

Rungsuriyawiboon, Supawat; Wang, Xiaobing

**Working Paper**

## Recent evidence on agricultural efficiency and productivity in China: a metafrontier approach

Discussion Paper, No. 104

**Provided in Cooperation with:**

Leibniz Institute of Agricultural Development in Transition Economies (IAMO), Halle (Saale)

*Suggested Citation:* Rungsuriyawiboon, Supawat; Wang, Xiaobing (2007) : Recent evidence on agricultural efficiency and productivity in China: a metafrontier approach, Discussion Paper, No. 104, Leibniz Institute of Agricultural Development in Central and Eastern Europe (IAMO), Halle (Saale), <https://nbn-resolving.de/urn:nbn:de:gbv:3:2-1678>

This Version is available at:

<https://hdl.handle.net/10419/28510>

**Standard-Nutzungsbedingungen:**

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

**Terms of use:**

*Documents in EconStor may be saved and copied for your personal and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.*

# **DISCUSSION PAPER**

**Leibniz Institute of Agricultural Development  
in Central and Eastern Europe**

**RECENT EVIDENCE ON AGRICULTURAL  
EFFICIENCY AND PRODUCTIVITY IN CHINA:  
A METAFRONTIER APPROACH**

**SUPAWAT RUNGSURIYAWIBOON, XIAOBING WANG**

**DISCUSSION PAPER No. 104  
2007**



Theodor-Lieser-Straße 2, 06120 Halle (Saale), Germany  
Phone: +49-345-2928 110  
Fax: +49-345-2928 199  
E-mail: [iamo@iamo.de](mailto:iamo@iamo.de)  
Internet: <http://www.iamo.de>

Dr. Supawat Rungsuriyawiboon is an Assistant Professor at Faculty of Economics, Chiang Mai University, Thailand. His research mainly focuses on production economics, efficiency and productivity measurement, energy economics and applied econometrics.

Mailing address: Faculty of Economics  
Chiang Mai University  
50200 Chiang Mai  
Thailand

Phone: +66 53 944923  
Fax: +66 53 942202  
E-mail: [supawat@econ.cmu.ac.th](mailto:supawat@econ.cmu.ac.th)  
Internet: [www.econ.cmu.ac.th](http://www.econ.cmu.ac.th)

Dr. Xiaobing Wang is Researcher at the Leibniz Institute of Agricultural Development in Central and Eastern Europe (IAMO), Department: Agricultural Markets, Marketing and World Agricultural Trade, in Halle (Saale), Germany. Her research focused on labor market and production in China.

Mailing address: Leibniz Institute of Agricultural Development in Central and Eastern Europe (IAMO)  
Theodor-Lieser-Strasse 2  
06120 Halle (Saale)  
Germany

Phone: +49-345-2928124  
Fax: +49-345-2928399  
E-mail: [wang@iamo.de](mailto:wang@iamo.de)  
Internet: <http://www.iamo.de>

*Discussion Papers* are interim reports on work of the Leibniz Institute of Agricultural Development in Central and Eastern Europe (IAMO) and have received only limited reviews. Views or opinions expressed in them do not necessarily represent those of IAMO. Comments are welcome and should be addressed directly to the author(s).

The series *Discussion Papers* is edited by:

Prof. Dr. Alfons Balmann (IAMO)  
Prof. Dr. Gertrud Buchenrieder (IAMO)  
Prof. Dr. Thomas Glauben (IAMO)

ISSN 1438-2172

**ABSTRACT**

Economic reform in China helped transform the structure and volume of agricultural production and resulted in significant changes in efficiency and productivity. This paper measures agricultural technical efficiency (TE) and total factor productivity (TFP) in China by allowing producers operating under their own technologies. A metafrontier function approach is applied using a panel data set on 28 provinces during 1991-2005. The provinces are categorized into advanced-technology and low-technology provinces. Based on the metafrontier estimation, TFP growth is decomposed into TE change (TEC), technical change (TC) and scale efficiency change (SEC). This information is useful for policy makers to design suitable policies in enhancing agricultural TE and TFP growth in China. Our major findings indicate that TC was mostly attributed to Chinese agricultural TFP growth throughout the period of study. SEC and TEC exhibited negative effects to TFP growth for the advanced- and low-technology provinces, respectively. Most of the advanced-technology provinces exhibited higher TE than the low-technology provinces. The comparatively low TE scores in the low-technology provinces imply that the low-technology provinces were operating far from the metafrontier. The fluctuation of TE measured with respect to the metafrontier function indicates it is possible that Chinese agricultural TFP growth can be improved through the improvement of TE. The results also show that labor and fertilizer still make important contributions to output, and thus improving the quality of farmers and applying modern physical inputs is also crucial to TFP growth.

---

JEL: Q16, Q18, P27

Keywords: Metafrontier, Agriculture, China, Technical Efficiency, Total Factor Productivity.

**ZUSAMMENFASSUNG****NEUE ANHALTSPUNKTE FÜR EFFIZIENZ UND PRODUKTIVITÄT IN DER CHINESISCHEN  
AGRARPRODUKTION: EINE METAFRONTIER UNTERSUCHUNG**

Chinas wirtschaftliche Reformen halfen der Landwirtschaft, die Struktur und dem Umfang der landwirtschaftlichen Produktion umzubauen. Signifikante Erhöhungen der Effizienz und der Produktivität waren die Folge. Die vorliegende Arbeit misst technische Effizienz (TE) und total factor productivity (TFP) in China unter der Annahme individueller Technologien der Landwirte. Mit Hilfe eines Paneldatensatzes für 28 Provinzen über den Zeitraum 1991-2005 wird ein metafrontier Ansatz angewandt. Die Provinzen werden in technologisch fortschrittliche und weniger entwickelte Regionen eingeteilt. Auf der Basis des metafrontier Ansatzes wird das TFP Wachstum in Änderung der technischen Effizienz (TEC), technischen Fortschritt (TC) und Änderung der Skaleneffizienz (SEC) zerlegt. Daraus abgeleitete Informationen sind für die Entwicklung angepasster Politiken zur Förderung technischen Fortschritts und TFP-Wachstums in der chinesischen Landwirtschaft erforderlich. Zentrale Ergebnisse der Analyse zeigen, dass das Wachstum der TFP hauptsächlich durch den technischen Fortschritt erklärt wird. Dagegen weisen SEC und TEC negative Effekte auf das Wachstum der TFP in beiden Provinz-Untergruppen auf. Die Mehrzahl der technisch weiterentwickelten Provinzen weisen eine höhere technische Effizienz als die weniger entwickelten Regionen auf. Die vergleichsweise niedrigen TE-Werte der letzteren deuten auf

die weiter entfernte Lage dieser Provinzen von der Metafrontier hin. Die Ergebnisse zeigen, dass Chinas TFP-Wachstum durch eine Steigerung der TE erhöht werden kann. Des Weiteren leisten die Faktoren Arbeit und Düngemittel einen wichtigen Beitrag zur Produktion. Somit sind zusätzlich die Ausbildung der Landwirte und die Bereitstellung moderner Produktionsmittel für die Steigerung der TFP von Bedeutung.

---

JEL: Q16, Q18, P27

Schlüsselwörter: Metafrontier, Landwirtschaft, Stochastic Frontier Schätzung, China, Technische Effizienz, Technischer Fortschritt, Skaleneffizienz, Total Factor Productivity.

**CONTENTS**

<b>Abstract</b> .....	<b>3</b>
<b>Zusammenfassung</b> .....	<b>3</b>
List of tables.....	6
List of figures.....	6
<b>1 Introduction</b> .....	<b>7</b>
<b>2 Model specification</b> .....	<b>9</b>
2.1 Define group-specific technology and metatechnology.....	10
2.2 Decomposition technical efficiency under metatechnology.....	10
2.3 SFA approach to metafrontier.....	12
2.4 Decomposition of total factor productivity change.....	14
<b>3 Data source and descriptions</b> .....	<b>14</b>
<b>4 Results</b> .....	<b>17</b>
4.1 Discussions of parameter estimates and production structure.....	17
4.2 Discussions of decomposition technical efficiency under metafrontier.....	19
4.3 Discussions of TFP decomposition.....	21
<b>5 Conclusions</b> .....	<b>26</b>
<b>References</b> .....	<b>26</b>

**LIST OF TABLES**

Table 1:	Descriptive statistics of variables .....	16
Table 2:	Estimated parameters of stochastic group-specific frontier and metafrontier models .....	17
Table 3:	Annual average production elasticities for different inputs.....	19
Table 4:	TE scores by the group-specific and metafrontier technologies and TGR for each group .....	20
Table 5:	Weighted annual growth rates of decomposed TFPC by provinces group.....	21
Table A1:	Average TE, TGR and the TFP decomposition by province.....	28

**LIST OF FIGURES**

Figure 1:	Group-specific frontier and metafrontier.....	9
Figure 2:	Decomposition of technical efficiency under the metafrontier .....	12
Figure 3:	The location of advanced- and low-technology provinces.....	15
Figure 4:	Cumulative indices of TEC, TC, SEC and TFPC by groups of the provinces .....	22
Figure 5:	Cumulative indices of TEC, TC, SEC and TFPC by the advanced-technology groups.....	24
Figure 6:	Cumulative indices of TEC, TC, SEC and TFPC by the low-technology groups .....	25

## 1 INTRODUCTION

Given the important role of agriculture in the economy and trade, the pursuit of efficiency and productivity in agricultural production with better access to food security has posed major issues for the Chinese policy makers and WTO accession negotiation. The impressive growth of agricultural production in 1978-1984 acknowledged to the successful reform from the collective system to household responsibility system (HRS). Subsequently, an unexpected stagnation of grain yield and a drop in agricultural production occurred in the later 1980s. Though the market-oriented reform through 1990s has been a start-and-stop affair (BRUEMMER et al., 2006), the direction of policy implication is to explore the potential TE, increase the capital improvement and expand the new technology in production (HUANG et al., 2002; HUANG et al., 2002; LIU and WANG, 2005). By the end of 1990s, it is witnessed that China's leader decided to make another push at grain marketing reform with the goal of increasing the efficiency of farming and allowing farmers to pursue activities in which they have a comparative advantage. At the same time, the government actively promoted the shift of farmers into non-grain crops, such as cash crops, fruit and vegetables. After fifteen years of negotiations, China ratified an agreement committing itself to one of the most liberalized international trade regimes in the world. Further, the nation has adopted numerous trade-policy-oriented measures in preparation. Tariffs had been lowered from more than 60 % in 1990s to around 20 % in 2000. From 2002, the government began to subsidize the grain producers instead of collecting agricultural tax. Subsidies, although just beginning, are mostly thought to be decoupled (SONNTAG et al., 2005).

Much public attention has been paid to production and its enormous potential for higher efficiencies evolved in those undergoing sustained agricultural growth. Evaluating both the efficiency and productivity in Chinese agricultural production keeps pace with the evolution of the frontier methodology. A bulk of conclusions has surrounded the arbitrary selection and merits of a specific methodology, and the availability of the data sources. Efficiency measurements draw the supports from frontier functions using two approaches: Parametric and nonparametric approaches. Initially, a parametric estimation on the efficiency and productivity of Chinese agricultural production date back to a study by FAN (1991). Using the aggregated provincial data, FAN (1991) showed that the gaps of TE across regions inlay in the development of local economy and technology expansion. Moreover, 63 % of productivity growth could be devoted to the improvement of TE obtained from the unique impact of institutional reform over 1965-85. Following a time-varying TE model proposed by CORNWELL et al. (1990), WU (1995) assumed TE consists of linear and quadratic time-trend and province-specific components. The main finding of his study is that TFP growth differs largely among regions through the regional variation of TE. With a more flexible form of the varying coefficients frontier function model, KALIRAJAN et al. (1996) revealed that TE improved greatly after the reform but turned to negative during the stagnation of yield in 1984-987.

In order to identify the determinants of TE scores, the studies turn to apply frontier models to farm household-level datasets. Vesting in a profit frontier functions, WANG et al. (1996) defined a shadow-price profit frontier model to examine production efficiency of Chinese rural households. Their study showed that the profit efficiency score in agriculture production ranges from 0.06 to 0.93, with the average of 0.62. Factors such as educational level, family size and net income are positively related to production efficiency. TIAN and WAN (2000) employed deterministic frontiers into one-sided components of stochastic variation estimated by the traditional stochastic frontier functions. TE scores for several crops were evaluated and decomposed. They found that TE is responsive to crop varieties and planting system, which is



under the influence of technology improvement. Recently, BRUEMMER et al. (2006) estimated a multiple-output distance functions for individual households data attained from Zhejiang province. Their study showed that the difference in productivity prior to and post-1990s resulted from the difference in TE in the two periods, which could owe to the land policy and the frequent adjustment of market policies. CHEN et al. (2006) applied the traditional stochastic frontier analysis (SFA) model proposed by BATTESE and COELLI (1992) and used the same fixed-point survey data sources as BRUEMMER et al. (2006). They concluded that TE is determined by the farm size and the village intrinsic characteristics.

The implicit assumption of the parametric estimation on TE is the frontier function can be estimated under functional form specification. Without specifying an ex-ante functional form and assuming the behavior of producers, some studies seek to a nonparametric method using index accounting approaches. MAO and KOO (1997) applied a data envelopment analysis (DEA) model to decompose Malmquist index into TC and TEC indices. They identified that TE did not perform identically among provinces and potential for the further improvement of TE is still great, even for the important agricultural provinces.

All the above-mentioned studies followed the frontier production function approach initiated by FARRELL (1957). The foundation for the measurement of TE using a parametric approach is a stochastic frontier model originally proposed by AIGNER et al. (1977). This approach has been expanded by various models of measuring and computing production functions and TE (KUMBHAKAR and LOVELL, 2000). These models assume that all producers in different groups of a given industry have access to the same technology, and thereby facing the same best practice frontier. However, each producer may choose to operate on a different part of its technology due to the geographic influences, resources endowment and policy implication on technology. When the resource is endowed differently in the regions, the empirical evaluation without considering the location specific factors of production and TC can not provide useful policy application. To take account of the technology variation, BETTESE et al. (2002) recently presented a metafrontier function model using the parametric estimation to allow measuring the TE for each producer operating under different production frontiers.

This paper extends the empirical analysis on TE of Chinese agricultural production in several dimensions. First, the parametric estimation of the metafrontier function model is applied to investigate TE of the provinces in China. The provinces are categorized into two groups due to distinctive levels of economic development and production technologies. Secondly, a more recent panel data set of 28 provinces covering the time period of 1991 to 2005 is used in this paper. Since the start of China's WTO agricultural commitments and subsidizing the grain producers in 2002 promoted structural changes in subsequent years, the analysis in this paper will reflect a period of more rapid market-oriented reform and structure changes of agricultural production in China. Thirdly, TFP growth is measured using the defined metafrontier function and TFP growth is decomposed into associated components. This information is useful for policy makers to design suitable policies in enhancing agricultural TE and TFP growth in China. To our knowledge, it is the initial application of this technique into the empirical application.

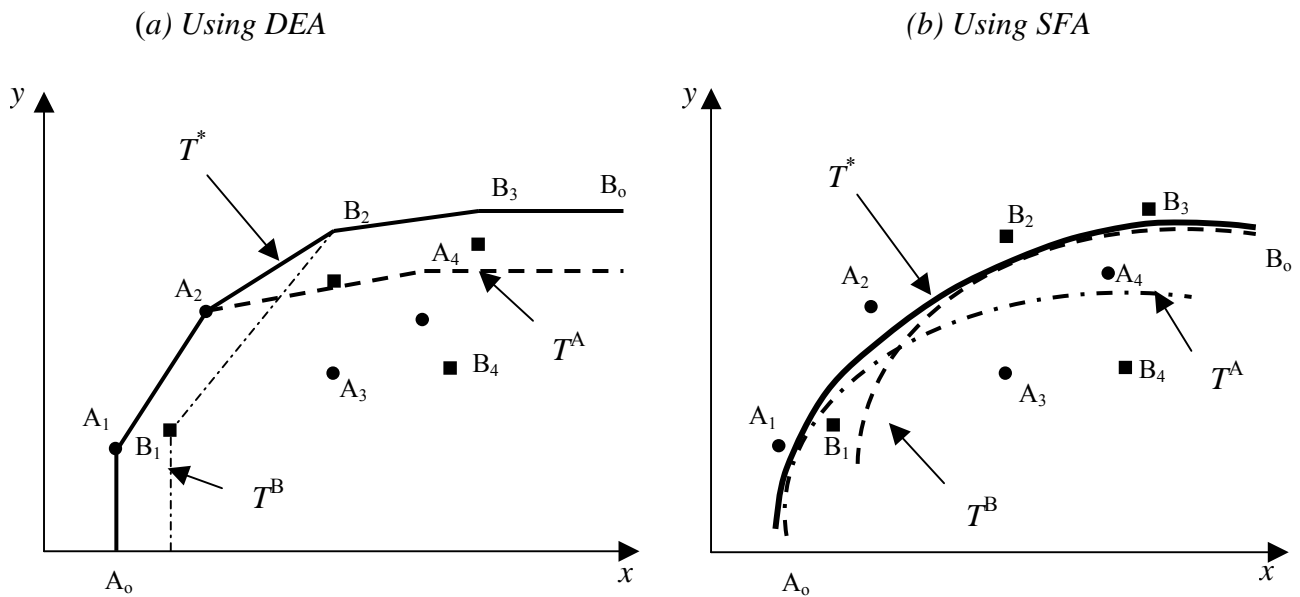
The remainder of this paper is organized as follows. The next section presents a theoretical concept of a metafrontier approach, followed by a discussion of the empirical techniques used to estimate efficiency and productivity using the metafrontier analysis. Then, we describe the data set and the definitions of all variables. The empirical results are presented and discussed, and the final section summarizes our main conclusions.

## 2 MODEL SPECIFICATION

When all producers in different groups of a given industry have a potential access to the same technology but each producer may choose to operate on a different part of their technologies depending on circumstances such as the natural endowments, relative prices of inputs and the economic environment, then the assessment of producer's efficiency and productivity can be measured using a metafrontier concept. HAYAMI and RUTTAN (1970) initially proposed a metaproduction function which is defined as the envelope of commonly conceived neoclassical production functions. Thus, it is a common underlying production function that is used to represent the input-output relationship of a given industry.

The metafrontier function can be measuring using both nonparametric and parametric approaches. The nonparametric approach is known as DEA and the parametric approach is known as SFA. Figure 1 (a) and (b) illustrate how the metafrontier function is constructed using the DEA and SFA approaches, respectively. Consider there are two different groups of technologies, namely A and B. Let points  $A_1, A_2, A_3$  and  $A_4$  indicate the input-output bundles of four producers in group A. These points are used to construct a frontier for production technology in group A or  $T^A$ . Similarly, points  $B_1, B_2, B_3$  and  $B_4$  show the input-output bundles of four producers in group B. These points are used to construct a frontier for production technology in group B or  $T^B$ . If each group of producers has potential access to the same technology, the grand frontier which envelops the two group-specific frontiers can be represented by line  $A_0A_1A_2B_2B_3B_0$ . This line is referred as a metafrontier function or  $T^*$ . The metafrontier function using DEA constructs piece-wise linear convex production technology by enveloping all observed data from each group-specific technology. It does not require specified functional form for each group-specific technology. On the other hand, the metafrontier function using SFA constructs a smooth production technology by tangencing a specified functional form of production functions from each group-specific technology. The metafrontier using SFA is a smooth function and not a segmented envelope of each group-specific technology.

**Figure 1: Group-specific frontier and metafrontier**



## 2.1 Define group-specific technology and metatechnology

Consider the case where all producers are categorized into  $K$  groups and producers in each group operate under a group-specific technology  $T^k$  where  $k=1,\dots,K$  denotes the index of producer groups. For a data set of each group  $k$  consisting of a vector of inputs and outputs for each of the  $i$ -th producer where  $i=1,\dots,I^k$  denotes a producer index. Let the input and output vectors for the  $i$ -th producer in the  $k$ -th group be denoted  $x_i^k = (x_{i1}^k, \dots, x_{iN}^k) \in R_+^N$  and  $y_i^k = (y_{i1}^k, \dots, y_{iM}^k) \in R_+^M$ , respectively. For any input vector of all producers in the  $k$ -th group  $x^k \in R_+^N$  and any output vector of all producers in the  $k$ -th group  $y^k \in R_+^M$ , an input vector  $x^k$  is transformed into net outputs  $y^k$  by a production technology  $T^k$ . The technology set for the  $k$ -th group technology  $T^k$  which satisfies the axioms presented in FÄRE et al. (1985) is defined as

$$T^k = \{(x^k, y^k) : x^k \text{ can produce } y^k\}. \quad (1)$$

Now, consider any input and output vectors of all producers in all groups are given by  $x = (x^1 \cup \dots \cup x^K) \in R_+^N$  and  $y = (y^1 \cup \dots \cup y^K) \in R_+^M$ , respectively. If a particular output  $y \in R_+^M$  can be produced using a given input vector  $x \in R_+^N$  in any one of the producer group, a pair  $(x, y)$  is belong to a metatechnology  $T^*$ . The  $T^*$  is defined as the grand technology which envelops all group-specific technologies,  $T^1, \dots, T^K$ . The technology set for the metatechnology ( $T^*$ ) is defined as<sup>1</sup>

$$T^* = \{(x, y) : x \text{ can produce } y \text{ in at least one group-specific technology}\}, \quad (2)$$

where the boundary of the metatechnology set indicates the metafrontier.

A measure of TE defined in FARRELL (1957) can be analyzed using a distance function. The distance function is defined as a rescaling of the length of an input or output vector with the production frontier as a reference. Because either inputs or outputs can be scaled, the distance function can have an input or output orientation. The output distance function of an observed data  $(x^k, y^k)$  relative to the group-specific technology  $T^k$  is defined as

$$D_o^k(x, y) = \min\{\mu^k : y^k / \mu^k \in T^k\}. \quad (3)$$

$D_o^k(x, y)$  is equal to output-orientated TE,  $TE_o^k(x, y)$ , of the observed data  $(x^k, y^k)$  with respect to  $T^k$ , so that  $0 \leq TE_o^k(x, y) = D_o^k(x, y) \leq 1$ . Similarly, the relationship between the output-orientated TE and output distance function of the observed data  $(x, y)$  relative to  $T^*$  is defined as  $0 \leq TE_o^*(x, y) = D_o^*(x, y) \leq 1$  where  $D_o^*(x, y) = \min\{\mu^* : y / \mu^* \in T^*\}$ .

## 2.2 Decomposition technical efficiency under metatechnology

Figure 2 shows a decomposition of TE under metatechnology. The metatechnology ( $T^*$ ) which is constructed from the two production technologies,  $T^A$  and  $T^B$ , is represented by line  $A_0A_1A_2B_2B_3B_{00}$ . The boundary of the metaechnology represents a metafrontier. Consider the production technology  $T^A$  where point  $A_1$ ,  $A_2$  and  $A_4$  lie on the frontier but point  $A_3$  lies below

<sup>1</sup> This metatechnology  $T^*$  satisfies all the production axioms in FÄRE et al. (1985) except the convexity axiom. In order to ensure the convexity property, the metatechnology is defined as the convex hull of the union of each group-specific technology as  $T^* = \text{Convex Hull}\{T^1 \cup T^2 \cup \dots \cup T^K\}$ .

the frontier.  $TE_o^A$  of the point  $A_1$ ,  $A_2$  and  $A_4$  corresponding to its own frontier is equal to one whereas  $TE_o^A$  of the point  $A_3$  is equal to the ratio of  $A_3^*A_3$  to  $A_3^*A_3^{***}$ . When the metafrontier ( $T^*$ ) is considered,  $TE_o^*$  of the point  $A_1$ ,  $A_2$  is still equal to one whereas  $TE_o^*$  of the point  $A_3$  is equal to the ratio of  $A_3^*A_3$  to  $A_3^*A_3^{**}$  and  $TE_o^*$  of the point  $A_4$  is equal to the ratio of  $A_4^*A_4$  to  $A_4^*A_4^{**}$ . Similarly, consider the production technology  $T^B$  where point  $B_1$ ,  $B_2$  and  $B_3$  lie on the frontier but point  $B_4$  lies below the frontier.  $TE_o^B$  of the point  $B_1$ ,  $B_2$  and  $B_3$  corresponding to its own frontier is equal to one whereas  $TE_o^B$  of the point  $B_4$  is equal to the ratio of  $B_4^*B_4$  to  $B_4^*B_4^{**}$ . When the metafrontier ( $T^*$ ) is considered,  $TE_o^*$  of the point  $B_2$ ,  $B_3$  and  $B_4$  is still the same as  $TE_o^B$  whereas  $TE_o^*$  of the point  $B_1$  is equal to the ratio of  $B_0B_1$  to  $B_0B_1^{**}$ . When the  $TE_o$  is measured relative to the group-specific technology and metatechnology, it can occur a gap between the two technologies used as a reference. This gap is called a technology gap which is defined as the ratio of the distance function using an observed data based on the metotechnology  $T^*$  to the group-specific technology  $T^k$ .

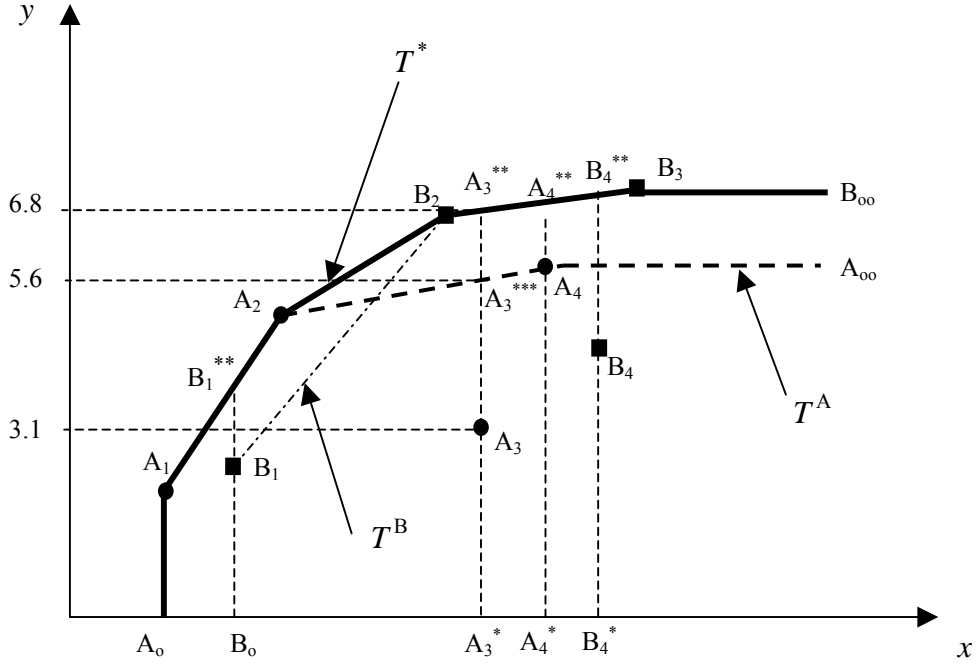
Using the output orientation, the technology gap ratio ( $TGR$ ) can be defined as

$$TGR_o^k(x, y) = \frac{D_o^*(x, y)}{D_o^k(x, y)} = \frac{TE_o^*(x, y)}{TE_o^k(x, y)}, \quad (4)$$

or it can be written as

$$TE_o^*(x, y) = TE_o^k(x, y) \times TGR_o^k(x, y). \quad (5)$$

Equation (5) shows that TE measured with respect to the metafrontier ( $T^*$ ) can be decomposed into the product of the TE measured with respect to the  $k$ -th group technology ( $T^k$ ) and the technology gap ratio. Note that the value of  $TGR_o^k(x, y)$  will be between zero and one so that  $TE_o^*(x, y) \leq TE_o^k(x, y)$ . For example, consider point  $A_3$  in Figure 2, TE with respect to  $T^A$  can be measured by the ratio of the distances between  $A_3^*A_3$  to  $A_3^*A_3^{***}$ . The  $TE_o^A(x_{A_3}, y_{A_3}) = 3.1/5.6 = 0.554$  implying that all outputs could be possibly produced by 45 % more from the given inputs by using  $T^A$  as a reference. The TE with respect to  $T^*$  can be measured by the ratio of the distances between  $A_3^*A_3$  to  $A_3^*A_3^{**}$ . The  $TE_o^*(x_{A_3}, y_{A_3}) = 3.1/6.8 = 0.456$  implying that all outputs could be possibly produced by 54 % more from the given inputs by using  $T^*$  as a reference. Therefore,  $TGR_o^k(x, y) = 0.456/0.554 = 0.823$  implying that the possible output for the  $T^A$  is 82.3 percent of that represented by the metafrontier ( $T^*$ ).

**Figure 2: Decomposition of technical efficiency under the metafrontier**

### 2.3 SFA approach to metafrontier

When suitable panel data for each producer in each group during the time period,  $t = 1, \dots, T$  are available, the metafrontier estimation using the SFA can be achieved using a two-step procedure. First, the stochastic production frontier for each group is estimated and compared with that for all producers. Then, a statistical test is performed to examine whether all producers in different groups have potential access to the same technology.

If the group  $k$  consists of data on  $I^k$  producers, the stochastic production frontier model for the  $i$ -th producer at time period  $t$  based on the group-specific data and the pooled data is given as follows.

$$\ln Y_{it}^c = \ln f(X_{it}^c, t; \beta^c) + v_{it}^c - u_{it}^c, \quad (6)$$

where superscript  $c$  refers to a choice of the stochastic production frontier model [If  $c = k$ , equation (6) refers to the stochastic group-specific production frontier model when the data for the  $i$ -th producer in the  $k$ -th group at the  $t$ -th time period are used, and if  $c = p$ , equation (6) refers to the stochastic pooled production frontier model when the data for all producers in all groups for all time periods are used];  $Y_{it}^c$  denotes the output quantity for the  $i$ -th producer at the  $t$ -th time period;  $X_{it}^c$  denotes the input quantity for the  $i$ -th producer at the  $t$ -th time period;  $\beta^c$  s are unknown parameters associated with the  $X$ -variables to be estimated;  $v_{it}^c$  s are a two-sided random-noise component assumed to be i.i.d.  $N(0, \sigma_v^{2c})$  and  $u_{it}^c$  s are a non-negative technical inefficiency component. The  $v_{it}^c$  and  $u_{it}^c$  are distributed independently of each other, and of the regressors. The non-negative technical inefficiency component,  $u_{it}^c$ , is assumed to

follow a half normal distribution,  $u_{it}^c \sim \text{i.i.d. } N^+(0, \sigma_u^{2c})$ , and is defined by some appropriate inefficiency model [see, BATTESE and COELLI (1992, 1995)]<sup>2</sup>.

Following BATTESE and COELLI (1992), the stochastic group-specific and pooled production frontier models, taking the log-quadratic translog functional form under a non-neutral TC assumption can be written as follows.

$$\begin{aligned} \ln Y_{it}^c = & \beta_0^c + \sum_{n=1}^N \beta_n^c \ln X_{nit}^c + \frac{1}{2} \sum_{n=1}^N \sum_{m=1}^N \beta_{nm}^c \ln X_{nit}^c \ln X_{mit}^c \\ & + \sum_{n=1}^N \beta_{nt}^c \ln X_{nit}^c \cdot t + \beta_t^c t + \frac{1}{2} \beta_t^c t^2 + v_{it}^c - u_{it}^c, \end{aligned} \quad (7)$$

where  $m, n = 1, \dots, N$  index of input quantities and  $u_{it}^c = \{\exp[-\eta(t-T)]\}u_i^c$  where  $\eta$ s are parameters to be estimated and  $u_i^c$ s are non-negative random variables which are assumed to account for technical inefficiency in production and are assumed to be i.i.d. as truncations at zero of the  $N^+(0, \sigma_u^{2c})$  distribution. Young's theorem requires that the symmetry restriction is imposed so that  $\beta_{nm} = \beta_{mn}$  for all  $m, n = 1, 2, 3$ .

An estimate of output-orientated TE for the  $i$ -th producer at the  $t$ -th time period is given by

$$TE_{oit}^c = \exp\{-u_{it}^c\}. \quad (8)$$

If the stochastic frontiers across groups do not differ, then the stochastic pooled frontier function can be used as a grand technology for each group. However, if the stochastic frontiers across groups do differ, the metafrontier function will be used as a grand technology for each group. The second step will involve estimating the metafrontier function. The metafrontier function using SFA does not fall below the deterministic functions for the stochastic group-specific frontier model as shown in Figure 2. In order to obtain estimated parameters of the metafrontier function, we need to ensure that the estimated function best envelops the deterministic components of the estimated stochastic frontiers for the different groups. BATTESE et al. (2004) proposed a method so called the minimum sum of absolute deviations to identify the best envelope. The parameter estimates of the metafrontier function are estimated by solving the following LP problem.

$$\text{Min } \sum_{i=1}^I \sum_{t=1}^T |(x_{it} \beta^* - x_{it} \hat{\beta}^k)| \equiv \bar{x} \beta^* \quad (9)$$

such that  $x_{it} \beta^* \geq x_{it} \hat{\beta}^k$ ,

where  $\bar{x}$  denotes the row vector of mean of the elements of the  $x_{it}$  vector for all observations in the data set;  $x_{it}$  is the logarithm form of the input quantity for the  $i$ -th producer in the  $t$ -th time period;  $\hat{\beta}^k$ s are the estimated coefficients obtained from the stochastic group-specific frontiers obtained from equation (7) and  $\beta^*$ s are parameters of the metafrontier function to be estimated.

<sup>2</sup> We follow the suggestion of BATTESE and CORRA (1977), and replace the two variance parameters with the two new parameters  $\sigma^2 = \sigma_v^2 + \sigma_u^2$  and  $\gamma = \sigma_u^2 / \sigma^2$ . By doing this we can search the parameter space of  $\gamma$  between 0 and 1, to provide good starting values for the iterative maximization routine which is used to calculate the maximum likelihood parameter estimates.

Once the  $\beta^*$  parameters of the metafrontier function in equation (9) are estimated, the decomposition of TE under the metafrontier can be calculated. The technology gap for the  $i$ -th producer in the  $k$ -th group at the  $t$ -th time period can be obtained by

$$TGR_{oit}^k(x, y) = \frac{e^{x_{it}\beta^k}}{e^{x_{it}\beta^*}}. \quad (10)$$

Then, a measure of the output-oriented TE relative to the metafrontier,  $TE_o^*(x, y)$ , can be obtained using equation (5).

## 2.4 Decomposition of total factor productivity change

TFP growth is generally defined as the residual growth in outputs not explained by the growth in input use. TFP growth can be measured and decomposed into associated components attributing to the TFP growth after the metafrontier function in equation (9) is estimated. This information is useful for policy makers to design suitable policies in enhancing the productivity growth in the industry.

Following OREA (2002), a measure of TFP change (TFPC) for each firm between any two time periods can be calculated by using the estimates of the coefficients of the metafrontier and the firm-level sample data. The logarithmic form of the TFPC between period  $t$  and  $t+1$  for the  $i$ -th firm is defined as

$$\ln\left(\frac{TFP_{it+1}}{TFP_t}\right) = \ln\left(\frac{TE_{oit+1}^*}{TE_{oit}^*}\right) + \frac{1}{2}\left[\frac{\partial \ln y_{it+1}}{\partial t} + \frac{\partial \ln y_{it}}{\partial t}\right] + \frac{1}{2}\sum_{n=1}^N [(SF_{it+1} \cdot E_{nit+1}) + (SF_{it} \cdot E_{nit})] \left(\frac{\ln x_{nit+1}}{\ln x_{nit}}\right), \quad (11)$$

where the three terms on the right-hand-side of equation (11) represents the output-oriented TEC, TC and SEC, respectively.

The output-orientated TE measure,  $(TE_o^*)$ , in equation (11) is the output-orientated TE prediction of the  $i$ -th firm in the  $t$ -th time period, and is calculated from equation (5). The TC measure,  $(TC_{it+1})$ , is the mean of the TC measures evaluated at the period  $t$  and period  $t+1$  data points. The SEC measure,  $(SEC_{it+1})$ , relates to the change in scale efficiency, which requires calculation of the scale factor ( $SF$ ) and input elasticity ( $E_n$ ) evaluated at the period  $t$  and period  $t+1$  data points. The  $SF$  of the  $i$ -th firm in the  $t$ -th time period  $(SF_{it}) = (E_{it} - 1)/E_{it}$

where  $E_{it} = \sum_{n=1}^N E_{nit}$  represents the scale elasticity and  $E_{nit} = \partial \ln y_{it} / \partial \ln x_{nit}$  is production elasticity for the  $n$ -th input.

## 3 DATA SOURCE AND DESCRIPTIONS

A balanced panel data set of 28 provinces covering the time period of 1991 to 2005 is used in the empirical analysis. Figure 3 illustrates the location of all provinces in China. Provinces selected for analysis include all provinces in China excluding Hainan and Tibet due to the

missing information<sup>3</sup>. Considering regional disparities, all provinces are ranked by using GDP per capita at 2001 according to the definition presented in KOO and MAO (1997)<sup>4</sup>. Provinces are divided into two groups of technologies: Advanced-technology and low-technology provinces. Each group consists of 14 provinces. A list of the provinces in each group is summarized in Figure 3.

**Figure 3: The location of advanced- and low-technology provinces**



The primary data on agricultural production were extracted from the official data sources – *China Statistical Yearbook* and *Chinese Agricultural Statistical Yearbook*. The data used in this study contains the measurements of agricultural output and input quantities. In this study, the production technology is represented by one output and six inputs. The definitions of these variables are summarized as follows:

**Dependent variable:** The gross output value of farming at 1990 constant prices in billions of yuan ( $y$ ) is chosen as the dependent variable. The gross output value of farming aggregates physical output from seven grain crops and twelve economic crops. However, it excludes the value of forestry, animal husbandry, handicraft products for self-consumption or for sales as sideline occupations and the total value of industries run by villages and cooperative organizations under villages.

**Independent variable:** Following the existing literatures, independent variables include six important physical inputs such as capital, labor, chemical fertilizer, pesticide, plastic film and irrigation (LIN, 1992; WU, 1995; LIU and WANG, 2005).

Capital input ( $x_1$ ) denotes farm machinery in the unit of millions of KW, mainly including the big tractor and walking tractors. Other inputs such as draft animals are excluded in this study due to the unavailable information in the provincial statistics.

<sup>3</sup> Although Chongqing is separated from Sichuan as a municipal administrative city, data series of Chongqing were added together with those of Sichuan due to the unavailability of its data before 1998. In addition, Macao, Hong Kong and Taiwan are not included in this study.

<sup>4</sup> <<http://www.demographia.com/db-china-reggdp-2001.htm>>.



Labor force denotes the number of total rural labors directly engaged in production of agriculture, forestry, animal husbandry and fishery annually. To measure the labor input in farming sector ( $x_2$ ), we followed the calculation by LIN (1992) to weight the labor input in agriculture by the value share of farming output in total agricultural output.

Chemical fertilizer ( $x_3$ ) refers to the pure-content quantity of chemical fertilizers applied in yearly agricultural production in tons. The pure-content gross quantity of chemical fertilizer is calculated to convert the gross weight into weight containing 100 percent of effective components.

Pesticide ( $x_4$ ) is the quantity of chemical pesticides applied in agriculture reported in tons annually.

Plastic film ( $x_5$ ) includes those for covering young plants and seeds listed in tons annually.

Irrigation is one of the very important factors in agricultural production. An effectively irrigated area including not only the full sets of technological irrigation facilities but also adequate water sources for the normally agricultural irrigation can be used as an irrigation variable<sup>5</sup>. The irrigation variable ( $x_6$ ) used in this study is defined as the ratio of effectively irrigated area to total cultivated area. Total cultivated land area refers to land that is plowed constantly for growing crops excluding the land of tea plantations, orchards, nurseries of young plants, forest land, natural and man-made grassland.

Table 1 presents the descriptive statistics of the variables used in the study summarized by the two groups of technology defined above. The advance-technology provinces show higher mean for each variable than the low-technology provinces expect for the labor input. However, the low-technology provinces exhibit lower standard deviation for each variable than the advance-technology provinces expect for the capital and labor inputs.

**Table 1: Descriptive statistics of variables, 1991-2002**

<i>Variables</i>	<i>Unit</i>	<i>Advanced-technology provinces</i>	<i>Low-technology provinces</i>	<i>All provinces</i>
<i>Dependent variable</i>				
Output	Billion Yuan	27.678 (19.520)	22.505 (17.094)	25.092 (18.507)
<i>Independent variables</i>				
Capital	Thousand KW	4615.148 (4453.458)	4160.390 (5604.301)	4387.769 (5060.772)
Labor	Thousand Person	4752.045 (3724.526)	7967.061 (5698.546)	6359.553 (5070.276)
Fertilizer	Million KG	1451.905 (1127.808)	1305.492 (1033.238)	1378.699 (1082.749)
Pesticide	Million KG	48.823 (40.953)	33.195 (31.282)	41.009 (37.228)
Plastic	Million KG	51.025 (52.847)	34.573 (28.218)	42.799 (43.106)
Irrigation	%	64.290 (24.070)	43.490 (18.510)	53.891 (23.837)

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

<sup>5</sup> The increased quantity of irrigation power may be used as a better proxy of the increasing and improving irrigated technique and project rather than the expended irrigated area. However, this variable can not be found in official statistical yearbooks, and thus can not be included in the specified models.

## 4 RESULTS

### 4.1 Discussions of parameter estimates and production structure

The data described in section 3 were used in the estimation of the stochastic group-specific and pooled production functions shown in equation (7). The stochastic group-specific production functions are estimated using the data of the advanced- and low-technology provinces separately whereas the stochastic pooled production function is estimated using the data of all provinces. The data variables used in the model estimation were normalized by their respective geometric means. 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. The estimated coefficients for each model are presented in Table 2. The estimation results from each model are similar and all first-order coefficients have the expected signs except for the estimated parameters,  $\beta_{x4}$  of the low-technology provinces model.

The likelihood ratio (LR) test statistic for the null hypothesis that the group-specific frontiers are identical is 106.44. The LR test statistic follows a chi-square distribution with 39 degrees of freedom. The null hypothesis was rejected with a p-value less than 0.001. This result implies that the group-specific frontiers are not the same. Therefore, the metafrontier function described in section 2.3 needs to be estimated. Table 2 also presents the estimated coefficients of the stochastic metafrontier function. All first-order coefficients have the expected signs and can also be interpreted as shadow shares. The estimates of the input elasticities under the stochastic metafrontier function model are 0.0413, 0.2446, 0.4341, 0.0530, 0.0690 and 0.5285 for capital, labor, fertilizer, pesticide, plastic and irrigation, respectively. The sum of the input elasticities provides information about scale economies and is 1.3705, indicating that the technology exhibits moderately increasing returns to scale at the sample mean. The first order coefficients of the time trend variable provide estimates of the average annual rate in TC. The stochastic metafrontier function model suggest that the technology is improving at a rate of 2.71 % per annum,

**Table 2: Estimated parameters of stochastic group-specific frontier and metafrontier models**

Parameters <sup>a</sup>	Stochastic frontier						Metafrontier <sup>b</sup>	
	Advanced-technology provinces		Low-technology provinces		All provinces			
$\beta_0$	2.6686	(0.0465)	2.5797	(0.0537)	2.5495	(0.0433)	2.6293	(0.0150)
$\beta_{x1}$	0.0420	(0.0317)	0.0184	(0.0289)	0.0439	(0.0164)	0.0413	(0.0085)
$\beta_{x2}$	0.3646	(0.0614)	0.3304	(0.1202)	0.2947	(0.0356)	0.2446	(0.0060)
$\beta_{x3}$	0.2906	(0.0727)	0.5293	(0.1149)	0.3859	(0.0552)	0.4341	(0.0167)
$\beta_{x4}$	0.0051	(0.0519)	-0.0140	(0.0658)	0.0358	(0.0312)	0.0530	(0.0113)
$\beta_{x5}$	0.0678	(0.0392)	0.0255	(0.0309)	0.0203	(0.0177)	0.0690	(0.0064)
$\beta_{x6}$	0.5520	(0.1193)	0.8039	(0.2364)	0.4799	(0.0748)	0.5285	(0.0310)
$\beta_t$	0.0421	(0.0059)	0.0207	(0.0078)	0.0365	(0.0033)	0.0271	(0.0010)
$\beta_{x11}$	0.0211	(0.0355)	-0.0295	(0.0267)	-0.0067	(0.0204)	-0.0027	(0.0110)
$\beta_{x12}$	-0.2059	(0.0510)	0.0128	(0.0575)	-0.0776	(0.0274)	-0.1603	(0.0126)
$\beta_{x13}$	0.1199	(0.0520)	-0.0125	(0.0660)	0.0672	(0.0398)	0.0946	(0.0250)

$\beta_{x14}$	0.0374	(0.0442)	-0.0420	(0.0339)	-0.0314	(0.0228)	0.0230	(0.0123)
$\beta_{x15}$	0.0408	(0.0359)	0.0009	(0.0218)	0.0176	(0.0159)	0.0825	(0.0116)
$\beta_{x16}$	-0.1707	(0.0775)	0.1570	(0.1130)	-0.0315	(0.0663)	-0.2160	(0.0231)
$\beta_{x22}$	0.3070	(0.1112)	-0.2944	(0.2748)	0.1332	(0.0685)	0.0839	(0.0289)
$\beta_{x23}$	-0.0850	(0.1230)	0.1517	(0.3298)	-0.1045	(0.0962)	-0.1217	(0.0589)
$\beta_{x24}$	-0.1129	(0.0713)	0.0083	(0.1219)	-0.0074	(0.0420)	0.0834	(0.0308)
$\beta_{x25}$	-0.0272	(0.0570)	0.0230	(0.0633)	-0.0007	(0.0282)	0.0424	(0.0130)
$\beta_{x26}$	0.7263	(0.1500)	-0.5272	(0.4302)	0.6944	(0.1135)	0.5261	(0.0411)
$\beta_{x33}$	-0.1962	(0.2384)	-0.0540	(0.5815)	0.2132	(0.1840)	0.5670	(0.1326)
$\beta_{x34}$	0.1590	(0.0900)	0.0428	(0.1775)	-0.0047	(0.0648)	-0.2128	(0.0448)
$\beta_{x35}$	0.1951	(0.1022)	-0.1470	(0.1087)	-0.0728	(0.0577)	-0.1915	(0.0198)
$\beta_{x36}$	-0.4919	(0.2330)	1.0752	(0.6946)	-0.3362	(0.1899)	-0.3234	(0.0722)
$\beta_{x44}$	-0.0311	(0.0210)	-0.1430	(0.1051)	-0.0005	(0.0192)	0.0379	(0.0107)
$\beta_{x45}$	-0.0691	(0.0408)	0.0990	(0.0506)	0.0330	(0.0258)	0.0380	(0.0131)
$\beta_{x46}$	-0.0037	(0.1043)	0.1337	(0.3230)	-0.0659	(0.0922)	-0.0456	(0.0623)
$\beta_{x55}$	-0.1638	(0.0637)	-0.0084	(0.0264)	0.0120	(0.0194)	0.0029	(0.0064)
$\beta_{x56}$	0.0586	(0.0959)	-0.3459	(0.1728)	-0.1349	(0.0819)	-0.0458	(0.0607)
$\beta_{x66}$	0.4344	(0.5484)	-2.6276	(0.9912)	1.1428	(0.4167)	0.3150	(0.1620)
$\beta_{x1t}$	-0.0213	(0.0048)	0.0039	(0.0055)	-0.0050	(0.0027)	-0.0212	(0.0014)
$\beta_{x2t}$	0.0324	(0.0085)	-0.0061	(0.0149)	0.0164	(0.0047)	0.0007	(0.0028)
$\beta_{x3t}$	-0.0369	(0.0103)	0.0174	(0.0164)	-0.0185	(0.0071)	-0.0024	(0.0023)
$\beta_{x4t}$	0.0115	(0.0058)	-0.0033	(0.0100)	0.0074	(0.0038)	0.0109	(0.0031)
$\beta_{x5t}$	0.0093	(0.0047)	0.0005	(0.0065)	-0.0003	(0.0033)	0.0087	(0.0022)
$\beta_{x6t}$	0.0501	(0.0122)	-0.0318	(0.0369)	0.0546	(0.0106)	0.0448	(0.0057)
$\beta_{\pi}$	0.0004	(0.0011)	0.0006	(0.0019)	0.0016	(0.0008)	0.0004	(0.0005)
$\sigma^2$	0.0146	(0.0019)	0.0122	(0.0016)	0.3107	(0.4543)		
$\gamma$	0.7200	(0.0633)	0.6612	(0.0568)	0.9830	(0.0249)		
$\eta$	-0.0075	(0.0120)	0.0136	(0.0089)	-0.0082	(0.0056)		
Log-likelihood	256.1712		235.9472		438.8973			

Note: Numbers in parentheses are standard errors.

<sup>a</sup> Subscripts on  $\beta_x$  coefficients refer to inputs: 1 = capital; 2 = labor; 3 = fertilizer; 4 = pesticide; 5 = plastic and 6 = irrigation.

<sup>b</sup> Standard deviations of the metafrontier estimates are calculated using parametric bootstrapping as presented in BATTESE, RAO and O'DONNELL (2004).

Table 3 provides annual average production elasticities of inputs – capital, labor, fertilizer, pesticide, plastic and irrigation – for the year 1991-2005. The production elasticity for capital decreases over the period 1991-2005 by 7.42 % per annum. The production elasticity for labor increases during 1991-1993 and decreases during 1994-2005 leading to a decrease by 2.40 % per annum. The production elasticity for fertilizer decreases over the period 1991-2002 and increases during the period 2003-2005 leading to an increase by 0.44 % per annum. The production elasticities for pesticide and plastic increase throughout the period by 12.79 % and 7.84 % per

anuum, respectively. The production elasticity for irrigation increases during 1991-2002 and decreases during 2003-2005 leading to an increase by 2.11 % per anuum. The results indicate that the annual rates of increase of production elasticities for fertilizer, pesticide, plastic and irrigation are greater than the rates of decrease for capital and labor. The results also show that labor and fertilizer still make important contributions to output, and thus improving the quality of farmers and applying modern physical inputs is also crucial to TFP growth.

**Table 3: Annual average production elasticities for different inputs, 1991-2005**

Year	Capital	Labor	Fertilizer	Pesticide	Plastic	Irrigation
1991-1993	0.081	0.297	0.434	0.029	0.053	0.471
1994-1996	0.075	0.306	0.426	0.032	0.054	0.489
1997-1999	0.054	0.299	0.412	0.053	0.071	0.537
2000-2002	0.036	0.278	0.399	0.076	0.072	0.650
2003-2005	0.029	0.215	0.453	0.101	0.114	0.589
<b>1991-2005</b>	<b>0.041</b>	<b>0.245</b>	<b>0.434</b>	<b>0.053</b>	<b>0.069</b>	<b>0.529</b>

#### 4.2 Discussions of decomposition technical efficiency under metafrontier

Table 4 provides average TE scores relative to the stochastic group-specific frontier and metafrontier technologies as well as TGR scores for each group of provinces during 1991-2005. Moreover, Table A1 in Appendix reports TE scores relative to the stochastic group-specific frontier and metafrontier technologies as well as TGR score for all 28 provinces over the period 1991 to 2005. TE scores relative to the group-specific technology for the advanced-technology provinces range from 0.688 by Hebei to 0.978 by Guangdong with an average of 0.806. TE scores relative to the group-specific technology for the advanced-technology provinces were decreasing over time. Based on the metafrontier technology as a reference, TE scores for the advanced-technology provinces range from 0.661 by Hebei to 0.940 by Guangdong with an average of 0.764. The average TE score implies that the advanced-technology provinces in this study were, on average, producing 80.6 % of the outputs that could be potentially produced from the given inputs by using their own technologies as a reference and 76.4 % using the metafrontier technology as a reference. The estimates of TGR for the advanced-technology province range from 0.847 by Shanghai to 0.980 by Helongjian with an average of 0.948. This result implies that the possible outputs for the advanced-technology provinces based on their groups-specific technology is, on average, 94.8 % of that represented by the metafrontier technology. Hebei and Tianjin are the two lowest ranked TE scores relative to both group-specific and metafrontier technologies whereas Guangdong and Liaoning are the two highest ranked TE scores relative to both technologies. The ranking of the TE scores from other provinces is not much different relative to both technologies except for Shanghai. Shanghai is the third highest ranked TE score relative to its group-specific technology while it is the fifth lowest ranked TE scores relative to the metafrontier technology.

Turning to the low-technology provinces, TE score relative to their own technology range from 0.581 by Ningxia to 0.979 by Sichuan with an average of 0.732. TE scores relative to the group-specific technology for the low-technology provinces were increasing over time. Based on the metafrontier technology as a reference, TE scores for the low-technology provinces range from 0.443 by Ningxia to 0.842 by Inner-Mongolia with an average of 0.644. The average TE score implies that the low-technology provinces in this study, on average, could be potentially produced 27 % more outputs from the given inputs by using their own technologies as a reference

and 36 % more outputs using the metafrontier technology as a reference. The estimates of TGR for the low-technology provinces range from 0.764 by Ningxia to 0.975 by Gansu with an average of 0.882. This result implies that the possible outputs for the low-technology provinces based on their group-specific technology is, on average, 88.2 % of that represented by the metafrontier technology. Ningxia and Anhui are the two lowest ranked TE scores relative to the group-specific technology while Ningxia is still the lowest ranked TE scores relative to the metafrontier technology and Anhui is the fourth lowest ranked TE scores relative to the metafrontier technology. Sichuan and Inner-Mongolia are the two highest ranked TE scores relative to both technologies. The ranking of the TE scores from other provinces is quite different relative to both technologies.

The empirical findings show that the advanced-technology provinces had average province TE higher than the low-technology provinces. The advanced-technology provinces generally led in terms of TGR and had smaller variation of TGR than the low-technology provinces. The comparatively low TE scores in the low-technology provinces imply that the low-technology provinces were operating far from the metafrontier. The fluctuation of TE measured with respect to the metafrontier function indicates it is possible that Chinese agricultural TFP growth can be improved through the improvement of TE.

**Table 4: TE Scores by the group-specific and metafrontier technologies and TGR for each group, 1991-2005**

Year	Advanced-technology provinces			Low-technology provinces		
	TE <sup>k</sup>	TGR	TE <sup>*</sup>	TE <sup>k</sup>	TGR	TE <sup>*</sup>
1991	0.815 (0.075)	0.911 (0.055)	0.744 (0.096)	0.710 (0.142)	0.904 (0.113)	0.636 (0.115)
1992	0.814 (0.076)	0.916 (0.042)	0.746 (0.078)	0.714 (0.140)	0.907 (0.076)	0.645 (0.119)
1993	0.813 (0.076)	0.957 (0.042)	0.778 (0.078)	0.717 (0.139)	0.904 (0.073)	0.646 (0.126)
1994	0.811 (0.077)	0.966 (0.029)	0.784 (0.083)	0.720 (0.138)	0.909 (0.071)	0.653 (0.126)
1995	0.810 (0.077)	0.977 (0.022)	0.791 (0.079)	0.723 (0.136)	0.901 (0.066)	0.649 (0.116)
1996	0.809 (0.078)	0.979 (0.014)	0.792 (0.077)	0.726 (0.135)	0.899 (0.067)	0.651 (0.123)
1997	0.808 (0.078)	0.973 (0.036)	0.785 (0.077)	0.729 (0.133)	0.885 (0.072)	0.643 (0.113)
1998	0.806 (0.079)	0.946 (0.088)	0.761 (0.092)	0.732 (0.132)	0.871 (0.089)	0.636 (0.117)
1999	0.805 (0.079)	0.959 (0.055)	0.771 (0.084)	0.735 (0.131)	0.869 (0.098)	0.637 (0.122)
2000	0.804 (0.080)	0.963 (0.055)	0.773 (0.083)	0.738 (0.129)	0.817 (0.140)	0.599 (0.131)
2001	0.802 (0.080)	0.956 (0.053)	0.766 (0.074)	0.741 (0.128)	0.886 (0.079)	0.655 (0.123)
2002	0.801 (0.081)	0.936 (0.066)	0.749 (0.086)	0.743 (0.127)	0.881 (0.076)	0.656 (0.129)
2003	0.800 (0.081)	0.940 (0.064)	0.751 (0.089)	0.746 (0.125)	0.869 (0.087)	0.648 (0.124)
2004	0.799 (0.082)	0.925 (0.075)	0.739 (0.101)	0.749 (0.124)	0.869 (0.090)	0.650 (0.120)
2005	0.797 (0.082)	0.919 (0.080)	0.732 (0.102)	0.752 (0.123)	0.868 (0.098)	0.652 (0.124)
<b>1991-2005</b>	<b>0.806</b> (0.076)	<b>0.948</b> (0.058)	<b>0.764</b> (0.086)	<b>0.732</b> (0.128)	<b>0.883</b> (0.089)	<b>0.644</b> (0.119)

### 4.3 Discussions of TFP decomposition

Table 5 presents weighted growth rate of TFP decomposition by the group of the provinces during 1991-2005. TFP growth by all provinces increases by 62.45 % over the sample period with a weighted average of about 3.234 % per annum. TEC is nearly negligible; it decreases by 0.43 % over the sample period (average of about 0.029 % per annum). SEC is less important; it increases by 1.46 % over the sample period (average of 0.097 % per annum). Overall, TC explains most of the TFP growth. It increases by 60.79 % with a weighted average of 3.166 % per annum. The major findings show that TFP change in China agriculture over the study period was mainly driven by technological progress. These aggregate figures dissimulate the diversity of effects across the two groups of provinces, although TC changes are dominant in both of two groups.

The advance-technology provinces show TFP growth of 65.6 % over the sample period (average of about 3.362 % per annum). TC increases by 66.3 % (average of about 3.391 % per annum) and the technical progress with the highest rate occurred during 2000-2002. TEC increases by 0.57 % with a weighted average incline of about 0.038 % per annum even though it indicates a decline after the period 1997. SEC decreases by 0.99 % with a weighted average decrease of about 0.066 % per annum although the entire decline is due to the negative SEC during 1997-2005. TC explains most of the TFP growth throughout the period. There is an impressive technical progress during 2000-2002. TEC is a major contribution to TFP growth together with TC during 1991-1996 and 2000-2005. However, TEC is negligible relative to TC and SEC during 1997-1999. SEC is negligible relative to TC and SEC throughout the period.

The low-technology provinces countries experience a TFP increase of 58.92 % over the sample period (average of about 3.088 % per annum). TC and SEC increase by 54.26 % (average of about 2.890 % per annum) and 4.57 % (average of about 0.298 % per annum). There is a major deteriorate in SEC during 2000-2002. TEC slightly decreases by 1.48 % over the sample period with a weighted average decline of about 0.099 % per annum. TC explained most of the TFP growth for the entire period. There is an impressive technical progress during 2000-2002. TEC is negligible relative to TC and SEC throughout the period except the period of 1997-1999. SEC is a major contribution to TFP growth together with TC during 2000-2002.

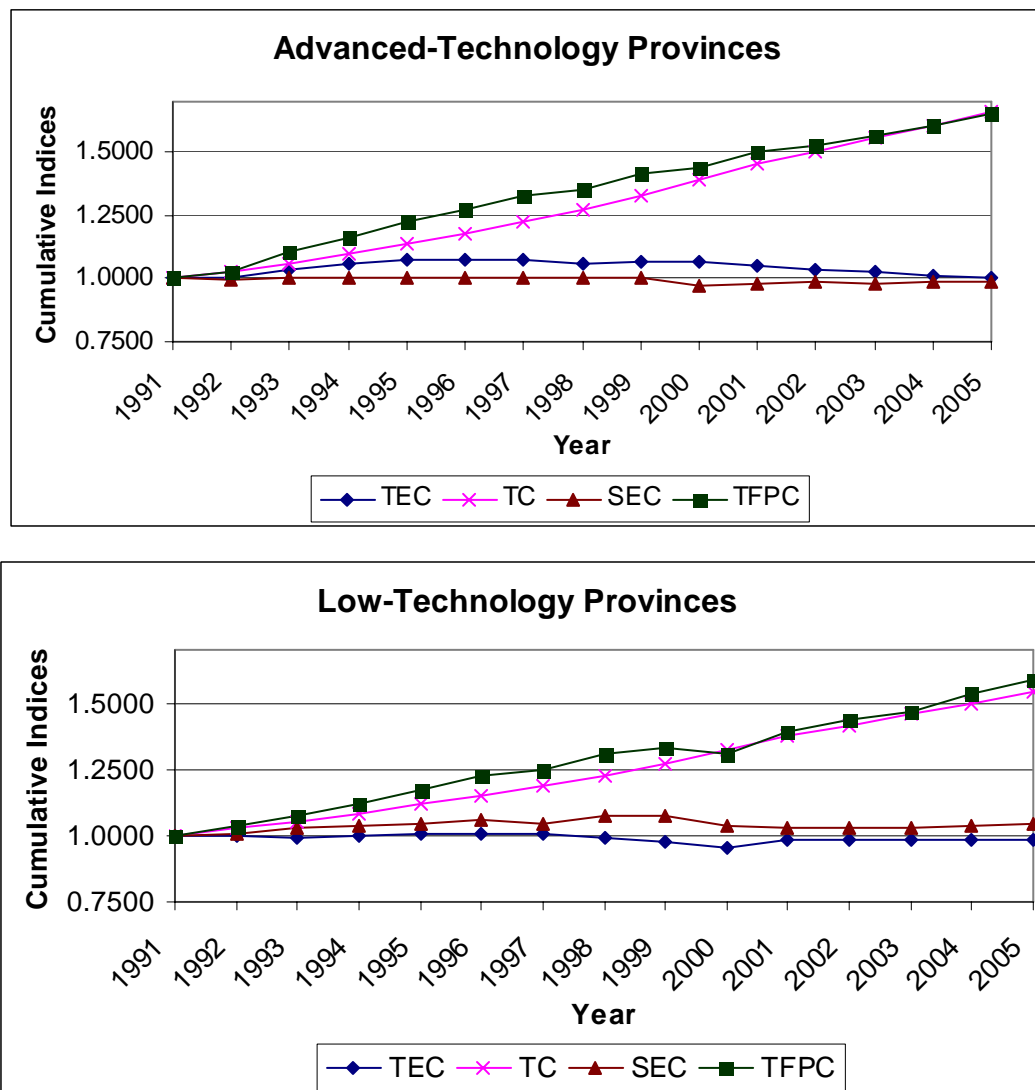
**Table 5: Weighted annual growth rates of decomposed TFPC by provinces group (%)**

<i>Period</i>	<i>TEC</i>	<i>TC</i>	<i>SEC</i>	<i>TFPC</i>
<i>Advanced-technology provinces</i>				
1991-1993	1.267	1.938	0.158	3.363
1994-1996	1.100	3.612	0.003	4.714
1997-1999	-0.283	3.829	-0.032	3.514
2000-2002	-1.056	4.238	-0.667	2.515
2003-2005	-0.840	3.338	0.206	2.703
<b>1991-2005</b>	<b>0.038</b>	<b>3.391</b>	<b>-0.066</b>	<b>3.362</b>
<i>Low-technology provinces</i>				
1991-1993	-0.335	1.730	0.958	2.354
1994-1996	0.512	2.957	0.901	4.371
1997-1999	-0.853	3.215	0.463	2.825
2000-2002	0.219	3.671	-1.419	2.471
2003-2005	-0.041	2.875	0.587	3.420
<b>1991-2005</b>	<b>-0.099</b>	<b>2.890</b>	<b>0.298</b>	<b>3.088</b>
<i>All provinces</i>				
1991-1993	0.529	1.842	0.525	2.897
1994-1996	0.838	3.320	0.403	4.561
1997-1999	-0.537	3.555	0.184	3.202
2000-2002	-0.493	3.983	-1.005	2.484
2003-2005	-0.480	3.132	0.377	3.028
<b>1991-2005</b>	<b>-0.029</b>	<b>3.166</b>	<b>0.097</b>	<b>3.234</b>

Figure 4 contains a set of the cumulative index plots of the TFP growth and its associated components by the group of the advanced- and low-technology provinces over the entire 1991-2005 period. The plot of the advanced-technology provinces shows that there was TFP progress over time and mainly driven by TC. The advanced-technology provinces showed a decline in TFP growth during 1991-1993 and 2000-2005 which was resulted from a decline in TEC. There was a significant increase in TEC in 1993 and a major decrease in SEC in 2000. The plot of the advanced-technology provinces shows that TFP change was closely driven by TC throughout the period. The TFP and TC changes were steadily improved while TEC and SEC was steadily stable leading to an increase of TFP growth for the entire periods. Overall, TC explains most of the TFP growth. However, the TEC was attributed to TFP growth more than the SEC throughout the period.

The plot of the low-technology provinces shows that TFP change was closely driven by TC. TFPC change was steadily improved throughout the period except in 2000. A decrease in TEC led to a decrease in TFPC in 2000. TC change was steadily improved throughout the period. TEC was steadily stable and showed a small decrease during 1999-2000. SEC was steadily stable and showed an increase during 1993-1999. Overall, TC explains most of the TFP growth and the SEC was attributed to TFP growth more than the TEC throughout the period.

**Figure 4: Cumulative indices of TEC, TC, SEC and TFPC by groups of the provinces, 1991 to 2005**



The proportional growth of the average TEC, TC and SEC components constituting the average TFP growth for all provinces in each group over the time period of 1992 to 2002 are also reported in Table A1 in Appendix. All provinces can be divided into different categories according to their TFP growth and what sources are attributed to their TFP growth. All advanced-technology provinces except Helongjiang indicated TPF progress over the time period. TFP regress for Helongjiang was driven by a decline of TC and SEC. Hebei is the only province which TFP progress was driven by an increase in TEC, TC and SEC. TFP progress for Beijing, Zhejiang, Fujian and Guangdong was driven by an increase in TEC and TC with a decrease in SEC. TFP progress for Tianjin, Shanghai, Jiangsu, Hubei was mainly attributed by technical progress with a decline in TEC and SEC. Liaoning, Jilin, Shandong and Xijiang showed an increase in TC and SEC but a decrease in TEC attributing to their TFP progress.

Similarly, all low-technology provinces except Inner-Mongolia indicated TPF progress over the time period. TFP regress for Inner-Mongolia was driven by a decline of TEC and TC. TFP progress for all provinces except Qinghai and Ningxia was mainly driven by technical progress. Shanxi, Henan, Guizhou, Yunnan, Shaanxi, Gansu showed an increase in TEC, TC and SEC attributing to their TFP progress. TFP progress for Anhui and Guangxi Guangdong was driven by an increase in TC and SEC but a decrease in TEC. TFP progress for Jiangxi, Hunan and Sichuan was mainly attributed by technical progress with a decline in TEC and SEC.

The results of TFP growth decomposition by selected provinces are discussed here. The provinces are selected as a representation to explain agricultural productivity for each group of provinces. We select four provinces – two provinces with highest output shares and two provinces with lowest output shares – from each group. Two provinces with the highest output shares for the advanced-technology provinces are Shandong and Jiangsu, respectively, and two provinces with the lowest output shares are Shanghai and Tianjin, respectively. For the low-technology provinces, two provinces with the highest output shares are Sichuan and Henan, respectively, and two provinces with the lowest output shares are Qinghai and Ningxia, respectively.

The unweighted TFP growth and its associated components over the sample period for each province are reported in Table A1 in Appendix. The unweighted TFP growth for the advanced-technology provinces over the sample period was 3.585 percent by Shandong, 3.327 percent by Jiangsu, 4.484 percent by Shanghai and 3.384 percent by Tianjin. Shandong showed its agricultural productivity progress driven by TC and SEC whereas Jiangsu, Shanghai and Tianjin showed their productivity progress mainly driven by technology progress with a decline in the TEC and SEC effects.

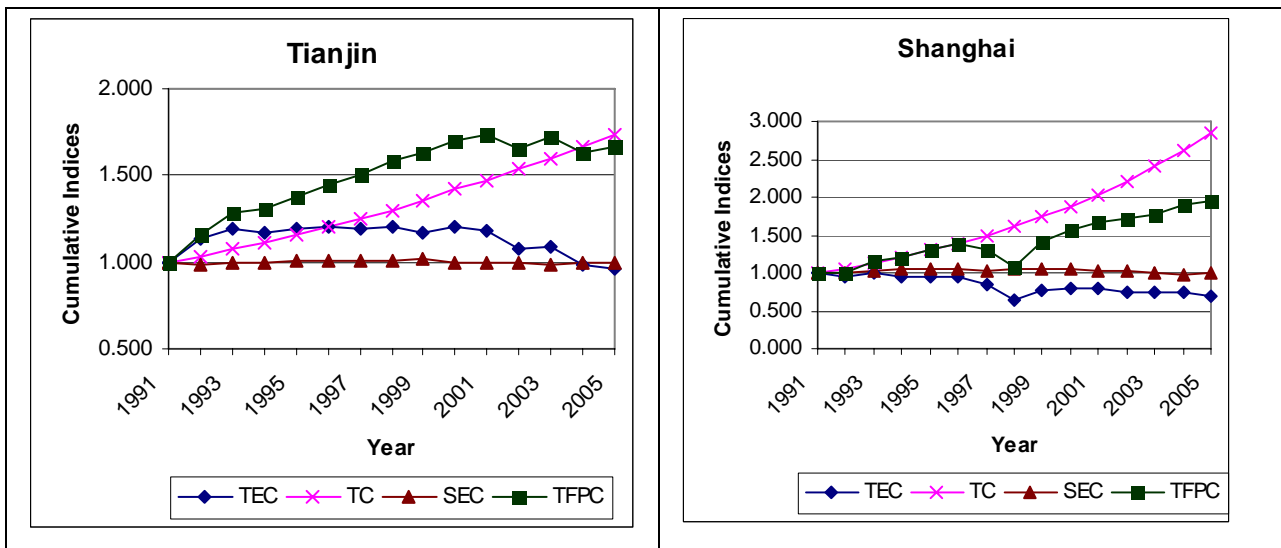
Figure 5 contains a set of the cumulative index plots of the TFP growth and its associated components by Tianjin, Shanghai, Jiangsu and Shandong over the entire 1991-2005 period. Tianjin showed agricultural productivity progress throughout the period except in 2002 and 2004. TEC was a major contribution to TFP progress during 1991-1996 whereas TC was a major contribution to TFP progress during 1997-2005. A decrease in TEC led to TFP regress in 2002 and 2004. TC was steadily improved throughout the period while SEC was steadily stable. Shanghai exhibited agricultural productivity progress over the sample period except in 1999 due to a decline of TEC in this period. TC was steadily improved throughout the period while SEC was steadily stable. Jiangsu and Shandong showed that TFP change was closely driven by TC throughout the period. The TFP and TC changes were steadily improved while TEC and SEC was steadily stable leading to an increase of TFP growth for the entire periods. Overall, TC explains most of the TFP growth. However, the TEC was attributed to TFP growth more than the SEC during 1991-2001.



Turning to the TFP growth decomposition for the low-technology provinces, the unweighted TFP growth over the sample period reported in Table A1 in Appendix was 3.774 percent by Sichuan, 3.054 percent by Henan, 1.980 percent by Qinghai and 1.523 percent by Ningxia. The high output share provinces such as Sichuan and Henan showed that technical progress led to their agricultural productivity progress. The low output share provinces such as Qinghai and Ningxia showed technical regress over time and an increase in TEC and SEC was led to their agricultural productivity progress.

Figure 6 contains a set of the cumulative index plots of the TFP growth and its associated components by Henan, Sichuan, Qinghai and Ningxia over the entire 1991-2005 period. Henan exhibited agricultural productivity progress over the sample period. All TEC, TC and SEC effects were major contributions to its TFP progress during 1991-1999 and 2003-2005. During 2000-2002, TEC was declining and TC and SEC were major contributions to its TFP progress during these periods. Sichuan showed that TFP change was closely driven by TC throughout the period. The TFP and TC changes were steadily improved while TEC and SEC was steadily stable leading to an increase of TFP growth for the entire periods. Qinghai showed agricultural productivity progress during 1991-1999 and a significant TFP regress in 2000 following with TFP regress during 2002-2005. TEC was a major contribution to TFP growth throughout the period. TC changes were steadily decreased for the entire periods. SEC was steadily stable throughout the period except a significant increase in 2000. Ningxia showed agricultural productivity progress throughout the period except in 1998, 2000 and 2002-2003. A decrease in TEC resulted in TFP regress. SEC was major contributions to its TFP progress for the entire periods. TC changes were steadily decreased for the entire periods.

**Figure 5: Cumulative indices of TEC, TC, SEC and TFPC by the advanced-technology groups, 1991 to 2005**



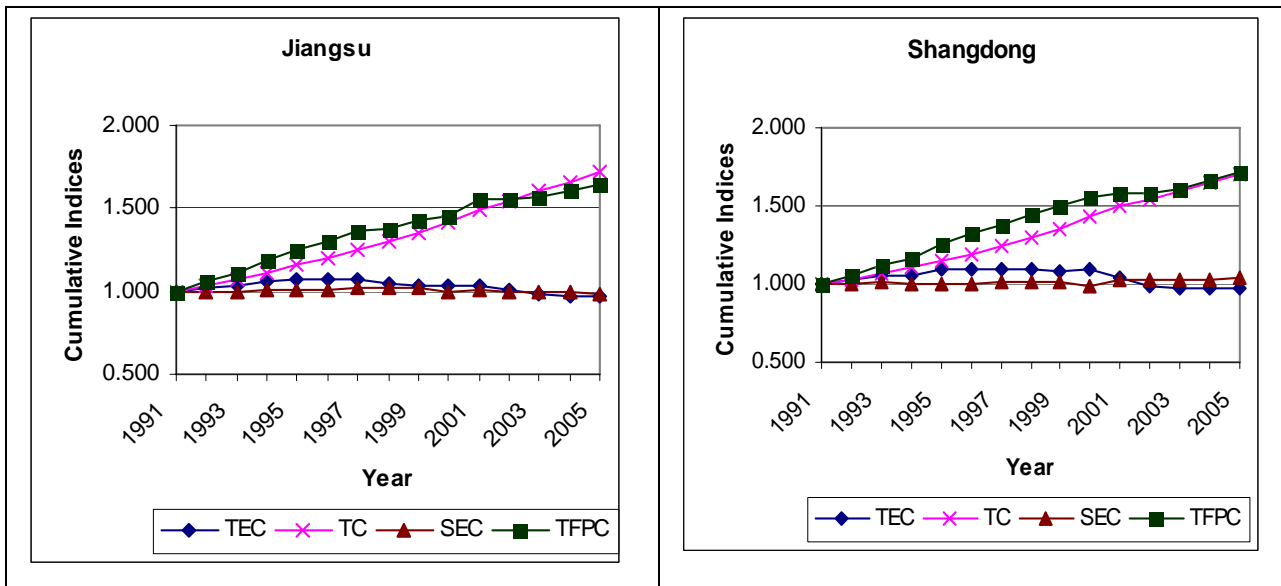
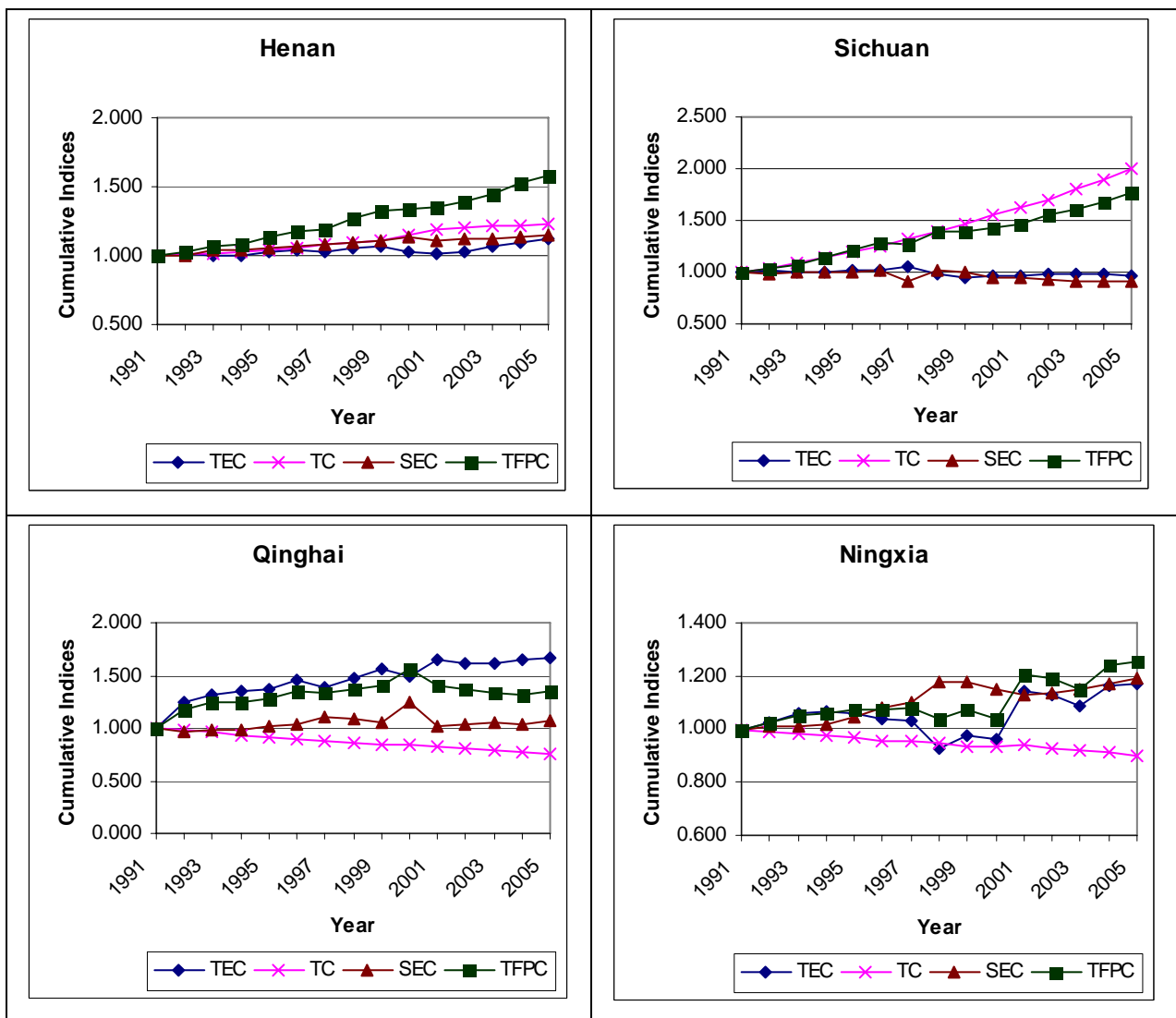


Figure 6: Cumulative indices of TEC, TC, SEC and TFPC by the low-technology groups, 1991 to 2005



## 5 CONCLUSIONS

With nearly one quarter of the potential agricultural resources and one-fifth of the world's population, China has the potential to supply a substantial share of the expected growth in food demand forecast for the first half of this century. This study utilizes a parametric meta-frontier function approach presented in BATTESE et al. (2002, 2004) to measure and decompose Chinese agricultural TE and TFP growth in 28 provinces over the period from 1991-2005. The provinces are categorized into advanced- and low-technology provinces due to distinctive levels of economic development and production technologies. The metafrontier approach allows to investigate whether all producers in different regions have potential access to the same technology or they may choose to operate on a different part of their own technologies.

The empirical findings indicate that the weighted average TFP growth in the Chinese agriculture over the study period grew at 3.234 % per annum, which was driven primarily by a 3.166 % increase in TC. SEC exhibited a positive effect to TFP growth whereas TEC showed positive in early years, then negative starting in 1997. TC was a major contribution to TFP growth in both advanced- and low-technology provinces. SEC and TEC exhibited negative effects to TFP growth for the advanced- and low-technology provinces, respectively. Most of the advanced-technology provinces exhibited higher TE than the low-technology provinces. The comparatively low TE scores in low-technology provinces were found to be related to the TE measured with respect to its own-group technology and the technology gap ratio. As researchers and policy makers discuss the "pros and cons" of China's WTO commitments in agriculture, the analysis in this study suggests that there may be benefits through the improvement of TE. The empirical results also show that labor and fertilizer still make important contributions to output, and thus improving the quality of farmers and applying modern physical inputs is also crucial to TFP growth.

## REFERENCES

- AIGNER, D. J., LOVELL, C. A. K., SCHMIDT, P. (1977): Formulation and estimation of stochastic frontier production models, *Journal of Econometrics*, 6, pp. 21-37.
- BATTESE, G. E., CORRA, G. S. (1977): Estimation of a production frontier model: With application to the pastoral zone off Eastern Australia, *Australian Journal of Agricultural Economics*, 21(3), pp. 169-179.
- BATTESE, G. E., RAO, D. S. P. (2002): Technology gap, efficiency and a stochastic metafrontier function, *International Journal of Business and Economics*, 1(2), pp. 1-7.
- BATTESE, G. E., COELLI, T. J. (1992): Frontier production functions, technical efficiency and panel data: With application to paddy farmers in India, *Journal of Productivity Analysis*, 3, pp. 153-169.
- BATTESE, G. E., COELLI, T. J. (1995): A model for technical inefficiency effects in a stochastic frontier production function for panel data, *Empirical Economics*, 20, pp. 325-332.
- BATTESE, G. E., RAO, D. S. P., O'Donnell, C. J. (2004): A metafrontier production function for estimation of technical efficiencies and technology gaps for firms operating under different technologies, *Journal of Productivity Analysis*, 21(1), pp. 91-103.
- BRUEMMER, B., GLAUBEN, T., LU, W. (2006): Policy reform and productivity change in Chinese agriculture: A distance function approach, *Journal of Development Economics*, 81 (1), pp. 61-79.
- CHEN, A. Z., HUFFMAN, W. E., ROZELLE, S. (2006): Farm technology and technical efficiency: Evidence from four regions in China, *Working papers 50011 in Department of Economics*, Iowa State University.

- CORNWELL, C., SCHMIDT, P., SICKLES, R. C. (1990): Production frontiers with cross-sectional and time-series variation in efficiency levels, *Journal of Econometrics*, 46, pp. 185-200.
- FAN, S. (1991): Effects of technological change and institutional reform on production growth in Chinese agriculture, *American Journal of Agricultural Economics*, 73, pp. 266-275.
- FÄRE, R., GROSSKOPF, S., LOVELL, C. A. K. (1985): The measurement of efficiency of production, Kluwer Academic Publishers, Boston.
- FARRELL, M. J. (1957): The measurement of productive efficiency, *Journal of the Royal Statistical Society A CXX*, pp. 253-290.
- HAYAMI, Y., RUTTAN, V. (1970): Agricultural productivity differences among countries, *American Economic Review*, 60(5), pp. 895-911.
- HUANG, J., ROZELLE, S., PRAY, C., WANG, Q. (2002): Plant biotechnology in China, *Science*, 295, pp. 674-677.
- HUANG, J., PRAY, C., ROZELLE, S. (2002): Enhancing the crops to feed the poor, *Nature*, 418, pp. 678-684.
- KALIRAJAN, K. P., OBWONA, M. B., ZHAO, S. (1996): A decomposition of total factor productivity growth: The case of Chinese agricultural growth before and after reforms, *American Journal of Agricultural Economics*, 78, pp. 331-338.
- KUMBHAKAR, S. C., LOVELL, C. A. K. (2000): Stochastic frontier analysis, Cambridge University Press.
- LAU, L. J., YOTOPOULOS, P. A. (1989): The meta-production function approach and change in world agriculture, *Journal of Development Economics*, 31, pp. 241-269.
- LOVELL, C. A. K., SCHMIDT, P. (1988): A comparison of alternative approaches to the measurement of productive efficiency, in: DORGRAMACI, A., FÄRE, R. (eds.): Application of Modern Production Theory: Efficiency and Productivity, Kluwer Academic Publishers, Boston.
- LIU, Y., WANG, X. (2005): Technological progress and Chinese agricultural growth in the 1990s, *China Economic Review*, 16, pp. 419-440.
- MAO, W., KOO, W. W. (1997): Productivity growth, technological progress, and efficiency change in Chinese agriculture after rural economic reforms: A DEA approach, *China Economic Review*, 8(2), pp. 157-174.
- OREA, L. (2002): Parametric decomposition of a generalized malmquist productivity index, *Journal of Productivity Analysis*, 18(1), pp. 5-22.
- SONNTAG, H. B., HUANG, J., ROZELLE, S., SKERRITT, H. J. (2005): China's agricultural and rural development in the early 21<sup>st</sup> century, ACIAR.
- TIAN, W., WAN, G. H. (2000): Technical efficiency and its determinants in China's Grain production, *Journal of Productivity Analysis*, 13, pp. 159-174.
- WANG, J., WAILES, E. J., CRAMER, G. L. (1996): A shadow price frontier measurement of profit efficiency in Chinese agriculture, *American Journal of Agricultural Economics*, 78, pp. 146-156.
- WU, Y. (1995): Productivity growth, technological progress, and technical efficiency change in China: A three-sector analysis, *Journal of Comparative Economics*, 21, pp. 207-229.

## Appendix

Table A1: Average TE, TGR and the TFP decomposition by province

<i>Provinces</i>	<i>TE<sup>k</sup></i>	<i>TGR</i>	<i>TE<sup>*</sup></i>	<i>TEC</i>	<i>TC</i>	<i>SEC</i>	<i>TFPC</i>
<i>Advanced-technology provinces</i>				(in percentage)			
Beijing	0.820	0.948	0.778	0.180	4.190	-0.173	4.197
Tianjin	0.740	0.938	0.694	-0.286	3.693	-0.024	3.384
Hebei	0.688	0.960	0.661	0.499	2.049	0.534	3.082
Liaoning	0.948	0.948	0.898	-0.239	3.076	0.143	2.979
Jilin	0.784	0.969	0.760	-0.392	0.705	0.325	0.638
Helongjiang	0.839	0.980	0.822	0.012	-0.410	-0.344	-0.741
Shanghai	0.840	0.847	0.712	-2.439	6.957	-0.034	4.484
Jiangsu	0.793	0.960	0.761	-0.221	3.636	-0.088	3.327
Zhejiang	0.742	0.958	0.710	0.909	4.974	-0.914	4.969
Fujian	0.771	0.943	0.728	0.708	5.556	-0.257	6.007
Shandong	0.797	0.951	0.758	-0.198	3.559	0.225	3.585
Hubei	0.742	0.950	0.705	-0.037	4.486	-0.067	4.382
Guangdong	0.978	0.962	0.940	0.613	4.662	-0.786	4.489
Xijiang	0.806	0.958	0.772	-0.715	2.788	0.359	2.431
<b>Average</b>	<b>0.806</b>	<b>0.948</b>	<b>0.764</b>	<b>-0.115</b>	<b>3.566</b>	<b>-0.079</b>	<b>3.372</b>
<i>Low-technology provinces</i>							
Shanxi	0.615	0.903	0.554	0.277	1.188	0.534	2.000
Inner-Mongolia	0.976	0.863	0.842	-1.092	-0.602	1.285	-0.408
Anhui	0.596	0.938	0.558	-0.306	2.435	0.446	2.575
Jiangxi	0.694	0.844	0.584	-1.698	6.440	-0.770	3.972
Henan	0.726	0.858	0.623	0.743	1.378	0.934	3.054
Hunan	0.699	0.789	0.551	-0.895	6.074	-0.724	4.455
Guangxi	0.720	0.934	0.672	-0.588	2.393	0.547	2.351
Sichuan	0.980	0.842	0.825	-0.184	4.642	-0.683	3.774
Guizhou	0.731	0.888	0.650	0.577	3.082	0.043	3.702
Yunnan	0.711	0.941	0.669	0.214	2.231	0.942	3.387
Shaanxi	0.649	0.966	0.627	0.549	0.668	1.160	2.378
Gansu	0.649	0.975	0.633	0.135	0.977	1.401	2.512
Qinghai	0.917	0.851	0.781	3.423	-1.893	0.449	1.980
Ningxia	0.581	0.764	0.443	1.048	-0.692	1.167	1.523
<b>Average</b>	<b>0.732</b>	<b>0.883</b>	<b>0.644</b>	<b>0.157</b>	<b>2.023</b>	<b>0.481</b>	<b>2.661</b>

**DISCUSSION PAPERS  
DES LEIBNIZ-INSTITUTS FÜR AGRARENTWICKLUNG  
IN MITTEL- UND OSTEUROPA (IAMO)**

**DISCUSSION PAPERS  
OF THE LEIBNIZ INSTITUTE OF AGRICULTURAL DEVELOPMENT  
IN CENTRAL AND EASTERN EUROPE (IAMO)**

- No. 1 FROHBERG, K., HARTMANN, M. (1997):  
Promoting CEA agricultural exports through association agreements with the EU  
– Why is it not working? –
- No. 2 FROHBERG, K., HARTMANN, M. (1997):  
Comparing measures of competitiveness: Examples for agriculture in the Central  
European Associates
- No. 3 POGANIETZ, W. R., GLAUCH, L. (1997):  
Migration durch EU-Integration? Folgen für den ländlichen Raum
- No. 4 WEINGARTEN, P. (1997):  
Agri-environmental policy in Germany – Soil and water conservation –
- No. 5 KOPSIDIS, M. (1997):  
Marktintegration und landwirtschaftliche Entwicklung: Lehren aus der Wirtschafts-  
geschichte und Entwicklungsökonomie für den russischen Getreidemarkt im  
Transformationsprozeß
- No. 6 PIENIADZ, A. (1997):  
Der Transformationsprozeß in der polnischen Ernährungsindustrie von 1989 bis  
1995
- No. 7 POGANIETZ, W. R. (1997):  
Vermindern Transferzahlungen den Konflikt zwischen Gewinnern und Verlierern  
in einer sich transformierenden Volkswirtschaft?
- No. 8 EPSTEIN, D. B., SIEMER, J. (1998):  
Difficulties in the privatization and reorganization of the agricultural enterprises  
in Russia
- No. 9 GIRGZDIENE, V., HARTMANN, M., KUODYS, A., RUDOLPH, D., VAIKUTIS, V.,  
WANDEL, J. (1998):  
Restructuring the Lithuanian food industry: Problems and perspectives
- No. 10 JASJKO, D., HARTMANN, M., KOPSIDIS, M., MIGLAVS, A., WANDEL, J. (1998):  
Restructuring the Latvian food industry: Problems and perspectives

- No. 11 SCHULZE, E., NETZBAND, C. (1998):  
Ergebnisse eines Vergleichs von Rechtsformen landwirtschaftlicher Unternehmen in Mittel- und Osteuropa
- No. 12 BERGSCHMIDT, A., HARTMANN, M. (1998):  
Agricultural trade policies and trade relations in transition economies
- No. 13 ELSNER, K., HARTMANN, M. (1998):  
Convergence of food consumption patterns between Eastern and Western Europe
- No. 14 FOCK, A., VON LEDEBUR, O. (1998):  
Struktur und Potentiale des Agraraußenhandels Mittel- und Osteuropas
- No. 15 ADLER, J. (1998):  
Analyse der ökonomischen Situation von Milchproduktionsunternehmen im Oblast Burgas, Bulgarien
- No. 16 PIENIADZ, A., RUDOLPH, D. W., WANDEL, J. (1998):  
Analyse der Wettbewerbsprozesse in der polnischen Fleischindustrie seit Transformationsbeginn
- No. 17 SHVYTOV, I. (1998):  
Agriculturally induced environmental problems in Russia
- No. 18 SCHULZE, E., TILLACK, P., DOLUD, O., BUKIN, S. (1999):  
Eigentumsverhältnisse landwirtschaftlicher Betriebe und Unternehmen in Russland und in der Ukraine – Befragungsergebnisse aus den Regionen Nowosibirsk und Shitomir
- No. 19 PANAYOTOVA, M., ADLER, J. (1999):  
Development and future perspectives for Bulgarian raw milk production towards EU quality standards
- No. 20 WILDERMUTH, A. (1999):  
What kind of crop insurance for Russia?
- No. 21 GIRGZDIENE, V., HARTMANN, M., KUODYS, A., VAIKUTIS, V., WANDEL, J. (1999):  
Industrial organisation of the food industry in Lithuania: Results of an expert survey in the dairy and sugar branch
- No. 22 JASJKO, D., HARTMANN, M., MIGLAVS, A., WANDEL, J. (1999):  
Industrial organisation of the food industry in Latvia: Results of an expert survey in the dairy and milling branches
- No. 23 ELSNER, K. (1999):  
Analysing Russian food expenditure using micro-data
- No. 24 PETRICK, M., DITGES, C. M. (2000):  
Risk in agriculture as impediment to rural lending – The case of North-western Kazakhstan

- No. 25 POGANIETZ, W. R. (2000):  
Russian agri-food sector: 16 months after the breakdown of the monetary system
- No. 26 WEBER, G., WAHL, O., MEINLSCHMIDT, E. (2000):  
Auswirkungen einer EU-Osterweiterung im Bereich der Agrarpolitik auf den  
EU-Haushalt  
(steht nicht mehr zur Verfügung – Aktualisierte Version DP 42)
- No. 27 WAHL, O., WEBER, G., FROHBERG, K. (2000):  
Documentation of the Central and Eastern European Countries Agricultural Simulation  
Model (CEEC-ASIM Version 1.0)
- No. 28 PETRICK, M. (2000):  
Land reform in Moldova: How viable are emerging peasant farms? An assessment  
referring to a recent World Bank study
- No. 29 WEINGARTEN, P. (2000):  
Buchbesprechung: BECKMANN, V. (2000): Transaktionskosten und institutionelle  
Wahl in der Landwirtschaft: Zwischen Markt, Hierarchie und Kooperation
- No. 30 BROSIG, S. (2000):  
A model of household type specific food demand behaviour in Hungary
- No. 31 UVAROVSKY, V., VOIGT, P. (2000):  
Russia's agriculture: Eight years in transition – Convergence or divergence of regional  
efficiency
- No. 32 SCHULZE, E., TILLACK, P., GERASIN, S. (2001):  
Eigentumsverhältnisse, Rentabilität und Schulden landwirtschaftlicher Großbetriebe  
im Gebiet Wolgograd
- No. 33 KIELYTE, J. (2001):  
Strukturwandel im baltischen Lebensmittelhandel
- No. 34 ШУЛЬЦЕ, Э., ТИЛЛАК, П., ГЕРАСИН, С. (2001):  
Отношения собственности, рентабельность и долги крупных сельскохозяйст-  
венных предприятий в Волгоградской области
- No. 35 FROHBERG, K., HARTMANN, M. (2002):  
Konsequenzen der Integration im Agrar- und Ernährungssektor zwischen Beitritts-  
ländern und EU-15
- No. 36 PETRICK, M. (2001):  
Documentation of the Poland farm survey 2000
- No. 37 PETRICK, M., SPYCHALSKI, G., ŚWITŁYK, M., TYRAN, E. (2001):  
Poland's agriculture: Serious competitor or Europe's Poorhouse? Survey results on  
farm performance in selected Polish voivodships and a comparison with German  
farms



- No. 38 HOCKMANN, H., KASHTANOVA, E., KOWSCHIK, S. (2002):  
Lage und Entwicklungsprobleme der weißrussischen Fleischwirtschaft
- No. 39 SCHULZE, E., TILLACK, P., PATLASSOV, O. (2002):  
Einflussfaktoren auf Gewinn und Rentabilität landwirtschaftlicher Großbetriebe im Gebiet Omsk, Russland
- No. 40 ШУЛЬЦЕ, Э., ТИЛЛАК, П., ПАТЛАССОВ, О. (2002):  
Факторы, влияющие на прибыль и рентабельность крупных сельскохозяйственных предприятий в Омской области в России
- No. 41 BAVOROVÁ, M. (2002):  
Entwicklung des tschechischen Zuckersektors seit 1989
- No. 42 FROHBERG, K., WEBER, G. (2002):  
Auswirkungen der EU-Osterweiterung im Agrarbereich
- No. 43 PETRICK, M. (2002):  
Farm investment, credit rationing, and public credit policy in Poland – A microeconomic analysis –
- No. 44 KEDAITYENE, A., HOCKMANN, H. (2002):  
Milk and milk processing industry in Lithuania: An analysis of horizontal and vertical integration
- No. 45 PETRICK, M. (2003):  
Empirical measurement of credit rationing in agriculture: A methodological survey
- No. 46 PETRICK, M., LATRUFFE, L. (2003):  
Credit access and borrowing costs in Poland's agricultural credit market: A hedonic pricing approach
- No. 47 PETRICK, M., BALMANN, A., LISSITSA, A. (2003):  
Beiträge des Doktorandenworkshops zur Agrarentwicklung in Mittel- und Osteuropa 2003
- No. 48 SCHULZE, E., TILLACK, P., MOSASHWILI, N. (2003):  
Zur wirtschaftlichen Situation georgischer Landwirtschaftsbetriebe
- No. 49 ЛИССИТСА, А., БАБИЧЕВА, Т. (2003):  
Теоретические основы анализа продуктивности и эффективности сельскохозяйственных предприятий
- No. 50 ЛИССИТСА, А., БАБИЧЕВА, Т. (2003):  
Анализ Оболочки Данных (DEA) – Современная методика определения эффективности производства
- No. 51 ЛИССИТСА, А., ОДЕНИНГ, М., БАБИЧЕВА, Т. (2003):  
10 лет экономических преобразований в сельском хозяйстве Украины – Анализ эффективности и продуктивности предприятий

- No. 52 LISSITSA, A., STANGE, H. (2003):  
Russischer Agrarsektor im Aufschwung? Eine Analyse der technischen und Skaleneffizienz der Agrarunternehmen
- No. 53 VALENTINOV, V. (2003):  
Social capital, transition in agriculture, and economic organisation: A theoretical perspective
- No. 54 BORKOWSKI, A. (2003):  
Machtverteilung im Ministerrat nach dem Vertrag von Nizza und den Konventionsvorschlägen in einer erweiterten Europäischen Union
- No. 55 KISS, P., WEINGARTEN, P. (2003):  
Cost of compliance with the *acquis communautaire* in the Hungarian dairy sector
- No. 56 WEINGARTEN, P., FROHBERG, K., WINTER, E., SCHREIBER, C. (2003):  
Quantitative analysis of the impacts of Croatia's agricultural trade policy on the agri-food sector
- No. 57 БОКУШЕВА, Р., ХАЙДЕЛЬБАХ, О. (2004):  
Актуальные аспекты страхования в сельском хозяйстве
- No. 58 DERLITZKI, R., SCHULZE, E. (2004):  
Georg Max Ludwig Derlitzki (1889-1958)
- No. 59 VÖNEKI, E. (2004):  
Zur Bewertung des Ungarischen SAPARD-Programms unter besonderer Berücksichtigung der Investitionen im Milchsektor
- No. 60 ЧИМПОЕШ, Д., ШУЛЬЦЕ, Э. (2004):  
Основные экономические проблемы сельского хозяйства Молдовы
- No. 61 BAUM, S., WEINGARTEN, P. (2004):  
Interregionale Disparitäten und Entwicklung ländlicher Räume als regionalpolitische Herausforderung für die neuen EU-Mitgliedstaaten
- No. 62 PETRICK, M. (2004):  
Can econometric analysis make (agricultural) economics a hard science? Critical remarks and implications for economic methodology
- No. 63 SAUER, J. (2004):  
Rural water suppliers and efficiency – Empirical evidence from East and West Germany
- No. 64 PETRICK, M., BALMANN, A. (2004):  
Beiträge des 2. Doktorandenworkshops zur Agrarentwicklung in Mittel- und Osteuropa 2004
- No. 65 BOJNEC, S., HARTMANN, M. (2004):  
Agricultural and food trade in Central and Eastern Europe: The case of Slovenian intra-industry trade

- No. 66 GLITSCH, K., EERITS, A. (2004):  
Der slowakische Markt für Milch und Milchprodukte – Vom Beginn der Transformation bis zum EU-Beitritt
- No. 67 FISCHER, C. (2004):  
Assessing Kosovo's horticultural potential – The market for fruit and vegetables on the balkans
- No. 68 PETRICK, M., SCHREIBER, C., WEINGARTEN, P. (2004):  
Competitiveness of milk and wine production and processing in Albania
- No. 69 ШТАНГЕ, Г., ЛИССИТСА, А. (2004):  
Аграрный сектор России на подъеме?! Анализ технической эффективности аграрных предприятий
- No. 70 SAUER, J. (2004):  
Die Ökonomie der (Ländlichen) Wasserversorgung
- No. 71 HAPPE, K., BALMANN, A., KELLERMANN, K. (2004):  
The Agricultural Policy Simulator (Agripolis) – An agent-based model to study structural change in agriculture (Version 1.0)
- No. 72 BAUM, S., TRAPP, CH., WEINGARTEN, P. (2004):  
Typology of rural areas in the Central and Eastern European EU new member states
- No. 73 PETRICK, M. (2004):  
Governing structural change and externalities in agriculture: Toward a normative institutional economics of rural development
- No. 74 RODIONOVA, O., SCHULZE, E., UERKOV, E., KARPOVA, G. (2004):  
Zur Besteuerung von Agrarholdings in Russland
- No. 75 HEIDELBACH, O., BOKUSHEVA, R., KUSSAYINOV, T. (2004):  
Which type of crop insurance for Kazakhstan? – Empirical results
- No. 76 BOKUSHEVA, R. (2004):  
Crop insurance in transition: A qualitative and quantitative assessment of insurance products
- No. 77 RAMANOVICH, M., LAJTOS, I. (2004):  
Milchproduktion und -verarbeitung in Weißrussland: Eine Analyse der Wettbewerbsfähigkeit
- No. 78 LUKA, O., LEVKOVYCH, I. (2004):  
Intra-industry trade in agricultural and food products: The case of Ukraine
- No. 79 EINAX, CH., LISSITSA, A., PARKHOMENKO, S. (2005):  
Getreideproduktion in der Ukraine – Eine komparative Analyse von Produktionskosten
- No. 80 ИВАХНЕНКО, О., ЛИССИТСА, А. (2005):  
Информационно-консультационная служба в аграрно-промышленном комплексе России на примере Омской области

- No. 81 ROTHE, A., LISSITSA, A. (2005):  
Der ostdeutsche Agrarsektor im Transformationsprozess – Ausgangssituation, Entwicklung und Problembereich
- No. 82 РОТЭ, А., ЛИССИТСА, А. (2005):  
Аграрный сектор Восточной Германии в переходном периоде – Исходная ситуация, развитие и основные проблемы
- No. 83 CURTISS, J., PETRICK, M., BALMANN, A. (2004):  
Beiträge des 3. Doktorandenworkshops zur Agrarentwicklung in Mittel- und Osteuropa 2005
- No. 84 SVETLOV, N., НОСКМАНН, Н. (2005):  
Technical and economic efficiency of Russian corporate farms: The case of the Moscow region
- No. 85 МЕЛЬНИЧУК, В., ПАРХОМЕНКО, С., ЛИССИТСА, А. (2005):  
Процесс формирования рынка сельскохозяйственных земель в Украине
- No. 86 MELNYCHUK, V., PARKHOMENKO, S., LISSITSA, A. (2005):  
Creation of agricultural land market in Ukraine: Current state of development
- No. 87 ROTHE, A., LISSITSA, A. (2005):  
Zur Wettbewerbsfähigkeit der ostdeutschen Landwirtschaft – Eine Effizienzanalyse landwirtschaftlicher Unternehmen Sachsen-Anhalts und der Tschechischen Republik
- No. 88 BROSIG, S., ЯАШШИЛИКОВ, Y. (2005):  
Interregional integration of wheat markets in Kazakhstan
- No. 89 GRAMZOW, A. (2005):  
Experience with Endogenous Rural Development Initiatives and the Prospects for Leader+ in the Region "Dolina Strugu", Poland
- No. 90 GRAMZOW, A. (2006):  
Local partnership as an incubator for rural development: The case of Dębrzno, North-western Poland
- No. 91 ЧИМПОЕШ, Д., ШУЛЬЦЕ, Э. (2006):  
Экономическое состояние сельскохозяйственных предприятий Республики Молдова
- No. 92 ЛИССИТСА, А., ЛУКА, О., ГАГАЛЮК, Т., КВАША, С. (2006):  
Единая аграрная политика Европейского Союза – Путь становления и принципы функционирования
- No. 93 SCHMITZ, S., BROSIG, S., DEGTYAREVICH, J., DEGTYAREVICH, I., GRINGS, M. (2006):  
Grodno household survey – Sources and utilization of foodstuffs in Belarusian households
- No. 94 RUNGSURIYAWIBOON, S., LISSITSA, A. (2006):  
Agricultural productivity growth in the European Union and transition countries

- No. 95 GRAMZOW, A. (2006):  
Endogenous initiatives as a chance to improve rural livelihood? Results of a case study in Bałtów, South-eastern Poland
- No. 96 DUFHUES, T., BUCHENRIEDER, G., FISCHER, I. (2006):  
Social capital and rural development: Literature review and current state of the art
- No. 97 WOLZ, A., FRITZSCH, J., PENCÁKOVÁ, J. (2006):  
Social capital among agricultural producers in the Czech Republic: Its impact on economic performance
- No. 98 BOKUSHEVA, R., BUCHENRIEDER, G. (2006):  
Contributions to the 4<sup>th</sup> Young Scientists Workshop on agricultural development in Central and Eastern Europe – YSW-2006
- No. 99 HOCKMANN, H., RAMANOVICH, M. (2006):  
Zur Wettbewerbsfähigkeit der weißrussischen Milchwirtschaft: Eine Anwendung des Porterschen Diamanten
- No. 100 GRAMZOW, A. (2006):  
Doświadczenia oddolnych inicjatyw rozwoju regionalnego oraz perspektywy dla programu leader+ w regionie Doliny Strugu w Polsce
- No. 101 GRAMZOW, A. (2006):  
Partnerstwo lokalne jako inkubator rozwoju terenów wiejskich: Przypadek Debrzna, północno-zachodnia Polska
- No. 102 XIANGPING, J., BUCHENRIEDER, G. (2006):  
Documentation of a questionnaire-based survey in rural China: From credit access perspective
- No. 103 GRAMZOW, A. (2007):  
Oddolne inicjatywy jako szansa poprawy jakości życia na wsi? Wyniki studium przypadku w Bałtowie (Południowo-Wschodnia Polska)
- No. 104 RUNGSURIYAWIBOON, S., WANG, X. (2007):  
Agricultural efficiency and productivity in China: A metafrontier approach

Die Discussion Papers sind erhältlich beim Leibniz-Institut für Agrarentwicklung in Mittel- und Osteuropa (IAMO) oder im Internet unter <http://www.iamo.de>.

The Discussion Papers can be ordered from the Leibniz Institute of Agricultural Development in Central and Eastern Europe (IAMO). Use our download facility at <http://www.iamo.de>.

