Agricultural Productivity in China: National and Regional Growth Patterns, 1993-2005

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Chapter 9

Agricultural Productivity in China: National and Regional Growth Patterns, 1993-2005

Haizhi Tong
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Abstract. Agricultural productivity growth in Chinese provinces is examined for the 1994-2005 period. It is studied using a data set seldom used and with two alternative approaches. Results show that productivity growth rates have been high, about 4 percent, on average, during the period. The East outperformed the Central region, which in turn outperformed the West. Growth rates show a slight slowdown during the 1990s, an increase in the early 2000’s, and a slowdown in 2004 and 2005. While the Malmquist estimates show convergence between the East and the West, the stochastic frontier estimates do not show the same pattern.

Keywords: Provincial TFP growth, stochastic production frontier, Malmquist index.

JEL Classification: O4, O5, Q1

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Introduction

Since the economic reforms of 1978, China’s agricultural sector has had an impressive performance. According to China’s statistical yearbook, by 2005 output from farming, forestry, animal industry and fishery had increased by more than four times since the reforms were initiated. China has nine percent of the world’s total arable land, twenty percent of the world’s population with seventy percent living in rural areas.

Many studies have examined Chinese agricultural growth. These studies point towards rapid expansion of agricultural output and productivity during the 1980’s and a slow down during the 1990’s raising questions about the sustainability of these growth rates. Few of these studies cover the 2000’s and most estimate productivity at the national level rather than the provincial level.

In this study our objective is to examine regional agricultural productivity growth in China twenty years after the introduction of reforms in the sector. China is a country with diverse ecosystems and it is relevant to identify how productivity growth patterns differ across regions. We focus on the 1993-2005 period, which includes 1998 the year in which some of the reforms of the 1970’s were due to expire, in particular the 20-year leases on land. Most commonly one would develop a Fisher or Tornquist productivity index from observed price and quantity data as it is done by USDA for U.S. states but prices and input shares are not available. Even if they were, these prices would not represent opportunity costs given the high degree of interventions in the economy, including the strong restrictions on input mobility. With only quantities used and produced available from China’s Statistical Yearbook (CSY) we estimate multifactor productivity growth (TFP) with a nonparametric Malmquist index and alternatively with a
stochastic and parametric production frontier. The period of analysis is critical as during these years some of the policies and contracts implemented by the Household Responsibility System of the 1970’s were due to expire. This may have increased uncertainty considerably, possibly having a stifling effect on productivity growth.

Several issues motivate the present study. First, most studies on Chinese agricultural productivity are done at the national level using FAO data. Some have focused on specific agricultural commodities. For this analysis we use provincial data from an alternative source, China’s Statistical Yearbook. Second, the period of analysis in this study corresponds to the twentieth anniversary of the reforms implemented in the 1970’s. A slight slowdown in output growth was observed during the late 1990’s raising concerns that the rapid growth of the previous twenty years was fueled by increases in inputs rather than by innovations. By 2003 though the rate of output growth picked up, returning to pre-1996 levels. Third, we use two very different approaches to the measurement of productivity growth, one stochastic and parametric, the other non-parametric and non-stochastic with the objective of identifying sensitivity to choice of technique.

We find that productivity growth in Chinese agriculture has been higher in the mid 1990’s than in the late 1990’s, consistent with a slowdown mentioned by others. But we also find indication of a trend reversal around 1998 with productivity picking up pace again in the 2000’s.

**China’s Agricultural Policies**

Before 1978, agriculture in China was under a collective system. The first step in China’s agricultural reform was the introduction of the “household production responsibility system” (HRS) in 1978. Under the HRS system, farmland is not privately owned but farmers have long
term user rights. They are also free to allocate resources as they see fit but were required to deliver a quota to the government at procurement prices. The leftover output could be traded freely in the market. The objective was to align market signals to farmer’s incentives to encourage them to raise output, reduce costs and adopt new technologies. Under this system, the fruits, vegetables and livestock markets have been less controlled than the grain markets. While farmers pay taxes and local fees, the local government is responsible for extension services and for the introduction of new technologies and seed varieties.

A second step in the reform process occurred at the beginning of the 1990’s, when China abandoned its food rationing system. Under the grain-rationing system, urban consumers used coupons to buy a fixed amount of grain at a low price, with more available at market prices. Due to budget pressures in 1991-1992, the government reduced the gap between controlled and market prices finally eliminating it in 1994 as no resistance from urban consumers materialized.

An important reform was introduced in 1995, the Grain-Bag responsibility system, requiring leaders in each province to maintain overall balance of grain supply and demand within each province and to regulate local markets. This policy advocates self-sufficiency in grain production and resulted in potentially inefficient reallocation of resources towards grain production.

More recently, the following important reforms were introduced. In 1998 a second HRS wave replaced the one introduced in 1978 as land leases expired and were replaced by new ones. Starting in 2000, taxes to the farming sector were gradually eliminated. In 2001, China became a member of the WTO.
Other Studies

We find numerous studies of agricultural productivity growth in China. They covered different periods, different aggregation levels, used different data sets and different methodologies. We discuss here these studies and their findings. We focus our attention, however, in those studies that report yearly estimates of total factor productivity growth in Chinese agriculture overlapping with the years covered by this study. Summary of these studies is given in Table 1.

McMillan, Whalley and Zhu (1989) examined agricultural performance in 1978-1984 and the effects of price increases and of the institutional reform introduced by the household responsibility system (HRS). Fan (1991) used a frontier production function to separate agricultural growth into input growth, technical change, institutional reform, and efficiency change. Lin (1992) employed a fixed effects model on provincial data to evaluate the effects of decollectivization (HRS), price adjustments and other factors on productivity growth. In a follow up paper, Lin (1993), studied the issue of efficiency of different systems and showed that household farms outperformed cooperative farms, which gave support for institutional reform in China. In yet another study, Lin (1995) examined rice production and tested the induced institutional innovation theory. A study by Huang and Rozelle (1995) used data from 1952 to 1990 and found that environmental stress was an important factor in reducing TFP growth after the mid 1980’s. Spitzer (1997) applied a nonparametric index number approach to decompose total factor productivity in China's agriculture. He found that technical change was positive and efficiency change negative during the period from 1985 to 1994. Zhang and Carter (1997)
constructed a Cobb-Douglas production function to separate the contribution of inputs, weather and efficiency to growth of grain production from 1980 to 1990.

Zhang and Fan (2001) used a generalized maximum entropy approach to estimate a multi-output production technology for twenty-five provinces during the period of 1979-1996. They did not, however, calculate and decompose total factor productivity growth. Jin et al. (2010) use a stochastic production frontier function approach to estimate the rate of change in TFP for 23 of China’s main farm commodities. To do so they rely on the National Cost of Production Data Set. They find negative rates of efficiency change outweighed by positive rates of technical change. They do not, however, report yearly productivity growth at an aggregate level.

Regarding the role of market institutions and transaction costs on productivity, Rozelle et al (1997) examined market integration after the implementation of liberalized economic policies in food markets. Rozelle, Taylor and DeBrauw (1999) used a labor migration framework to model the effect of migration and remittances on agricultural productivity growth in China. DeBrauw, Huang and Rozelle (2000) examined how market liberalization influenced the behavior of producers.

Many authors have estimated agricultural productivity growth based on data from FAO in a multi-country context, including China. Coelli and Rao (2005) used a DEA approach to Malmquist indices of TFP growth for many countries based on data from FAO for the period 1980-2000. They found that agricultural TFP in China grew at an average yearly rate of 1.06% during this period. Bravo-Ortega and Lederman (2004) also use FAO data to calculate agricultural TFP growth for China (among other countries) during the 1961-2000 period. They estimate a translog production function and calculate TFP as a residual. While they found that the Chinese agricultural TFP grew 1.67%/year in this period, they do not report annual figures of TFP growth after 1994. Ludena et
al. (2007) constructed TFP indices for Chinese agriculture based on a DEA directional distance function. Using data from FAO, they calculated an average agricultural TFP growth of 3.05%/year for the period 1990-2000, consistent with Bravo-Ortega and Lederman (2004). These studies did not report yearly TFP growth estimates and, hence, are not directly comparable to our analysis.

A number of studies have calculated and decomposed agricultural total factor productivity growth in China within a time frame overlapping (at least partially) with that considered in this analysis (see Table 1). Using provincial data, Lambert and Parker (1998) constructs a Divisia index for the period 1979-1995. They found an increase in total factor productivity of 5.8% per year in the period 1993-1995. Jin et al. (2002) also used an accounting approach and constructed a Tornqvist index. They concluded that new technologies were the main driver of agricultural productivity growth during the period 1980-1995. However, in contrast with Lambert and Parker (1998), they found that total factor productivity declined by 3.2% per year in the period 1994-1995. Mead (2003) reexamines data on Chinese agricultural productivity growth using an alternative calculation of China’s labor force. This estimate is employed in a TFP calculation based on a constant-returns-to-scale Cobb Douglas production function. He finds a strong correlation between policies and productivity growth and 1984-1999. In contrast, Dekle and Vandenbroucke (2006) calculating productivity growth in China as a residual based on a constant-returns-to-scale Cobb Douglas approximation to the technology, found a strong TFP growth in the period 1994-2003 (6.6% per year).

Using national data, Wu et al. (2001) constructed Malmquist indices for the period 1980-1995. They found that TFP grew at an annual rate of 2.3% in the 1994-1995 period. This is in line with Wu et al. (2001), Colby, Diao and Somwaru. (2000), Fan and Zhang (2002), Hsu, Yu
and Chang (2003), Lezin and Wei. (2005), and Bosworth and Collins. (2008) who found a rather strong growth in agricultural TFP during different parts of the 1994-2005 period.

Colby Diao and Somwaru (2000) used a Tornqvist index to analyze the sources of output growth in grains and in four major crops in China (rice, wheat, corn and soybean). They found that agricultural TFP grew, on average, at an annual rate of 0.8%. Fan and Zhang (2002) adjusted previous measures of growth in outputs and inputs and calculated a Tornquist-Theil index of TFP at the national and provincial levels for the period 1952-1997. In particular, they found an increase in TFP during the period 1978-1997. Lezin and Wei. (2005) also estimated a Cobb Douglas production function for the province of Zhejiang and found a positive TFP growth in the period 1994-1997. Hsu Yu and Chang (2003) calculated output-orientated Malmquist productivity indexes using a non-parametric DEA (Data Envelopment Analysis) approach covering the period 1984-1999. They estimated that TFP growth was, on average, 1% per year. Bosworth and Collins (2008) calculate productivity growth in China as a residual based on a constant returns to scale Cobb Douglas approximation to the technology. They calculate average national productivity of China and India and compare their performance in the period 1978-2004. They estimate China’s agricultural TFP growth at 1.7% per year in the 1993-2004 period.

In a cross-country study, Fuglie (2008) estimated an annual rate of TFP growth in Chinese agriculture of approximately 3.5% from 1990 to 2006. Nin Pratt, Yu and Fan (2009) also using in a multi-country study context, and with FAO data calculate both a Tornquist-Theil index and a Malmquist index of TFP growth for China. They found increases in Chinese agricultural productivity in the post-reform period up until 2003 (growth averaged 5% per year when calculated with a Malmquist index and 3% with a Tornqvist-Teil index). They also found that both efficiency and technical change were important drivers of productivity growth and that returns to
agricultural R&D had been high.

Based on the above studies, we learn that:

1) Studies have used data from the Chinese Statistical Yearbook, and from FAO. In general, studies that use FAO data show higher TFP growth rates for 1970-2000.

2) Methodologies used include econometric estimation of production functions, some of them stochastic frontiers, growth accounting TFP indices, and data envelopment analysis (DEA).

3) Studies cover different periods that extend from the time when policy reforms were introduced up until the early 2000’s.

Estimates indicate that agricultural productivity growth in China was higher immediately after the introduction of the Household Responsibility System (from 1978 to mid 80’s) making institutional reform the main contributor to TFP growth in that period. However, there is evidence that TFP growth slowed down after that period and towards the end of 1990’s which was speculated to be due to exhaustion of the institutional effect, the introduction of the procurement price system, environmental stress, or lack of agriculture investments and innovations that hindered further gain in productivity growth.

**Regional Productivity Growth**

Productivity refers to output per unit of input and can be measured using different approaches. We care about productivity growth because it indicates an increase in output in perpetuity. The most direct way to measure productivity is by constructing indexes of outputs and inputs with costs and revenue shares as weights. Given the difficulty in obtaining these shares, two alternative methods are used in this paper: a nonstochastic, Malmquist index and a stochastic production frontier. Both methods allow for estimation of the rate of productivity
growth when no reliable information on prices is available. We refer to this rate as the total factor productivity (TFP) growth rate.

Data

Data used are from China Statistical Yearbook (CSY) for thirty “provinces” during 1993-2005. Some of these provinces are municipalities like Beijing, Shanghai, and Tianjin. Sichuan includes Chongqing, considered since 1997 a provincial-level municipality. Others are not provinces but autonomous regions like Inner Mongolia, Tibet, Xinjiang, Ningxia, and Guanxi. Hainan is an island province. We use agricultural output (gross output value for the agriculture sector, including farming, forestry, animal industry and fishery) in constant 1993 Yuans and the corresponding quantity indexes converted using 1993 as the base year. We obtain the 1993 data from 1994 China Statistical Yearbook (page 330, Agriculture, table 11-4 Gross Output Value and Indices of Farming, Forestry, Animal Husbandry and Fishery), the 1994 data from the same table but in the 1995 China Statistical Yearbook. The data from 1995-2005 can be found online. The following inputs used in the analysis are also obtained from corresponding tables in the Agriculture chapter of the China Statistical Yearbook. They are: total sown areas, agricultural machinery, labor, and fertilizer. Fertilizer includes nitrogen, phosphate, potash and compound fertilizer. Table 2 summarizes the data at the national level. (data by province is available from the authors).

The Malmquist Index

The Malmquist index used in this study is the version specified by Färe, Grosskopf and Lovell (1994). Productivity change is decomposed into efficiency change (first term) and technical change (second term)

\[
M_0(x_{t+1}, y_{t+1}, x_t, y_t) = \frac{D_{t+1}^f(x_{t+1}, y_{t+1})}{D_0^f(x_t, y_t)} \left[ \frac{D_{t+1}^f(x_{t+1}, y_{t+1})}{D_0^f(x_{t+1}, y_{t+1})} \ast \frac{D_t^f(x_t, y_t)}{D_0^f(x_t, y_t)} \right]^{1/2}
\]

(1)
where $D_o$ is the output distance function, $x$ and $y$ are input and output vectors, and $t$ indicates the time period. Data Envelopment Analysis (DEA), a programming approach, is used to calculate $D_o$ as follows (Coelli 2008):

$$[D'_o(x_i,y_i)]^{-1} = \max_{\phi, \lambda} \phi,$$

st. $-\phi y_i + Y_i \lambda \geq 0,$  

$$x_i - X_i \lambda \geq 0,$$

$$\lambda \geq 0$$

where $X$ and $Y$ are the $(K\times N)$ input and the $(M\times N)$ output matrices respectively. $\lambda$ is a $N\times 1$ vector of constants, or intensity variables. Here $I=\phi < \infty$ and $(\phi - I)$ is the proportional increase in outputs achieved by the $i$-th region while maintaining input quantities constant. This approach constructs the production surface as an envelope of the observations each period, defined by those representing best performance.

Technical efficiency change, also known as the ‘catching up’ component of the index, indicates whether a particular region is moving closer or further away from the frontier. Technical change, or the innovations component of the index, refers to a shift of the best practice frontier. Indexes smaller than one represent deteriorations. The Malmquist index is calculated with information from two consecutive data periods and it is very sensitive to extremes but it is free of specification error. We use Coelli’s DEAP programming code to compute the Malmquist index and its components.

Table 3 reports the national average rate of productivity growth derived using the Malmquist method and breaks this down into technical change and efficiency change components. China experienced high rates of productivity growth in 1994 and 1995 followed by a decrease from 1996 to 1998, and a reversal of this trend after 1999 with annual productivity
growth rates between 4% and 2% between 2000 and 2005. On average, total factor productivity growth in Chinese agriculture during 1993-2005 was a robust 3.97% annually, compared to 1.73% productivity growth in U.S. agriculture during the same period.

Table 4 reports average productivity rates of growth for each province and region, also using the Malmquist method. Most provinces experienced positive TFP growth, mainly as a result of technical change resulting from the adoption of new innovations. Jiangsu, Fujian, and Liaoning were the best performers with average annual TFP growth rates of 6% to 7%. The rural areas around Beijing and Shanghai were also strong performers, probably due to a shift in output toward higher-valued vegetable and fruit production. Provinces with productivity growth rates around 5% per year are Hebei, Hainan, Guangdong, Shandong, Jilin, Heilongjiang, and Zhejiang. A second set of provinces cluster around growth annual rates of 3%. The worst performer was Tibet, which actually experienced a productivity decline.

In Figure 1 we aggregate performance in three geographical regions: East, Center, and West (see Table 4 for a list of the provinces assigned to each region). The East (with an average annual TFP growth rate of 5.7%) outperformed the Central (TFP growth of 2.9%/year) and West (TFP growth of only 0.9%/year) during this period. It is interesting to note that the TFP growth rates in the West region improved rapidly after 2000, while those of the East region slightly decreased. By 2004-2005, TFP growth rates in all three regions had converged to about 3%/year.4

Some of the factors that might have affected economic performance during this period are: 1) bad weather conditions in the late 1990’s; 2) government efforts to encourage diffusion and

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3 Annual total factor productivity growth indexes for province and regions from the Malmquist method are given in Appendix Table A1.
4 A reviewer suggested that the Central region be divided into a North Central and a South Central region given differences in agronomic characteristics. We found that doing this shows that in later years, the North Central region has marginally outperformed the South Central region. On average annual TFP growth rates are 3.3% for the North Central and 2.5% for the South Central region.
adoption of new technologies and production processes; 3) elimination of the rationing system in years 1994 and 1995; 4) steady decline in procurement prices during this period; 5) introduction of the Grain-Bag Responsibility System in 1995; 6) a new round of reforms around 1998 (especially, a second HRS with renegotiation of land contracts), 7) the reinforcement of market oriented policies and tax exemptions to the agricultural sector, and 8) WTO membership.

**Stochastic Production Frontier**

As an alternative to the Malmquist index a stochastic parametric translog production frontier is econometrically estimated, following Battese and Coelli (1992), to use in the calculation of TFP growth rates. The specification used is:

\[
\ln Y_{it} = \alpha_0 + \sum_m \alpha_m \ln x_{mit} + \alpha_t t + \frac{1}{2} \sum_m \sum_n \beta_{mn} \ln x_{mit} \ln x_{nmt} + \frac{1}{2} \beta_{tt} t^2 + \sum_m \beta_m \ln x_{mit} * t + v_i + u_i
\]

\[i=1, \ldots, 30; \ t=1, \ldots, 9,\]

(3)

where \( Y_{it} \) is output level of the \( i \)-th province in the \( t \)-th time period, \( x_{it} \) are inputs (land, labor, fertilizer and machinery), \( t \) a time trend representing disembodied technical change, \( \beta \) are coefficients to be estimated, \( v \) are random errors assumed to be iid N \((0, \sigma_v^2)\), \( u \) are assumed to be one sided errors distributed iid \( \text{HN} \left( \mu, \sigma_u^2 \right) \) and independent of \( v \). \( u_i = (u_i \exp(-\eta(t-T))) \)

and accounts for technical inefficiency, \( \eta \) is a parameter to be estimated.

Equation (3) is estimated using Coelli’s Frontier 4.1 econometric package with symmetry imposed. The maximum likelihood estimates of the parameters are in Table 5. Yearly production elasticities evaluated at the mean of the variables, in Table 6, indicate that the estimates are not globally concave. Nevertheless, they show a decreasing production elasticity of land and labor and an increasing production elasticity for fertilizer and machinery over time.

Technical change is obtained through differentiation of equation (3) with respect to \( t \):
Technical efficiency level of region \( i \) at time \( t \) is defined as follows:

\[
TE_{it} = \exp(-u_{it})
\]  

(5)

and efficiency change is the difference in TE across years.

The growth rate of TFP change is defined as the rate of change in output that is not accounted for by input change (where a dot over a variable represents rate of change):

\[
TFP = \dot{y} - \sum_m \epsilon_m \dot{x}_m = \text{Technical change + Efficiency change}
\]  

(6)

where \( \epsilon_m \) are input production elasticities, \( m = \text{land, labor, machinery and fertilizer} \).

The national, regional and provincial average rates of technical and efficiency change and the rates of TFP change for years 1993 to 2005 are reported in tables 7 and 8. We estimate strong and positive rates of technical change and a negative rate of efficiency change throughout the period. This yields positive TFP growth rates throughout the period of analysis. The average annual TFP change for the whole period is estimated to be about 4%, showing a slight declining trend, as evident in Figure 2.. The translog functional form used here smoothes out yearly changes and imposes linearity in technical change. This turns out to be a very restrictive maintained hypothesis when inflexions are present and might explain the different patterns of evolution of the TFP growth rates across methods.

In Table 8 we present the econometric estimates of TFP growth by province. Liaoning, Zhejiang, Shanghai and Fujian define the frontier throughout the period. The average TFP growth rates across provinces are less dispersed than in the Malmquist estimation. The TFP growth rates for Shanghai, Hainan, Beijing, Liaoning and Fujian are the highest, about 5% to 6%
per year. Tibet, Ningxia, Guizhou, and Qinghai show the lowest rate of growth. A summary of the information in these tables is presented in Figure 4 where the evolution of the annual growth rate of TFP is shown for three regions, with the East (4.6%) performing better than the Central (3.7%) and West (3.5%) region. Again, the pattern of these evolutions mimic the evolution of the TFP growth rates for the whole country and do not show the variability evident in the evolution of TFP growth rates estimated non-parametrically with the Malmquist index. While the Malmquist index is subject to extreme variability because it relies on information of two consecutive periods only and because of its deterministic nature, the econometric estimates may suffer from specification error from the linearity evident in equation 4.

Only a few previous studies estimated provincial agricultural productivity growth rates for a period as recent as the one in our paper (see Table 1). For the overlapping years, our results are consistent with those of Lambert and Parker (1998), Colby, Diao and Somwaru (2000), Wu et al. (2001), Fan and Zhang (2002), Lezin and Wei (2005), Hsu, Yu and Chang (2003), Dekle and Vandenbroucke (2006) and Bosworth and Collins (2008). The differences between results in this study and those of Jin et al. (2002) and Meade (2003) are not surprising considering the many differences in terms of data, periods and sectors covered. Jin et al. (2002) used data collected by the State Price Bureau and calculated provincial and national TFP indices based on a sampling framework. Meade (2003), on the other hand, uses a time series of provincial data and obtains TFP growth rates residually from the estimation of a Cobb-Douglas production function.

Only the studies by Dekle and Vandenbroucke (2006) and Bosworth and Collins (2008) include information up until 2004. Bosworth and Collins (2008) uses the same approach as Meade (2003) with data for the country as a whole obtained from China’s Statistical Yearbook.

5 Detailed information for all provinces and all years from the stochastic frontier method is provided in the Appendix Table A2.
6 Separating the Central region into a North Central and a South Central shows that the North Central region outperformed the South Central region throughout the whole period. Average TFP growth rate in the North Central is 4.2% versus 3.7% in the South Central.
Dekle and Vandenbroucke (2006) also fit a Cobb-Douglas production function but using provincial data. Consistent with our results, both studies found evidence of positive TFP growth rates.

There are many multi-country studies that include China among the many countries included in the analysis. These studies use FAO as the source of data, focus on a national aggregate and cover a period of time starting in 1961. These studies are not methodologically comparable to ours but they are of empirical interest. We mention here two of the latest studies of this type, Nin Pratt, Yu and Fan (2010) and Fuglie (2008). Nin Pratt, Yu and Fan (2010) calculate Tornquist and Malmquist indexes for fifty-nine countries, one of them China. Both indexes yield high and positive average rates of growth of agricultural TFP in China, but also both identify some slowdown in the 1990’s. Fuglie’s (2008) study calculates productivity growth for a large set of countries using a fixed weight index for the 1961-2006 period. These weights are carefully calculated with expenditure data from a reduced set of countries then applied to other countries in the same geographical area. China’s weights are calculated with information from China’s Statistical Bureau. For the period of interest Fuglie (2008) estimated a rate of TFP growth in Chinese agriculture of approximately 3.5%/year. The rates obtained for China in these two multi-country studies are consistent with the ones in this study.

Conclusions

In this study a Malmquist index and a stochastic production frontier are estimated to examine agricultural productivity growth in China’s provinces during 1993 to 2005. Three important conclusions follow.

First, China achieved high rates of agricultural productivity growth throughout the whole period. The average annual TFP growth rate estimated is around 4% per year. These rates are
supported by high rates of technical change indicating that agricultural productivity growth in China was driven by technological innovations rather than increases in input use. Productivity growth rates show a slowdown during the 1990s, a rebound in the early 2000’s and a slight slowdown in 2004 and 2005.

The second major finding from this study is that there have been significant regional disparities in productivity performance. Among the three regions, the East outperforming the Central and West. The evolution of productivity growth among these regions though shows a different pattern across methods. The Malmquist index shows an important improvement in performance in the West, not much change in the Central region, and a slight deterioration through time in the East, indicating a convergence between them over time. Stochastic frontier estimates show all three regions with slight deteriorations through time.

Finally, this study shows important differences across methods in the estimation of productivity growth rates. While the Malmquist index reveals that average annual TFP growth rates in China decreased from 6% in 1994 to 0.3% in 1998 followed then by an increase to 2% to 4% after 1998, the econometric stochastic frontier estimates indicate a slight but continuous decline in TFP growth from 4.5% to 3.5% during the period of analysis. These differences are also notable in the evolution of the regional TFP growth rates as we pointed out above. We suspect that the choice of an econometric specification such as the translog implies a strong maintained hypothesis on the derivatives of the level function of interest. The Malmquist results show wide variation across years leading to question its deterministic nature and the fact that it uses information only on two adjacent periods possibly making it very sensitive to data errors and to any temporary changes in the data. Caution indicates that studies of productivity growth should use alternative approaches. While the Malmquist index, due to its nature,
exacerbates variability, the econometric estimates exacerbate uniformity and smoothness.

The findings of this study are important because they provide a contrast with most other studies of Chinese agricultural productivity growth. By estimating rates of productivity growth for thirty provinces using two different approaches and an alternative data source we provide additional information that support results of earlier studies and extend the period of analysis. Future research should look into understanding the differences in patterns most obvious in our Malmquist estimates.
References


Table 1. Studies of TFP growth in Chinese Agriculture.  
(figures indicate the estimated annual growth rate (%) in agricultural TFP)

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*Methods:
SPF = Stochastic Production Frontier
DEA-M = Malmquist index based on Data Envelopment Analysis
A-D = Growth accounting method with Divisia or Tornqvist-Thiel Index
CD = Cobb-Douglas production function estimation or growth accounting
<table>
<thead>
<tr>
<th>Year</th>
<th>Gross Output Value (Constant 1993 Yuan, 100 millions)</th>
<th>Land Sown (10,000 hectares)</th>
<th>Fertilizer (10,000 metric tons)</th>
<th>Labor (10,000 persons)</th>
<th>Machinery Power (10,000 kw)</th>
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<tbody>
<tr>
<td>1993</td>
<td>10,996</td>
<td>14,774</td>
<td>3,152</td>
<td>33,258</td>
<td>31,817</td>
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<td>11,931</td>
<td>14,824</td>
<td>3,318</td>
<td>32,690</td>
<td>33,802</td>
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<td>13,232</td>
<td>14,988</td>
<td>3,594</td>
<td>32,335</td>
<td>36,118</td>
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<tr>
<td>1996</td>
<td>14,473</td>
<td>15,238</td>
<td>3,828</td>
<td>32,261</td>
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<td>15,397</td>
<td>3,981</td>
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<td>1998</td>
<td>16,119</td>
<td>15,571</td>
<td>4,086</td>
<td>32,627</td>
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<tr>
<td>1999</td>
<td>16,880</td>
<td>15,637</td>
<td>4,124</td>
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<td>15,630</td>
<td>4,147</td>
<td>32,798</td>
<td>52,574</td>
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<tr>
<td>2001</td>
<td>18,234</td>
<td>15,571</td>
<td>4,254</td>
<td>32,451</td>
<td>55,172</td>
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<td>2002</td>
<td>19,136</td>
<td>15,464</td>
<td>4,339</td>
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<td>15,241</td>
<td>4,412</td>
<td>31,260</td>
<td>60,387</td>
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<tr>
<td>2004</td>
<td>21,327</td>
<td>15,355</td>
<td>4,637</td>
<td>30,596</td>
<td>64,028</td>
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<tr>
<td>2005</td>
<td>22,521</td>
<td>15,549</td>
<td>4,766</td>
<td>29,976</td>
<td>68,398</td>
</tr>
</tbody>
</table>

Annual rate of change (%) | 5.97 | 0.43 | 3.46 | -0.87 | 6.37 |

Source: *China Statistical Yearbook*, State Statistical Bureau (various annual issues).
Table 3. Productivity Growth Indexes for China's Agriculture, 1993-2005: Malmquist Method

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Factor Productivity (index, 1993 = 100)</th>
<th>Technical Efficiency</th>
<th>Technical Change</th>
<th>Total Factor Productivity (^1)</th>
<th>Efficiency Change</th>
<th>Technical Change</th>
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<tr>
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<td>100</td>
<td>100</td>
<td>100</td>
<td>--</td>
<td>--</td>
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<td>1994</td>
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<td>96</td>
<td>111</td>
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<td>109</td>
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<td>86</td>
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<td>1998</td>
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<td>87</td>
<td>134</td>
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<tr>
<td>1999</td>
<td>119</td>
<td>85</td>
<td>143</td>
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<tr>
<td>2000</td>
<td>122</td>
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<tr>
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<tr>
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<td>182</td>
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<td>183</td>
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Average annual growth rate (unweighted)  
3.03  -1.80  4.93

Average annual growth rate (weighted by output)  
3.98

\(^1\) The rate of growth in total factor productivity equals the rate of efficiency change plus the rate of technical change.
Table 4. Agricultural Productivity Growth in China's Provinces and Regions: Malmquist Method

<table>
<thead>
<tr>
<th>Regions</th>
<th>Provinces</th>
<th>Total Factor Productivity Growth</th>
<th>Efficiency Change</th>
<th>Technical Change</th>
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<tr>
<td></td>
<td></td>
<td>(average annual growth rate in %, 1994-2005)</td>
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<tr>
<td>East*</td>
<td>Beijing</td>
<td>5.9</td>
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<tr>
<td></td>
<td>Fujian</td>
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<td>-1.9</td>
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<td></td>
<td>Guangdong</td>
<td>5.5</td>
<td>-1.7</td>
<td>7.3</td>
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<td>-1.7</td>
<td>3.9</td>
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<td></td>
<td>Hainan</td>
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<td></td>
<td>Hebei</td>
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<td>5.3</td>
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<td>-1.4</td>
<td>4.3</td>
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<td>Henan</td>
<td>5.0</td>
<td>-1.8</td>
<td>6.9</td>
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<td>-3.6</td>
<td>6.2</td>
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<td>Gansu</td>
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<td>Yunnan</td>
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*Output weighted regional averages
Table 5. Translog Stochastic Frontier Maximum Likelihood Estimates for China's Agriculture

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<tr>
<th>Parameters (description)</th>
<th>Parameters (symbols)</th>
<th>Coefficient Estimates</th>
<th>Standard Error</th>
<th>T-ratio</th>
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<tr>
<td>Intercept</td>
<td>$\alpha_0$</td>
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<td>1.3598</td>
<td>3.48</td>
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<td>log(land)</td>
<td>$\alpha_D$</td>
<td>-2.2786</td>
<td>0.5841</td>
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</tr>
<tr>
<td>log(labor)</td>
<td>$\alpha_L$</td>
<td>1.7028</td>
<td>0.3488</td>
<td>4.88</td>
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<tr>
<td>log(fertilizer)</td>
<td>$\alpha_F$</td>
<td>0.0667</td>
<td>0.3793</td>
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</tr>
<tr>
<td>log(power)</td>
<td>$\alpha_P$</td>
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<td>0.2997</td>
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<tr>
<td>time</td>
<td>$\alpha_t$</td>
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<td>0.0214</td>
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<tr>
<td>log(land)$^2$</td>
<td>$\beta_{DD}$</td>
<td>0.2907</td>
<td>0.0976</td>
<td>2.98</td>
</tr>
<tr>
<td>log(labor)$^2$</td>
<td>$\beta_{LL}$</td>
<td>0.0214</td>
<td>0.0369</td>
<td>0.58</td>
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<tr>
<td>log(fertilizer)$^2$</td>
<td>$\beta_{FF}$</td>
<td>0.0644</td>
<td>0.0333</td>
<td>1.93</td>
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<tr>
<td>log(power)$^2$</td>
<td>$\beta_{PP}$</td>
<td>0.0030</td>
<td>0.0257</td>
<td>0.12</td>
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<tr>
<td>log(land)*log(labor)</td>
<td>$\beta_{DL}$</td>
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<td>0.0998</td>
<td>-1.87</td>
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<tr>
<td>log(land)*log(fertilizer)</td>
<td>$\beta_{DF}$</td>
<td>-0.2896</td>
<td>0.1041</td>
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<td>$\beta_{DP}$</td>
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<td>0.0958</td>
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<tr>
<td>log(labor)*log(fertilizer)</td>
<td>$\beta_{LF}$</td>
<td>0.2304</td>
<td>0.0616</td>
<td>3.74</td>
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<tr>
<td>log(labor)*log(power)</td>
<td>$\beta_{LP}$</td>
<td>-0.1841</td>
<td>0.0565</td>
<td>-3.26</td>
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<tr>
<td>log(fertilizer)*log(power)</td>
<td>$\beta_{FP}$</td>
<td>0.0903</td>
<td>0.0493</td>
<td>1.83</td>
</tr>
<tr>
<td>log(land)*time</td>
<td>$\beta_{Dt}$</td>
<td>-0.0057</td>
<td>0.0069</td>
<td>-0.83</td>
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<tr>
<td>log(labor)*time</td>
<td>$\beta_{Lt}$</td>
<td>-0.0034</td>
<td>0.0038</td>
<td>-0.88</td>
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<tr>
<td>log(fertilizer)*time</td>
<td>$\beta_{Ft}$</td>
<td>0.0038</td>
<td>0.0041</td>
<td>0.92</td>
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<tr>
<td>log(power)*time</td>
<td>$\beta_{Pt}$</td>
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<td>0.0038</td>
<td>0.40</td>
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<tr>
<td>time$^2$</td>
<td>$\beta_{tt}$</td>
<td>-0.0009</td>
<td>0.0003</td>
<td>-3.45</td>
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</table>

The econometric model is estimated using annual panel data for 30 provinces over 1993-2005.
<table>
<thead>
<tr>
<th>Year</th>
<th>Land</th>
<th>Fertilizer</th>
<th>Labor</th>
<th>Power</th>
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<td>0.124</td>
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<td>0.206</td>
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<td>1994</td>
<td>0.110</td>
<td>0.464</td>
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<td>0.084</td>
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<td>0.091</td>
<td>0.478</td>
<td>0.203</td>
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<td>0.078</td>
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<td>0.104</td>
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<tr>
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<td>0.505</td>
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<td>0.109</td>
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<tr>
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<td>0.049</td>
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These elasticities are derived from the estimated translog stochastic frontier production function (see Table 5) evaluated at the mean values of the variables for 30 provinces.
Table 7. Productivity Growth Indexes for China's Agriculture, 1993-2005:
Stochastic Frontier Method

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Average annual growth rate (unweighted) 4.04 -1.19 5.23
Average annual growth rate (weighted by output) 4.13 -0.89 5.02

1 The rate of growth in total factor productivity equals the rate of efficiency change plus the rate of technical change.
Table 8. Agricultural Productivity Growth in China's Provinces and Regions: Stochastic Frontier Method

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*Output weighted regional averages
Figure 1 – Agricultural TFP Growth Rates by Region over 1994-2005: Malmquist Method

![Malmquist Method Diagram]

Figure 2 – Agricultural TFP Growth Rates by Region over 1994-2005: Stochastic Frontier Method

![Stochastic Frontier Method Diagram]
### Appendix: Regional and Provincial TFP Growth Rates for China’s Agriculture

Table A9.1 - Agricultural TFP Indexes for China’s Provinces and Regions: Malmquist Method

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