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Not for Quotation

Chinese Regional Agricultural Productivity in the 1990's[1]

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May 2002

[1] Paper selected for presentation at the annual meetings of the American Agricultural Economics Association, Long Beach, CA, July 2002.
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Part I. Introduction

Since the economic reform in 1978, China's agricultural output has grown by leaps and bounds. According to China's statistical yearbook, the gross output value of agriculture in 1999 is more than 1.4 trillion Yuan, while in 1978 the gross output value of agriculture was only 0.1 trillion Yuan. After taking into account inflation, this is still an important increase.

The following facts[3] may give some idea of the importance of agriculture in China.

- China's total population was 1,259 billion people at the end of 1999
- 69 percent of China's people live in rural areas
- China is fourth in the world in land area
- China has 9 percent of the world's total arable land, and 22 percent of the world's population.

Chinas's agricultural sector is an attractive research topic given the importance of agriculture in China and the rapid expansion of production. Actually, many studies have n examined agricultural growth of China. The studies can be divided by the time period of analysis into two sets. The first set covers the 1980's. The second set refers to the 1990's. During the1980's, China's agricultural output and productivity experienced very rapid growth. On the contrary, it seems that growth slowed down in the 1990's and there are no regional studies that analyze this period with any depth, except this one. In addition, most other studies have focused on aggregate productivity at the national level while the main purpose of this paper is to explore the differential agricultural productivity growth at the regional level.

[3] From ERS in US department of agriculture website.

This paper's objective is to examine regional agricultural productivity growth in China during the 1990's. This involves three steps: a) its measurement using a Malmquist index method, b) its measurement using a stochastic frontier production function, and c) the identification of particular factors that might have contributed to productivity change.

The reason for examining productivity growth at the provincial level is that some factors may be disguised in national data. China is a country with diverse ecosystems and with a large population working on agriculture. So different practices in each province will lead to different outcomes. Finding the source of productivity growth will be helpful for those provinces experiencing lower growth rate.

There is also a wealth of information at the provincial level that lends itself to this analysis and provides detailed information about regional production systems. When using cross regional data, the analysis is affected by different institutions prevailing in the different regions but in China, the political environment across regions has been similar. This allows extraction of sources of growth beyond "institutional factors." This is important because past studies have reported this as the main contributor of economic growth in China.

The Malmquist index and a stochastic frontier production function are particularly suitable to examine the China's agricultural productivity because they rely on quantity data only. There is no need to use prices, which is an advantage given that they were distorted due to government intervention. Compared with a production function, the Malmquist index does not suffer from specification error. But the disadvantage of Malmquist index is that it will be very sensitive to errors. So a stochastic frontier translog production function is also used to compare measurements across methods.

Both the Malmquist Index and the stochastic frontier production function show that there is higher productivity growth in the mid 1990's. They also show that there is decreasing productivity growth in the late 1990's.

In Part II a literature review is found. Part III has some background on China's agricultural sector policies and the reforms during the 1980's and 1990's. Part IV reports the Malmquist index results. Part V reports the outcome from the stochastic frontier production function. Part VI presents a model that includes potential explanations for differential growth across regions. Part VII concludes and suggests future work.

Part II. Literature Review

As mentioned above, lots of work has been done on the agricultural growth of China. In this part, the main works and their findings are summarized.

McMillan, Whalley and Zhu (1989) examined the effects of price increase and introduction of HRS (house hold responsibility system) on agricultural performance from 1978 to 1984. They set up an "institutional" production function to capture the contribution of institutional change and price change to productivity growth. They found about 78 percent of agricultural productivity growth is due to institutional change and about 22 percent is due to price increase. Their reported productivity growth ranged from around 2 percent to 10 percent for different years.

Fan (1991) used a frontier production function to separate the agricultural growth into input growth, technical change and institutional reform. So total productivity change includes technical change and institutional change. He divided the nation into 7 regions to examine the cross regional difference. He found that different regions benefited differently from HRS. He also found that institutional change contributed more than technical change to TFP growth. In his later work in 1997, he compared the constant price index with the Tornqvist index and concluded that the constant price index is not appropriate. He also pointed out that investment in the agricultural sector was needed for long run production growth when institutional changes were almost exhausted. In his recent work with Zhang (2001), they used a generalized maximum entropy approach to estimate a multi output production technology, for twenty five provinces during the period of 1979-1996. They found that technological growth was input bias toward fertilizer and labor in the grain sector and output biased toward cash crops (against grain crops).

Lin (1992) employed a fixed effects models (using provincial level data) to evaluate the effects of decollectivization (HRS), price adjustments and other factors on productivity growth. He found that institutional reform contributed most to productivity growth during this period. Inputs were found to respond heavily to procurement prices. He also pointed out that stagnation after 1984 may be due to “exodus of labor force” and “decline in the growth rate of fertilizer usage”[4] which accompanied the procurement price decline. His work on efficiency of different systems (1993) showed that household farms outperformed cooperative farms, which gave support for institutional reform in China. In his work of 1995, he examined the rice production of China and tested the induced institutional innovation theory. He concluded that there were improved resource allocation and productivity after lifting the legal restrictions. In his work of 1997, he examined the agricultural growth from 1952 to 1995. He divided the whole period into

[4] Lin, 1992, pp. 48.

three sub-periods: 1952-1978 (pre-reform period), 1979-1984 and 1984-1995. The growth in the first and the third sub periods was slow and in the second period was fast. He analyzed that the slow growth in the first period was due to the collective farming system, which was "detrimental to farmers' incentives"[5]. The second period's high growth came from the institutional change (HRS). The third period's low growth is due to the procurement price system. He concluded that freeing prices and further market liberalization were needed to improve China's grain production.

Huang and Rozelle (1995) studied environmental stress and grain production using a fixed effect model and data from 1952 to 1990. They found the production growth in the period of 1984 to 1990, which was 1.8%, was much lower than that of 1978-1984, which was 4.7%. They concluded that the "erosion, salinization, soil exhaustion and degradation of the local environment may be partially responsible for the slowdown" of the period of 1984-1990.

Rozelle, Park, Huang and Jin (1997) examined market integration after the implementation of liberalized economic policies in food markets. They found there was evidence of market integration and improvement in market efficiency and producer efficiency.

Rozelle, Taylor and DeBrauw (1999) used a labor migration framework to model the effect of migration and remittances on agricultural productivity growth in China. They found that "net effect of migration and remittances on maize production is negative."[6]

De Brauw, Huang and Rozelle (2000) examined how market liberalization influenced the behavior of producers. They found that producers were more responsive

[5] Lin, 1997, pp. 201.
[6] Rozelle, etc, pp. 291.

after liberalization.

Zhang and Carter (1997) constructed a Cobb-Douglas production function to separate the contribution of input, weather and efficiency to growth of grain production from 1980 to 1990. They examined cross regional data and found that institutional contribution had less impact than previous studies if good weather was taken into account. Their results also showed that input growth is a big factor contributing to grain output growth. Their results also showed that the contribution of efficiency change was higher at the end of 80's than that at the beginning of 80's, which was inconsistent with the work of others.

Colby, Diao and Somwaru (2000) used Tornqvist Index approach to analyze the sources of outputs growth in total grain and four major crops in China (rice, wheat, corn and soybean). Their data ranged from 1978 to 1997 and the data was broken down to three periods: 1978-1985, 1986-1994 and 1995-1997. They found that the growth rate of output and TFP are quite different for each period. TFP growth rate is highest during the period of 1978 to 1985 and lowest during the period of 1986 to 1994, which seems quite consistent with the work of Lin (1997). Their outcomes showed that TFP contribution to output growth is decreasing. Then they used a restricted profit translog function to study the output supply and input demand response. They found "own price elasticities of soybean, corn and rice are grater than unity while wheat's elasticity is less than unity."[7] They also found that input demands are price elastic.

The above studies are the most important work done on agricultural productivity growth (and grain growth) in China. Based on the above studies, we can draw the following conclusions: agricultural productivity growth in China was higher after

[7] Colby, etc. 2000, pp.15.

introduction of the HRS (from 1978 to mid 80's) than that in recent years; the main contribution of TFP growth in the period 1978 to mid 80's is institutional reform (which can be viewed partly as efficiency change); there is evidence that the TFP growth is slowing down during the recent years, which may be due to the exhaustion of the institutional effect, the procurement price system and lack of agriculture investment that hinder further grain productivity growth in China.

Part III. China's Agricultural Policies

Before 1978, agriculture in China was under a collective system. After 1978, China adopted the "household production responsibility system (HRS)". Under HRS system, although farmland is not privately owned, peasants can have long term use rights to land and allocate resources but need to deliver a quota to government by using the procurement prices regulated by the government and trade the leftover freely in the markets. Of course peasants also need to pay taxes and local fees. Local government is responsible for some extension services and introduction of new technologies and seed varieties.

China's agricultural policies experienced a lot of change over the last 20 years. Generally speaking, China is going the reform from planning economy to market economy. What the government was trying to do is to eliminate some government intervention and facilitate the role of market force. The first biggest step in China's agricultural reform is the introduction of HRS in 1978. HRS motivated the farmers to pursue profit. This system gives farmers the incentives to reduce costs and adopted high tech in production. Another very important reform happened at the beginning of 1990's

(1993), when China abandoned the food rationing system. Under the grain-rationing system, urban consumers used coupon to buy a fixed amount of grain at a low price. If consumers wanted to buy more than rationed amount, they can purchase at the free market with a higher price. Due to the budget pressure, the government began to reduce the gap between ration price and market price in 1991 and 1992. Seeing no resistance from urban consumer, the government finally eliminated the rationing price in the early of 1994.

Among different agricultural products, the government also has different policy practicing. The government has relative less intervention in the production of fruits, vegetables and livestock and much more intervention on grain production.

A recent reform involves the Grain-Bag responsibility system, which requires leaders in each province maintain overall balance of grain supply and demand for their province and regulate local markets. This policy advocated self-efficiency of grain production. The result of the Grain-Bag policy is that output of grain increased due to the shift of land and other agricultural inputs to grain[8]. The effect of this policy may introduce some negative impacts such as inefficiency in resource allocation and regional protectionism.

Part IV The Malmquist Index

In this part, we used the provincial data from year 1993-1999 to construct a Malmquist productivity index. The Malmquist index is a non-parametric method used to examine productivity change. Productivity growth is different from output growth. Productivity refers to output per unit of input and can be measured by dividing an output

[8] China's Grain Policy at a Crossroads, Economic Research Service/USDA.

index by an input index. We care about productivity because it indicates an increase in output for given resources.

Because the Malmquist index is a quantity index, it is more suitable to China's situation due to the existence of procurement price and quotas. As specified by Fare et al (1994) this index is:

$$M_0(x_{t+1}, y_{t+1}, x_t, y_t) = [\frac{D_o^t(x_{t+1}, y_{t+1})}{D_0^t(x_{t,} y_t)} * \frac{D_o^{t+1}(x_{t+1}, y_{t+1})}{D_0^{t+1}(x_{t,} y_t)}]^{1/2}$$

The subscript *0* shows that this is an output oriented Malmquist index. Here D_o refers to an output distance function. D_o is calculated as follows.[9]

$[d^t{}_o(x_{t,} y_t)]^{-1} = \max_{\phi,\lambda,} \phi,$

st. $-\phi y_{it} + Y_t\lambda \geq 0,$

$x_{it} - X_t\lambda \geq 0,$

$\lambda \geq 0$

where x and y are input and output vectors respectively. *X (K*N)* and *Y (M*N)* are the input and output matrixes respectively. λ is a *N*1* vector of constants. Here $1 =< \phi < \infty$ and $\phi - 1$ is the proportional increase in inputs that could be achieved by the i-th DMU (decision making units, in this article it refers to each region), with input quantities held constant. Fare et al also show that the index can be factored into efficiency change and technical change, which is a geometric mean of technologies in two periods:

[9] Coelli 1996, pp. 27.

$$M_0(x_{t+1}, y_{t+1}, x_t, y_t) = \frac{D_o^{t+1}(x_{t+1}, y_{t+1})}{D_0^t(x_{t,} y_t)} [\frac{D_o^t(x_{t+1}, y_{t+1})}{D_0^{t+1}(x_{t+1,} y_{t+1})} * \frac{D_o^t(x_t, y_t)}{D_0^{t+1}(x_{t,} y_t)}]^{1/2}$$

By furthering factoring, the TFP change can be separated into technical efficiency change, scale efficiency change and technology change. Technical efficiency change tells us whether a particular region is moving closer to the frontier or further away from the frontier. Scale efficiency change indicates if the frontier is moving away or closer to a constant return to scale frontier. Technical change refers to a shift of the frontier. In all the above-mentioned efficiencies, efficiency indexes smaller than one refer to inefficiencies. There is also pure efficiency, which is efficiency taking into account scale efficiency.

In this paper the Data Envelopment Analysis (Computer) Program (DEAP) developed by Tim Coelli is used to calculate the Malmquist Index. All the data used in the construction of this index are from China Statistical Yearbook. Agricultural output values for 30 provinces are used as the measurement of output. The data range is from 1993 to 1999. The Statistical Yearbook gives out the gross output value in agricultural (farming) sector. To get the real output for each province we use the output indices to deflate the gross output value. Therefore we can get the output quantity in constant Yuan. There are four inputs. Total sown areas of agricultural products are denoted by thousands of hectares. Total power of agricultural machinery is denoted by 10 thousands of KW. Labor in agricultural is denoted by 10 thousands persons and fertilizer is in 10 thousands tons. Fertilizer includes Nitrogenous fertilizer, Phosphate fertilizer, Potash fertilizer and compound fertilizer. A summary of the data is attached in the appendix.

Table 1 reports the mean productivity of all the regions for each year from 1994 to 1999 with 1993 serving as the base year. Table 2 reports the mean productivity index during the period of 1993 to 1999 for each region.

Here all the means reported are geometric means. The last column is the Malmquist index, which measures total factor productivity change (tfp change). This can be separated into three parts, efficiency change, technical change and scale change. Ignoring the scale change effect, we can get the pure efficiency change, which is reported in the fourth column.

From table 1 we can see that in 1994 and 1995, China experienced very high productivity growth [(tfpch-1)*100 is the productivity growth]. From 1996 to 1999, the agricultural sector was suffering from decreased productivity. One of the reasons is the low technical change and decreasing return to scale. The other reason is technical inefficiency.

The work done in this paper only covers a very short period of time. So there are few comparisons that we can do with other studies done on this area by using other method. The most recent work done on agricultural productivity of China we found is the USDA's piece by Colby, et al. They used a Tornqvist index to measure China's grain productivity. Although there is some overlapping with our period of analysis, our results depart from theirs. They concluded that there is higher productivity growth in the mid 1990s. While ours also show higher growth in the mid 1990s but our definition of mid 1990s is different from theirs. In their study, mid 1990s refers to 1995-1997 while ours refer to 1994-1995. They do not show yearly productivity growth in their paper. Also, they measure the productivity of grains and we measure productivity for the whole agricultural sector.

From table 1, we see that in 1994 there was very high productivity growth. We examined the national data (see appendix) and found that this outcome should not be surprising because the gross output values jumped a lot from 1993 to 1994 with no much change in inputs.

One of the shortages of the Malmquist Index is that it can only provide productivity change and cannot give us any information relative to sources of growth. Therefore we do not know why there is such high productivity growth in 1994.

TABLE 1. MALMQUIST INDEX SUMMARY OF ANNUAL MEANS

year	effch	techch	pech	sech	tfpch
1994	1.029	1.279	1.029	0.999	1.316
1995	1.013	1.118	1.011	1.002	1.133
1996	0.97	1.019	0.982	0.987	0.988
1997	0.923	1.023	0.983	0.938	0.944
1998	0.98	0.946	0.991	0.988	0.927
1999	1.015	0.924	0.998	1.016	0.938
MEAN	0.987	1.045	0.999	0.988	1.032

From Table 2 we can see that most of the regions experienced positive technical change while experiencing increased inefficiency. By examining the regional Malmquist indexes from 1993 to 1999, we identify the most productive region, that region that defines the best practice frontier (efficiency index = 1.) Beijing, Shanghai and Guangdong define the frontier throughout the period and are the regions whose technical change indicate the shift of the overall frontier. Here Beijing and Shanghai refer the rural area around these two cities. Guangdong is a very big province in the south of China.

Table2 MALMQUIST INDEX SUMMARY OF REGIONAL MEANS					
REGION	effch	techch	pech	sech	tfpch
Beijing	1	1.078	1	1	1.078
Tianjin	0.994	1.009	0.995	1	1.003
Hebei	0.993	1.049	1.041	0.954	1.041
Shanxi	1.013	1.043	1.028	0.985	1.056
Inner mon	0.976	1.041	0.994	0.981	1.016
Liaoning	0.997	1.054	1.018	0.979	1.051
Jilin	0.977	1.059	1.019	0.959	1.035
Heilongjiang	0.971	1.042	0.983	0.988	1.011
Shangai	1	1.075	1	1	1.075
Jiangsu	0.973	1.066	1.011	0.962	1.037
Zhejiang	1.005	1.049	1	1.005	1.054
Anhui	0.961	1.036	1.006	0.955	0.995
Fujian	0.98	1.051	0.988	0.993	1.03
Jiangxi	0.99	1.047	1	0.989	1.036
Shandong	1.006	1.051	1	1.006	1.058
Henan	0.979	1.053	1.005	0.974	1.031
Hubei	1.001	1.054	1.019	0.982	1.055
Hunan	0.99	1.039	0.998	0.992	1.029
Guangdong	1	1.037	1	1	1.037
Guangxi	0.95	1.036	0.954	0.996	0.985
Hainan	0.984	1.033	0.989	0.995	1.016
Sichuan	0.99	1.033	1	0.99	1.022
Guizhou	1.008	1.036	1	1.008	1.044
Yunnan	1.008	1.041	1.01	0.998	1.049
Tibet	1	1.036	1	1	1.036
Shaanxi	0.963	1.05	0.977	0.985	1.011
Gansu	0.995	1.041	0.989	1.006	1.036
Qingghai	1.015	1.042	1.016	0.999	1.058
Ningxia	0.938	1.044	0.936	1.003	0.979
Xinjiang	0.974	1.03	1	0.974	1.003
MEAN	0.987	1.045	0.999	0.988	1.032

Although the Malmquist index does give us the reasons why there are different productivity growth rates through this period, we can make some conjectures consistent with economic insights and the economic situation of China in that period of time.

The elimination of the rationing system may have contributed to productivity change in years 1994 and1995. As mentioned before, in early 1994, the Chinese government eliminated the rationing system. Although farmers needed to submit a quota to the government, farmers still had the right to sell the additional production in the free market. This means that economic incentives market affect the farmers' behavior. The elimination of rations induced an increase of market prices resulting in increased production. This also gives the farmers more incentive to adopt new technologies. Another explanation may come from the change in the government's procurement price system. Table 3 shows the government procurement price index in years 1993 to 1999. We can see that the procurement price pattern is very similar to the pattern of the productivity index. Fulginiti and Perrin (1993) used a Cobb-Douglas production function to model price as a technical change variable and found that price is a factor that influenced productivity change in 18 LDCs.

The third conjecture about factors affecting productivity change is the introduction of the Gain-Bag Responsibility System in 1995. This policy was intended to put more pressure on provincial leaders to support the development of their province's agricultural production. The policy required the provincial leaders to maintain an overall balance of grain within their province. The introduction of this policy has had some positive effects such as increased investment in agriculture leading to a reversal of the decline in sown areas. By emphasizing self-sufficiency, this new policy may also introduce resource allocation inefficiency, which may be reflected in scale inefficiency as seen in table 1.

Table 3. General procurement price index

Year	Preceding year=100
1993	113.4
1994	139.9
1995	119.9
1996	104.2
1997	95.5
1998	92.0
1999	87.8

Note: The General procurement price index includes the grain procurement price index and Industrial crops procurement price index

Part V. Stochastic Frontier Translog Production Function

We follow Battese and Coelli 's proposal (1992) of a stochastic frontier production function for panel data. The model is expressed as follows.

$$Y_{it} = x_{it}\beta + (V_{it} - U_{it})$$

For our data, I=1, 2, ……, 30. t=1, 2, ……, 7.

Here Y_{it} is the logarithm of the output level of the *i-th* province in the *t-th* time period. x_{it} is a *4*1* vector of the logarithm of the input quantities of the *i-th* province in the *t-th* time period. β is the coefficient vector. The V_{it} are random errors which are assumed to be iid N (0, $\sigma_V{}^2$) and are independent of U_{it}. $U_{it} = (U_i \exp(-\eta(t-T)))$. U_i are iid one sided errors that are assumed to account for technical inefficiency and to be truncated at zero of the N ($\mu, \sigma_V{}^2$) distributions. And η is a parameter to be estimated.

The specific translog production function is as follows.

$$\ln Y_{it} = \alpha_0 + \sum_m \alpha_m \ln x_{mit} + \alpha_t t + \frac{1}{2}\sum_m \sum_n \beta_{mn} \ln x_{mit} \ln x_{nit} + \frac{1}{2}\beta_{tt} t^2 + \sum_m \beta_{tm} \ln x_{mit} * t + v_{it} - u_{it}$$

m, n=*D*(land), *L*(labor), *F*(fertilizer) and *P*(power).

Land, labor, fertilizer and power are the traditional inputs used in the construction of Malmquist index.

The above equation is estimated using Coelli's Frontier 4.1 econometric package with symmetry imposed. The maximum likelihood estimates of the parameters are reported in appendix 2.

Technical change is obtained through differentiating the above equation with respect to *t:*

$$\frac{\partial \ln Y_{it}}{\partial t} = \alpha_t + \beta_{tt} t + \sum_m \beta_{tm} \ln x_{mit}$$

Technical efficiency level of firm i at time t is defined as follows.

$$TE_{it} = \exp(-u_{it})$$

It is the ratio of the actual output to the potential output.

The elasticity of output with respect to the mth input is defined by

$$\varepsilon_m = \frac{\partial \ln f(x,t)}{\partial \ln x_m} = \alpha_m + \sum_{n \neq m} \beta_{mn} \ln x_n + \beta_{mm} \ln x_m + \beta_{tm} * t,$$

m, n=*D, L, F* and *P*.

Using the output elasticities of inputs, we can obtain an estimate of aggregate returns to scale. The returns to scale is obtained by summing the input elasticities, that is

$\varepsilon = \sum_m \varepsilon_m$. When *RTS>1, =1* and *<1*, there is an increasing return, constant return and decreasing return to scale.

The rate of TFP (total factor productivity) is defined as the rate of change in output that is not explained by the input change:

$$T\dot{F}P = \dot{y} - \sum_m \varepsilon_m \dot{x}_m$$

The national and regional average rate of technical change and technical efficiency change along with the rate of change of TPF from 1993 to 1999 are reported in table 4 and table 5 respectively. Comparing the national average from this approach with the results from the Malmquist index we can see that the growth rate of technical change is consistent in the two approaches. The stochastic frontier approach also estimates regression during the late 1990's. However, the estimation of technical efficiency change in the two approaches is not as consistent. The Malmquist index indicates that technical efficiency deteriorated first but picked up at the end of the 1990's. The stochastic frontier approach indicates technical deterioration through all the period, although the trend is very weak.

Comparing the technical growth by region across methods, we found that the results coincide in only one third of the regions.[10]. Comparing technical efficiency, we found that more than one half of the regions have similar rankings.

[10] If the ranking is not exceeding 6, we thought they are very similar from 2 approaches.

Table 4

Stochastic Frontier Summary of Annual Means

Year	Rate of Technical Change	Rate of Technical Efficiency Change	Rate of TFP change
1993	0.26		
1994	0.19	-0.007	0.331
1995	0.12	-0.007	0.199
1996	0.05	-0.007	0.028
1997	-0.02	-0.007	-0.044
1998	-0.1	-0.007	-0.047
1999	-0.17	-0.007	-0.068
Mean	0.05	-0.007	0.066

Table 5

Stochastic Frontier Summary of Regional Means

Region	Technology change rate	Technical Efficiency Change Rate	TFP change rate
Beijing	0.057	-0.004	0.091
Tianjin	0.065	-0.024	0.072
Hebei	0.053	-0.056	0.067
Shanxi	0.055	-0.105	0.094
Iinner Mongolia	0.063	-0.075	0.059
Liaoning	0.046	-0.029	0.071
Jilin	0.045	-0.041	0.091
Heilongjiang	0.062	-0.054	0.048
Shanhai	0.046	-0.023	0.082
Jiangsu	0.04	-0.019	0.051
Zhejiang	0.048	-0.036	0.066
Anhui	0.042	-0.068	0.052
Fujian	0.035	-0.044	0.050
Jiangxi	0.043	-0.038	0.074
Shandong	0.044	-0.038	0.060
Henan	0.044	-0.049	0.054
Hubei	0.038	-0.027	0.091
Hunan	0.043	-0.038	0.065
Guangdong	0.039	-0.002	0.043
Guangxi	0.041	-0.069	0.034
Hainan	0.047	-0.060	0.044
Sichuan	0.039	-0.005	0.073
Geizhou	0.04	-0.040	0.089
Yunnan	0.044	-0.065	0.064
Tibet	0.055	-0.072	0.084
Shaanxi	0.041	-0.069	0.051
Gansu	0.054	-0.088	0.092
Qingghai	0.06	-0.117	0.064
Ningxia	0.053	-0.115	0.059
Xinjiang	0.053	-0.037	0.055

Output elasticities for each input evaluated at the national mean are reported in the appendix. The elasticity of scale is also presented in the appendix. China's agricultural sector shows decreasing return to scale.

Results from both approaches are reported in the appendix for three geographic regions, East, Central, and West.

Part VI. A Model for Differential Performance of the Regions.

In an attempt to identify variables that are potential contributors to technical inefficiency, we follow the specification of Battese and Coelli (1995). They suggest that technical inefficiency, which reflects regional heterogeneity, may be influenced by particular variables. In our case we hypothesize that differential performance of the regions will be affected by public goods like public agricultural expenditures, education, and infrastructure.

The model is specified as follows using a translog form:

$$\ln Y_{it} = \alpha_0 + \sum_m \alpha_m \ln x_{mit} + \alpha_t t + \frac{1}{2}\sum_m \sum_n \beta_{mn} \ln x_{mit} \ln x_{nit} + \frac{1}{2}\beta_{tt} t^2 + \sum_m \beta_{tm} \ln x_{mit} * t + v_{it} - u_{it}$$

Y_{it}, x_{it} and β are the same as defined earlier.

V_{it} are still assumed to be random errors which are iid N (0 $\sigma_V{}^2$) and are independent of U_{it}. U_{it} are non negative random variables that account for technical inefficiency. U_{it} are independently distributed as truncations at zero of the N (m_{it} , $\sigma_U{}^2$). And $m_{it} = z_{it}\delta$. Here z_{it} is a *3*1* vector of variables that may contribute to the technical efficiency of a region. And δ is the parameter vector to be estimated.

The three variables in the z vector are: public agricultural expenditure, the rate of illiterate individuals, and the irrigation ratio. We expect that the first and the third will increase technical efficiency, and the second will lower technical efficiency.

Public agricultural expenditures includes expenditures on agricultural water conservancy, meteorology, resource investigation, subsidies to well drilling, sprinkling irrigation project and popularization of improved varieties, etc. The amount of expenditure is related to the production level. To get a unit level expenditure, total agricultural expenditure of each province is divided by total sown areas in each province. This can be viewed as a provision of a public good to farmers and we should expect it to contribute positively to productivity.

The rate of illiterate people in the population the illiterate and semi-literate population ratio aged 15 and over. This variable can be viewed as a proxy for education, which reflects the quality of the labor input. We should expect a negative sign here.

Irrigation denotes the irrigation ratio, which states the ration of irrigated area to total sown area. This can be viewed as a proxy for land quality and a positive sign is expected.

Because the Yearbook only provides data on agricultural expenditure after 1996, the estimated regression is based on the data from 1996 to 1999.

The estimated regression is reported in table 6. It should be noted that the models defined here doesn't have the model defined earlier as a special case. So the two specifications are non-nested. Also we have fewer observations available in this specification than in the last one. So we will not compare the estimated coefficients from the two specifications. Table 6 only reports the estimates of the parameter of the z vector of variables.

Table 6 Estimates of the Parameters of the z Vector

		Coefficients	Standard-error	t-ratio
Irrigation	delta 1	-0.67	0.14	-4.74
Illiterate	delta 2	2.50	0.26	9.51
Ag expenditure	delta 3	-6.57	0.43	-15.13

All three variables are statistical significant. Signs are consistent with our expectations.

Estimating the above model to find the variables that may influence technical efficiency may seems superficial. However, it may still give us some insight on the factors that contribute to the different performance of the regions. We found that government expenditures have been in steady increase during the period. This may be due to the grain bag policy. To achieve self-sufficiency the governor of each province has invested more on its own region and regional expenditures have increased

.

Part VII. Conclusion

In this paper, a Malmquist Index was constructed to examine agricultural productivity growth in Chinese provinces during the 1990's. There is very high productivity growth in the mid 1990's with productivity growth decreasing in later years. A stochastic frontier translog production function is estimated to obtain an alternative measure of total factor productivity growth. Results are compared across models. Although average growth in technical change is similar in the two models, the regional rates are dissimilar. A model that includes three variables hypothesized to explain the difference in performance across regions is also estimated. Variables representing public inputs and that adjust the inputs for quality improvements were shown to have a significant impact on differential provincial performance.

We also hypothesize that productivity growth might be closely associated to policy reform, although we have not done anything in this paper to show that this is the case. The procurement price system seems to be a factor hindering productivity growth. The elimination of the rationing system may have contributed to higher productivity growth in the mid 1990s. The Grain Bag system may have contributed positively to technical change by inducing increased investment in local agriculture, but it may have also induced resource misallocation.

Future work includes the examination of productivity growth of crops, and livestock separately as the government has had more intervention in the grain sector. We should expect higher productivity growth in the less distorted sectors. It would also be interesting to estimate technical biases to establish their consistency with the ideas of the induced innovation theory.

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Appendix 1

Data Summary Across Regions

	Year	Total Output	Power	Land	Fertilizer	Labor
Mean		202	1061	4925	1109	105
SD	1993	154	860	3489	975	89
Mean		271	1127	4941	1090	111
SD	1994	201	953	3495	952	90
Mean		326	1204	4996	1078	120
SD	1995	240	1055	3523	939	98
Mean		345	1285	5079	1075	128
SD	1996	258	1193	3569	928	105
Mean		337	1403	5132	1081	133
SD	1997	252	1368	3598	924	108
Mean		331	1507	5190	1088	136
SD	1998	248	1493	3655	917	113
Mean		314	1633	5212	1097	137
SD	1999	238	1657	3671	936	115

Appendix 2. Estimated parameters for stochastic frontier translog production function

Parameters	Estimates	T-ratio
α_0	-3.67	-0.99
α_D	1.41	0.79
α_L	0.015	0.016
α_F	0.10	0.13
α_P	0.09	0.01
α_t	0.26	4.46
β_{DD}	0.34	0.69
β_{LL}	-0.046	-0.294
β_{FF}	0.178	1.09
β_{PP}	-0.028	-0.196
β_{DL}	0.191	0.706
β_{DF}	-0.437	-2.43
β_{DP}	-0.288	-1.05
β_{LF}	-0.12	-0.867
β_{LP}	-0.068	-0.62
β_{FP}	0.456	2.96
β_{Dt}	0.016	0.988
β_{Lt}	-0.018	-1.5
β_{Ft}	-0.01	-1.01
β_{Pt}	0.01	1.12
β_{tt}	-0.08	-0.22

Appendix 3

Output elasticity of input evaluated at national mean				
	Power	Land	Fertilizer	Labor
1993	0.257	0.202	0.228	0.127
1994	0.257	0.222	0.229	0.105
1995	0.254	0.247	0.226	0.083
1996	0.256	0.268	0.223	0.061
1997	0.267	0.271	0.235	0.037
1998	0.276	0.274	0.250	0.013
1999	0.291	0.266	0.270	-0.009
Mean	0.266	0.250	0.237	0.060

Appendix 4

Elasticity of scale	
1993	0.814
1994	0.814
1995	0.811
1996	0.809
1997	0.811
1998	0.813
1999	0.819
Mean	0.813

Appendix 5

Annual Average of Technical Efficiency for Each Region (Stochastic Frontier Method)

	1993	1994	1995	1996	1997	1998	1999
East	0.71	0.71	0.71	0.70	0.70	0.70	0.69
Central	0.57	0.57	0.56	0.56	0.55	0.55	0.54
West	0.52	0.52	0.51	0.51	0.50	0.50	0.49

Note: East area includes the following regions: Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Guangxi and Hainan. The central area includes Shanxi, Inner Mongolia, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan. The west area includes Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia and Xingjiang.

Appendix 6

Annual Average Technology Change Rate for Each Area (Stochastic Frontier Method)							
Year	1993	1994	1995	1996	1997	1998	1999
East	0.263	0.191	0.118	0.046	-0.025	-0.097	-0.169
Central	0.264	0.192	0.120	0.048	-0.024	-0.095	-0.166
West	0.265	0.193	0.121	0.048	-0.024	-0.096	-0.165

Appendix 7

Annual Average Growth Rate of Technical change for Each Area (Stochastic Frontier Method)						
Year	1994	1995	1996	1997	1998	1999
East	0.295	0.178	0.023	-0.053	-0.027	-0.050
Central	0.399	0.181	0.034	-0.057	-0.053	-0.085
West	0.310	0.246	0.029	-0.020	-0.068	-0.076

Appendix 8

Annual Average of Technical Efficiency Change for Each Area (Malmquist Index Method)						
Year	1994	1995	1996	1997	1998	1999
East	0.995	1.020	0.963	0.975	0.999	1.000
Central	1.073	1.023	0.955	0.889	0.981	1.013
West	1.035	1.001	1.002	0.906	0.963	1.050

Appendix 9

Annual Average Technical change for Each Area (Malmquist Index Method)						
Year	1994	1995	1996	1997	1998	1999
East	1.280	1.117	1.042	0.985	0.970	0.943
Central	1.274	1.110	1.044	1.048	0.949	0.902
West	1.290	1.128	0.975	1.068	0.914	0.928

Appendix 10

Annual Average TFP change for Each Area (Malmquist Index Method)						
Year	1994	1995	1996	1997	1998	1999
East	1.273	1.138	1.002	0.957	0.969	0.941
Central	1.366	1.136	0.995	0.918	0.929	0.912
West	1.333	1.129	0.974	0.957	0.880	0.975

Appendix 11

TFP Growth Rate for Each Region						
	1994	1995	1996	1997	1998	1999
Beijing	0.323	0.198	0.057	-0.035	0.005	0.000
Tianjin	0.236	0.252	-0.043	-0.065	0.005	0.048
Hebei	0.278	0.283	-0.028	-0.030	-0.056	-0.045
Shanxi	0.303	0.445	0.011	-0.021	-0.091	-0.080
Iinner Mongolia	0.334	0.183	-0.055	-0.022	-0.021	-0.063
Liaoning	0.358	0.175	-0.047	0.002	-0.021	-0.044
Jilin	0.494	0.114	0.002	-0.010	-0.022	-0.033
Heilongjiang	0.468	0.191	0.065	-0.106	-0.177	-0.151
Shanhai	0.483	0.165	0.047	-0.111	-0.016	-0.078
Jiangsu	0.380	0.114	-0.018	-0.068	-0.033	-0.071
Zhejiang	0.305	0.173	-0.004	-0.019	0.002	-0.059
Anhui	0.452	0.093	-0.027	-0.073	-0.047	-0.088
Fujian	0.238	0.164	0.007	-0.057	0.007	-0.057
Jiangxi	0.321	0.173	0.071	-0.061	-0.006	-0.054
Shandong	0.156	0.290	0.060	-0.032	-0.049	-0.064
Henan	0.300	0.176	0.098	-0.115	-0.042	-0.093
Hubei	0.525	0.118	0.066	-0.030	-0.017	-0.116
Hunan	0.395	0.139	0.072	-0.075	-0.052	-0.086
Guangdong	0.250	0.142	0.039	-0.096	-0.026	-0.049
Guangxi	0.262	0.154	0.139	-0.058	-0.126	-0.168
Hainan	0.271	0.023	0.066	-0.065	-0.016	-0.016
Sichuan	0.315	0.175	0.090	-0.025	-0.042	-0.076
Geizhou	0.356	0.213	0.081	0.005	-0.050	-0.069
Yunnan	0.238	0.185	0.107	-0.043	-0.065	-0.038
Tibet	0.011	0.603	-0.060	0.076	-0.140	0.012
Shaanxi	0.233	0.167	0.042	-0.018	-0.059	-0.059
Gansu	0.498	0.263	-0.005	-0.070	-0.076	-0.056
Qingghai	0.341	0.220	-0.009	-0.058	-0.022	-0.086
Ningxia	0.391	0.164	0.026	-0.035	-0.054	-0.139
Xinjiang	0.407	0.226	-0.009	-0.015	-0.101	-0.175