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Development, Transition and Agricultural Performance in Asia

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Supawat Rungsuriyawiboon[1]

ABSTRACT

This study aims to investigate interregional and intercountry differences in terms of the magnitude and direction of agricultural growth in Asian countries. In the paper we give special attention to the transition economies. This study utilizes a parametric output distance function approach to decompose total factor productivity (TFP) growth into its associated components. The paper also examines how input and output intensities shift in response to the adoption of innovations. The most recent Food and Agricultural Organisation (FAO) data set of 27 Asian countries over the period from 1980-2004 is used. Our major finding indicates that Asian countries on average achieved TFP growth at nearly 2 percent per annum. However, there were large differences among the transition countries in terms of the magnitude and direction of TFP growth. Some transition countries such as China and Mongolia exhibited above average growth. Others, such as, Kyrgyzstan, Uzbekistan, Laos, and Vietnam did not do so well.

Keywords: Agriculture, Productivity, Transition countries, Biased technical change, Asia

บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์เพื่อตรวจสอบและเปรียบเทียบความแตกต่างของผลการดำเนินการทางการเกษตรของประเทศต่างๆ ในทวีปเอเชีย โดยมุ่งศึกษาถึงผลการดำเนินการของกลุ่มประเทศเปลี่ยนผ่านในภูมิภาคนี้ แบบจำลองการประมาณค่าตัวแปรจากฟังก์ชันระยะทางผลผลิตถูกกำหนดขึ้นเพื่อใช้แยกค่าการเติบโตผลิตภาพทางการเกษตรออกเป็นองค์ประกอบต่างๆ ที่สำคัญ นอกจากนั้น งานวิจัยนี้ยังได้กำหนดแบบจำลองเพื่อใช้ศึกษาถึงผลของการใช้ปัจจัยการผลิตและผลผลิตชนิดต่างๆ ที่ได้ที่ส่งผลต่อการนำเอาเทคโนโลยีใหม่ๆ มาใช้ในกระบวนการผลิต โดยงานวิจัยนี้อาศัยฐานข้อมูลการผลิตทางการเกษตรของประเทศต่างๆ ในทวีปเอเชียจำนวน 27 ประเทศขององค์กรอาหารและการเกษตรของสหประชาชาติ ระหว่างปี ค.ศ. 1980-2004 ผลการศึกษาแสดงให้เห็นว่า ค่าเฉลี่ยการเติบโตผลิตภาพปัจจัยการผลิตรวมทางการเกษตรในทวีปเอเชียมีค่าเท่ากับ 2 เปอร์เซ็นต์ต่อปีระหว่างปี ค.ศ. 1980-2004 ปัจจัยหลักที่ส่งผลต่อการเติบโตผลิตภาพทางการเกษตร คือ การเปลี่ยนแปลงเทคโนโลยี นั่นแสดงว่าประเทศต่างๆ ได้มีการนำ

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เอาเทคโนโลยีใหม่ๆ มาใช้ในกระบวนการผลิตเพื่อส่งเสริมให้เกิดการเติบโตผลิตภาพทางการเกษตรขึ้นในภูมิภาค ผลการศึกษายังแสดงให้เห็นว่าค่าการเติบโตผลิตภาพปัจจัยการผลิตรวมของประเทศต่างๆ ในภูมิภาคเอเชียมีความแตกต่างกันมาก ประเทศที่แสดงค่าการเติบโตผลิตภาพปัจจัยการผลิตรวมทางการเกษตรอยู่ในเกณฑ์สูง ได้แก่ ประเทศจีน และมองโกเลีย ในขณะที่ประเทศคีร์กีซสถาน อุซเบกิสถาน ลาว และเวียดนาม แสดงค่าการเติบโตผลิตภาพปัจจัยการผลิตรวมทางการเกษตรอยู่ในเกณฑ์ต่ำ

คำสำคัญ: การเกษตร ผลิตภาพ ประเทศเปลี่ยนผ่าน การเปลี่ยนแปลงเทคโนโลยีที่เบี่ยงเบน เอเชีย

1. INTRODUCTION

During the past two decades, Asia has experienced impressive growth in rice and wheat production after the Green Revolution was successfully introduced (Pingali and Heisey, 1999). The Green Revolution in Asia was achieved through the application of the high-yielding varieties of major cereals, chemical fertilizers, pesticides and the development of irrigation system. Increased input use such as landmass, number of tractors, fertilizer and so on, however, cannot guarantee a long-run sustainable growth rate of yields and output (Huang, Pray and Rozelle, 2002). Over time, cultivated land per capita has declined due to population growth, urbanization, industrialization in a set of rapidly developing Asian nations that were already characterized as relatively limited in terms of their land resources. The decline in arable area was exacerbated by a series of land degradation processes (Pingali et al., 1997). Moreover, rapid economic growth in many countries has enhanced the availability of off-farm employment and increased the opportunity cost of rural labor.

In fact, it is possible to paint a fairly pessimistic picture of Asian agriculture. As well-established in the literature, agricultural production depends critically on the factors that contribute to the improved TFP beyond the quantity of resources, including labor, land and fertilizer. Pingali et al. (1997) show that the potential sources of inputs are mostly exhausted in many countries. Hence future agricultural growth in most countries will not rely on the mobilization inputs but will mainly depend on rising productivity, including the adoption of innovations, a more efficient use of inputs and an improved efficiency by the expansion of the scale of production. However, over the long run the record in the literature is not very encouraging. Indeed, in one of the most exhaustive studies of the productivity of Asian agriculture, Suhariyanto and Thirtle (2001) estimated that between 1965 and 1996 the annual growth rate of TFP was only 0.31 percent, although over their study period the rate was rising somewhat.

For several reasons in our analysis we seek to build on the previous literature and believe it is time to reevaluate TFP in Asia. The literature on the analysis of intercountry differences in agricultural efficiency and TFP growth has expanded significantly in the past two decades due to the availability of new panel data sets and the development of frontier analysis. One type of frontier analysis, Stochastic Frontier Analysis (SFA) which is a parametric approach, allows the analyst to not only calculate TFP, but also decompose changes in TFP into three components: technical change, changes in technical efficiency and scale economy changes.[2] Previous attempts to examine TFP across a wide number of Asian countries (e.g., Suhariyanto and Thirtle, 2001) used an index approach. Details on the SFA technique are described later in the paper and in Coelli et al (2005).

[2] Another type of frontier analysis is called non-parametric; it is also known as a Data Envelopment Analysis (DEA) model.

In our paper, we also pay particular attention to the former centrally planned economy (CPE) that are currently in transition—for example, countries like China and Mongolia in East Asia; Laos, Myanmar and Vietnam in Southeast Asia; and the nations of Central Asia. It is important when trying to sketch a picture of all of Asia that transition countries be included for several reasons. In the past because of data problems many analyses of the economy just ignored most of these countries (e.g., Young, 1995; Otsuka, Chuma and Hayami, 1992; Pingali et al., 1997). Yet these countries account for almost half of the regions population and more than half of the land area. In Suhuriyanto and Thirtle (2001), although China and some East and Southeast Asia nations were included, those in Central Asia were not.

Including the transition countries is also important since without them it is difficult to predict what is happening for overall Asia since predicting the direction of TFP change is difficult for transition countries. On the one hand they generally have a long history of investment into pro-technology R&D and, in some cases, may be somewhat behind the rest of the world in terms of level of new technology adoption. As a result of this, it might be expected that there is relative great potential for expanding TFP by improving the technological base of some of the nations and this in turn would suggest that there could be above average shifts in TFP. However, at the same time, these countries are, by definition, in transition. As a result it is possible that in some cases this means that the set of institutions that are needed in agriculture to produce and extend new technologies are weak or deteriorating enough (because they are in transition and there has not been an equilibrium attached) that there has been a fall in technical efficiency. Indeed, in a recent book that examines the impact of the economic reforms on agricultural production in transition countries found that the effect differed widely across countries and over time within countries (Swinnen and Rozelle, 2006). Moreover, given the timing of the analysis in Suhuriyanto and Thirtle (2001), which was conducted in the years soon after the beginning of the reforms (which did examine the cases of China and Vietnam, but not Central Asia), it is possible that it was difficult to understand the real situation in transition countries since there was still a lot of disequilibrium in the 1970s, 1980s and early 1990s in many transition countries. As a result, making an assessment with data through the mid-2000s may be able to reveal what is happening (and what will be happening) to transition countries.

Finally, increased availability of data on enough variables on enough countries for sufficient years makes it possible to use the new methods to rigorously analyze differences in productivity for a large number of nations over time and update the analysis to a more recent time period. In the past, a number of papers looked at the effect of market-orient reforms on agricultural performance (e.g., Lerman, 2000; Macours and Swinnen, 2002; and Lissitsa, Rungsuriyawiboon and Parkhomenko, 2007). But limited data kept the authors from looking at a broad range of countries and only allowed them to use partial measures of productivity. Swinnen and Rozelle (2006) is one of the only cross regional papers that examines intercountry comparisons (including transition nations) of agricultural TFP. In their work, however, they admit that the coverage of their work is spotty and their use of different productivity measures in different countries does not facilitate comparisons. In our paper, we examine 27 countries for 25 years. The size of this sample allows us to examine TFP for almost all major nations in Asia over time.

To fill these gaps, the main purpose of the paper is to understand the state of productivity improvements in Asia the world's most populated region. To meet this overall goal we have three specific objectives. First, we seek to measure TFP growth in Asia for the years between 1980 and 2004. Second, this study proposes a parametric decomposition of productivity growth using an output distance function. This approach allows one to perform a hypothesis test whether productivity growth can be decomposed into three of the sources of productivity growth: technical change, changes in technical efficiency and shifts in scale economies. This paper also highlights the contribution of scale change as another major source in driving agricultural productivity growth in Asian countries. In addition, the technical change component is further decomposed to uncover evidence of how input and output intensities shift in response to the adoption of innovations. Finally, because of the importance transition countries, we are going to pay particular attention to their trends and the contribution to overall Asian TFP growth.

The reminder of the paper is organized as follows. The next section presents the methodology used to construct the TFP growth and its decomposition. The following section discusses the data set and the definitions of the variables used in this study. The empirical results are presented and discussed in the next section. Finally, the last section shows the concluding remarks from the study.

2. MODEL SPECIFICATION

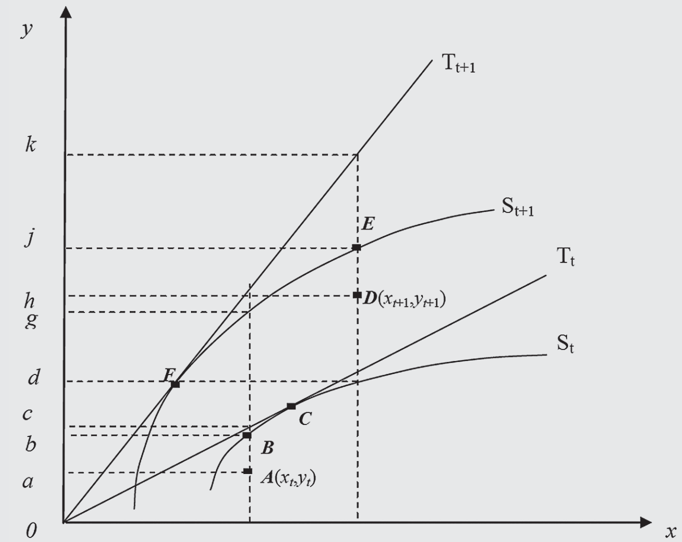
2.1 DECOMPOSITION OF A TFP GROWTH

TFP growth is theoretically defined as the residual growth in outputs not explained by the growth in input use. For example, if agricultural output grew by 2.20 percent and total inputs grew by 1.05 percent between 2004 and 2005, then TFP would grow by 1.15 percent during the years between 2004 and 2005. TFP growth in agriculture is important as it is one source for increasing food production, keeping agricultural prices low and raising incomes of farmers.

TFP growth, however, is not always easy to track or to predict since there are many different factors that affect its growth. To help understand the forces that affect the growth of TFP in a given economy, conceptually it is possible to decompose TFP into three parts—technical change (TC); changes in technical efficiency (TEC) and changes in scale economies (SEC). The TC-related effect results when the “frontier of production” shifts and there is more output for a given set of inputs, given that producers are already producing efficiently. The TEC-related effect (when it is positive) explains the “catching-up” part of the TFP growth. In other words, TEC occurs when output rises while inputs are constant, given a specific production frontier, because the producer is using the inputs more efficiently. Finally, the SEC-related effect represents the effect of adjusting the optimal farm size to the TFP growth. Understanding which of these components are driving overall TFP growth is important because they provide useful information to policy makers that want to design suitable policies to maintain or achieve greater rates of TFP growth.

Figure 1 illustrates the decomposition of TFP growth into its TEC, TC and SEC components. Consider production technologies of a given industry (e.g., agriculture) for the time period, t and $t+1$. S_t and S_{t+1} are constructed using the input-output bundles of all producers in period t and $t+1$, respectively. They represent the production technologies under variable returns to scale (VRS) at the time period t and $t+1$. The boundary of the production technology set indicates the production frontier. The movement of the production frontier from S_t to S_{t+1} represents TFP growth due to TC. A measure of TC can be defined as the geometric mean of the shift in S_t and S_{t+1} at input levels x_t and x_{t+1} which is given by the ratio $\left[\frac{\left(\overline{0h}/\overline{0d}\right)}{\left(\overline{0h}/\overline{0j}\right)} \times \frac{\left(\overline{0a}/\overline{0b}\right)}{\left(\overline{0a}/\overline{0g}\right)}\right]^{1/2}$. The shift of the production frontier from S_t to S_{t+1} in Figure 1 represents technological improvement as a source attributing to TFP growth.

Figure 1. Decomposition of TFP Growth



Source: Author

TFP growth due to TEC and SEC can be illustrated as follows. Consider a producer that is operating at point A and D for the time period t and $t+1$. The observed input-output combinations are located inside the production frontiers, implying that production is not technically efficient in either period. In this scenario it is possible that the producer could produce more outputs from a given set of inputs in either period by adjusting his/her production to points B and E in period t and $t+1$. An output-oriented measure of TE defined in Farrell (1957) for the observation at time t, relative to the production frontier S_t, is given by the ratio $\left(\overline{0a}/\overline{0b}\right)$, while the output-oriented TE for the observation at time $t+1$, relative to the production frontier S_{t+1}, is given by the ratio $\left(\overline{0h}/\overline{0j}\right)$. The producer can increase the productivity by adjusting his/her production to operate at the frontier. This results in an improvement of TFP growth during period t and $t+1$ due to TEC during these periods. TEC which measures the changes in the output-oriented TE measures between periods t and $t+1$ is given by the ratio $\left(\overline{0h}/\overline{0j}\right)/\left(\overline{0a}/\overline{0b}\right)$.

Although the producer is operating on the frontier in period t and $t+1$ (point B and E, respectively), the producer could still be operating at a non-optimal scale in either period. In other words, it is possible that the producer might still be able to improve his/her productivity by exploiting scale economies. Taking advantage of scale economies can be done by adjusting production to points C and F in period t and $t+1$. The tangent points, C and F in Figure 1, represent the maximum possible degree of productivity. It can also be called the point of technically optimal scale of the production frontier S_t and S_{t+1}, where T_t (T_{t+1}) is defined as a ray from the origin that is at a tangent to the production frontier S_t (S_{t+1}). The ray T_t (T_{t+1}) can be represented as a distance function when S_t (S_{t+1}) satisfies free disposability, convexity and constant returns to scale (CRS). Therefore, T_t and T_{t+1} represent the CRS technology at the most productive scale size at the time period t and $t+1$. TFP growth between periods t and $t+1$ can rise from progress in SEC in these periods. A measure of SEC represented by the changes in output SE between the period t and period $t+1$ data is given by the ratio $\left(\overline{0j}/\overline{0k}\right)/\left(\overline{0b}/\overline{0c}\right)$.

2.2 A GENERALIZED MPI CHANGE DECOMPOSITION AND A PARAMETRIC FRAMEWORK

In the literature, TFP growth can be measured by using a productivity index. The most commonly used TFP index is the Malinquist Productivity Index (MPI) presented in Caves, Christensen, and Diewert (1982) and Färe et al. (1994). The MPI has gained more interest in practice because it allows one to identify the various components of TFP growth (specifically, TC, TEC and SEC), which (as discussed above) are often of particular interest to policy makers. The MPI can be empirically calculated using the DEA or SFA technique. Both techniques involve the estimation of a production technology. Färe et al. (1994) initially presented a non-parametric DEA approach to measure the change in the MPI between two time periods. The MPI is defined using an output distance function.[3] By imposing an assumption of Constant Returns to Scale (CRS) on the production technology, the MPI change can be decomposed into TEC and TC.

Since it is of interest to understand which factors of production are contributing to production (and finding the technologies that enhance those factors), the MPI has another important characteristic. Specifically, Färe et al. (1997) extended the measure of the change in the MPI and is able to show that the TC component can be decomposed into two components: input- and output-biased TC and non-neutral TC. This decomposition allows one to investigate how the inputs and outputs are reallocated when there is TC. With the availability of new panel data sets and the development of a non-parametric DEA technique, a number of papers decomposing MPI change appeared. However, Färe et al. (1994) raised a fundamental criticism of the decomposition of MPI change using DEA. Fare's work demonstrated that it may not provide an accurate measure of TFP growth because the DEA-based measure ignores shifts in scale economies (SE). Subsequently, Orea (2002) proposed a parametric counterpart of the output-oriented MPI change and produced a way to take shifts in SE into account. Using this new methodology, SEC is considered as an additional component of the TFP growth.

2.2.1 Using Distance Functions to Measure and Decompose TFP Growth

To implement the methods in the literature, one must first introduce the approach of empirical estimation. In our paper, we measure the TFP growth (and decompose the MPI) using an output distance function. The output distance function is defined as a rescaling of the length of an output vector with the production frontier as a reference.

3 It can also be extended using an input distance function.

The first step in explaining our approach is to consider a multi-input, multi-output production technology where the $i\text{–}th$ producer ($i = 1, \ldots, I$) at time period t ($t = 1, \ldots, T$) uses a non-negative $K \times 1$ input vector $X_{it} \in R_{+}^{K}$ to produce a non-negative $M \times 1$ output vector $Y_{it} \in R_{+}^{M}$. The set of all technologically feasible input-output combinations at time period t satisfying the standard properties discussed in Färe and Primont (1995) is $S_t = \{(X, Y) : X \text{ can produce } Y\}$.

The output distance function for the period t is defined as

$$D_t^o(X_t, Y_t) = \inf\{\theta : (X_t, Y_t/\theta) \in S_t\}, \quad (1)$$

where the superscript o refers to an output orientation of the distance function. The output distance function is non-decreasing, linearly homogenous and convex in Y, and non-increasing and quasi-convex in X. $D_t^o(X_t, Y_t) \le 1$ if and only if $(X_t, Y_t) \in S_t$. Moreover, $D_t^o(X_t, Y_t)$ is equal to Farrell's the output-oriented TE measured at time t, that is $0 \le TE_t^o(X_t, Y) \equiv D_t^o(X_t, Y_t) \le 1$.

Orea (2002) employs a parametric technique and applies Diewert's (1976) Quadratic Identity Lemma to derive a generalized MPI change decomposition. The logarithmic form of a generalized output-oriented MPI change index between periods t and $t+1$ can be written as

$$\begin{aligned} m_{t,t+1}^{o,v} &= \left(\frac{d_{t+1}^{o,v}}{d_t^{o,v}}\right) - \frac{1}{2}\left[\frac{\partial d_{t+1}^{o,v}(\cdot)}{\partial t} + \frac{\partial d_t^{o,v}(\cdot)}{\partial t}\right] \\ &+ \frac{1}{2}\left[\sum_{k=1}^{K}\left(-\sum_{k=1}^{K} e_{kt+1} - 1\right)\cdot s_{kt+1} + \left(-\sum_{k=1}^{K} e_{kt} - 1\right)\cdot s_{kt}\right]\left(\frac{x_{kt+1}}{x_{kt}}\right), \\ &= \ln TEC^{o,v} + \ln TC^{o,v} + \ln SEC^{o,v}, \end{aligned} \quad (2)$$

where the superscript v refers to a measure that is calculated from the distance function corresponding to VRS technology; m^o is the logarithm of the MPI change index between periods t and $t+1$; $d_t^{o,v}$ is the logarithm of output distance term which is equivalent to the logarithm of output-oriented measure of Farrell TE in period t ; $d_t^{o,v}(\cdot)$ is the logarithm of the output distance function; x_{kt} is the logarithm of the k^{th} input in period t ; $e_{kt} = \partial d_t^{o,v}(\cdot)/\partial x_{kt}$ is the distance elasticity for the k^{th} input in period t, and $s_{kt} = e_{kt} \Big/ \sum_{k=1}^{K} e_{kt}$ is the distance elasticity share for the k^{th} input in period t. In our paper $\ln TEC^{o,v}$ represents the logarithmic form of TEC, $\ln TC^{o,v}$ represents the logarithmic form of TC, and $\ln SEC^{o,v}$ represents the logarithmic form of SEC. Equation (2) is expressed in terms of proportional rates of growth instead of a product of indices.

2.2.2 Estimating the Distance Function

The components of the generalized MPI change can be measured by estimating the output distance function. To estimate the parameters of an output distance function, however, we must first specify a functional form. The output distance function taking the log-quadratic translog functional form can be defined as[4]

$$d_{it}^{o,v}(\cdot) = \beta_0 + \sum_{m=1}^{M} \beta_{y_m} y_{mit} + \frac{1}{2} \sum_{m=1}^{M} \sum_{n=1}^{M} \beta_{y_m y_m} y_{mit} y_{mit} + \sum_{k=1}^{K} \beta_{x_k} x_{kit} + \frac{1}{2} \sum_{k=1}^{K} \sum_{l=1}^{K} \beta_{x_k x_l} x_{kit} x_{lit}$$
$$+ \sum_{k=1}^{K} \sum_{m=1}^{M1} \beta_{x_k y_m} x_{kit} y_{mit} + \beta_t t + \frac{1}{2} \beta_{tt} t^2 + \sum_{k=1}^{K} \beta_{x_k t} x_{kit} t + \sum_{m=1}^{M} \beta_{y_m t} y_{mit} t \,, \tag{3}$$

where the βs are unknown parameters to be estimated. Young's theorem requires that the symmetry restriction is imposed so that $\beta_{x_k x_l} = \beta_{x_l x_k}$.

Linear homogeneity in outputs requires the following restrictions:

$$\sum_{m=1}^{M} \beta_{y_m} = 1, \ \sum_{n=1}^{M} \beta_{y_m y_n} = 0 \ (m = 1, ..., M), \ \sum_{m=1}^{M} \beta_{x_k y_m} = 0 \ (k = 1, ..., K) \text{ and } \sum_{m=1}^{M} \beta_{y_m t} = 0. \tag{4}$$

Imposing the linear homogeneity in outputs yields the estimating form of the output distance function, in which the distance term, $d_{it}^{o,v}(\cdot)$, can be viewed as an error term as follows:[5]

$$-y_{Mit} = \beta_0 + \sum_{m=1}^{M-1} \beta_{y_m} y^{*}_{mit} + \frac{1}{2} \sum_{m=1}^{M-1} \sum_{n=1}^{M-1} \beta_{y_m y_m} y^{*}_{mit} y^{*}_{mit} + \sum_{k=1}^{K} \beta_{x_k} x_{kit}$$
$$+ \frac{1}{2} \sum_{k=1}^{K} \sum_{l=1}^{K} \beta_{x_k x_l} x_{kit} x_{lit} + \sum_{k=1}^{K} \sum_{m=1}^{M-1} \beta_{x_k y_m} x_{kit} y^{*}_{mit} + \beta_z t + \frac{1}{2} \beta_{tt} t^2$$
$$+ \sum_{k=1}^{K} \beta_{x_k t} x_{kit} t + \sum_{m=1}^{M-1} \beta_{y_m t} y^{*}_{mit} t - d_{it}^{o,v} \,, \tag{5}$$

where $y^{*}_{mit} = (y_{mit} - y_{Mit})$. By replacing the distance term, $-d_{it}^{o,v}$, with a composed error term, $v_{it} - u_{it}$, equation (5) can be estimated as a standard stochastic frontier function where $v_{it}\,s$ are a two-sided random-noise component assumed to be i.i.d. $N(0, \sigma_v^2)$ and $u_{it}\,s$ are a non-negative technical inefficiency component assumed to be a half normal distribution, $N^{+}(0, \sigma_u^2)$. The two terms, v_{it} and u_{it}, are error terms that are assumed to be distributed independently of each other, and of the regressors.

4 The log-quadratic translog functional form is employed because it has the following advantages over other functional forms. First, it has flexibility and can apply for a multi-output production technology without destroying the curvature and symmetry properties of the production technology. Second, it can impose a linear homogeneity to the production technology.

5 Homogeneity can be imposed by estimating the model with $M-1$ output variables normalized by the M^{th} output variable.

2.2.3 Accounting for the Bias in Technological Change

Following a parametric distance function approach for the period t the MPI decomposition proposed by Fuentes, Grifell-Tatjé, and Perelman (2001) can be used to decompose the TC component of TFP growth two additional parts: an input- and output-biased TC part; and a non-neutral TC part. The further decomposition into these two subcomponents would allow one to investigate how inputs and outputs which are reallocated when there are shifts in technology can be attributed to TC. The parametric distance function approach of the MPI change decomposition requires that analyst imposes the assumption of CRS on the production technology. The CRS assumption implies homogeneity of degree minus one in inputs, which requires the following restrictions: $\sum_{k=1}^{K}\beta_{x_k} = -1,\ \sum_{l=1}^{K}\beta_{x_k x_l} = 0\ (k = 1, \ldots, K),\ \sum_{k=1}^{K}\beta_{x_k y_m} = 0\ (m = 1, \ldots, M-1)$ and $\sum_{k=1}^{K}\beta_{x_k t} = 0$.

To impose these CRS restrictions the analyst must make changes to the data. Specifically, the restrictions can be imposed in equation (5) by normalizing input data by one of the K inputs. After doing so, the translog output distance function under the CRS model is

$$\begin{aligned} -y_{Mit} + x_{Kit} = \beta_0 &+ \sum_{m=1}^{M-1}\beta_{y_m} y^{*}_{mit} + \frac{1}{2}\sum_{m=1}^{M-1}\sum_{n=1}^{M-1}\beta_{y_m y_m} y^{*}_{mit} y^{*}_{mit} + \sum_{k=1}^{K-1}\beta_{x_k} x^{*}_{kit} \\ &+ \frac{1}{2}\sum_{k=1}^{K-1}\sum_{l=1}^{K-1}\beta_{x_k x_l} x^{*}_{Kit} x^{*}_{Kit} + \sum_{k=1}^{K-1}\sum_{m=1}^{M-1}\beta_{x_k y_m} x^{*}_{Kit} y^{*}_{mit} + \beta_z t + \frac{1}{2}\beta_{tt} t^2 \\ &+ \sum_{k=1}^{K-1}\beta_{x_k t} x^{*}_{Kit} t + \sum_{m=1}^{M-1}\beta_{y_m t} y^{*}_{mit} t - d^{o,c}_{it}, \end{aligned} \tag{6}$$

where $x^{*}_{kit} = (x_{kit} - x_{Kit})$ and superscript c on $d^{o,c}_{it}$ refers to a measure that is calculated from the distance function corresponding to the CRS technology. By replacing $-d^{o,c}_{it} = v_{it} - u_{it}$, equation (6) can also be estimated as a standard stochastic frontier function.

After equation (6) is estimated, the TC component can be decomposed into a magnitude of TC ($MTC^{o,c}$) and a biased TC ($BTC^{o,c}$). The $BTC^{o,c}$ can be further decomposed into input-biased TC ($IBTC^{o,c}$) and output-biased TC ($OBTC^{o,c}$). The logarithmic form of the $MTC^{o,c}$, $IBTC^{o,c}$ and $OBTC^{o,c}$ are given as

$$\ln MTC^{o,c} = \frac{d^{o,c}_{t}(\cdot)}{d^{o,c}_{t+1}(\cdot)}, \tag{7}$$

$$\ln IBTC^{o,c} = \sum_{k=1}^{K}\frac{\partial d^{o,c}_{it}(\cdot)}{\partial t\,\partial x_{kit}}\left(\frac{x_{kt+1}}{x_{kt}}\right), \tag{8}$$

$$\ln OBTC^{o,c} = \sum_{m=1}^{M}\frac{\partial d^{o,c}_{it}(\cdot)}{\partial t\,\partial y_{mit}}\left(\frac{y_{mt+1}}{y_{mt}}\right). \tag{9}$$

If $\ln \mathrm{IBTC}^{o,c}$ and $\ln \mathrm{OBTC}^{o,c}$ are simultaneously equal to zero, the $\mathrm{MTC}^{o,c}$ equals the TC under joint Hicks neutrality. The value of $\ln \mathrm{MTC}^{o,c}$ can be less than, equal to, or greater than zero, depending upon whether productivity is declining, unchanged, or improving, respectively. The value of $\ln \mathrm{IBTC}^{o,c}$ of the $k\text{-}th$ input can be greater than (less than or equal to) zero, implying that technology change increases (decreases or remains unchanged) the use of the $k\text{-}th$ input. Similarly, the value of $\ln \mathrm{IBTC}^{o,c}$ of the $m\text{-}th$ output can also be greater than (less than or equal to) zero, implying that technology change leads the firm to produce more (less or unchanged) of the $m\text{-}th$ output.

3. DATA

The empirical analysis in this study focuses on agricultural production of 27 Asian countries. The primary source of data is obtained from the website of the FAO of the United Nations (UN). Specifically, the agricultural statistics were acquired from the AGROSTAT system, which is supported by the Statistics Division of the FAO. The data used to measure agricultural performance contain the measurements of agricultural output and input quantities. In this study, the production technology is presented by two output variables (i.e., crop output and livestock output) and five input variables (i.e. land, tractor power, labor, fertilizer and livestock).

3.1 OUTPUT VARIABLES

In this study, the output series are derived by aggregating detailed output quantity data on 127 agricultural commodities (115 cropping commodities and 12 livestock commodities). The construction of the output data series used two basic steps. First, the Geary-Khamis method was used to construct output aggregates from the output quantity data. To do so, we used average international prices (expressed in US dollars) for the base period 1999 to 2001.[6] Second, the aggregate output values during the base period were used to generate an aggregate output series from 1992-2002 using the FAO production indices for crops and livestock separately.[7]

3.2 INPUT VARIABLES

Given limitations on the number of input variables that could be used in the analysis (due to lack of data on other variables on the FAO website), only five input variables are used in our study. Our input variables are defined as follows:

Land input variable represents arable land in each country in each year. Arable land includes both land under permanent crops as well as the area under permanent pasture. The variable is measured in hectares.

Tractor input variable represents the total number of wheeled-and crawler tractors that are used in agriculture. We exclude garden tractors.

Labor variable refers to the number of economically active people in agriculture. It is best thought of as a measure of the number of laborers in the agricultural sector.

6 Detailed information on how international average prices are constructed can be found in Rao (1993).
7 See the FAO STAT (FAO, 2004) for details regarding the construction of production index numbers.

Fertilizer input variable sums up, in nutrient-equivalent terms, the commercial use of nitrogen, potassium and phosphate fertilizers. The variable is expressed in thousands of metric tons. The fertilizer input variable is defined by following the approaches of other studies on inter-country comparison of agricultural productivity (Hayami and Ruttan, 1970; Fulginiti and Perrin, 1997).

Livestock input variable is the sheep-equivalent of the six categories of animals used in constructing this variable. The six categories considered are buffaloes, cattle, pigs, sheep, goats and poultry. The total number of each category of these animals is converted into sheep equivalents using a standard conversion factor: 8.0 for buffalos and cattle; 1.00 for sheep, goats and pigs; 0.1 for poultry (Hayami and Ruttan, 1970).

Panel data on 27 Asian countries over the time period of 1980 through 2004 are used in the empirical analysis. These countries account for more than 46 percent of global agricultural outputs and 56 percent of world's population. The countries account for 94 percent of the population of Asia. Only a small number of nations (e.g., Bahrain; Brunei; Bhutan; Cyprus; Jordan; Kuwait; Lebanon; Maldives; Oman; Qatar; Singapore) are excluded due to the absence of data.

Countries selected for analysis are categorized into six regions: Central Asia (CA), Eastern Asia (EA), Southern Asia (SA), Southeast Asia (SEA), Western Asia (WA) and China (CN).[8] In recognition of its size and due to differences in its accounting practices over time, China is treated as a region by itself.[9] A list of the countries in each region is summarized in Table 1.

Table 1. Classification of Selected Countries

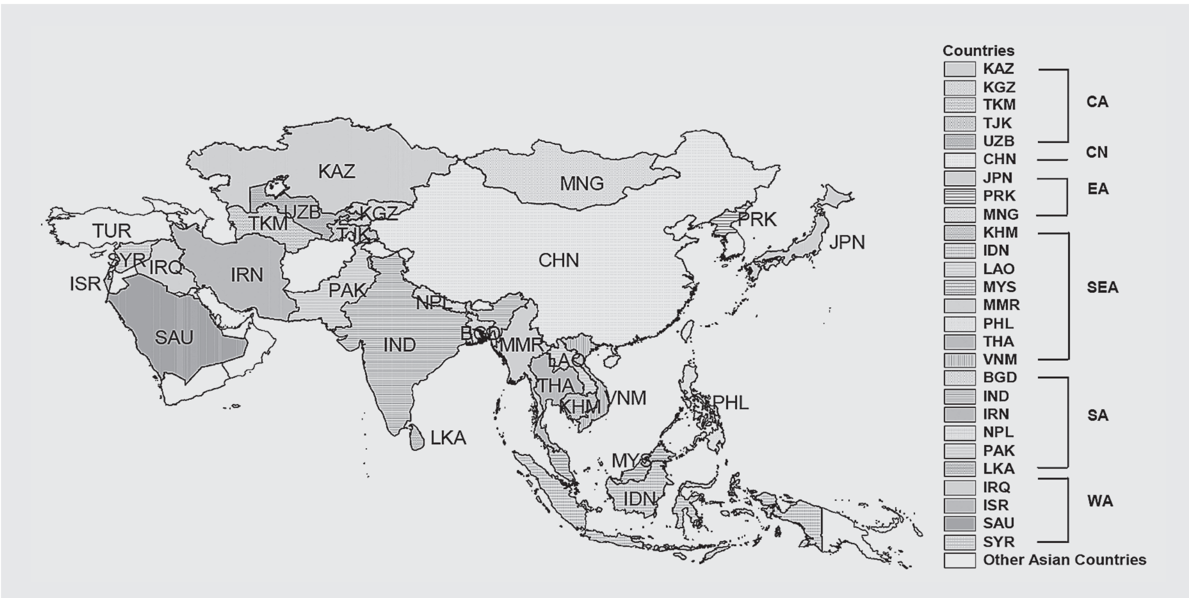
Region	Country	Region	Country
Central Asia (CA)	Kazakhstan (KAZ)	Southeast Asia (SEA)	Cambodia (KHM)
	Kyrgyzstan (KGZ)		Indonesia (IDN)
	Tajikistan (TKM)		Laos (LAO)
	Turkmenistan (TJK)		Malaysia (MYS)
	Usbekistan (UZB)		Myanmar (MMR)
Eastern Asia (EA)	Japan (JPN)		Philippines (PHL)
	Republic of Korea (PRK)		Thailand (THA)
	Mongolia (MNG)		Vietnam (VNM)
Southern Asia (SA)	Bangladesh (BGD)	Western Asia (WA)	Iraq (IRQ)
	India (IND)		Israel (ISR)
	Islamic Rep of Iran (IRN)		Saudi Arabia (SAU)
	Nepal (NPL)		Syrian Arab Republic (SYR)
	Pakistan (PAK)	China (CN)	China (CHN)
	Sri Lanka (LKA)		

Source: United Nations Statistics Division (http://unstats.un.org/unsd/).

8 The regional groupings are based on their geographical used in UN Statistics Division.
9 According to the UN definition, China is located within the EA region.

Figure 2 presents a map of Asia map indicating the location of each country used in this study. Descriptive statistics of the variables summarized by each region is presented in Table 2. China shows that it produces the highest share of agricultural output values for both crop and livestock commodities.[10] China also accounts for the highest share of agricultural land, labor and fertilizer use. The EA region exhibits the highest share of tractors whereas the SA region shows the highest share of livestock input.[11]

Figure 2. Map of the Countries Used in This Study



Source: Author

[10] Agricultural output values for crops account for 43.78% by CN, 30.13% by SA, 15.3% by SEA, 5.96% by WA, 3.54% by EA and 1.23% by CA, and agricultural output values for livestock account for 43.36% by CN, 33.08% by SA, 7.74% by EA, 7.73% by SEA, 5.77% by WA and 2.32% by CA.

[11] Agricultural land accounts for 37.30% by CN, 20.43% by SA, 14.43% by WA, 10.72% by CA, 9.53% by EA and 7.58% by SEA. Agricultural labor accounts for 50.84% by CN, 33.25% by SA, 12.97% by SEA, 1.73% by WA, 0.86% by EA and 0.35% by CA. Fertilizer used in agriculture accounts for 49.63% by CN, 29.18% by SA, 10.83% by SEA, 4.86% by WA, 4.56% by EA and 0.93% by CA. Tractor used in agriculture accounts for 34.19% by EA, 28.79% by SA, 14.85% by WA, 13.94% by CN, 4.88% by SEA and 3.36% by CA. Livestock used in agriculture accounts for 58.02% by SA, 25.88% by CN, 8.70% by SEA, 3.78% by WA, 2.08% by EA and 1.54% by CA.

Table 2. Descriptive Statistics of Variables, 1980-2004

Variable	Units	Region						
		CA*	EA	SEA	SA	WA	CN	All
Outputs								
Crops	$\times 10^6$ US $	1793 (1446)	4465 (3496)	7267 (6423)	19020 (30127)	4517 (6221)	165817 (44930)	14794 (35694)
Livestock	$\times 10^6$ US $	1282 (1072)	3711 (3369)	1389 (1099)	7926 (11919)	1660 (1844)	62344 (33658)	5616 (14707)
Inputs								
Land	$\times 10^3$ ha	57.31 (78.46)	44.13 (57.43)	13.17 (12.24)	47.33 (63.19)	40.11 (53.12)	518.41 (36.23)	54.29 (107.67)
Tractors	$\times 10^3$	76.46 (64.03)	674.65 (903.59)	36.13 (53.64)	284.01 (514.45)	175.78 (292.12)	825.24 (92.53)	231.25 (476.38)
Labor	$\times 10^3$	1.29 (0.90)	2.72 (2.01)	15.33 (13.67)	52.42 (85.03)	3.28 (5.08)	480.97 (35.18)	36.96 (101.00)
Fertilizer	$\times 10^6$ ton 3	206 (350)	871 (734)	775 (840)	2785 (4626)	557 (630)	28418 (9009)	2237 (6096)
Livestock	$\times 10^6$	32.86 (26.61)	38.53 (10.89)	60.45 (41.32)	537.65 (850.03)	42.07 (56.95)	1439.04 (272)	217.18 (525.27)

* Data for each country in this region are only available during the time period of 1992 to 2004.

Notes: Means are calculated. Standard deviations are presented in parentheses

Source: Author's calculation

4. RESULTS

The panel data on 27 Asian countries during the time period from 1980 to 2004 were used to estimate the translog output distance function under the VRS model from equation (5) and the CRS model from equation (6). The variables used in the model estimation were each transformed by dividing by their respective geometric means.[12] The maximum likelihood parameter estimates are listed in Table 3.

In general, the estimation performed well. All first-order coefficients from both models have the expected signs, implying that the output distance functions are increasing in outputs and decreasing in inputs at the sample mean.[13] The estimates of the distance elasticities with respect to outputs estimated by the VRS model are 0.490 and 0.510 for crops and livestock. The output elasticities estimated by the CRS model are fairly consistent, 0.436 for crops and 0.564 for livestock. The estimates of the distance elasticities with respect to inputs estimated by the VRS model are -0.099, -0.184, -0.192, -0.224 and -0.334 for land, tractors, labor, fertilizer, and livestock, respectively. The point estimate of the sum of the input elasticities from the VRS model is -1.033, indicating that the technology exhibits small to moderately increasing returns to scale at the sample mean. When the CRS model is used, the estimates of the input elasticities are -0.064, -0.202, -0.136, -0.342 and -0.255 for land, tractors, labor, fertilizer, and livestock, respectively, and by definition add to -1.

[12] This transformation does not alter the performance measures obtained, but does allow one to interpret the estimated first-order parameters as elasticities, evaluated at the sample means.

[13] Tests of the regularity conditions are checked at each data point in all 615 observations. We find the convexity condition and the monotonicity constraints on outputs are satisfied at all observations in the output distance function for both models. The monotonicity constraints in inputs are violated at 9, 3, 6, 5, and 10% of all observations in the case of land, tractors, labor, fertilizer and livestock inputs, respectively, for the VRS model. In the CRS model, the monotonicity constraints in the corresponding inputs are violated at 11, 5, 12, 3, and 10% of all observations.

According to the results of our two models, we find some evidence that there are moderate economies of scale in Asian agriculture. Our hypothesis test that the CRS model accurately captures the nature of the economies of scale in cropping and livestock production was conducted using a likelihood ratio (LR) test. The LR test is rejected at the 90 percent level implying the economies of scale may be marginally significant[14]. Because of this result, in the rest of the analysis the parameter estimates of the VRS model are used to calculate the components of the MPI change decomposition.[15]

Table 3. Estimated Parameters of the Output Distance Model

Parameter[a]	VRS Model		CRS Model	
	Estimates	t-Statistic	Estimates	t-Statistic
β_0	0.277	8.781	0.532	9.438
β_{y1}	0.490	20.114	0.436	15.200
β_{y1y1}	0.331	5.253	0.340	5.524
β_{x1}	-0.099	-7.126	-0.064	-4.128
β_{x2}	-0.184	-15.228	-0.202	-14.205
β_{x3}	-0.192	-8.222	-0.136	-5.153
β_{x4}	-0.224	-16.310	-0.342	-28.582
β_{x5}	-0.334	-11.067		
β_{x1x1}	-0.101	-7.517	-0.098	-6.898
β_{x2x2}	0.033	3.321	0.027	2.272
β_{x3x3}	0.151	2.455	0.220	3.775
β_{x4x4}	-0.022	-3.161	-0.027	-3.405
β_{x5x5}	-0.228	-2.034		
β_{x1x2}	0.043	5.147	-0.006	-0.726
β_{x1x3}	-0.103	-4.426	-0.086	-3.816
β_{x1x4}	0.048	5.470	0.075	7.118
β_{x1x5}	0.035	1.179		
β_{x2x3}	0.195	8.454	0.348	14.712
β_{x2x4}	-0.060	-7.818	-0.095	-10.992
β_{x2x5}	-0.128	-4.866		
β_{x3x4}	-0.214	-10.331	-0.231	-10.274
β_{x3x5}	-0.008	-0.103		
β_{x4x5}	0.296	12.564		
β_{x1y1}	-0.051	-2.115	-0.051	-2.351
β_{x2y1}	-0.093	-4.688	-0.169	-7.606
β_{x3y1}	-0.182	-3.831	-0.311	-6.767
β_{x4y1}	0.189	10.061	0.216	10.204
β_{x5y1}	0.114	2.067		
β_t	-0.008	-6.887	-0.006	-4.240
β_{tt}	-0.001	-2.590	-0.002	-4.654

[14] The 10% level of significance is selected to highlight the contribution of scale efficiency change as another major source in driving agricultural productivity growth in Asian countries.

[15] Investigating how the inputs and outputs are reallocated attributed to TC requires the CRS assumption. Hence, the estimates from the CRS model are used to calculate the components of the TC decomposition.

Table 3. (Continue)

Parameter[a]	VRS Model		CRS Model	
	Estimates	t-Statistic	Estimates	t-Statistic
β_{x1t}	-0.008	-6.996	-0.009	-7.168
β_{x2t}	0.003	3.128	0.002	1.534
β_{x3t}	0.002	0.808	-0.007	-2.748
β_{x4t}	0.001	1.036	0.007	5.569
β_{x5t}	-0.006	-2.564		
β_{y1t}	-0.001	-0.410	-0.002	-0.758
σ^2	0.062	8.042	0.072	4.819
γ	0.788	11.257	0.581	3.091
Likelihood Value	**215.501**		**81.959**	

[a] Subscripts on βx coefficients refer to inputs: 1 = land; 2 = tractors; 3 = fertilizer; 4 = labor; 5 = livestock input and subscripts on βy coefficients refer to outputs: 1 = crops; 2 = livestock output

Source: Author's calculation

Perhaps the most general and important finding in our paper is that over the entire time period of our analysis (1980 to 2004), the annual growth rate of TFP across all of Asia (the 27 countries in our study) was positive and nearly 2 percent (1.902 percent—Table 4, section A, row 6, column 6). A growth rate of 2 percent is typically considered as a sign that agriculture is healthy in terms of its improvement in productivity. It is higher than the rate of growth of the population of Asia during 1990s (around 1.5 percent—Asia Development Bank, 2001). Most developed countries that are considered to have well performing agricultural economies (e.g., the United States, Germany, Australia) have consistently posted TFP growth rates of more than 1.5 percent (Bureau, Färe and Grosskopf, 1995).

The importance of examining productivity has shifted over the past decade since this fairly robust rate of TFP growth for Asia the entire study period to a large extent are driven by rises in TFP during the past 10 years (Table 4, Section A, column 6). Between 1980 and 1995, TFP growth average only a bit over 1 percent (rising from 0.343 percent in the 1980-85 period to 1.775 (1.857) percent during the 1984-90 (1990-95) period. These numbers are remarkably consistent with those of Suhariyanto and Thirtle (2001) that found the growth of TFP in Asia before 1996 was around 1 percent. After 1995, the rate of growth of TFP accelerates, rising by 2.023 percent in 1995-2000 and by nearly 4 percent in 2000-04.

The findings of the decomposition analysis demonstrate convincingly that the relatively high overall rate of TFP growth and its recovery over the past two decades has relied, in general, on technological change (TC—Table 4, Section A, column 4). In fact, through the entire period (except after 2000), the rate of TC exceeds TFP growth. Between 1980 and 2004, the adoption of new varieties of crops, the extension of new breeds of livestock and other breakthroughs have pushed up the production frontier by 2.321 percent annually. During the past decade TC has grown by nearly 3 percent annually (2.847 percent between 1995 and 2000; and 3.245 percent between 2000 and 2004). While in this paper it is beyond the scope of our analysis to identify the exact sources of TC, according to work by Evensen and Golin (2003), David and Otsuka (1994), and Pingali et al. (1997), the second generation of the Green Revolution appears to be succeeding in keeping the rate of TC high.

Table 4. Weighted Average Growth Rates of the TE Scores and MPI Change for Each Region over the Time Period of 1980 to 2004 (in %)

Region	Period	TEC	TC	SEC	TFP Growth
A) All	1980-1985	-0.598	1.422	-0.481	0.343
	1985-1990	0.371	1.897	-0.494	1.775
	1990-1995	-0.218	2.376	-0.300	1.857
	1995-2000	-0.885	2.847	0.061	2.023
	2000-2004	0.835	3.245	-0.165	3.916
	1980-2004	**-0.138**	**2.321**	**-0.280**	**1.902**
B) SA	1980-1985	-0.613	1.833	-0.179	1.041
	1985-1990	-0.235	2.154	-0.145	1.774
	1990-1995	-0.121	2.479	-0.085	2.273
	1995-2000	-0.104	2.819	0.019	2.734
	2000-2004	0.285	3.128	0.103	3.516
	1980-2004	**-0.176**	**2.456**	**-0.064**	**2.216**
C) SEA	1980-1985	0.041	0.199	-0.032	0.208
	1985-1990	1.159	0.607	0.047	1.813
	1990-1995	-0.100	0.872	-0.223	0.549
	1995-2000	0.101	1.105	-0.132	1.074
	2000-2004	0.248	1.472	0.123	1.843
	1980-2004	**0.292**	**0.825**	**-0.050**	**1.066**
D) WA	1980-1985	0.405	-0.854	0.374	-0.076
	1985-1990	-0.689	-0.295	-0.022	-1.005
	1990-1995	-0.401	0.201	-0.155	-0.355
	1995-2000	-0.705	0.578	-0.077	-0.203
	2000-2004	-0.674	0.949	-0.484	-0.208
	1980-2004	**-0.402**	**0.081**	**-0.056**	**-0.376**
E) EA	1980-1985	-0.280	-2.083	-3.386	-5.749
	1985-1990	0.163	-1.721	-1.059	-2.617
	1990-1995	0.103	-1.328	-1.016	-2.241
	1995-2000	-0.581	-0.914	-0.032	-1.528
	2000-2004	1.532	-0.607	-2.689	-1.763
	1980-2004	**0.131**	**-1.361**	**-1.592**	**-2.822**
F) EA+CN	1980-1985	-0.810	1.598	-0.865	-0.077
	1985-1990	0.613	2.189	-0.911	1.892
	1990-1995	-0.381	2.838	-0.475	1.982
	1995-2000	-1.613	3.420	0.186	1.993
	2000-2004	1.430	3.877	-0.388	4.919
	1980-2004	**-0.218**	**2.739**	**-0.495**	**2.026**
G) CA	1992-1995	1.360	1.612	-0.177	2.795
	1995-2000	-0.623	1.808	-1.083	0.103
	2000-2004	-0.502	2.350	-0.041	1.806
	1992-2004	**-0.087**	**1.940**	**-0.509**	**1.344**

Source: Author's calculation

Rates of TC that exceeded TFP growth, in fact, were needed to keep TFP growing at a healthy rate since our decomposition analysis shows that during the study period TFP has been pulled down due to declining technical efficiency (TEC—Table 4, Section A, column 3). According to our results, TFP growth between 1980 and 2004 would have been 0.138 percent high had efficiency levels not fallen. Over time there has been less of a consistent change in TEC. In the most recent period (2000 to 2004), somewhat surprisingly (given the continued rise in off farm employment—which might be one factor is behind falling efficiencies), TEC rose by 0.835 percent. When combined with TC, it is clear now why TFP growth was so high in the 2000 to 2004.

TFP growth rate during the study period would have been even higher had changes in scale economies (SEC) not deteriorated (Table 4, Section A, column 5). Between 1980 and 2004, the contribution of scale economies to TFP growth was negative (-0.280 percent). In other words, TFP growth would have been 0.280 percent higher had not efficiencies due to economies of scale fallen. The result, with the exception of the 1995 to 2000 period (perhaps associated with the Asian Crisis), most likely was reflecting the continued tendency for farm sizes in Asia to decline (Kuhnen, 1996).

In summary, then, for Asia as a region as a whole, productivity growth is relatively robust and rising. This is good news for those concerned about keeping balance in Asia and world food markets, especially given the secular declining trends in cultivated land, labor and water (Pingali, 2001). If Asia's food output is going to help contribute to world supplies, productivity is going to need to continue since it is likely that resources will continue to flow out of the sector as development in many of the region's countries continues. The importance of agricultural R&D is clear from our findings as TC accounts for all of the growth in TFP. One implication of the results is that if the factors that are contributing to the falls in TEC and SEC can be reversed, it is possible that TFP could grow even faster.

4.1 SOURCES OF TFP GROWTH IN ASIA'S MAJOR REGIONS AND THE IMPORTANCE OF TRANSITION NATIONS

If we examine TFP growth during the study period in the regions of Asia that have been the focus of most studies in the past it is clear that the aggregate story of TFP growth would be somewhat different than when looking at the region as a whole (as we did in the previous section). The record of the major regions from traditional Asia can be seen in Sections B, C, D and E in Table 4. In the table, the results of our TFP analysis are given for each of the study's subperiods as well as the findings of the decomposition analysis.

Interestingly, the patterns of TFP growth in South Asia (SA) parallel those of the rest of Asia (Table 4, Section B). The annual growth rate of TFP is around 2 percent (2.216 percent) and it is rising over time. In addition, the rate of TC exceeds that of TFP growth in all periods, except the period after 2000, meaning that TC in SA, as in Asia as a whole, is responsible for all of the growth. This high rate of TC in SA is needed since the TEC and SEC components are negative (also like that in Asia as a whole). It is clear from these results that the increasingly robust performance of SA is at least one driver of the results found in Asia more generally.

The healthy performance in SA is not matched by the other regions (Table 4, Sections C, D and E). The growth rate of TFP in Southeast Asia (SEA) is only around 1 percent, about half that of Asia as a whole. This rate in SEA, however, is at least positive; those in Western Asia (WA) and Eastern Asia (EA) are negative. Especially in the case of EA, between 1980 and 2004, on average, TFP has fallen by 2.822 percent annually.

In the case of all three of these regions, SEC has detracted from productivity (especially in EA where land tenure laws and agricultural support policies discourage farm consolidation). Technological change, although contributing to TFP growth slightly in SEA and WA, drags down TFP growth in EA. Finally, while TEC is negative in WA, it is slightly positive in SEA and EA.

It is clear that the story of Asia, had it relied on these four regions (SA, SEA, WA and EA) alone, would not have been such an encouraging story. In fact, if we had only included the countries in these regions (the nations that were mostly studied in the past), the estimated rate of TFP growth would have been much lower. Although not reported in the table, the rate of increase in TFP from the four regions between 1980 and 2004 was 1.543 percent. The importance of SA in the record of Asia as a whole is shown by computing the rate of TFP growth with only SEA, WA and EA (0.664 percent). Such low growth rates would be the source of concern for those that worry that Asia is not able to contribute significantly to world food production. If both TFP and input levels are falling, food output in the region would also necessarily fall.

The performance of Asia's productivity growth, however, is greatly enhanced by including the former CPE countries in East and Central Asia (Table 4, Sections F and G). In fact, the record of China—coupled with its size—shows that it (like SA) is also one of the driving forces behind the rebound of Asian productivity. In fact, the rate of growth of TFP for China for most of the entire period and the rate of growth in the most recent period are nothing short of remarkable. Between 1985 and 2000, there was no five-year period in which China's TFP growth fell below 2 percent annually. Between 2000 and 2004 TFP grew at a rate above 5 percent. While extremely high, in fact, these rates are most consistent with those estimated by Jin et al. (2007) which shows (with a completely different set of data) that TFP rates of cropping and livestock are high by international standards and growing over time.

The performance of China's productivity, like that of SA and Asia as whole, are driven by TC—and hurt by TEC and SEC (Table 4, Section F). Indeed, during the entire study period TC rose by 3.209 percent annually. As shown in Jin et al. (2002) most of this growth can be accounted for by investments into R&D. The analysis of China's agricultural economy over the entire reform period, described in Huang, Otsuka and Rozelle (2007), is able to explain why it is that TEC and SEC falls. Problems with the extension system, disequilibrium from rapid change and the relatively rigid tenure system (as well as pure demographics) have kept farms in China relatively small and inefficient.

While not as spectacular as China, the record of CA nonetheless is a positive one (Table 4, Section G). During the entire period (1992 to 2004 for CA—due to absence of data in earlier periods) the growth rate of TFP reached 1.344 percent. Between 2000 and 2005 TFP rose by a rate of 1.806 percent almost as fast as Asia as a whole for the study period. This area, which is sometimes thought to be an underperformer (Swinnen and Rozelle, 2006), in fact, has not performed that poorly in terms of TFP growth. Like Asia as a whole (and China), shifts in TC are fully responsible for the growth in TFP. TEC and SEC (especially) detracted from TFP growth.

4.2 EXAMINING TRANSITION COUNTRIES IN MORE DETAIL

Given that transition countries started their market reforms at different periods, this section will investigate their agricultural performance after the start of their market reforms. When breaking down the transition countries in more detail, it actually is possible to see that overall they have contributed a lot to the growth of Asia's TFP during the study period (Table 5, Section A). When taking all countries in aggregate, it is clear to see that the record of them is an important part of the Asian experience. Overall TFP growth was 2.419 percent for the whole study period and rising over time. Most of the growth was due to TC, and TEC and SEC were negative. These trends suggest that the former CPE nations and the leaders of their Transition governments may have been able to maintain TFP growth mostly through their investments into agricultural R&D or other initiatives to promote technology. At the same time, transition, even a decade or two or after the end of transition may be dragging down TFP growth due to continued disequilibrium (which is inherent in many transition phenomenon).

Table 5. Weighted Average Growth Rates of the TE Scores and MPI Change Decomposition by Transition Countries after the Start of Their Market Reform (in %)

Transition Country*	Periods	TEC	TC	SEC	TFP Growth
A) All	1980-1985	-0.737	2.015	-0.438	0.840
	1985-1990	0.622	2.568	-0.818	2.372
	1990-1995	-0.304	3.058	-0.411	2.344
	1995-2000	-1.552	3.520	0.097	2.065
	2000-2004	1.252	3.916	-0.179	4.989
	1980-2004	**-0.202**	**2.978**	**-0.357**	**2.419**
B) China	1980-1985	-0.895	2.205	-0.440	0.871
	1985-1990	0.679	2.751	-0.883	2.547
	1990-1995	-0.437	3.302	-0.409	2.456
	1995-2000	-1.696	3.791	0.202	2.297
	2000-2004	1.435	4.191	-0.237	5.388
	1980-2004	**-0.250**	**3.209**	**-0.358**	**2.600**
C) Mongolia	1991-1995	-1.365	3.456	1.777	3.868
	1995-2000	-3.401	4.105	3.102	3.806
	2000-2004	6.232	4.489	-7.315	3.406
	1991-2004	**0.078**	**3.983**	**-0.347**	**3.714**
D) Vietnam	1986-1990	-1.301	-0.346	-0.143	-1.790
	1990-1995	1.797	-0.101	-1.112	0.583
	1995-2000	0.358	0.153	-1.452	-0.941
	2000-2004	-1.364	0.616	-0.100	-0.848
	1986-2004	**-0.062**	**0.052**	**-0.734**	**-0.744**
E) Laos	1986-1990	-0.267	-0.032	0.950	0.651
	1990-1995	0.043	0.438	0.935	1.417
	1995-2000	-5.314	0.805	-0.218	-4.728
	2000-2004	0.653	1.059	0.500	2.212
	1986-2004	**-1.320**	**0.542**	**0.544**	**-0.234**

Table 5. (Continue)

Transition Country*	Periods	TEC	TC	SEC	TFP Growth
F) Myanmar	1989-1992	0.275	1.085	-0.153	1.207
	1992-1996	-1.577	1.472	-0.026	-0.131
	1996-2000	-0.372	1.848	0.442	1.917
	2000-2004	1.705	2.410	1.917	6.033
	1989-2004	**0.008**	**1.704**	**0.545**	**2.256**
G) Kazakhstan	1992-1996	2.977	2.990	-1.297	4.669
	1996-2000	-2.746	3.412	-3.423	-2.757
	2000-2004	0.444	3.833	-0.346	3.932
	1980-2004	**0.225**	**3.412**	**-1.689**	**1.948**
H) Kyrgyzstan	1992-1996	-0.007	0.247	-0.124	0.117
	1996-2000	-1.621	0.477	0.109	-1.034
	2000-2004	0.969	1.036	-3.045	-1.040
	1980-2004	**-0.219**	**0.587**	**-1.020**	**-0.653**
I) Tajikistan	1992-1996	0.290	-0.139	-1.469	-1.318
	1996-2000	-1.764	0.323	-0.705	-2.146
	2000-2004	3.027	0.512	2.978	6.518
	1980-2004	**0.517**	**0.232**	**0.268**	**1.018**
J) Turkmenistan	1992-1996	0.556	1.063	0.150	1.768
	1996-2000	-1.497	1.469	0.110	0.082
	2000-2004	1.149	2.055	1.801	5.004
	1980-2004	**0.069**	**1.529**	**0.687**	**2.285**
K) Uzbekistan	1992-1996	0.098	0.830	0.278	1.206
	1996-2000	-0.250	1.173	0.094	1.017
	2000-2004	-2.698	1.642	-0.006	-1.062
	1980-2004	**-0.950**	**1.215**	**0.122**	**0.387**

* Year market reforms taken place: China (1979-1980); Mongolia (1991); Vietnam and Laos (1986); Myanmar (1989); Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan (1992)
Source: Author's calculation

Because of the danger that the China's record (Table 5, Section B) dominates the findings when aggregating the region as a whole, we can also examine the other 9 transition economies. When doing so we find that there are sharp differences among them. Excluding China, in the case of 5 of them (Mongolia—section C; Myanmar—section F; Kazakhstan—section G; Tajikistan—section I; and Turkmenistan—section J), there was positive TFP growth above 1 percent. In fact, four of them had rates of growth that were more than (or close to) 2 percent annually. Interestingly, in all cases in which the transition nation's experienced positive TFP growth, the rate of growth of TC was positive. In all of these countries, TEC was also positive. Therefore, the negative disequilibrium effect found for China may not have been due to transition, but rather a function of its extremely fast growth rates. All of the countries with positive TFP growth which also had a positive contribution of TEC during the 2000-2004 period, actually experienced negative TEC in an earlier period. What these results suggest is that the disequilibrium of transition which detracted from growth in earlier period was a temporary phenomenon and now growth from TEC is positive.

There were, however, four nations (Vietnam—Section D; Laos—Section E; Kyrgyzstan—Section H; Uzbekistan—Section K) that had either negative or small positive TFP growth rates (Table 5). It is difficult—and beyond the scope of this paper—to determine why some of these countries had TFP growth rates of rose while those of others did not. Swinnen and Rozelle (2006) state that in no large part differences in the performance of the transition countries, in general (including those inside and outside of Asia) are due to differences in pricing, land rights and marketing policies. If this were the case in our sample, it would then lead to the further question about why it is that different countries adopted different policy regimes. Such questions need to be answered in further research.

4.3 THE NATURE OF TECHNOLOGICAL CHANGE

Because of the importance in all nations of TC, in this section we are going to extend our analysis to examine the nature of that change. As discussed in the methodological section above, it is possible to estimate if the technological changes that are occurring in the countries are output biased and/or input biased. It is also possible to estimate what particular factors are being saved and which ones are being used.

According to our analysis, the sum of input-biased TC across all of Asia was larger than that of output-biased TC (Table 6, Sections A). It is clear that technology improvements had increased the efficient use of inputs (input saving) more than they had increased the capability to produce output (output or yield enhancing). Overall, TC was biased toward livestock output but against crops. On the input side, TC was biased toward tractors, fertilizer and livestock input but against land and labor. In summary, technology improvement in Asia used more tractors, fertilizer and livestock input but less land and labor to produce more livestock than crops. The record of Asia as a region as a whole had it relied on the SA, SEA, CN (Table 6, Sections B, C and F).

When investigating the transition countries in more detail, there were large differences among the transition countries in terms of how input and output intensities shift in response to the adoption of innovations. The records of transition countries in EA (Table 7, Section A and B) show that TC was biased toward crops but against livestock output in Mongolia whereas TC was biased toward livestock output but against crops in China. On the input side, the input-biased TC results imply that technology improvement in Mongolia increased use of labor but decreased use of land, tractor, fertilizer and livestock input while technology improvement used more tractors, fertilizer and livestock input but less land and labor in China. The outcome suggests that China had drastically reduced use of such inputs as land and labor.

Three nations in SEA (Vietnam—Section C; Laos—Section D; Myanmar—Section E) show that technology improvements had increased the capability to produce more livestock in Laos and Myanmar, and more crops in Vietnam. On the input side, technology improvements had increased use of tractor, fertilizer and livestock input in Laos while livestock input increased in Myanmar and land, labor and livestock input increased in Vietnam. Other five nations in CA (Kazakhstan—Section F; Kyrgyzstan—Section G; Tajikistan—Section H; Turkmenistan—Section I and Uzbekistan—Section J) show that TC was biased toward crops but against livestock output in Kazakhstan and Kyrgyzstan whereas TC was biased toward livestock output but against crops in Turkmenistan and Uzbekistan. In Tajikistan, TC was biased against both crops and livestock output. On the input side, the input-biased TC results imply that TC in Kazakhstan increased use of land and labor but decreased use of tractors, fertilizer and livestock input while the direction of TC uses more labor but less land, tractors, fertilizer, and livestock inputs in Kyrgyzstan. The outcomes suggest that these countries had not significantly increased the output except in Turkmenistan and they had reduced use of such inputs as tractors. Land input had also been reduced in Kyrgyzstan and Turkmenistan while labor input had proven to decrease in Tajikistan and Turkmenistan. Fertilizer input had been reduced in Kazakhstan and Kyrgyzstan while livestock input had proven to decrease in Kazakhstan, Kyrgyzstan and Tajikistan.

Table 6. Weighted Average Growth Rates of the TC Decomposition by Regions (in %)

Region	Period	MTC*	Output-Biased TC		Input-Biased TC				
			crop	livestock	land	tractor	labor	fertilizer	livestock
A) All	1980-1985	-1.052	-0.008	0.011	-0.011	0.010	-0.009	0.043	0.013
	1985-1990	-0.327	-0.005	0.010	-0.007	0.008	-0.008	0.052	0.015
	1990-1995	0.471	-0.005	0.012	0.000	0.004	-0.004	0.028	0.015
	1995-2000	1.316	-0.005	0.008	-0.003	0.011	-0.003	0.005	0.001
	2000-2004	2.136	-0.005	0.008	-0.001	0.003	-0.002	0.025	0.010
	1980-2004	**0.441**	**-0.006**	**0.010**	**-0.005**	**0.007**	**-0.005**	**0.031**	**0.011**
B) SA	1980-1985	-1.567	-0.008	0.010	-0.001	0.015	-0.008	0.062	0.011
	1985-1990	-0.954	-0.006	0.007	-0.001	0.016	-0.007	0.047	0.009
	1990-1995	-0.186	-0.005	0.007	0.001	0.009	-0.011	0.022	0.006
	1995-2000	0.607	-0.004	0.007	0.000	0.009	-0.010	0.027	0.001
	2000-2004	1.461	-0.003	0.005	0.000	0.009	-0.010	-0.007	0.002
	1980-2004	**-0.194**	**-0.005**	**0.007**	**-0.001**	**0.012**	**-0.009**	**0.032**	**0.006**
C) SEA	1980-1985	-0.404	-0.006	0.010	-0.008	0.009	-0.013	0.076	0.027
	1985-1990	0.313	-0.005	0.009	-0.013	0.017	-0.012	0.039	0.007
	1990-1995	0.966	-0.006	0.009	0.002	0.022	-0.008	0.044	0.010
	1995-2000	1.732	-0.005	0.003	-0.010	0.013	-0.006	0.030	-0.011
	2000-2004	2.660	-0.007	0.010	-0.006	-0.001	-0.004	-0.017	0.011
	1980-2004	**0.986**	**-0.006**	**0.008**	**-0.007**	**0.013**	**-0.009**	**0.037**	**0.009**
D) WA	1980-1985	-1.596	-0.010	0.011	-0.006	0.013	0.000	0.105	0.005
	1985-1990	-0.800	-0.005	0.005	-0.007	0.009	0.013	0.033	0.010
	1990-1995	0.233	-0.003	-0.002	-0.015	0.009	0.000	0.005	-0.003
	1995-2000	1.039	0.001	0.010	0.000	0.003	0.002	0.014	0.007
	2000-2004	1.797	-0.008	0.006	0.002	-0.001	0.002	0.028	0.002
	1980-2004	**0.065**	**-0.005**	**0.006**	**-0.006**	**0.007**	**0.004**	**0.037**	**0.004**
E) EA	1980-1985	-3.425	-0.004	0.006	0.004	0.019	0.018	0.017	0.027
	1985-1990	-2.742	0.001	0.004	0.005	0.014	0.029	-0.006	-0.004
	1990-1995	-2.005	0.002	0.003	0.009	0.008	0.033	-0.017	0.015
	1995-2000	-1.146	0.001	0.001	0.005	0.006	0.034	-0.021	-0.015
	2000-2004	-0.420	0.003	0.000	0.018	0.002	0.040	0.019	-0.002
	1980-2004	**-2.011**	**0.001**	**0.003**	**0.008**	**0.010**	**0.030**	**-0.003**	**0.005**
F) EA+CN	1980-1985	-0.862	-0.009	0.012	-0.019	0.007	-0.009	0.017	0.009
	1985-1990	-0.056	-0.005	0.013	-0.010	0.000	-0.009	0.058	0.023
	1990-1995	0.767	-0.006	0.017	0.000	-0.005	0.000	0.034	0.023
	1995-2000	1.605	-0.006	0.010	-0.004	0.012	0.001	-0.007	0.005
	2000-2004	2.345	-0.006	0.008	-0.001	0.000	0.003	0.047	0.013
	1980-2004	**0.694**	**-0.006**	**0.012**	**-0.007**	**0.003**	**-0.003**	**0.029**	**0.015**

Table 6. (Continue)

Region	Period	MTC*	Output-Biased TC		Input-Biased TC				
			crop	livestock	land	tractor	labor	fertilizer	livestock
G) CA	1992-1995	0.963	0.024	-0.004	0.004	-0.008	0.004	-0.127	-0.011
	1995-2000	2.371	-0.006	-0.004	0.002	-0.014	0.006	-0.176	-0.037
	2000-2004	3.276	-0.008	0.009	0.000	-0.001	0.002	0.161	0.033
	1980-2004	**2.321**	**0.001**	**0.001**	**0.002**	**-0.008**	**0.004**	**-0.051**	**-0.007**

* MTC represents the magnitude of TC defined in equation (7)

Source: Author's calculation

Table 7. Weighted Average Growth Rates of the TC Decomposition by Transition Countries after the Start of their Market Reform (in %)

Country	Period	Output-Biased TC		Input-Biased TC				
		crop	livestock	land	tractor	labor	fertilizer	livestock
A) Mongolia	1991-1995	0.033	-0.004	0.010	-0.014	0.001	-0.292	0.013
	1995-2000	0.010	0.011	-0.017	-0.015	0.006	0.078	0.031
	2000-2004	-0.011	-0.017	0.000	0.003	0.004	0.089	-0.077
	1991-2004	**0.012**	**-0.003**	**-0.002**	**-0.010**	**0.004**	**-0.051**	**-0.006**
B) China	1980-1985	-0.009	0.013	-0.023	0.005	-0.013	0.018	0.006
	1985-1990	-0.006	0.014	-0.012	-0.002	-0.014	0.067	0.026
	1990-1995	-0.007	0.019	-0.001	-0.006	-0.003	0.039	0.024
	1995-2000	-0.007	0.010	-0.004	0.013	-0.002	-0.006	0.006
	2000-2004	-0.006	0.009	-0.002	0.000	0.000	0.049	0.014
	1980-2004	**-0.007**	**0.013**	**-0.009**	**0.002**	**-0.007**	**0.033**	**0.016**
C) Laos	1986-1990	-0.008	0.012	-0.003	0.005	-0.014	-0.042	0.026
	1990-1995	0.004	0.014	-0.004	0.005	-0.017	0.208	0.027
	1995-2000	-0.021	0.005	-0.013	0.002	-0.016	-0.004	-0.014
	2000-2004	-0.004	0.006	-0.014	0.000	-0.018	0.704	0.021
	1986-2004	**-0.007**	**0.009**	**-0.008**	**0.003**	**-0.016**	**0.191**	**0.015**
D) Myanmar	1989-1992	-0.004	-0.009	-0.001	-0.008	-0.012	-0.048	-0.011
	1992-1996	-0.010	0.007	-0.002	-0.009	-0.012	0.175	0.012
	1996-2000	-0.009	0.011	-0.006	0.012	-0.010	0.031	0.014
	2000-2004	-0.008	0.014	-0.009	0.000	-0.009	-0.604	0.015
	1989-2004	**-0.008**	**0.006**	**-0.005**	**-0.001**	**-0.011**	**-0.112**	**0.008**
E) Vietnam	1986-1990	-0.058	-0.007	0.008	0.001	-0.008	-0.018	0.026
	1990-1995	0.413	-0.009	0.009	-0.009	0.047	-0.012	0.115
	1995-2000	0.843	-0.011	0.012	-0.037	0.018	-0.008	0.091
	2000-2004	1.667	-0.008	0.013	-0.018	0.000	-0.009	0.003
	1986-2004	**0.666**	**-0.009**	**0.010**	**-0.016**	**0.015**	**-0.012**	**0.062**
F) Kazakhstan	1992-1996	0.037	-0.018	0.010	-0.018	0.019	-0.150	-0.061
	1996-2000	-0.008	-0.009	0.005	-0.045	0.023	-0.597	-0.096
	2000-2004	-0.008	0.008	-0.001	0.000	0.013	0.575	0.035
	1992-2004	**0.007**	**-0.006**	**0.005**	**-0.021**	**0.018**	**-0.057**	**-0.041**

Table 7. (Continue)

Country	Period	Output-Biased TC		Input-Biased TC				
		crop	livestock	land	tractor	labor	fertilizer	livestock
G) Kyrgyzstan	1992-1996	0.003	-0.009	-0.005	-0.010	0.005	0.000	-0.089
	1996-2000	-0.021	0.005	-0.001	0.011	0.001	0.000	0.000
	2000-2004	-0.004	0.001	-0.002	-0.006	-0.001	-0.518	0.006
	1992-2004	**-0.007**	**-0.001**	**-0.003**	**-0.002**	**0.002**	**-0.173**	**-0.028**
H) Tajikistan	1992-1996	0.010	-0.032	0.003	-0.008	-0.004	-0.291	-0.037
	1996-2000	-0.001	0.000	0.005	-0.009	-0.001	-0.005	-0.018
	2000-2004	-0.019	0.022	0.003	-0.004	-0.005	0.779	0.027
	1992-2004	**-0.003**	**-0.003**	**0.004**	**-0.007**	**-0.003**	**0.161**	**-0.009**
I) Turkmenistan	1992-1996	0.033	0.014	-0.001	-0.010	-0.016	0.009	0.050
	1996-2000	-0.030	0.012	-0.001	0.000	-0.011	-0.097	0.028
	2000-2004	-0.009	0.016	-0.002	0.000	-0.011	0.266	0.073
	1992-2004	**-0.002**	**0.014**	**-0.002**	**-0.003**	**-0.013**	**0.060**	**0.050**
J) Uzbekistan	1992-1996	0.004	-0.003	0.001	-0.002	-0.004	-0.053	0.001
	1996-2000	-0.001	0.003	0.000	0.000	-0.002	-0.045	0.000
	2000-2004	-0.007	0.008	0.003	0.000	-0.003	-0.194	0.028
	1992-2004	**-0.001**	**0.003**	**0.001**	**-0.001**	**-0.003**	**-0.097**	**0.010**

Source: Author's calculation

5. CONCLUSIONS

With nearly half of the potential agricultural resources, Asia has the potential to supply an increase in world food demand. More than half of the population in Asia is living in the rural area where agricultural products are the main source of food supply and income of rural households. It has been recognized that during the past two decades, many countries in this continent have undergone a transformation from the CPE to a market-oriented economy. Understanding the magnitude and direction of TFP growth as well as what sources attributing to TFP growth is important because they provide useful information to policy makers that want to design suitable policies to maintain or achieve greater rates of TFP growth in these countries.

To meet this purpose, this study employs a parametric output distance function approach to construct and decompose TFP growth into three of the sources of productivity growth: TC, TEC and SEC. The TC component is further decomposed to uncover evidence of how input and output intensities shift in response to the adoption of innovations. This model is empirically implemented using the most recent FAO data set of 27 Asian countries over the period from 1980-2004. Our major finding indicates that Asian countries on average achieved TFP growth at nearly 2 percent per annum, which is typically considered as a sign that agriculture is healthy in terms of its improvement in productivity. The decomposition of TFP showed convincingly that the relatively high rate of TFP growth was mainly driven by technology improvement. TFP growth rate over the past two decades would have been even higher if TEC had not declined or SEC not deteriorated. The findings of this study show that in order to achieve higher and more sustainable growth in agriculture most countries in all regions have to adjust the farm size to the optimal scale. In addition, countries in SA, WA and CA also require to improve the more efficient use of input factors in their agricultural production such as labor, fertilizer, livestock and tractor whereas the EA countries (except China) also need to adopt new technology in agriculture. Focusing on the transition economies, there were large differences among the transition countries in terms of the magnitude and direction of TFP growth during the transition process. Market reforms have contributed to the progress achieved to date in most countries in CA, China, Mongolia and Myanmar. Transition countries such as China, Vietnam, Mongolia, Kazakhstan and Kyrgyzstan showed that the impact by adjusting the farm size under the current land allocation system and the thin land rental market did not guarantee the healthy economy through the scale of economy, but through the improvement of technology or the more efficient use of input factors. The innovation adoption resulted in various reallocations of inputs and outputs among the transition countries where land, labor, fertilizer and tractor were the main inputs contributing to TFP growth.

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