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# *Agricultural Productivity Growth in Asian Countries*

## INTRODUCTION

The agricultural sector in Asian countries is being transformed from a traditional to a modern one. In order to increase production, more modern inputs such as high-yielding varieties, fertilizer and machinery have been applied. As a result, agricultural production has grown rapidly. However, the question of the role of agricultural total factor productivity (TFP) in output growth has not yet been answered. This study has been undertaken in order to answer the question. To measure agricultural TFP, the Malmquist productivity index is used because of its desirable properties. One of them is that the index decomposes productivity change into two components: technical efficiency change (TEC) and technical change (TC). This property is very useful, since the policies required to address a decline in productivity growth due to increased inefficiency are likely to be different from those required to address a decline stemming from a lack of technical change (Grosskopf, 1993).

A number of studies have examined agricultural productivity differences among countries using the Malmquist productivity index (see, for example, Thirtle *et al.*, 1995; Fulginiti and Perrin, 1997, 1998; Arnade, 1998). In this paper the Malmquist productivity index is constructed with respect to a *contemporaneous* frontier technology by applying a linear programming method known as data envelopment analysis (DEA). One of the critical issues not discussed in the previous studies is the dimensionality problem; that is, the dimensionality of the input/output space relative to the number of observations in the cross-section. The problem arises when the number of observations is relatively small compared with the number of factors (outputs plus inputs) used. The presence of the dimensionality problem may create two main difficulties. First, given enough inputs, all or most of the countries can be rated 'efficient' as a direct result of the dimensionality problem (Leibenstein and Maital, 1992). This causes the changes of technical efficiency to grow at zero rate and creates the situation where technical efficiency changes make no contribution to productivity growth. Second, production technologies move back and forth, producing a large number of intersections, making the results difficult to interpret. There is no exact rule on the relationship between the number of factors and the number of observations that should be used in the

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model. Charnes and Cooper (1990) stated that, for the DEA model to be discriminatory, the number of observations should exceed the number of factors by at least three times, while Fernandez-Cornejo (1994) argued that it should be larger than five. However, the simulation study done by Smith (1997) showed that, even though the number of observations exceeds the number of factors by more than 13 times, it still overestimates the true efficiency by 27.1 per cent.

Surprisingly, little attention has been paid to the problem of dimensionality in empirical studies, not only for the agricultural sector but also in general. Since the problem affects the results severely, this paper considers the issue further in empirical analysis. As a preliminary attempt, the Malmquist productivity index is constructed with respect to the contemporaneous frontier, following previous empirical studies. Further investigation shows that the results are unstable because of the dimensionality problem. For this reason, the Malmquist productivity index with respect to the contemporaneous frontier should not be used in a study involving only a small number of cross-section observations and a complicated technology. In order to solve the problem, this paper applies the Malmquist technique with respect to the *sequential* frontier, as the best alternative. It moves on to a description of sources and definitions of the data used before reaching the empirical results and conclusions.

## MALMQUIST PRODUCTIVITY INDEX: SEQUENTIAL FRONTIERS

Tulkens and Vanden Eeckaut (1995) explained the basic difference between the contemporaneous and sequential frontiers. In the former approach, the frontier is constructed at *each period* using the observations at *that period only*; that is, the frontier is constructed for each year separately. It is assumed that the frontiers at each year are completely different from one another, without there being any *a priori* relation between them. The frontier may move inward, outward or intersect at any time, producing regress and progress in technology. This approach may be appropriate when the number of observations is large enough and the time period is short. When the number of observations is small, it can easily create the dimensionality problem. In the sequential approach, the frontier is constructed at *each year* on the basis of all observations from *the first year up to the year considered.* Using this approach, the frontier may move only by inward shift (in input orientation) producing only technological progress. No outward or intersect shift is possible, meaning that the possibility of technological decline is excluded. Technical knowledge is assumed to accumulate over time, that is, information is not lost as in econometric approaches. This can be appropriate when the number of observations is small and the time period is large. Furthermore, it will remove the dimensionality problem.

The Malmquist productivity index with respect to the sequential frontier can be described briefly as follows. Let country $j = 1, 2, \ldots, J$ use inputs $x^t \in R_+^N$ to produce outputs $y^t \in R_+^M$ during the period $t = 1,2,\ldots, T$. The production technology set can be defined as

$$S^{(1,t)} = \{(x^s, y^s) : x^s \text{ can produce } y^s\}, s = 1 \text{ up to } s = t$$

Alternatively, the production technology may also be represented with an input requirement set $L^{(1,t)}(y^t) = \{x^t: (x^t, y^t) \in S^{(1,t)}\}$. The within-period input distance functions are defined as:

$$D_i^s(y^t, x^t) = \max\{\lambda : (x^t / \lambda) \in L^{(1,t)}(y^t)\}$$

and

$$D_i^{s+1}(y^{t+1}, x^{t+1}) = \max\{\lambda : (x^{t+1} / \lambda) \in L^{(1,t+1)}(y^{t+1})\}$$

The values of these distance functions are equal to or greater than one. Only if the values are equal to one are the countries efficient and therefore on the frontier. The adjacent-period input distance functions may also be defined as

$$D_i^s(y^{t+1}, x^{t+1}) = \max\{\lambda : (x^{t+1} / \lambda) \in L^{(1,t)}(y^{t+1})\}$$

and

$$D_i^{s+1}(y^t, x^t) = \max\{\lambda : (x^t / \lambda) \in L^{(1,t+1)}(y^t)\}$$

These four input distance functions can be used to construct the Malmquist productivity index. Following Fare *et al.* (1994a, 1994b), the Malmquist productivity index using input orientation for country $i$ between period $s$ and $s + 1$ is defined as

$$M_i^{s,s+1} = \left( \frac{D_i^s(y^t, x^t)}{D_i^{s+1}(y^{t+1}, x^{t+1})} \right) \left( \frac{D_i^{s+1}(y^{t+1}, x^{t+1})}{D_i^s(y^{t+1}, x^{t+1})} \frac{D_i^{s+1}(y^t, x^t)}{D_i^s(y^t, x^t)} \right)^{1/2}$$

The ratio in the first bracket captures technical efficiency change (TEC) and that in the second provides a measure of technical change (TC). TEC is greater than, equal to or less than unity as technical efficiency accordingly improves, remains unchanged or declines between periods $s$ and $s + 1$. TC is greater than or equal to unity, and shows whether the frontier is improving or stagnant. *Notice that, using the sequential frontier, TC cannot decline.* The value of the Malmquist productivity index is greater than, equal to or less than unity. If the value of the index is greater than unity, it reveals improved productivity and, if the value is less than unity, a decrease in productivity occurs. For detailed explanation of the methodology and the calculation, see Grifell-Tatje and Lopez Sintas (1995) and Suhariyanto (1999). Note that the input-based Malmquist productivity in this study is expressed as the inverse of that in Fare *et al.* (1994a) for ease of interpretation.

## SCOPE OF THE STUDY AND DATA SOURCES

The number of countries included in this study is 18 and the time period covered is 1961–96. Agricultural TFP is measured using one output–five input technology. The inputs are land, labour, livestock, fertilizer and machinery. The data on output are obtained from USDA, while the input information comes from FAO. In the analysis 'aggregate agricultural output' is the total value of agricultural production which is expressed in 1979–81 international dollars and includes food and non-food output (fibres, hides and skins, rubber and tobacco). 'Agricultural land' is the total area of arable and permanent cropland, measured in 1000 hectares, while 'agricultural labour' (in thousands) covers the economically active population in agriculture. 'Livestock' is the aggregate of the various kinds of animals in livestock units irrespective of their age and the place or purpose of their breeding. It includes cattle, sheep, goats, pigs, mules, horses, asses, buffaloes, camels, ducks, chicken and turkeys. The weights for aggregation are those used by Hayami and Ruttan (1985, p.450). 'Fertilizer' is the sum of the nitrogen (N), potassium ($P_2O_5$) and phosphate ($K_2O$) content of fertilizer used, measured in thousands of metric tonnes of nutrient units. The 'Machinery' variable covers the total number of wheeled and crawler tractors (excluding garden tractors) used in agriculture.

## EMPIRICAL RESULTS AND CONCLUSIONS

The Malmquist productivity index is computed for 18 Asian countries over the period 1961–96 under the assumption of constant returns to scale using input orientation. In order to guarantee that the dimensionality problem does not exist at the beginning of the period of the study, it is assumed that technology in Asian agriculture was stagnant in 1961–65. This assumption is quite reasonable since the 'Green Revolution' did not occur in most Asian countries until the late 1960s. Using the assumption, the number of observations at the beginning of the period of the study is $18 \times 5 = 90$ observations. The ratio of the number of observations to the number of factors (1 output plus 5 inputs) is 15. Thus the condition that the ratio should exceed 13 in order to avoid the dimensionality problem, as shown in the simulation study done by Smith (1997), is satisfied.

Table 1 presents the annual growth rates of agricultural TFP, TEC, TC, output and inputs. The results show that only nine out of 18 Asian countries have positive productivity growth during the 1965–96 period. Four countries (China, Mongolia, Indonesia, Sri Lanka) have less than 1 per cent positive growth, two (Laos PDR and the Philippines) are between 1 and 2 per cent and only three countries (Malaysia, South Korea and Japan) grow at more than 2 per cent per annum. The productivity growth in these three countries is totally attributable to innovation, since their agricultural sectors are efficient for most of the period of study. Using the translog total cost function, Kuroda (1997) also found that, on average, 90 per cent of the TFP growth in Japanese agriculture is explained by the effect of technological change for the period 1960–90.

**TABLE 1** *Percentage annual growth rates of productivity, output and inputs, 1965–96**

| Countries | TEC | TC | TFP | Output | Land | Labour | Livestock | Fertilizer | Machinery |
|---|---|---|---|---|---|---|---|---|---|
| *East Asia* | | | | | | | | | |
| China | –0.41 | 0.88 | 0.47 | 4.34 | 0.14 | 1.77 | 2.45 | 10.64 | 8.85 |
| Japan | 0.00 | 2.70 | 2.70 | 1.15 | –0.92 | –4.06 | 1.66 | –0.13 | 15.16 |
| Korea, DPR | –0.70 | 0.40 | –0.30 | 3.99 | 0.54 | 0.91 | 2.88 | 4.60 | 6.84 |
| Korea, Rep. | 0.00 | 3.30 | 3.30 | 3.78 | –0.26 | –1.71 | 3.46 | 3.05 | 31.77 |
| Mongolia | –0.31 | 0.82 | 0.51 | 0.90 | 2.54 | 0.60 | 0.32 | 10.63 | 3.22 |
| *Southeast* | | | | | | | | | |
| Cambodia | –3.02 | 1.19 | –1.83 | 0.27 | 0.92 | 1.07 | 0.98 | 3.51 | 0.99 |
| Indonesia | –0.45 | 0.63 | 0.18 | 4.04 | 0.60 | 1.65 | 1.42 | 11.37 | 7.60 |
| Laos, PDR | –0.26 | 2.02 | 1.76 | 3.60 | 1.08 | 1.81 | 2.77 | 9.96 | 9.67 |
| Malaysia | 0.00 | 3.55 | 3.55 | 5.25 | 1.96 | –0.01 | 1.05 | 8.77 | 9.58 |
| Myanmar | –0.09 | 0.07 | –0.02 | 2.78 | –0.07 | 1.86 | 2.04 | 9.21 | 5.39 |
| Philippines | 0.07 | 1.26 | 1.33 | 2.74 | 1.29 | 1.66 | –0.42 | 5.90 | 2.42 |
| Thailand | –1.33 | 0.33 | –1.00 | 3.89 | 1.87 | 1.84 | 0.37 | 12.32 | 11.10 |
| Vietnam | –0.71 | 0.54 | –0.17 | 3.67 | 0.33 | 1.78 | 1.51 | 7.66 | 12.24 |
| *South Asia* | | | | | | | | | |
| Bangladesh | –0.77 | 0.35 | –0.42 | 1.74 | 0.06 | 1.04 | 0.37 | 11.19 | 6.19 |
| India | –1.05 | 0.55 | –0.50 | 2.90 | 0.15 | 1.42 | 0.81 | 10.35 | 11.88 |
| Nepal | –0.89 | 0.20 | –0.70 | 2.73 | 1.17 | 1.96 | 2.13 | 16.48 | 10.35 |
| Pakistan | –1.29 | 0.82 | –0.47 | 3.72 | 0.54 | 2.11 | 2.27 | 11.85 | 13.54 |
| Sri Lanka | –0.62 | 1.29 | 0.67 | 1.49 | 0.19 | 1.63 | 0.19 | 2.94 | 5.30 |

*Note*: *The data used cover 1961–96. However, the Asian data for 1961–65 have been pooled to ensure an adequate sample size at the beginning of the period of study.

For the other six countries which have positive growth, the agricultural productivity increases are mainly due to improvement in innovation (technical progress). All of them, except the Philippines, have experienced a fall in technical efficiency.

The other nine countries have experienced a productivity decline. They are North Korea, Cambodia, Myanmar, Thailand, Vietnam and all the South Asian countries, except Sri Lanka. Technical efficiency in all these cases has declined and at the same time there is no significant technological progress, except in Cambodia. In general, these results are in agreement with those obtained from the previous studies, even though the magnitude of growth rates differs slightly. Arnade (1998) found that these nine countries are among others whose agricultural productivity growth declined over the period 1961–93. Wong (1989) concluded that productivity had declined in Indian agriculture during 1964–83 at an annual rate of 1.63 per cent. The same results for Indian and Pakistan agriculture were also obtained by Frisvold and Lomax (1991), who estimated that agricultural productivity declined at annual rates of 1.15 per cent in India and 1.43 per cent in Pakistan during the period 1970–80.

Table 1 also presents the annual growth rates of output and inputs. It appears that Japan is the only Asian country which obtains growth in agricultural output due to growth in agricultural productivity. Notice that productivity growth in South Korea and Malaysia, even though high, is still lower than agricultural output growth. In South Korea, agricultural output growth stems from increased productivity and machinery use, while in Malaysia, it is caused by growth in productivity, fertiliser and machinery use. In the other Asian countries, agricultural growth has been due principally to increased input supplies. The growth of input use, especially fertilizer and machinery, in Asian countries is spectacular during the period 1965–96. This leads to a high growth rate of agricultural output, but not productivity. In Indonesia, for instance, the use of fertilizer and tractors, growing by almost 12 per cent and 8 per cent per year, respectively, result in an increase of agricultural output at an annual growth rate of 4.04 per cent. However, the productivity in this country increases only very slightly, at an average growth rate of 0.20 per cent per year. The same pattern also occurs in China. Countries in South Asia, except Sri Lanka, exhibit even more dramatic results. In Bangladesh, India, Nepal and Pakistan, both fertilizer and tractor use grow by more than 10 per cent annually, but productivity growth is negative. The evidence of declining productivity in many Asian countries shows that increased agricultural output has been achieved mainly by increasing the use of inputs. Thus agricultural output in most Asian countries is input-led rather than productivity-led.

A key finding from this study, therefore, is that, while agricultural output grows rapidly, agricultural productivity has declined in nine of the 18 Asian countries during the period 1965–96. This result confirms previous findings. Using the Malmquist productivity index with respect to a contemporaneous frontier, Fulginiti and Perrin (1997, 1998) and Arnade (1998) found that, on average, agricultural productivity seems to have declined in many developing countries. Using a different technique, Frisvold and Lomax (1991) also concluded that the developing countries experienced negative productivity growth between 1970 and 1980, with the notable exception of the Philippines. Note that, in the previous studies, a decline in productivity is mainly attributed to technological regression since the method they used allows a decline in technology. This study suggests a different explanation since the method used, which is a sequential frontier, excludes the possibility of technological decline. It can be concluded that agricultural productivity in Asian countries has dropped because many countries have experienced a loss in technical efficiency and stagnation in technological progress.

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