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Crawford School of Economics and Government
The Australian National University, Canberra

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Agricultural productivity growth in traditional and transitional economies in Asia

Supawat Rungsuriyawiboon and Xiaobing Wang*

This paper reports estimates of agricultural productivity growth in Asian countries, with special attention to the transition economies. A parametric output distance function approach is formulated to decompose total factor productivity (TFP) growth into its associated components and to examine how input and output intensities shift in response to the adoption of innovations. The results show that by including the transition economies, Asia achieved healthy TFP growth at an annual average rate of 1.9 per cent. However, TFP growth and its components differ widely across the transition countries and at different stages of the transition periods within these countries.

Asia has achieved impressive growth in rice and wheat output since the Green Revolution was introduced (Pingali and Heisey 1999). The Green Revolution in Asia was achieved through the application of high-yielding varieties of major cereals, chemical fertilisers, and pesticides and the development of irrigation systems. Increased input use, however, cannot guarantee sustainable growth rates in yields and output (Huang et al. 2002). Over time, cultivated land per capita has declined because of population growth, urbanisation, and industrialisation in the rapidly developing Asian nations that were already characterised as relatively limited in terms of 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 labour.

It is possible to paint a fairly pessimistic picture of Asian agriculture. As well established in the literature, agricultural output depends critically on the factors that contribute to improved total factor productivity (TFP) beyond the quantity of resources applied, including labour, land and fertiliser. 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 mobilisation of inputs but will mainly depend on rising productivity, including from the adoption of innovations, more efficient use of inputs and expansion of the scale of production. However, over the long run the record is not very encouraging. Indeed, in one of the most exhaustive

* Supawat Rungsuriyawiboon (supawat@econ.tu.ac.th) is Associate Professor, Faculty of Economics, Thammasat University, Thailand. Xiaobing Wang (wang@iamo.de) is a Research Associate at the Leibniz-Institute of Agricultural Development in Central and Eastern Europe (IAMO), Germany and Center for Chinese Agricultural Policy, Institute of Geographical Sciences and Natural Resource Research, Chinese Academy of Science, China. The authors gratefully acknowledge financial support from the Thailand Research Fund, the Commission on Higher Education, Ministry of Education (Thailand) and the IAMO. This paper is a revised version of a paper given at the 2008 Asia-Pacific Productivity Conference, Academia Sinica, Taiwan on 17–19 July 2008. The authors would like to thank Alfons Balman, Scott Rozelle, Thomas Glauben, and two anonymous referees for their valuable comments. The usual disclaimer applies.

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 per cent, although over their study period the rate was rising somewhat.

We believe that it is time to re-evaluate the TFP story in Asia. The former socialist countries in Asia are currently in transition. Since the introduction of the household responsibility system in its rural areas, China has embarked on a program of market-oriented reform. Almost a decade later, other heavily regulated Asian economies, for example, Laos, Myanmar and Vietnam, undertook liberalisation. The nations of Central Asia (CA; some of the Newly Independent States of the former Soviet Union) began major market-oriented reform of their planned economies in the late 1980s and early 1990s.

When sketching a picture of all of Asia, it is important to include the transition countries, which account for almost half of the population and more than half of the land area. In the past, mainly because of data problems (both the absence of data and differences in the nature of data between socialist and nonsocialist countries) many economic analyses ignored most of these countries (for example, Coelli and Rao 2005; Otsuka et al. 1992; Pingali et al. 1997; Suhariyanto and Thirtle 2001; Young 1995). It is possible that it was difficult to understand the situation in transition countries because there was a great deal of disequilibrium in the 1970s and 1980s and even in the early 1990s. As a result, making an assessment from data through the mid-2000s may be able to reveal what has been happening in transition countries.

Transition countries generally have a long history of investment in pro-technology R&D but in some cases may be somewhat behind the rest of the world in terms of level of adoption of new technology. As a result, it might be expected that there is great potential for expanding TFP by improving the technological base of some of the countries, 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 institutions that are needed in agriculture to produce and extend new technologies are weak or deteriorating and that there has been a fall in technical efficiency (TE) (Tonini and Jongeneel 2006). Indeed, in a recent book that examines the impact of the economic reforms on agricultural output in transition countries it was found that the effect differed widely across countries and over time within countries (Swinnen and Rozelle, 2006).

Finally, increased availability of data on variables and countries for sufficient years makes it possible to use new statistical methods to analyse rigorously differences in productivity growth for a larger number of countries and update the analysis. In the past, papers looked at the effect of market-oriented reforms on agricultural performance (for example, Lerman 2000; Macours and Swinnen 2002). 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 few cross-regional studies that make intercountry comparisons (including transition nations) of agricultural TFP. However, they admit that the coverage of their work is spotty and that their use of different productivity measures in different countries does not facilitate comparisons.

To fill these gaps, the main purpose of the paper is to understand the state of productivity improvement in Asia, the world's most populated region. To meet this goal we have three specific objectives. First, we seek to measure TFP growth in Asia for the years between 1980 and 2004. Second, we formulate a general model to construct and decompose TFP growth into the sources contributing to productivity growth. This general model allows one to uncover evidence of how input and output intensities shift in response to the adoption of innovations. The model is constructed by integrating parametric output distance function approaches presented in Fuentes et al. (2001) and Orea (2002). Finally, because of the importance of transition countries, we pay particular attention to their contribution to overall Asian TFP growth.

We measure TFP growth in Asian agriculture across 27 countries and 25 years, including most major countries and the Asian transition economies. The results obtained from the parametric output distance function allow calculation of TFP growth and decomposition of changes in TFP into the sources attributing to its growth. These results will be very helpful for policymakers evaluating the impact of agricultural policy on performance and in designing policies for maintaining or achieving robust rates of TFP growth.

The remainder of the paper is organised as follows. The next section presents the methodology used to estimate TFP growth and to decompose it into the sources of growth. The following section discusses the data set and the definitions of the variables used. The results are presented and discussed in the next section, while the final section summarises and concludes.

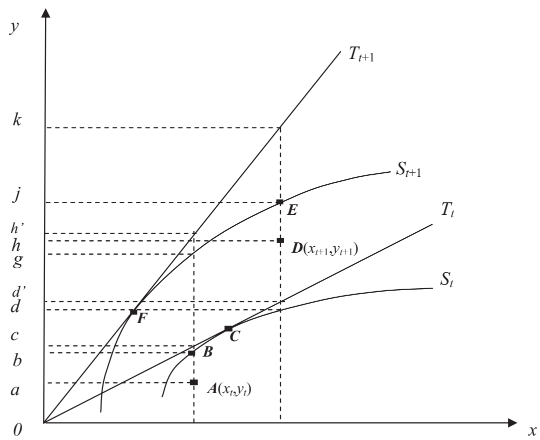
Model specification

Decomposition of TFP growth

TFP growth is defined as the difference between the growth rate of total output and the growth rate of total inputs. For example, if agricultural output grew by 2.2 per cent and total inputs grew by 1.05 per cent, then TFP would have grown by 1.15 per cent. TFP growth in agriculture is important as a source of increased food output, slowing increases in agricultural prices and raising incomes of farmers.

However, TFP growth is not always easy to measure because there are many factors that affect it. To help understand the forces that affect the growth of TFP, conceptually it is possible to decompose TFP into three parts: technological change (TC), changes in TE (TEC) and changes in scale economies (SEC). The TC-related component results when the 'frontier of production' shifts and there is more output for a given quantity of inputs—given that producers are already producing efficiently. The TEC-related component (when it is positive) explains the 'catching-up' part of TFP growth. In other words, TEC occurs when output rises although inputs are constant—given a specific production frontier—because producers are using inputs more efficiently. Finally, the SEC-related component represents the effect from optimising farm size.

Figure 1
Decomposition of total factor productivity growth



Source: Authors.

Figure 1 illustrates the decomposition of TFP growth into its TEC, TC and SEC components. Consider the production technologies of agriculture for the time periods t and $t + 1$. S_t and S_{t+1} are sets constructed using the input–output bundles of all producers in periods t and $t + 1$, respectively. They represent the production technologies under variable returns to scale (VRS) at the time periods 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 because of 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} given by the ratio $\left[\frac{(\overline{0h}/\overline{0d})}{(\overline{0h}/\overline{0j})} \times \frac{(\overline{0a}/\overline{0b})}{(\overline{0a}/\overline{0g})}\right]^{1/2}$.

TFP growth because of TEC and SEC can be illustrated as follows. Consider a producer operating at point A and D for the time periods

t and t + 1. The observed input–output combinations are located inside the production possibility set, implying that production is not technically efficient in either period. In this scenario it is possible that the producer could produce more output from a given set of inputs in either period by adjusting production to points B and E in periods t and t + 1. As defined in Farrell (1957), an output-oriented measure of TEC at time t, relative to the production frontier S_t, is given by the ratio $(\overline{0a}/\overline{0b})$, while the output-oriented TEC at time t + 1, relative to the production frontier S_{t+1}, is given by the ratio $(\overline{0h}/\overline{0j})$. The producer can increase productivity by adjusting production to operate at the frontier. This results in an increase in TFP during periods t and t + 1 because of TEC. TEC, which measures the change in the output-oriented TEC measures between periods t and t + 1, is given by the ratio $(\overline{0h}/\overline{0j})/(\overline{0a}/\overline{0b})$.

Although the farm is operating at the frontier in periods t and t + 1 (points B and E, respectively), it could still be operating at a non-optimal scale in either period. In other words, it is possible that productivity may be increased by exploiting SEC. Taking advantage of SEC can be illustrated by adjusting production to points C and F in periods t and t + 1. The tangent points, C and F in Figure 1, represent the maximum possible degree of productivity. They can also be called the points of technically optimal scale of the production frontiers 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 CRS technology at the most productive scale size at time periods t and t + 1. TFP growth between periods t and t + 1 can arise from progress in SEC in these periods. A measure of SEC represented by the changes in output SEC between periods t and t + 1 data is given by the ratio $(\overline{0j}/\overline{0k})/(\overline{0b}/\overline{0c})$.

Generalised malmquist productivity index (MPI) decomposition and a parametric framework

TFP growth can be measured using a productivity index. The most commonly used TFP index is the MPI, as presented in Caves et al. (1982) and Färe et al. (1994). The MPI has received considerable interest because it allows one to identify the various components of TFP growth, which (as discussed above) are often of interest to policymakers. The MPI can be estimated using the Data Envelopment Analysis (DEA) or Stochastic Frontier Analysis techniques. Both techniques involve the estimation of a production technology.

Färe et al. (1994) initially presented a nonparametric DEA approach to measure the change in the MPI between two time periods. The MPI is defined using an output distance function.[1] By imposing the assumption of CRS on the production technology, the MPI change can be decomposed into TEC and TC. Because it is of interest to understand which factors of production are contributing to output (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 to show that the TC component can be decomposed into two components: input and output-biased TC and non-neutral TC. This decomposition allows investigation of how the inputs and outputs are reallocated when there is TC.

With the availability of new panel data sets and the development of a nonparametric DEA technique, papers decomposing MPI change appeared. However, Färe et al. (1994) raised a fundamental criticism of the decomposition of MPI change using DEA because it cannot be applied to all types of technologies. Subsequently, Orea (2002) proposed a parametric counterpart of the decomposition of output-oriented MPI change to apply to any technology while accounting for measurement errors and random factors.

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

Using distance functions to measure and decompose TFP growth

We measure 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.

Consider a multi-input, multi-output production technology where the i-th producer ($i = 1,\ldots,I$) at time period t ($t = 1,\ldots,T$) uses a non-negative $K \times 1$ input vector $X_{it} \in \Re_+^K$ to produce a non-negative $M \times 1$ output vector $Y_{it} \in \Re_+^M$. The set of all technologically feasible input–output combinations at time period t satisfying the standard properties discussed in Färe and Primont (1995) is $S_t = \{(X, Y) : X$ 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 the output orientation of the distance function. The output distance function is nondecreasing, linearly homogenous and convex in Y, and nonincreasing 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 output-oriented TE measured at time t; that is, $0 \le TE_t^o(X_t, Y) \equiv D_t^o(X_t, Y) \le 1$.

Orea (2002) employs a parametric technique and applies Diewert's (1976) Quadratic Identity Lemma to derive a generalised MPI change decomposition. The logarithmic form of a generalised output-oriented MPI change index between the periods t and $t+1$ can be written as[2]

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

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 the periods t and $t+1$; $d_t^{o,v}$ is the logarithm of the output distance term, which is equivalent to the logarithm of the output-oriented measure of Farrell's 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 this paper $\ln TEC^{o,v}$ represents the logarithmic form of TEC, $\ln TC^{o,v}$ represents the logarithmic form of TC and $\ln SCE^{o,v}$ represents the logarithmic form of SEC. Equation 2 is expressed in terms of proportional rates of growth instead of a product of indices.

Estimating the distance function

The components of the generalised 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

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

2 If the technology of the given industry exhibits CRS technology, the ln SEC^o component will become zero and the logarithmic form of a generalised output-oriented MPI change index between periods t and $t+1$ can be reduced to $m^o_{t,t+1} = \ln TEC^o + \ln TC^o$.

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:

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

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[3]:

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

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.

Accounting for the bias in TC

This section presents an analysis of the direction of TC with respect to each individual input and output. The concept of reallocating inputs and outputs attributed to TC was originated by Hicks (1963) and subsequently developed by Antle (1984) and Färe et al. (1997). The rate of TC as computed in the previous section can be further decomposed into input and output-biased TC. These measures provide information for policymakers about how input and output intensities shift in response to the adoption of innovations. The input- (output) biased TC is the relative measure of input (output) bias that explains how a firm uses or saves (produces or reduces) individual inputs (outputs) in response to the adoption of innovations.

Following a parametric distance function approach for the period t, the MPI decomposition proposed by Fuentes et al. (2001) can be used to decompose the TC component of TFP growth into two additional parts: an input and output-biased TC part and a non-neutral TC part. The further decomposition into these two subcomponents allows investigation of how inputs and outputs are reallocated when there are shifts in TC. The parametric distance function approach to the MPI change decomposition requires the imposition of 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 $\sum_{k=1}^{K} \beta_{x_k t} = 0$.

3 Homogeneity in outputs can be imposed by estimating the model with M-1 output variables normalised by the M^{th} output variable. Further, a test for the presence of economies of scale can be performed by imposing the CRS assumption on Equation 5. The CRS assumption requires that the output distance function holds the property of the homogeneity of degree minus one in inputs. Lists of the CRS restrictions are shown below and the translog output distance function under the CRS model is presented in Equation 6. Homogeneity in inputs can be imposed by estimating the model in Equation 5 with K-1 input variables normalised by the K^{th} input variable. Hypothesis tests for the presence of economies of scale are conducted using a likelihood ratio (LR) test.

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

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

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 the magnitude of TC ($MTC^{o,c}$) and 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 forms of the $MTC^{o,c}$, $IBTC^{o,c}$ and $OBTC^{o,c}$ are given as

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

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

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

If ln $IBTC^{o,c}$ and ln $OBTC^{o,c}$ are equal to zero, the $MTC^{o,c}$ equals the TC under joint Hick's neutrality. The value of ln$MTC^{o,c}$ can be less than, equal to, or greater than zero depending upon whether productivity is declining, unchanged, or improving, respectively. The value of ln $IBTC^{o,c}$ of the k-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-th input. Similarly, the value of ln $IBTC^{o,c}$ of the m-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-th output.

Data

The empirical analysis focuses on agricultural production in 27 Asian countries using an unbalanced data set covering the period 1980–2004. The primary source of data is the AGROSTAT web site of the UN Food and Agriculture Organisation (FAO). In this study, the production technology is presented by two output variables (crop output and livestock output) and five input variables (land, tractor power, labour, fertiliser and livestock).

Output variables

The output series were derived by aggregating quantity data for 127 agricultural commodities (115 crops 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 1999–2001.[4] Second, the aggregate output values in the base period were used to generate an aggregate output series for the period 1992–2002 using the separate FAO production indices for crops and livestock.[5]

4 Detailed information on how international average prices are constructed can be found in Rao (1993).
5 See the FAO Statistical Database (FAO 2004) for details regarding the construction of production index numbers.

Input variables

Lack of data on other variables limited the input variables to the following five:

- *Land*—arable land (in hectares) in each country in each year. Arable land includes land under permanent crops and the area under permanent pasture.
- *Tractors*—the total number of wheeled and crawler tractors used in agriculture. Garden tractors were excluded.
- *Labour*—the number of economically active people in agriculture; a measure of the number of labourers in the agricultural sector.
- *Fertiliser*—aggregates in nutrient-equivalent terms, the commercial use of nitrogen, potassium and phosphate fertilisers (expressed in thousands of metric tons). The fertiliser input variable is defined by following the approaches of other studies on intercountry comparison of agricultural productivity (Fulginiti and Perrin 1997; Hayami and Ruttan 1970).
- *Livestock*—the sheep equivalent of six categories of animals used (buffaloes, cattle, pigs, sheep, goats and poultry). The total number of each category is converted into sheep equivalents using standard conversion factors: 8.0 for buffalos and cattle; 1.0 for sheep, goats and pigs; and 0.1 for poultry (Hayami and Ruttan 1970).

The 27 countries selected account for more than 46 per cent of global agricultural output, 56 per cent of the world's population and 94 per cent of the population of Asia. Only a small number of countries (Bahrain, Brunei, Bhutan, Cyprus, Jordan, Kuwait, Lebanon, Maldives, Oman, Qatar and Singapore) were excluded because of the absence of data.

The selected countries were arranged into six regions: CA, Eastern Asia (EA), Southern Asia (SA), Southeast Asia (SEA), Western Asia (WA), and China (CN).[6] In recognition of its size and because of changes in its accounting practices over time, China is treated as a separate region.[7] The countries in each region are shown in Table 1. A map of Asia indicating the location of each country used in this study is presented in Figure 2.

The means of the output and input variables for each region are presented in Table 2. China has the highest value of agricultural output for both crop and livestock commodities. China has the largest area of agricultural land, number of agricultural labourers and quantity of fertiliser used. The EA region has the largest number of tractors, whereas the SA region has the highest volume of livestock inputs.

The agricultural sector dominates the economies of most Asian countries. In 2008, China and India, the two most populous countries, continued to derive a significant share of their GDP (11.3 and 16.6 per cent, respectively) from agriculture. In Cambodia, Kyrgyzstan, Laos, Myanmar and Nepal agriculture contributed more than 40 per cent of their GDP. During the past two decades many Asian countries have undertaken the liberalisation of their economies. Economic transformation has been accompanied by a steady reduction in the GDP share of agriculture across the region. But although the share of agriculture decreased, the sector continues to make an important contribution to the economy and by extension to food security and rural poverty alleviation in many countries.

Food production in the region has shown a general upward trend during the past decade. Despite the considerable population increase in many of these countries, average food availability per capita is now significantly higher than in the 1970s, with the increase being marked in such countries as Vietnam, Cambodia, Indonesia and Malaysia. However, food availability per capita has not increased much in some regions. In SA, for example, although birth rates and population growth have slowed and agricultural output has increased dramatically over the past two decades, there is still not sufficient food to ensure adequate nourishment for everyone. Researchers often use malnutrition as an indicator of endemic poverty. Overall, 34 per cent of the population in developing countries

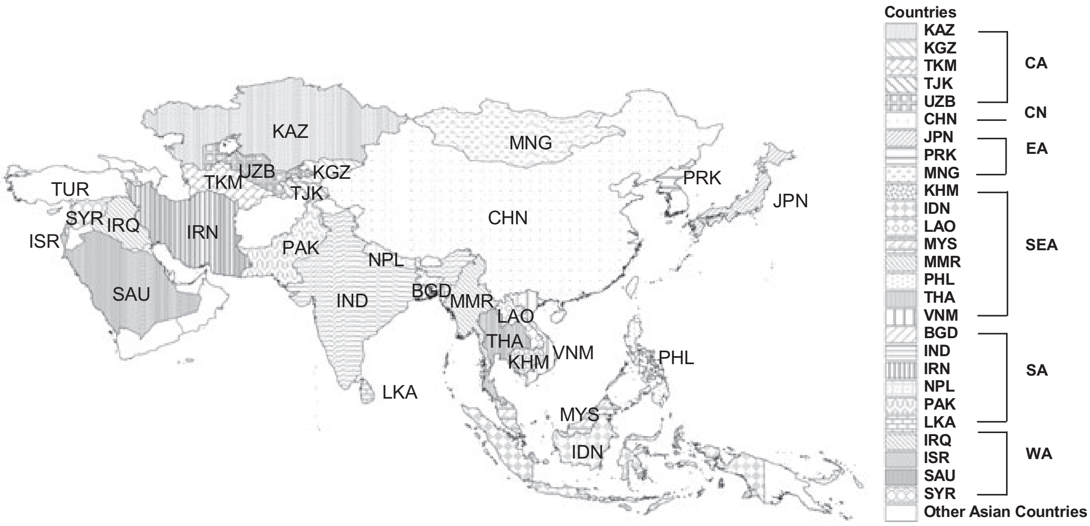
6 The regional groupings are those used by the UN Statistics Division.
7 According to the UN's definition, China is located within the EA region.

Table 1
Regional distribution of selected countries

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

Source: Based on definitions in text.

Figure 2
Map of the countries used in this study



Source: Authors.

Table 2
Descriptive statistics of variables, 1980–2004

		Region						
Variable	Units	Central Asia[a]	Eastern Asia	Southeast Asia	Southern Asia	Western Asia	China	All
Outputs								
Crops (y_1)	×10^6 US$	1793	4465	7267	19020	4517	165817	14794
		(1446)	(3496)	(6423)	(30127)	(6221)	(44930)	(35694)
Livestock (y_2)	×10^6 US$	1282	3711	1389	7926	1660	62344	5616
		(1072)	(3369)	(1099)	(11919)	(1844)	(33658)	(14707)
Inputs								
Land (x_1)	×10^3 ha	57.31	44.13	13.17	47.33	40.11	518.41	54.29
		(78.46)	(57.43)	(12.24)	(63.19)	(53.12)	(36.23)	(107.67)
Tractors (x_2)	×10^3	76.46	674.65	36.13	284.01	175.78	825.24	231.25
		(64.03)	(903.59)	(53.64)	(514.45)	(292.12)	(92.53)	(476.38)
Fertiliser (x_3)	×10^6 ton^3	206	871	775	2785	557	28418	2237
		(350)	(734)	(840)	(4626)	(630)	(9009)	(6096)
Labour (x_4)	×10^3	1.29	2.72	15.33	52.42	3.28	480.97	36.96
		(0.90)	(2.01)	(13.67)	(85.03)	(5.08)	(35.18)	(101.00)
Livestock (x_5)	×10^6	32.86	38.53	60.45	537.65	42.07	1439.04	217.18
		(26.61)	(10.89)	(41.32)	(850.03)	(56.95)	(272)	(525.27)

[a] Data for countries in this region are only available for the period 1992–2004.
Notes: Means are calculated. Standard deviations are presented in parentheses.
Source: Authors' calculations.

is malnourished. The International Food Policy Research Institute estimates that the incidence of malnutrition varies by geographical regions from 15–25 per cent in most Asian regions to 60 per cent in SA. Therefore, it is important that Asia keeps its agricultural TFP growth high in order to supply sufficient food to meet the domestic and global demand for food.

Results

Translog output distance functions in the form of the VRS model from Equation 5 and the CRS model from Equation 6 were estimated. The variables used in estimations were transformed by dividing by their respective geometric means.[8] A hypothesis test regarding the presence of SEC in cropping and livestock production was conducted using the LR test. The LR test of the null hypothesis of VRS was rejected at the 95 per cent level, implying that economies of scale are not significant in crop and livestock production. Therefore, in the remainder of the analysis the parameter estimates of the CRS model are used to calculate the components of the MPI change decomposition and to investigate how the inputs and outputs are reallocated with TC.[9] The maximum likelihood parameter estimates for the CRS model are shown in Table 3.

In general, the estimations performed well. All first-order coefficients have the expected signs, implying that the output distance functions are increasing in outputs and decreasing in inputs at the sample mean.[10] The estimates of

8 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.
9 CRS technology is often assumed when aggregate country-level data are analysed. See further discussion in Coelli and Rao (2005).
10 Tests of the regularity conditions were checked at each data point in all 615 observations. It was found that the convexity condition and the monotonicity constraints on outputs are satisfied at all observations in the output distance function for

Table 3
Estimated Parameters of the Output Distance Function for the CRS Model

Parameter[a]	Estimates	*t*-Statistics	Parameter[a]	Estimates	*t*-Statistics
β_o	0.518	9.076	β_{x3x4}	–0.231	–10.436
β_{y1}	0.427	15.324	β_{x3x5}	–0.251	–3.378
β_{y1y1}	0.340	5.420	β_{x4x5}	0.279	11.756
β_{x2}	–0.211	–14.232	β_{x2y1}	–0.169	–7.615
β_{x3}	–0.125	–5.141	β_{x3y1}	–0.311	–6.712
β_{x4}	–0.331	–28.755	β_{x4y1}	0.216	10.239
β_{x5}	–0.247	–7.540	β_{x5y1}	0.315	6.161
β_{x2x2}	0.027	2.276	β_t	–0.006	–4.225
β_{x3x3}	0.220	3.681	β_{tt}	–0.002	–4.592
β_{x4x4}	–0.027	–3.433	β_{x2t}	0.002	1.535
β_{x5x5}	0.131	1.227	β_{x3t}	–0.007	–2.703
β_{x2x3}	0.348	14.718	β_{x4t}	0.007	5.528
β_{x2x4}	–0.095	–11.013	β_{x5t}	0.007	2.317
β_{x2x5}	–0.274	–10.435	β_{y1t}	–0.002	–0.757

[a] Livestock output (y_2) and land input (x_1) were normalised.
Note: Subscripts on β_x coefficients refer to inputs: 2 = tractors; 3 = fertiliser; 4 = labour; 5 = livestock, and subscripts on β_y coefficients refer to outputs: 1 = crops.
Source: Authors' calculations.

the distance elasticities with respect to outputs are 0.43 and 0.57 for crops and livestock, respectively, and by definition add to 1.0.[11] The estimates of the distance elasticities with respect to inputs are –0.086, –0.21, –0.125, –0.33 and –0.25 for land, tractors, labour, fertiliser and livestock, respectively, and by definition add to –1.0.[12]

Perhaps the most important finding is that over the time period of the analysis (1980–2004), the average annual growth rate of TFP across the Asian region was nearly 1.9 per cent (Table 4, section A, row 6, column 5). A growth rate of this magnitude is a sign that agriculture is healthy in terms of improvements in productivity. It is higher than the rate of growth of the population of Asia during the 1990s (around 1.5 per cent; Asian Development Bank 2001). Developed countries considered to have well-performing agricultural sectors (for example, the USA, Germany and Australia) have consistently posted TFP growth rates of more than 1.5 per cent (Bureau et al. 1995).

The examination of productivity changes over the past decade was seen as important because this robust rate of TFP growth for Asia over the study period is, to a large extent, driven by increases in TFP during the past ten years (Table 4, section A, column 5). Between 1980 and 1995, TFP growth averaged a little over 1 per cent (increasing from 0.58 per cent in the 1980–85 period to 1.66 (1.77) per cent during the 1985–90 (1990–95) period. These estimates are consistent with those of Suhariyanto and Thirtle (2001), who found that the growth of TFP in Asia before 1996 was around 1 per cent.[13]

both models. The monotonicity constraints on inputs are violated at 11, 5, 12, 3 and 10 per cent of all observations in the case of land, tractors, labour, fertiliser, and livestock inputs, respectively.

11 The output distance function satisfies linear homogeneity in outputs.

12 Under the CRS technology assumption, the property of homogeneity of degree minus one in inputs is imposed.

13 Data used in Suhariyanto and Thirtle (2001) were also obtained from the FAO Agrostat database. In their study, production technology was defined using one output variable (total value of agricultural production including food and nonfood outputs) and five input variables (land, labour, livestock, fertiliser and machinery). The number of inputs used is the same, but the definition of each input variable is slightly different from this paper. When comparing TFP growth estimates, special attention needs to be paid to the number and definition of inputs and outputs used in the analysis because differences may invalidate the comparison.

Table 4
Weighted average growth rates of the MPI change and TC decomposition for each region over the time period 1980–2004 (in per cent)[a]

						Output-biased TC		Input-biased TC				
Region	Period	TEC	TC	TFP growth	MTC	Crop	Livestock	Land	Tractor	Labour	Fertiliser	Livestock
A) All	1980–85	–0.304	0.885	0.580	–1.182	0.014	–0.009	–0.013	0.012	–0.010	0.046	0.014
	1985–90	0.201	1.457	1.658	–0.457	0.013	–0.006	–0.009	0.010	–0.009	0.055	0.016
	1990–95	–0.305	2.073	1.769	0.341	0.015	–0.006	–0.002	0.006	–0.005	0.031	0.016
	1995–2000	–0.716	2.734	2.018	1.186	0.011	–0.006	–0.005	0.013	–0.004	0.008	0.002
	2000–04	0.429	2.950	3.379	2.006	0.011	–0.006	–0.003	0.005	–0.003	0.028	0.011
	1980–2004	–0.163	2.020	1.857	0.211	0.013	–0.007	–0.006	0.009	–0.007	0.033	0.012
B) SA	1980–85	–0.106	1.593	1.487	–1.437	0.013	–0.009	–0.003	0.017	–0.009	0.065	0.012
	1985–90	0.015	1.887	1.902	–0.824	0.010	–0.007	–0.003	0.018	–0.008	0.050	0.010
	1990–95	–0.194	2.184	1.990	–0.056	0.010	–0.006	–0.001	0.011	–0.012	0.025	0.007
	1995–2000	–0.056	2.482	2.426	0.737	0.010	–0.005	–0.002	0.011	–0.011	0.030	0.002
	2000–04	–0.054	2.781	2.727	1.591	0.008	–0.004	–0.002	0.011	–0.011	–0.005	0.003
	1980–2004	–0.080	2.185	2.105	0.036	0.010	–0.007	–0.002	0.014	–0.011	0.033	0.007
C) SEA	1980–85	0.096	–0.567	–0.471	–0.534	0.013	–0.007	–0.010	0.011	–0.014	0.079	0.028
	1985–90	0.976	0.121	1.097	0.183	0.012	–0.006	–0.015	0.019	–0.013	0.042	0.008
	1990–95	–0.079	0.790	0.711	0.836	0.012	–0.007	-	0.024	–0.009	0.047	0.011
	1995–2000	0.140	1.528	1.668	1.602	0.006	–0.006	–0.012	0.015	–0.007	0.033	–0.010
	2000–04	0.589	2.448	3.037	2.53	0.013	–0.008	–0.008	0.001	–0.005	–0.015	0.012
	1980–2004	0.334	0.798	1.132	0.756	0.011	–0.007	–0.009	0.014	–0.010	0.037	0.010
D) WA	1980–85	0.401	–1.733	–1.332	–1.466	0.014	–0.011	–0.008	0.015	–0.001	0.108	0.006
	1985–90	–0.264	–0.968	–1.232	–0.67	0.008	–0.006	–0.009	0.011	0.012	0.036	0.011
	1990–95	0.019	0.032	0.051	0.363	0.001	–0.004	–0.017	0.011	–0.001	0.008	–0.002
	1995–2000	–0.336	0.860	0.524	1.169	0.013	-	–0.002	0.005	0.001	0.017	0.008
	2000–04	0.086	1.616	1.702	1.927	0.009	–0.009	-	0.001	0.001	0.031	0.003
	1980–2004	–0.023	–0.108	–0.131	0.295	0.009	–0.006	–0.007	0.009	0.002	0.040	0.005

Table 4
(Continued)

Region	Period	TEC	TC	TFP growth	MTC	Output-biased TC		Input-biased TC				
						Crop	Livestock	Land	Tractor	Labour	Fertiliser	Livestock
E) EA	1980–85	0.039	–3.578	–3.539	–3.555	0.009	–0.005	0.002	0.021	0.017	0.020	0.028
	1985–90	–0.359	–2.917	–3.276	–2.872	0.007	-	0.003	0.016	0.028	–0.004	–0.003
	1990–95	0.526	–2.176	–1.651	–2.135	0.006	0.001	0.007	0.010	0.032	–0.015	0.016
	1995–2000	–0.584	–1.337	–1.921	–1.276	0.004	-	0.003	0.008	0.033	–0.019	–0.014
	2000–04	1.374	–0.577	0.797	–0.55	0.003	0.002	0.016	0.004	0.039	0.022	–0.001
	1980–2004	0.150	–2.181	–2.031	–2.241	0.006	–0.001	0.007	0.012	0.029	0.001	0.005
F) EA	1980–85	–0.587	0.311	–0.276	–0.732	–0.01	0.015	–0.021	0.009	–0.010	0.020	0.010
+	1985–90	0.115	1.622	1.737	0.074	–0.006	0.016	–0.012	0.002	–0.010	0.061	0.024
CN	1990–95	–0.481	2.379	1.898	0.897	–0.007	0.020	–0.002	–0.003	–0.001	0.037	0.024
	1995–2000	–1.323	2.966	1.643	1.735	–0.007	0.013	–0.006	0.014	-	–0.005	0.006
	2000–04	0.732	3.158	3.890	2.475	–0.007	0.011	–0.003	0.002	0.002	0.050	0.014
	1980–2004	–0.352	2.043	1.690	0.924	–0.008	0.015	–0.009	0.005	–0.004	0.032	0.015
G) CA	1992–95	0.305	0.706	1.011	0.833	–0.011	0.019	0.002	–0.006	0.003	–0.125	–0.010
	1995–2000	–0.458	2.060	1.601	2.241	0.021	–0.006	-	–0.012	0.005	–0.174	–0.036
	2000–04	–1.203	3.178	1.974	3.146	0.018	–0.005	–0.002	0.001	0.001	0.164	0.034
	1992–2004	–0.516	2.094	1.578	2.091	0.009	0.002	-	–0.006	0.003	–0.045	–0.004

[a] Under the CRS assumption, the SEC component contributing to TFP growth becomes zero. The estimates of output-based TC and input-based TC are significantly different from zero at the 10 per cent level of significance.

Note: CA, Central Asia; CN, China; CRS, constant returns to scale; EA, Eastern Asia; MTC, magnitude of technological change; SA, Southern Asia; SEA, Southeast Asia; SEC, scale economies; TC, technological change; TEC, technical efficiency; TFP, total factor productivity; WA, Western Asia.

Source: Authors' calculations.

After 1995, the rate of growth of TFP accelerates to 2.02 per cent in 1995–2000 and to nearly 3.4 per cent in 2000–04.

The decomposition analysis demonstrates that the relatively high rate of TFP growth and its increase over the past two decades has relied on TC (Table 4, section A, column 4). In fact, throughout the entire period (except in 1985–90 and 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 out the production frontier by 2.02 per cent annually. During the past decade, TC has grown by nearly 2.9 per cent annually (2.73 per cent between 1995 and 2000 and 2.95 per cent between 2000 and 2004). While it is beyond the scope of our analysis to identify the exact sources of TC, according to work by Evenson 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.

Rates of TC that exceeded TFP growth were needed to keep TFP growing at a healthy rate because the decomposition analysis shows that during the sample period TFP has been pulled down because of declining TEC (Table 4, section A, column 3). According to the results, TFP growth between 1980 and 2004 would have been 0.16 per cent higher had efficiency levels not fallen. Over time there has not been a consistent change in TEC. In the most recent period (2000–04), TEC rose by 0.43 per cent because of the continuing rise in off-farm employment—which might be one factor behind improving efficiency. When combined with TC, it is clear why TFP growth was so high in the period 2000–04.

In summary, for Asia as a whole, productivity growth has been relatively robust and increasing. This is good news for those concerned about world food security, especially given the declining trends in cultivated land, labour and water (Pingali 2001). If Asia's food output is to contribute to world supplies, productivity increases need to continue because it is likely that resources will continue to flow out of the sector as development 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 can be reversed, it is possible that TFP could grow even faster.

Sources of TFP growth in Asia's major regions and the importance of transition nations

If we examine TFP growth 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 in the previous section). The record of the major regions of traditional Asia can be seen in sections B, C, D and E in Table 4. In the table, the results of the 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 SA parallel those of the rest of Asia (Table 4, section B). The annual growth rate of TFP is around 2 per cent and rising. In addition, the rate of TC exceeds that of TFP growth in all periods, except between 1985 and 1990, 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 because the TEC component is negative (also like that in Asia as a whole). It is clear from these results that the increasingly robust performance of SA is one driver of the results found for Asia as a whole.

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 SEA is only around 1 per cent, about half that of Asia as a whole. However, in SEA the rate is at least positive, whereas in WA and EA it is negative. In the case of EA, between 1980 and 2004 TFP fell by 2.03 per cent annually. Although contributing to TFP growth slightly in SEA, TC drags down TFP growth in WA and 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 been confined to these four regions (SA, SEA, WA and EA), would not have been so encouraging. In fact, if we had only included the countries in these regions (the countries 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 in the four regions between 1980 and 2004 was 1.44 per cent. The importance of SA in the record of Asia as a whole is shown by computing the rate of TFP growth for only SEA, WA and EA (0.49 per cent). Such low growth rates would be a source of concern for those who 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 fall.

However, the performance of Asia's productivity growth is greatly enhanced by including the former socialist countries in East and Central Asia (Table 4, sections F and G). The record of China—coupled with its size—shows that it (like SA) is one of the driving forces behind the rebound of Asian productivity. The rate of growth of TFP of China for most of the sample period and its 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 per cent annually (Table 5, section B). Between 2000 and 2004 TFP grew at more than 4 per cent. These estimates are consistent with those estimated by Jin et al. (2007), which (using a completely different set of data) supports our findings that TFP growth rates in crops and livestock are high by international standards and increasing.

China's productivity, like that of SA and Asia as whole, is driven by TC—and hurt by TEC (Table 5, section B). Over the sample period, TC rose by 2.54 per cent 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 et al. (2007), explains why it is that TEC falls. Problems with the farm extension system, disequilibrium resulting 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, nonetheless the record of CA is a positive one (Table 4, section G). During the sample period (1992–2004 for CA—because of the absence of data in earlier periods) the growth rate of TFP averaged 1.58 per cent. Between 2000 and 2004, TFP rose by a rate of 1.97 per cent—almost as fast as Asia as a whole. This region of Asia, which is sometimes thought to be an underperformer (Swinnen and Rozelle, 2006), in fact has not performed that poorly in terms of TFP growth. Similar to Asia as a whole (and China), shifts in TC are fully responsible for the growth in TFP, while TEC detracted from TFP growth.

Examining transition countries in more detail

Looking at the transition countries in more detail, it can be seen that they have contributed significantly to the growth of Asia's TFP (Table 5, section A). In aggregate, their record is an important part of the Asian experience. Overall, TFP growth was 2.05 per cent for the sample period and rising over time. Most of the growth was because of TC, while TEC was negative. These trends suggest that the former socialist countries and the leaders of their transition governments have been able to maintain TFP growth mostly through their investments in agricultural R&D and other initiatives to promote technology. At the same time, transition, nearly two decades after the collapse of the former Soviet Union, may be dragging down TFP growth because of continued disequilibrium (which is inherent in many transition situations).

Because of the danger that China's performance (Table 5, section B) dominates the findings when looking at the region as a whole, we examine the other nine transition economies separately. When doing so we find that there are sharp differences among them. In the case of five (Mongolia—section C; Myanmar—section F; Kazakhstan—section G; Tajikistan—section I; and Turkmenistan—section J), there has been TFP growth of more than 2 per cent annually. In all cases in which the transition country experienced positive TFP growth, the

Table 5
Average growth rates of the MPI change and TC change decomposition by transition countries after market reform (in per cent)[a]

					Output-biased TC		Input-biased TC				
Transition country	Periods	TEC	TC	TFP growth	Crop	Livestock	Land	Tractor	Labour	Fertiliser	Livestock
A) All	1980–85	–0.691	0.956	0.266	–0.008	0.013	–0.024	0.016	–0.014	0.029	0.017
	1985–90	0.200	2.137	2.338	–0.014	–0.001	-	0.004	–0.010	–0.005	0.028
	1990–95	–0.486	2.645	2.160	0.051	0.006	0.006	–0.007	0.005	–0.033	0.013
	1995–2000	–1.244	3.263	2.019	0.087	–0.003	0.002	–0.005	0.004	–0.062	0.012
	2000–04	0.575	3.353	3.928	0.168	–0.001	0.003	–0.001	0.001	0.118	0.022
	1980–2004	–0.367	2.413	2.047	0.082	-	0.004	–0.004	0.004	–0.006	0.009
B) China	1980–85	–0.691	0.956	0.266	–0.008	0.013	–0.024	0.016	–0.014	0.029	0.017
	1985–90	0.184	2.267	2.450	–0.005	0.014	–0.013	0.009	–0.015	0.078	0.037
	1990–95	–0.598	2.887	2.289	–0.006	0.021	–0.002	0.005	–0.004	0.050	0.035
	1995–2000	–1.245	3.335	2.090	–0.006	0.012	–0.005	0.024	–0.003	0.005	0.017
	2000–04	0.694	3.422	4.116	–0.005	0.011	–0.003	0.011	–0.001	0.060	0.025
	1980–2004	–0.403	2.538	2.135	–0.006	0.014	–0.010	0.013	–0.008	0.044	0.026
C) Mongolia	1991–95	0.221	3.966	4.188	–0.004	0.035	0.009	–0.015	0.012	–0.293	0.012
	1995–2000	–4.104	4.475	0.371	0.011	0.012	–0.018	–0.016	0.017	0.077	0.030
	2000–04	1.702	5.464	7.166	–0.017	–0.010	–0.001	0.002	0.015	0.088	–0.078
	1991–2004	–0.987	4.623	3.636	–0.003	0.012	–0.003	–0.010	0.015	–0.043	–0.012
D) Vietnam	1986–90	–0.745	–0.153	–0.897	–0.057	–0.007	0.019	-	0.003	–0.019	0.037
	1990–95	0.882	0.296	1.178	0.415	–0.009	0.020	–0.010	0.058	–0.013	0.126
	1995–2000	0.568	0.685	1.253	0.845	–0.013	0.023	–0.038	0.029	–0.009	0.102
	2000–04	–0.590	1.473	0.883	1.669	–0.010	0.024	–0.019	0.011	–0.010	0.014
	1986–2004	0.106	0.566	0.672	0.718	–0.010	0.022	–0.017	0.025	–0.013	0.070
E) Laos	1986–90	0.453	0.219	0.672	0.014	–0.008	–0.004	0.016	–0.015	–0.031	0.037
	1990–95	0.013	0.855	0.868	0.016	0.006	–0.005	0.016	–0.018	0.219	0.038
	1995–2000	–1.993	1.056	–0.937	0.007	–0.021	–0.014	0.013	–0.017	0.007	–0.003
	2000–2004	–2.194	1.200	–0.994	0.008	–0.004	–0.015	0.011	–0.019	0.715	0.032
	1986–2004	–0.937	0.846	–0.091	0.011	–0.007	–0.010	0.014	–0.017	0.228	0.026

Table 5
(Continued)

Transition country	Periods	TEC	TC	TFP growth	Output-biased TC		Input-biased TC				
					Crop	Livestock	Land	Tractor	Labour	Fertiliser	Livestock
F) Myanmar	1989–92	–0.210	1.733	1.523	–0.008	–0.004	–0.002	–0.009	–0.013	–0.049	-
	1992–96	–0.593	2.137	1.544	0.009	–0.010	–0.003	–0.010	–0.013	0.174	0.023
	1996–2000	–0.160	2.665	2.504	0.013	–0.011	–0.007	0.011	–0.011	0.030	0.025
	2000–04	1.273	4.268	5.541	0.016	–0.010	–0.010	–0.001	–0.010	–0.605	0.026
	1989–2004	0.096	2.765	2.862	0.007	–0.009	–0.006	–0.002	–0.012	–0.113	0.019
G) Kazakhstan	1992–96	1.249	1.685	2.934	0.039	–0.018	0.021	–0.019	0.030	–0.151	–0.050
	1996–2000	–2.171	3.859	1.688	–0.007	0.002	0.016	–0.046	0.034	–0.598	–0.085
	2000–04	0.955	4.484	5.439	–0.007	0.008	0.010	–0.001	0.024	0.574	0.046
	1980–2004	0.011	3.343	3.354	0.009	–0.004	0.016	–0.022	0.029	–0.058	–0.030
H) Kyrgyzstan	1992–96	–0.141	–0.234	–0.375	0.013	–0.009	–0.006	–0.011	0.016	–0.001	–0.090
	1996–2000	–0.686	0.866	0.180	–0.012	0.005	–0.002	0.010	0.012	–0.001	–0.001
	2000–04	–1.932	2.453	0.521	–0.004	0.006	–0.003	–0.007	0.010	–0.519	0.005
	1980–2004	–0.919	1.028	0.109	–0.001	0.001	–0.004	–0.003	0.013	–0.174	–0.029
I) Tajikistan	1992–96	1.312	1.860	3.172	0.015	–0.017	0.014	–0.009	–0.005	–0.280	–0.038
	1996–2000	–0.063	3.685	3.622	–0.001	0.018	0.016	–0.010	–0.002	0.006	–0.019
	2000–04	2.648	3.105	5.753	–0.011	0.012	0.014	–0.005	–0.006	0.790	0.026
	1980–2004	1.299	2.884	4.182	0.001	0.004	0.015	–0.008	–0.004	0.172	–0.010
J) Turkmenistan	1992–96	–0.033	1.558	1.525	0.016	0.043	–0.002	–0.011	–0.017	0.020	0.061
	1996–2000	–0.825	2.553	1.728	0.014	–0.031	–0.002	–0.001	–0.012	–0.086	0.039
	2000–04	0.998	2.793	3.791	0.018	–0.009	–0.003	–0.001	–0.012	0.277	0.084
	1980–2004	0.047	2.301	2.348	0.016	0.001	–0.002	–0.004	–0.014	0.070	0.061
K) Uzbekistan	1992–96	–0.230	–0.153	–0.383	–0.002	0.014	0.012	–0.003	–0.005	–0.054	0.012
	1996–2000	–0.405	0.771	0.367	0.005	0.001	0.011	–0.001	–0.003	–0.046	0.011
	2000–04	–0.524	1.910	1.386	0.010	–0.007	0.014	–0.001	–0.004	–0.195	0.039
	1980–2004	–0.386	0.843	0.457	0.004	0.003	0.012	–0.002	–0.004	–0.098	0.021

[a] Under the CRS assumption, the SEC component contributing to TFP growth becomes zero. The estimates of output-based TC and input-based TC are significantly different from zero at the 10 per cent level of significance.
Note: TC, technological change; TEC, technical efficiency; TFP, total factor productivity.
Source: Authors' calculations.

rate of growth of TC was positive. In all of these countries except Mongolia, TEC was also positive. Therefore, the negative disequilibrium effect found for China may not have been because of transition but rather a function of its extremely fast growth rates. All of the countries with positive TFP growth that also had a positive contribution of TEC during the 2000–04 period experienced negative TEC in an earlier period. What these results suggest is that the disequilibrium of transition that detracted from growth in earlier periods was temporary, and now growth from TEC is positive.

However, there are four countries (Vietnam—section D; Laos—section E; Kyrgyzstan—section H; and 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 in some of these countries TFP rose while in others it did not. Swinnen and Rozelle (2006) state that in no large part differences in the performance of the transition countries (including those outside Asia) were because of differences in pricing, land rights, and marketing policies. If this were the case in our sample, it would lead to the further question of why it is that different countries adopted different policy regimes.

Because only a few empirical studies have analysed agricultural productivity developments in SEA, we discuss the agricultural performance of some countries in this region such as Laos, Myanmar and Vietnam. Our findings show that Myanmar had high TFP growth, including impressive growth in recent years. This result implies that the reform process in Myanmar is in the right direction. The relatively high overall rate of TFP growth and the increase in recent years has relied on both the adoption of new technology and improvements in the efficiency of agricultural production.

By comparison, Laos had the lowest TFP growth. This result could be explained in two ways. First, while Laos could intensify cropping, mainly rice, by growing at least two crops a year, most farmers plant only once per year because of the scarcity of investment and technology and because of the constraints of agricultural infrastructure. Second, farmers are not trained to manage farming efficiently. As a consequence, the yield per hectare is low compared with that of other countries in this region.

Vietnam is among the leading countries in terms of agricultural output in SEA. It has not only achieved self-sufficiency in rice production but also is now a major global food exporter competing actively with Thailand and the USA. Our findings show that the adoption of new technology is the main factor driving TFP growth in Vietnam. At the beginning of its market reform, Vietnam experienced negative agricultural TFP, which was because of inefficient use of inputs and nonadoption of new technology. However, TFP growth improved significantly after five years of market reform. Over the past decade, government policies in Vietnam have encouraged farmers to invest in agricultural production, which has been so successful that Vietnam has achieved sustained agricultural growth.

In summary, for all Asian transition economies, agricultural productivity growth has been relatively robust and rising. The healthy agricultural growth in Asia has been driven in large part by transition countries such as China, Kazakhstan, Mongolia, Myanmar, Tajikistan, Turkmenistan and Vietnam. Our findings suggest that Asia, especially the transition economies, has the potential to supply a substantial share of the expected growth in world food demand forecast for the first half of this century.

The nature of TC

Because of the importance of TC, in this section we extend the analysis to an examination of the nature of that change. As discussed in the methodological section above, it is possible to estimate if the TCs that have been occurring are output biased and/or input biased. It also is possible to estimate which particular factors are being saved and which ones are being used more intensively.

According to the estimates, the sum of input-biased TC across all of Asia was larger than that of output-biased TC (Table 4, section

A). Technology improvements appear to have led to the more efficient use of inputs (input saving) more than they increased the capability to produce output (output or yield enhancing). Overall, TC was biased towards crop output and against livestock output. On the input side, TC was biased towards tractors, fertilisers, and livestock inputs but against land and labour. In summary, technology improvements in Asia led to more use of tractors, fertilisers, and livestock inputs and less land and labour to increase crops output faster than livestock output.

There were large differences among the transition countries in terms of how input and output intensities shifted in response to the adoption of innovations. The results for transition countries in EA (Table 5, sections A and B) show that TC was biased towards livestock output and against crops output in Mongolia and China. On the input side, the input-biased TC results imply that technology improvement in Mongolia increased the use of labour but reduced the use of land, tractors, fertilisers, and livestock inputs, while technology improvements led to more use of tractors, fertilisers, and livestock inputs and to sharp reductions in land and labour in China.

This result mirrors the evidence that over the past decade, the area of cultivated land in China declined 0.76 million hectares, while cultivated land per capita fell from 0.1061 to 0.094 hectares. Cultivated land is becoming an increasingly scarce factor in production, and thus, soil quality will be important in sustaining the growth of crop output. Although the use of chemical fertilisers facilitates the substitution of land (Hayami and Ruttan 1985; Lin 1992), the inefficient application of fertilisers could degrade the land, especially irrigated land.

The results for three countries in SEA (Vietnam—section C; Laos—section D; and Myanmar—section E) show that technology improvements increased their crop production capacity. On the input side, technology improvements increased the use of tractors, fertilisers, and livestock inputs in Laos, while livestock inputs increased in Myanmar and land, labour, and livestock inputs increased in Vietnam. Increases in land use in Vietnam could be explained in the following way. The per capita area of cultivated land in Vietnam is only 0.1 hectare and around 36 per cent of its land area was designated as nonfarming or barren land because of serious degradation. Therefore, the government actively promoted the reclamation of the barren land through improving irrigation systems and reforestation. Furthermore, according to new land laws in 1993, land tenure for cropping was extended to 20 years and that for perennial crops up to 50 years. The farmers are entitled to the rights of land transfer, inheritance and mortgage. These favourable changes encouraged farmers to invest in land and use it more efficiently.

Results for 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 towards crops but against livestock output in Kazakhstan, whereas TC was biased towards livestock output and against crops in Kyrgyzstan. In Tajikistan, Turkmenistan, and Uzbekistan, TC was biased against both crops and livestock output. On the input side, the results imply that TC in Kazakhstan increased the use of land and labour but reduced the use of tractors, fertilisers, and livestock inputs, while the direction of TC was to more labour and less land, tractors, fertilisers, and livestock inputs in Kyrgyzstan. The results suggest that these countries did not significantly increase output except in Turkmenistan and they reduced the use of inputs such as tractors. Land use was also reduced in Kyrgyzstan and Turkmenistan, while labour was reduced in Tajikistan, Turkmenistan, and Uzbekistan. Fertiliser use was reduced in Kazakhstan, Kyrgyzstan and Uzbekistan, while livestock inputs declined in Kazakhstan, Kyrgyzstan, and Tajikistan.

Thus our findings show that technology changes in transition economies in CA sharply reduced the use of most farm inputs following independence. The main reasons for lower input use are the relative scarcity of factors of production, economic contraction, the shift from cotton production—an input-intensive activity—and problems with marketing systems (Goletti and Chabor 2000).

Conclusions

With nearly half of the potential agricultural resources and more than half of the world population, Asia has the potential to supply a substantial share of the expected growth in food consumption forecast for the first half of this century. More than half of the population in Asia lives in rural areas where agricultural products are the main source of food supply and income of rural households. During the past two decades, many countries in Asia have undergone a transition from central planning to a market-oriented economy. The economic reforms have helped transform the structure of their agricultural activities. Understanding the magnitude and direction of TFP growth as well as the sources contributing to its growth is important because this will be useful information for policymakers wishing to design policies to maintain existing TFP growth rates or achieve even greater rates of TFP growth.

This study formulates a general model of a parametric output distance function approach to measure TFP growth. The model allows decomposition of TFP growth into the sources contributing to TFP growth and provides evidence of how input and output intensities shift in response to the adoption of innovations. The model is estimated using the most recent FAO data set for 27 Asian countries, including the transition economies, over the period 1980–2004. Because of the lack of data and the time frame involved, earlier studies were not able to include the transition countries. Therefore, the story of agricultural performance in Asia was incomplete.

With the inclusion of the transition economies, Asian countries in aggregate achieved a healthy TFP growth rate of 1.9 per cent per annum. Moreover, the rate of TFP growth has been increasing in recent years. There were, however, large differences among the transition countries in terms of the magnitude and direction of TFP growth during the transition process. While China, Kazakhstan, Mongolia, Myanmar, Tajikistan and Turkmenistan did very well, averaging above 2 per cent per annum, others such as Kyrgyzstan, Uzbekistan, and Laos did not do so well.

The TFP decomposition results showed that the relatively high rate of Asian TFP growth was mainly driven by technology improvements. The adoption of innovations increased the capability to produce more crops in most countries and resulted in reallocations of inputs and outputs within the transition countries where land, labour, fertilisers, and tractors were the main inputs contributing to TFP growth. However, Asian TFP growth over the past two decades would have been even higher if TEC had not declined. Therefore, there is room for policy improvements to improve resource allocation and increase TFP even further.

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