frontier between period t and $t+1$. It is important to note here that as to who the innovators are might be sensitive to the different content and time span of the sample. As can be seen in Table 8, under the constant-return-to-scale benchmark, Taiwan, and Japan both show their capability to shift the grand frontier during the 1961-70 period. For the last three periods, one other economy – Thailand – gets in the list of major innovators. A closer look at the source of growth for the three major innovators in the region suggest that while biased technical change is the most important source of agricultural growth for Taiwan and Japan, the growth of Thailand is mainly driven by improvements in scale efficiency.

Table 9 reports Tobit regression results of the Malmquist indexes. With Japan as the base group, multiplicative dummy variables allow us to obtain country-specific coefficients for international spillovers. The results in Table 9 indicate that, for most East Asian economies, international spillovers contribute positively to the productivity growth in the agriculture sector. However, international spillovers are found to have dampened agricultural growth for Indonesia. The two facets of research noted by Jaffe (1986) and Griliches (1979) might provide a reasonable explanation to these results. Jaffe specifically emphasizes that in addition to spillovers, there is another facet of competition for the firm’¦s research activities. If we extend this concept to the research activities of foreign firms, then as foreign R&D capital accumulates, it is the facet of spillovers that brings up domestic firms’¦ productivity, yet the facet of competition will dampen domestic firms’¦ contestability. More recent evidences as provided by Aitken and Harrison(1999), Damijan et al. (2001), Djankov and Hoekman (2000), Konings (2001) and Zukowska-Gagelmann (2001) also suggest the negative effects of the presence of multinationals on domestic firms on average.

The argument can be further elaborated by looking at the unique character of agricultural technology. As noted by Hayami (1997), Sachs (2001) and Gutierrez and Gutierrez (2003), the transfer of agricultural technology beyond the geographic boundaries is more difficult than the transfer of industrial technology. Without adaptive research to assimilate and exploit the freely available knowledge, countries located in the tropical zones may not benefit from international spillovers of agricultural R&D. Consequently, international spillovers may not unambiguously enhance the growth of the agriculture sector. For economies like Indonesia, whose agricultural R&D intensity is relatively low, in comparison to seven other East Asian economies, it is possible to observe a negative relationship between productivity and international spillovers.

Further regression analyses where the dependent variables are the two components of total factor productivity, i.e., technical progress and efficiency change, respectively, suggest that a positive relationship between the two components and international spillovers prevail as in the previous regression.

Country-specific elasticities for international R&D spillovers are reported in Table 10. Our results indicate the elasticities for Malaysia and Thailand are higher than those for Indonesia and Philippines. This further suggests that for tropical countries, economies with higher income seem to benefit more from international spillovers of agricultural technology. However, we are not able to make the same conclusion for temperate economies. Japan, which has the highest income in the region, is also the one benefit least from international R&D spillovers. Likewise, although Gutierrez and Gutierrez (2003) found countries located in temperate zones benefit more from international spillovers, our results do not reveal a consistent relationship between the geographic factors and the growth of East Asian agriculture.

V. CONCLUDING REMARKS

This study focuses on identifying the sources of agricultural growth for eight East Asian economies – with special emphasis on international knowledge spillovers. The

Malmquist productivity-change indexes suggest each of the economy made improvement over time, especially in the forth period. Nevertheless, most of the East Asian agriculture experience either technical regress or efficiency loss, and thus deterioration in productivity during the 1980's. Our results also suggest that most economies experiencing deterioration in productivity show technological regress at the same time, which is especially true for the South East economies such as the Philippines and Thailand.

Further decomposition results of efficiency change and technical change indicate that, with only very few exceptions, almost all East Asian economies achieve pure efficiency improvements over the entire time span, while input bias contribute positively to the performance of the agriculture sector in the form of technical progress. However, the major source of technical regress for most economies is the deterioration in magnitude. This magnitude technical regress provides a reasonable explanation to the deterioration of agricultural productivity experienced by the Philippines and Thailand, and especially Taiwan, over the entire time span. The case of Taiwan is slightly different in that, despite its input efficiency is the highest among all sample economies, its magnitude efficiency is also the lowest.

Under the constant-return-to-scale benchmark, Taiwan, and Japan both show their capability to shift the grand frontier during the 1961-70 period. For the last three periods, one other economy – Thailand – gets into the list of major innovators. A closer look at the source of growth for the three major innovators in the region suggest that while biased technical change is the most important source of agricultural growth for Taiwan and Japan, the growth of Thailand is mainly driven by improvements in scale efficiency.

Regression analysis with the Malmquist productivity growth index and its two components as dependent variables indicate that, for most East Asian economies, international spillovers contribute positively to the productivity growth in the agriculture sector. However, international spillovers are found to have dampened agricultural growth for Indonesia. The results imply that without adaptive research to assimilate and exploit the freely available knowledge, countries located in the tropical zones may not benefit from international spillovers of agricultural R&D. Consequently, international spillovers may not unambiguously enhance the growth of the agriculture sector. For economies like Indonesia, whose agricultural R&D intensity is relatively low, we observe a negative relationship between productivity and international spillovers.

Country-specific elasticities for international R&D spillovers further suggests that for tropical countries, economies with higher income benefit more from international spillovers of agricultural technology. However, we were not able to make the same conclusion for temperate economies. Japan, which has the highest income in the region, is also the one benefit least from international R&D spillovers. Likewise, our results do not reveal a consistent relationship between the geographic factors and the growth of East Asian agriculture.

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Table 1. Average Agricultural Production: 1961-1970, 1971-1980, 1981-1990 and 1991-2001 unit: 1000mt

East Asian economies	Average Production			
	1961-1970	1971-1980	1981-1990	1961-1970
China	348,662	488,885	723,572	1,054,303
Japan	67,246	81,360	80,540	89,108
Korea	1,476	21,069	26,826	23,267
Taiwan	18,864	21,068	18,004	14,177
Indonesia	56,374	75,688	117,103	165,126
Malaysia	5,910	13,936	29,801	5,258
Philippines	40,407	60,619	63,871	71,882
Thailand	24,769	51,241	82,748	114,158

Sources: Calculated from FAO (FAOSTAT database) and Council of Agriculture, Executive Yuan, R.O.C.

Table 2. Average Land in Agricultural: 1961-1970, 1971-1980, 1981-1990 and 1991-2001 unit: ha

East Asian economies	Land in Agriculture			
	1961-1970	1971-1980	1981-1990	1991-2001
China	135,127,690	138,428,662	142,834,329	1,054,302,527
Japan	7,139,357	5,479,153	4,744,195	4,980,370
Korea	3,149,983	3,024,477	2,671,956	2,204,431
Taiwan	1,660,321	1,566,759	1,271,076	991,296
Indonesia	18,411,211	20,299,346	24,225,305	29,704,908
Malaysia	2,526,937	3,497,137	4,333,285	5,345,695
Philippines	8,913,896	11,502,466	12,704,129	12,651,680
Thailand	9,760,657	13,710,079	17,345,416	17,284,743

Sources: Calculated from FAO (FAOSTAT database) and Council of Agriculture, Executive Yuan, R.O.C.

Table 3. Average Annual Labor in Agricultural: 1961-1970, 1971-1980, 1981-1990 and 1991-2001 unit: 1000 persons

East Asian economies	Labor			
	1961-1970	1971-1980	1981-1990	1991-2001
China	598,172	708,044	790,557	849,296
Japan	24,566	15,859	9,481	7,052
Korea	14,675	13,855	9,785	5,157
Taiwan	1,743	1,575	1,223	903
Indonesia	71,813	78,234	87,507	93,637
Malaysia	5,410	5,553	5,045	4,231
Philippines	19,320	23,285	26,630	29,104
Thailand	24,264	28,549	30,612	30,996

Sources: Calculated from FAO (FAOSTAT database) and Council of Agriculture, Executive Yuan, R.O.C.

Table 4. Average Annual Quantities of Fertilizer in Agricultural: 1961-1970, 1971-1980, 1981-1990 and 1991-2001 unit: Mt

East Asian economies	Fertilizer Quantity			
	1961-1970	1971-1980	1981-1990	1991-2001
China	1,691,214	7,434,063	37,669,870	64,492,585
Japan	3,083,434	4,133,060	3,610,850	3,514,964
Korea	803,960	1,489,554	1,667,999	1,797,877
Taiwan	78,606	1,147,867	1,218,784	1,299,665
Indonesia	179,528	1,006,970	3,651,397	4,876,664
Malaysia	144,921	435,157	1,332,631	2,295,427
Philippines	151,802	408,504	803,767	1,294,428
Thailand	91,999	275,568	1,135,840	2,909,830

Sources: Calculated from FAO (FAOSTAT database) and Council of Agriculture, Executive Yuan, R.O.C.

Table 5. Decomposition of the Malmquist Productivity-Change Index

East Asian economies	Malmquist			
	1961-1970	1971-1980	1981-1990	1961-1970
China	0.826	1.003	0.982	1.021
Japan	1.032	1.027	1.013	1.023
Korea	1.033	1.010	0.992	1.022
Taiwan	1.012	1.000	0.989	1.014
Indonesia	0.973	0.995	1.008	1.020
Malaysia	1.035	1.068	1.001	1.057
Philippines	0.992	0.999	0.984	0.984
Thailand	0.981	1.037	0.952	1.000
	Technical Change			
China	0.904	1.001	1.001	1.011
Japan	1.013	1.025	1.013	1.023
Korea	1.012	1.004	1.002	1.007
Taiwan	1.012	1.000	0.989	1.017
Indonesia	0.978	1.011	0.998	1.003
Malaysia	1.014	1.005	1.013	1.039
Philippines	0.992	0.999	0.984	0.984
Thailand	0.959	1.035	0.951	0.998
	Efficiency Change			
China	0.967	1.016	0.984	1.013
Japan	1.024	1.002	1.000	1.000
Korea	1.024	1.013	0.991	1.017
Taiwan	1.000	1.000	1.000	0.997
Indonesia	0.991	1.001	1.015	1.020
Malaysia	1.024	1.064	0.988	1.019
Philippines	1.000	1.000	1.000	1.000
Thailand	1.031	1.004	1.000	1.000

Table 6. Decomposition of Efficiency Change

East Asian economies	Scale Efficiency			
	1961-1970	1971-1980	1981-1990	1991-2001
China	0.967	1.016	0.984	1.013
Japan	1.024	1.002	1.000	1.000
Korea	1.004	0.987	0.995	0.983
Taiwan	1.000	1.000	1.000	0.997
Indonesia	0.994	1.002	0.996	1.020
Malaysia	1.024	1.064	0.986	1.017
Philippines	1.000	1.000	1.000	1.000
Thailand	1.001	1.004	1.000	1.001
	Pure Efficiency			
China	1.000	1.000	1.000	1.000
Japan	1.000	1.000	1.000	1.000
Korea	1.034	1.027	0.997	1.043
Taiwan	1.000	1.000	1.000	1.000
Indonesia	0.995	0.993	1.018	1.000
Malaysia	1.000	1.000	1.001	1.001
Philippines	1.000	1.000	1.000	1.000
Thailand	1.030	1.000	1.000	1.000

Table 7. Decomposition of Technical Change

East Asian economies	Magnitude			
	1961-1970	1971-1980	1981-1980	1991-2001
China	0.874	0.996	1.002	1.010
Japan	1.012	0.994	0.997	1.000
Korea	1.012	1.003	1.003	1.007
Taiwan	0.970	0.966	0.956	1.009
Indonesia	0.938	1.025	0.998	1.004
Malaysia	1.013	1.005	1.013	1.033
Philippines	0.939	0.946	0.934	0.948
Thailand	0.944	1.001	0.900	0.992
	Input Bias			
China	1.121	1.006	0.999	1.002
Japan	1.001	1.031	1.016	1.023
Korea	1.000	1.002	1.000	1.000
Taiwan	1.045	1.039	1.034	1.008
Indonesia	1.051	0.985	1.000	0.998
Malaysia	1.001	1.000	1.000	1.006
Philippines	1.060	1.060	1.054	1.037
Thailand	1.022	1.032	1.073	1.006

Table 8. Economies Shifting the Frontier, 1961-2001

Year	Constant Returns Benchmark	Year	Constant Returns Benchmark
1961 — 1962	—	1981 — 1982	—
1962 — 1963	—	1982 — 1983	—
1963 — 1964	—	1983 — 1984	Japan, Philippine
1964 — 1965	Taiwan	1984 — 1985	Japan, Thailand
1965 — 1966	—	1985 — 1986	—
1966 — 1967	Indonesia	1986 — 1987	Taiwan
1967 — 1968	Taiwan	1987 — 1988	Taiwan
1968 — 1969	—	1988 — 1989	Philippine, Taiwan, Thailand
1969 — 1970	Japan, Thailand	1989 — 1990	Japan
1970 — 1971	Taiwan	1990 — 1991	—
1971 — 1972	—	1991 — 1992	Taiwan, Thailand
1972 — 1973	—	1992 — 1993	—
1973 — 1974	Indonesia, Japan	1993 — 1994	Taiwan
1974 — 1975	Japan, Philippine	1994 — 1995	Japan, Thailand
1975 — 1976	Thailand	1995 — 1996	—
1976 — 1977	Taiwan, Thailand	1996 — 1997	Japan, Taiwan
1977 — 1978	Japan	1997 — 1998	—
1978 — 1979	—	1998 — 1999	—
1979 — 1980	Thailand	1999 — 2000	Philippine
1980 — 1981	—	2000—2001	Japan

Table 9. Results of the Tobit Regression

Variables	TFP		TECH		EFFI	
	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error
X2	0.9412*	0.2043*	0.9194	0.2032	0.9324*	0.2045
X3	1.0271*	0.2832*	1.0544*	0.2817	0.9990*	0.2835
D1	-0.5670	0.2585*	-0.5734	0.2571	-0.5582*	0.2588
D2	-4.4280	1.6775*	-4.4160	1.6684	-4.5025*	1.6792
D3	-8.4413	16.2901	-8.5844	16.2011	-11.2603	16.3067
D4	-5.2255	1.7967*	-5.2037	1.7868	-4.8699*	1.7985
Y1	0.2811*	0.4033	0.3111	0.4011	0.3155	0.4037
Y3	0.2622	0.2751	0.2451	0.2736	0.2777	0.2754
Y4	-1.4390	0.2485*	-1.4235*	0.2472	-1.3898*	0.2488
Y5	0.7591	0.2730*	0.7125*	0.2715	0.7735*	0.2733
Y6	1.6219	1.2238	1.6057	1.2171	1.8974	1.2251
Y7	3.9016	0.7946*	3.8743*	0.7903	3.7674*	0.7954
Y8	1.8078	0.5957*	1.7812*	0.5924	1.9103*	0.5963

Table 10. Estimated Elasticities of Growth and Its Components, with respect to International Spillover Index

Country	Malmquist	ETECH	EEFFI
Large, low-income			
China	0.49473	0.50129	0.47057
High Income			
Japan	0.41041	0.42341	0.40598
Korea	0.56943	0.58904	0.5556
Taiwan	1.55031	1.54902	1.50604
Middle-Income			
Malaysia	0.89269	0.90268	0.90048
Thailand	1.54856	1.55903	1.56269
Mid-size,Low-income			
Indonesia	-0.24199	-0.21742	-0.2278
Philippines	0.47977	0.49246	0.46185