Productivity in Chinese Provincial Agriculture

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Technical change, technical efficiency, and multifactor productivity indices are reported for a multiple-output, multiple-input production technology using Chinese provincial data for the 1979-95 period. Results show significant variation in productivity change from year-to-year and province-to-province. Using panel methods, we regress the three production indices on several factors important in explaining productivity changes. Decollectivization in the early 1980s accounts for a significant expansion of the frontier, while rural industrialization decreased agricultural productivity. Productivity is also sensitive to relative grain prices, to natural disasters such as flood and drought, and proximity of the provinces to coastal areas.

1. Chinese Agriculture under Economic Reform

Almost two decades have passed since economic reform began to transform the Chinese countryside. Under Chairman Mao Zedong, collectivization, political upheaval, low state purchase prices and the state?s monopoly on trade all led to stagnant growth in agriculture. Initial land reforms following the establishment of the People?s Republic in 1949 that redistributed land to poorer peasants while maintaining private property rights proved initially promising. However, productivity stagnated from 1957 (the year before the widespread creation of large rural communes) through the next two decades. China's grain production per capita grew over this period at an average rate of approximately one-twentieth of one percent per year. Rural residents fared worse than urban ones, and by 1977 internal government studies revealed that over 70 million people in the countryside lived in abject poverty.

Mao died in 1976, and Deng Xiaoping emerged as China's paramount leader by the end of 1978.[1] Under Deng's encouragement, the Chinese Communist Party recognized that drastic changes were necessary. The Communes were disbanded, and the household was made the primary production unit. The household responsibility system attempted to introduce private property incentives while leaving formal ownership of the land in state hands. Grain quotas were fixed, and agricultural prices were increased, particularly for above-quota production. Farmers were increasingly given greater latitude to choose what to plant without cadre interference, and by the mid-1980s were able to sell their products in a growing number of free markets. As a result, grain production grew by an average of five percent per year between 1978 and 1984, more than three times the rate of population growth.

However, beginning in the early 1980s, the reforms accompanying the household responsibility system also helped move rural China away from the once-primary goal of grain production. Since farmers could now produce more cash crops for free markets, continued state control of grain prices until the 1990s dampened producer enthusiasm for grain crops except as a way to meet the state's quota, particularly for farmers near urban areas or other lucrative markets. In many cases, banks which were required to pay farmers for grain procurement used their cash reserves for other purposes and instead paid farmers with I.O.U.s. Between 1984 and 1992, official average grain prices rose by 7.8 percent per year compared to 9.3 percent for cash crops and 10.2 percent for animal husbandry.

[1] In December of 1978, at the Third Plenum of the Eleventh Central Committee of the Chinese Communist Party, Deng's supporters assumed a number of key positions. Deng, however, never assumed a formal position higher than vice-chairman of the party and chairman of the military commission, and Mao's preferred successor was not fully removed from his chairmanship of the party until 1981 (Lieberthal, 1995).

During the same period, grain production slowed to an average annual growth rate of only 1.0 percent, while the officially deflated gross value of all agricultural output rose by 4.7 percent per year.

To employ farmers whose unemployment was no longer disguised by the commune system, the state began in 1979 to allow rural enterprises to enter markets once the monopoly of predominantly urban state-owned enterprises (Naughton, 1995: 147). Once restricted to making bricks and other simple items for rural use, many of these township and village enterprises soon attracted foreign investment and began producing for foreign markets. Because of these reforms, township and village industries have recently overtaken socialist China's state-owned enterprises in the production of gross industrial output. Development of China's countryside since then has almost quadrupled real rural per-capita incomes (an annual average increase of over eight percent). Policy-makers now worry about agricultural stagnation as incentives in the nonagricultural sectors distract rural labor from traditional agricultural pursuits.

In 1992, at the first plenum of its 14th central committee, the Chinese Communist Party announced its intention to transform China into a "Socialist Market Economy" (*Shehuizhuyi Shichang Jingji*). While this represented primarily an ideological shift and an acceleration of reform in urban areas, the state also began to quickly move away from the monopsony procurement system that kept grain's purchase price low and rationed it out to urban consumers at even lower subsidized prices. Farmer's use rights to the land have been increasingly acknowledged in an effort to encourage more investment in land. Allowing farmers to lease these use-rights, while undermining the state's constitutional ownership of land, is intended to reduce the tendency of farmers to leave their fields fallow when other job opportunities are available. By 1995, these new policies were revolutionizing China's rural economy.

Interest in China's agricultural sector has spurred numerous authors to consider changes in productivity under changing institutional structures governing production and marketing. In a study updated by Wen (1993), Tang (1984) used a discrete approximation to a Divisia index to estimate the effect of rural reforms on multifactor productivity (MFP). This MFP index exhibited a net decline of over 25 percent from 1952 to 1977, but by 1985 it had risen back by 74 percent. Initially higher output prices may have stimulated supplies, but McMillan, Whalley, and Zhu (1989) calculated that decollectivization alone improved productivity by 32 percent in the initial six years of reform. Lin (1992) applied a Cobb-Douglas production function to provincial-level data from 1970-1987, and estimated that MFP improved by only 20 percent during the initial reform period, still as great a contribution as the sum of additions to capital, labor, and fertilizer inputs. However, these estimates of MFP growth imposed structure on productivity improvements that may not be warranted by the evidence. Productivity was assumed to be Hicks-neutral and primarily a function of time, and regional variation was not considered. Further, these studies did not distinguish between movements of the technological frontier and improvements in average efficiency due to improved incentives and marketization.

In an effort to account for regional variances, Fan (1991) used a stochastic frontier production function for selected years of provincial data, and his findings showed not only that the sources of MFP growth were shifting from traditional towards modern inputs, but that regional variation in MFP growth differed dramatically. Using similar methods, Kalirajan, Obwana, and Zhao (1996) found that MFP growth was negative in virtually all provinces prior to reform, and positive in almost all provinces during reform, but from 1984 to 1987 their estimates showed that MFP growth was again negative for a majority of provinces. Even these efforts, however, fail to distinguish between the different types of outputs or allow for substitution between outputs. Using the deflated official output values requires that we accept the official prices as the appropriate output weights. Even if we use official prices to deflate outputs, this does not mean these prices reflect scarcity values.

In this paper, we apply the Malmquist-based productivity measures developed in F@re et al. (1994) to Chinese provincial agricultural data for the years 1978 to 1995. The advantages of this approach are several. The method is nonparametric, and so does not impose excessive structure on the nature of technology. Productivity can be estimated with multiple outputs as well as inputs, so we do not have to rely on price data to determine appropriate weights, as is necessary with either econometric or index number approaches. Constant shares are not imposed on inputs or outputs, so Färe et al.'s approach may be more appropriate when multiple outputs are used, and weights are unavailable or official prices diverge from scarcity values.

The Malmquist indices can be decomposed into technological change and technical efficiency. Calculated values of the Malmquist indices are then regressed against several possible explanatory factors in a second step. Factors affecting productivity and efficiency include: an index of the implementation of the household responsibility system, the share of land affected by severe natural disasters, the development of rural industry, and grain prices relative to the general provincial price level.

The Malmquist index has become increasingly popular in analyzing changes in MFP when panel data are available. F@re et al. (1994) measured gross domestic output for 17 OECD countries resulting from two factors, capital stock and employment. Bureau, F@re and Grosskopf (1995) used a similar Malmquist index in measuring differences in MFP for the agricultural sectors of nine European Union countries and the United States. Price and Weyman-Jones (1996) examined efficiency and total productivity gains in the United Kingdom's gas industry before and after its 1986 privatization. Finally, Mao and Koo (1997) estimated MFP in Chinese provinces using an approach similar to the one reported in this paper. However, their model includes a much more limited sample, and they fail to disaggregate outputs.

2. A Distance Function Measure of Productivity Change

Characterizing Chinese Agricultural Production

Consider the production possibilities set S available at time *t*:

$$S^t = \{ (\mathbf{x}, \mathbf{y}) : \mathbf{x} \text{ can produce } \mathbf{y} \text{ at time } t\} \qquad (1)$$

where $\mathbf{x} \in \Re^n$ is a vector of inputs and $\mathbf{y} \in \Re^m$ is a corresponding vector of outputs. S^t is conditional upon the technology available at time t. We assume set S^t satisfies the standard properties (Chambers, 1988: 252).

Output distance functions have been shown to completely characterize technology (Färe et al. 1994). The output distance function is defined at time t as:

$$D_o^t(\mathbf{x}, \mathbf{y}) = \inf\{q : (\mathbf{x}, \mathbf{y}/q) \in S^t\} \tag{2}$$

$$= (\sup\{q : (\mathbf{x}, q\,\mathbf{y}) \in S^t\})^{-1} .$$

The output distance function is the reciprocal of the maximum proportional expansion in output **y** given **x** and S^t. Values of $D_o^t(\cdot)$ less than 1 will lie within the boundary of S^t, implying that a proportional increase in outputs could occur for the observed level of inputs. A distance function value equal to 1 indicates the observed netput vector (**x**, **y**) lies on the frontier of S^t. No increase in the observed levels of **y** is possible given **x** and the technology available at t. Values of $D_o^t(\cdot)$ greater than 1 indicate that **y** cannot be produced given **x** and S^t. θ would indicate the minimal shrinkage of **y** to be on the boundary of S^t.

Given a set of K observations in time period t, the output distance function for each decision making unit, be it firm, province, or nation, for example, can be computed by solution of the following linear programming problem:

$$\left(D_o^k(\mathbf{x}^k, \mathbf{y}^k)\right)^{-1} = \text{Max} \quad \theta \tag{3}$$

subject to $\quad q\ \mathbf{y}^k \le \sum_{i=1}^{K} l_i\, y^i$

$$\sum_{i=1}^{K} l_i\, \mathbf{x}^i \le \mathbf{x}^k$$

$$l_i, q \geq 0$$

Placing no restrictions on the intensity variables, λ_I, defines a constant returns to scale technology. The distance function is the reciprocal of Farrell's (1957) measure of output technical efficiency. The solutions to (3) will thus indicate which provinces define the frontiers of the aggregate Chinese production function and which provinces are inefficient.

Färe et al. (1994) developed techniques to determine improvements in technical efficiency over time. Changes in technical efficiency for an individual province from period *t* to *t+1* is:

$$\text{Efficiency change} = \frac{D_o^{t+1}\left(\mathbf{x}^{t+1}, \mathbf{y}^{t+1}\right)}{D_o^{t}\left(\mathbf{x}^{t}, \mathbf{y}^{t}\right)}, \tag{4}$$

where the notation for province *k* is suppressed for notational convenience. If the province is on the frontier of the production frontier in both periods, the efficiency change measure will equal 1. Movements towards (away from) the frontier will be measured by values greater (less) than 1.

Technical change presumes the frontier of the production possibilities set shifts over time (Solow, 1957). The frontier in each period is determined by solution of problem (3). Changes in the frontier between period *t* and *t+1* is determined by comparing the observed period *t* production bundle for province *k* with the frontier in period *t+1*. Changes in the calculated distance function that are not explained by changes in technical efficiency are attributed to shifts in the production frontier. Rather than selecting an arbitrary reference technology, such as *t* or *t+1*, Färe et al. (1994) recommend comparing period t observations with the $t+1$ frontier and period $t+1$'s netput bundle with the period t frontier. Technical change can then be calculated as:

$$\text{Technical change} = \left[\frac{D_o^t\left(\mathbf{x}^{t+1}, \mathbf{y}^{t+1}\right)}{D_o^{t+1}\left(\mathbf{x}^{t+1}, \mathbf{y}^{t+1}\right)} \times \frac{D_o^t\left(\mathbf{x}^t, \mathbf{y}^t\right)}{D_o^{t+1}\left(\mathbf{x}^t, \mathbf{y}^t\right)}\right]^{1/2} \tag{5}$$

The output distance function associated with province k's production bundle in period t with the $t+1$ frontier is obtained by solution of the following linear programming model:

$$\left(D_o^{t+1}\left(\mathbf{x}^t, \mathbf{y}^t\right)\right)^{-1} = \text{Max } \theta \tag{6}$$

$$\text{subject to} \quad q\ \mathbf{y}^t \le \sum_{i=1}^{K} l_i\, \mathrm{y}^{i,\,t+1}$$

$$\sum_{i=1}^{K} l_i\, \mathbf{x}^{i,\,t+1} \le \mathbf{x}^t$$

$$l_i, q \ge 0$$

Output distance function $\left(D_o^t\left(\mathbf{x}^{t+1}, \mathbf{y}^{t+1}\right)\right)^{-1}$ is found by reversing the roles of t and $t+1$ in problem (6).

Considerable use has been made of the Malmquist productivity index since Caves et al.'s (1982) derivation of the theoretical properties of the index and Färe et al.'s (1994) empirical applications. The Malmquist index is a primal index based solely on observed input and output quantities. Cost and revenue shares need not be calculated for the Malmquist index, yet the index does yield multifactor productivity changes in a multiple-output setting (Färe et al., 1994). The Malmquist index can be decomposed into changes from period to period resulting from changes in a province's technical efficiency (4) times movements in the production frontier resulting from technical change (5). Consequently, the Malmquist output-based index for an individual province can be expressed:

$$M_o\left(\mathbf{x}^{t+1},\mathbf{y}^{t+1},\mathbf{x}^t,\mathbf{y}^t\right) = \frac{D_o^{t+1}\left(\mathbf{x}^{t+1},\mathbf{y}^{t+1}\right)}{D_o^t\left(\mathbf{x}^t,\mathbf{y}^t\right)} \times \left[\frac{D_o^t\left(\mathbf{x}^{t+1},\mathbf{y}^{t+1}\right)}{D_o^{t+1}\left(\mathbf{x}^{t+1},\mathbf{y}^{t+1}\right)} \times \frac{D_o^t\left(\mathbf{x}^t,\mathbf{y}^t\right)}{D_o^{t+1}\left(\mathbf{x}^t,\mathbf{y}^t\right)}\right]^{1/2} \tag{7}$$

The component distance functions of the Malmquist index will be calculated for each of 27 Chinese provinces over the period 1979-1995. Changes in MFP can be attributed to either changes in the technical efficiency of the individual provinces (expression 4) or shifts in the production frontier indicating technical change in Chinese agriculture (expression 5). We now turn to the data compiled to represent Chinese provincial agriculture.

3. Data

The data used in this paper was compiled by the China State Statistical Bureau and published in annual Chinese Statistical Yearbooks (*Zhongguo Tongji Nianjian*), Rural Statistical Yearbooks (*Zhongguo Nongcun Tongji Nianjian*), and the Historical Statistical Data Compilation (*Lishi Tongji Ziliao Huibian*), for every year from 1970 to 1995, for all 30 provinces, municipalities, and autonomous regions in the People's Republic of China. The data for Hainan Island was subtracted from Guangdong province, from which it split to become a separate province in the late 1980s. Missing data and inconsistent definitions make some of the provincial data before 1979 suspect, so only years from

1979 to 1995 are used for the distance function calculations. Furthermore, the municipalities of Beijing, Tianjin, and Shanghai are excluded from the sample since agriculture in these urban areas is distinctly different from that in China's rural areas. The resulting sample is a panel data set of 27 provinces and 17 years.

Outputs are separated into four categories: grain production, other farming, animal husbandry, and other agriculture.[2] Fisheries comprise 70 percent of the other agriculture category, and forestry 30 percent. Fisheries are split evenly between freshwater and ocean fisheries. Approximately 85 percent of the freshwater and a third of the ocean fishery is defined as cultured. Grain output is reported in tons of grain. In case of other outputs, real output indices are calculated by dividing nominal output values by implicit price deflators. These deflators are based on official reports for both real and nominal production of grain, all farming, animal husbandry, and all agriculture; cash crops are calculated as the difference between all farming and grain production, while other agriculture is calculated as the difference between all agriculture and the sum of all farming and animal husbandry. Since these deflators represent average prices, even if these prices are distorted, we expect that this deflation yields reasonably accurate measures of the different categories of real outputs.

Input categories are land, labor, draft animals, fertilizer, and machinery inputs. Land is measured in sown hectares, which adjusts cultivated land for the prevalence of multiple crops per year in many of the agricultural production areas. In addition, sown land is differentiated between irrigated and dryland

2 Aggregate input use for all agriculture, including fisheries and forestry, is reported in the Chinese Statistical yearbooks. Consequently, inability to separate input categories necessitates the use of the forestry and fishery production measures.

hectares. Cultivated land area is adjusted for underreporting following Crook's estimation (1993). Labor is measured as the number of provincial agricultural workers at year-end. Draft animals are reported in number of head. Fertilizer is measured in tons of effective content for nitrogenous, phosphate, potash, and complex fertilizers. The machinery input is measured in kilowatts of engine power capacity.

The data for the study is summarized in Table 1. Average gross output per hectare and output shares for 1979-1995 are presented. Percent of sown acres that is irrigated is listed in column 7. Finally, average input usage per hectare over the period is presented.

Table 2 shows the resulting average growth rates of China's agricultural inputs and outputs during several periods: 1970-1978, before reform began; 1979-1984, during the implementation of the household responsibility system; 1985-1989, as reforms shifted towards the urban economy; 1990-1992, during the post-Tiananmen stagnation of reform; and 1993-1995, when reforms accelerated on all fronts under the banner of the Socialist Market Economy. Several patterns appear to emerge from these growth rates. Grain production rose rapidly after legalization of the household responsibility system in 1979, but slowed by the mid-1980s as farmers substituted toward other agricultural outputs. Cultivated land has declined slowly, as rising incomes and the expansion of rural industry have increased the demand for building space. The agricultural workforce has grown slowly since reform began, and by 1992 it began to decline as farmers left for nonagricultural opportunities. Finally, modern inputs such as fertilizer and machinery have increased relatively rapidly, though growth rates have declined since the pre-reform period.

Using weights based on the averages given by Wen (1993) for inputs, and calculating an average share for outputs, a rough Divisia index can be calculated to illustrate aggregate MFP growth.[3] This is also shown in Table 2. Though merely a rough approximation since the share weights are necessarily arbitrary, MFP appears to have grown most rapidly in the period immediately after agricultural reform began, and again more recently under the acceleration of market reform. These results are consistent with the literature discussed in section 1 above.

4. Distance Function Estimates of Productivity Improvement

Using the distance function approach described in section 2 to calculate year-by-year and province-by-province Malmquist indices for both technological progress and technical efficiency, we are able to calculate a measure of MFP that is less subject to arbitrary structural assumptions or arbitrary weights on outputs and inputs than either production function approaches or a Divisia index. Malmquist productivity indexes were calculated for the 27 Chinese provinces in our data set, for each year from 1979 through 1995. The results show outward shifts in the production possibilities set over the period. The average annual rates of change in these indices are shown by province in Table 3. The overall Malmquist index of MFP in the first column is the combined effect of technological progress and

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[3] The Divisia index of MFP can be written as $\prod_{i=1}^{m} y_i^{a_i} \Big/ \prod_{j=1}^{n} x_j^{b_j}$ where y and x are outputs and inputs, and α and β are the respective weights. The output weights used are 0.45 for grain, 0.20 for cash crops, 0.22 for animal husbandry, and 0.13 for other agriculture. The input weights used are 0.30 for land, 0.35 for labor, 0.20 for capital (0.10 for machine power and 0.10 for draft

improvements in technical efficiency, shown respectively in the second and third columns. The last column presents the crude Divisia index for the 1979-1995 period for comparison with the Malmquist measures. This Divisia index is premised upon known, constant input and output shares, so it will differ from the Malmquist values. However, the correlation coefficient between the two measures was 0.33, indicating a moderate amount of agreement.

The provincial average annual change in MFP was 1.8 percent over the entire sample. Average values ranged from a high of +7.3 percent for Fujian province to -3.6 percent per year for Inner Mongolia. Although cross-country analyses are inexact, these provincial level results can be compared with the results reported in Bureau et al. (1995) in which similar procedures were used to derive productivity measures for ten OECD countries between 1973 and 1989. The values ranged from around 7 percent annual growth in MFP (in Denmark) to lows of 2 percent (in Belgium and Luxembourg). The top 12 performing provinces in China fall within this range. However, the remaining 15 provinces do not compare favorably with the OECD countries in terms of average changes in MFP. Chinese provinces show a great deal of variation in performance.

Most of the recorded changes in MFP for the most progressive provinces are attributable to shifts in the production possibilities frontier, as shown in the second column of Table 3. Fujian exhibited the greatest rate of technical progress, while Inner Mongolia again showed the highest rate of technical regress. In fact, the average rate of technological progress for the 27 provinces was 1.9 percent, greater than the average increase in the overall Malmquist index. Consequently, the average rate of

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animals), and 0.15 for current inputs (fertilizers).

change in technical efficiency was lower than the rate of technical change. Twelve provinces remained on the frontier over the 17 year period, underlying their efficiency change rates of 1.000. With the exception of Jiangxi, these provinces tended to be the leaders in agricultural productivity increases over the period. A few provinces did exhibit improvements in technical efficiency over the period. Shandong and Gansu both moved towards the frontier by an average of over one percent per year, and six other provinces exhibited positive rates of improvement in technical efficiency. Shandong's growth was assisted by improvements in technical efficiency of 9.6 percent in 1981, 8.8 percent in 1982, and 10.2 percent in 1988. Seven provinces moved away from the frontier over time, while Shaanxi province displayed the worst average annual change in technical efficiency, about -1.6 percent per year.

In Table 4, the overall Malmquist index is shown for each province for four periods. The highest rates of improvement in MFP are found in the 1979-84 period, as the process of decollectivization picked up speed, and in the three years after reform accelerated in 1992, under the goal of creating the Socialist Market Economy. Results, however, are not unambiguous. In the years from 1979 to 1984, 16 provinces experienced improvement in MFP while 11 experienced declines. In the years from 1985 to 1989, 19 provinces experienced declines in MFP; from 1990 to 1992, MFP improved in 19 provinces; and in 1993 and afterwards, MFP improved in all but four provinces. The most dramatic rates of improvement, over 20 percent per year for Tibet and Fujian, were found in the most recent period.

5. Factors Influencing Productivity Change in Chinese Agriculture

The Malmquist indices described above provide a panel data set for examining factors associated with the differences observed among the provinces over time. The results indicate a wide disparity in MFP changes, as well as the technical change and efficiency components comprising the Malmquist index. In this section we posit a relationship between productivity improvements and several exogenous variables. These exogenous variables include: the adoption rates of the household responsibility system for each province, which should explain an improvement in productivity as explained by Lin (1992), McMillan, et al. (1989), and others; the proportion of industry in the combined sum of provincial gross rural industrial and agricultural output, which should explain an apparent decrease in productivity if rural industry is attracting higher-quality inputs; the proportion of provincial agricultural land affected by natural disaster, primarily flood and drought, which may explain large declines in output relative to a given set of inputs; and finally the price of grain relative to the overall retail price index, which should have a positive supply effect if farmers are price-responsive.

Panel regressions are estimated in order to understand the differential effects of these factors on provincial-level MFP. Due to the presence of unit roots in the time series, variables measuring disaster-affected area, the rural industrial share, and relative grain prices are first-differenced, and these are regressed on the change indices. The adoption rate of the household responsibility system was left undifferenced to serve as a gradual shifter in the regressions; in essence, this specification implies that reform should not lead to just a one-time increase in productivity, but should instead lead to an increase in the growth rate as improved incentives encourages farmers to innovate in production methods. Finally, a dummy variable was introduced, assuming the value of one for the coastal provinces and zero otherwise.[4] The coastal provinces have generally experienced the greatest economic growth over the last 15 years, and we presume that their economic strength, as well as their access to both domestic and foreign markets due to improved infrastructure, would positively affect agricultural productivity. Results are seen in Table 5.

F-tests for the Malmquist, technical change, and full efficiency change models reject the hypothesis of common intercepts for all of the full models. Consequently, either a fixed effects or random effects model may be appropriate for the data. The introduction of the single dummy variable, *COAST*, resulted in singularity of the coefficient matrix using the least squares dummy variable model employed in the panel estimation procedures of TSP (Hall, 1994). Therefore, the first three columns of parameters in Table 5 result from random effects models. The null of common slopes and intercepts could not be rejected for the technical efficiency change model in which only the effects of change in disaster acres was considered. Consequently, pooled OLS estimates are reported for the last column of Table 5.

Overall provincial MFP changes were strongly influenced by initiation of the household responsibility system in 1979. As argued in Cheung (1969), granting of additional property rights to farmers over the products of their labor increases farmer incentives to increase productivity.[5] The onset of HRS increased overall provincial MFP by 5.8 percent, but the main influence of the HRS was to

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[4] Following Parker (1995), coastal provinces include Guangdong, Fujian, Zhejiang, Anhui, Jiangsu, Shandong, Hebei, Shanxi, Liaoning, Jilin, and Heilongjiang.

[5] Farmers have been given rights of control and rights to residual income, but not rights of transfer. Instead of ownership rights, farmers have use-rights of limited or indefinite tenure. Prosterman, Hanstad, and Li (1996) argue that significant investments into land quality would occur if

expand the production possibilities set, and some provinces fell further behind as a result. This is seen in the relatively greater significance of the variable HRS in influencing technical change, and the negative effect on efficiency change. Over 8.4 percent of the annual increase in the production frontier is attributed to this major institutional change.

Increasing industrialization within the provinces was negatively correlated with all three measures of MFP change, and this was statistically significant for the overall index. Labor mobility across sectors within the provinces, as well as more limited interprovincial movement, would appear to affect the marginal product of labor in both the agricultural and industrial sectors. As argued by Bhattacharyya and Parker (1997), greater opportunities for income growth through industrial activities or entrepreneurial opportunities in a rapidly growing economy would tend to attract the more motivated, and perhaps more talented, individuals away from traditional agriculture. The negative relationship between provincial industrialization and agricultural productivity would tend to support this conjecture. In addition, other resources whose quality is unmeasured, such as new capital investment, might also be attracted away from agriculture in rapidly industrializing areas.

Lin (1995) emphasized the influence of grain price increases in stimulating agricultural production. There appears here to be evidence that increasing grain prices leads to expansion of the production possibilities frontier over time. Lin found evidence of increasing grain prices increasing grain production. The price effect discovered by Lin is further supported here by the positive influence of changing relative prices on the frontier. There appears to have been induced innovation resulting from

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fully transferable rights were granted to farmers.

price increases, though again average efficiency declined somewhat as some provinces failed to keep up with shifts in the production possibilities frontier, but this was not statistically significant.

The primary factor explaining efficiency change, or movements relative to each year's production possibilities surface, is the proportion of agricultural land adversely affected by natural calamities. A one percent increase in the share of land affected by disasters resulted in about half a percentage point movement away from the production frontier. Acres affected by disasters averaged 2.2 percent over the entire sample. However, values ranged from zero acres up to over 10 percent of the acreage affected in Anhui in 1991. The effects of the disaster affected acres were reflected in a technical efficiency score of 0.80 for Anhui in 1991.

6. Summary

In this paper, we examine multi-factor productivity changes in Chinese agriculture. Using a panel data set for 27 provinces and autonomous regions from 1979 to 1995, we calculate Malmquist indices composed of technical and efficiency changes for a multiple-output, multiple-input production frontier. Improvements in productivity were most rapid in the years following the beginning of rural reform and in more recent years as China has accelerated its movement towards a more market-oriented economy. However, there is great variation in productivity change from year-to-year and province-to-province.

Using panel-data methods, we estimate the effect of various factors on productivity changes. The household responsibility system, which decollectivized both production decisions and incentives, accounted for a significant expansion of the production possibilities frontier. The expansion of rural industry, however, significantly decreased agricultural productivity, a result suggesting that rural township and village enterprises offer opportunities to relatively skilled workers, as well as other higher-quality resources. Grain prices, which have been held artificially low by the state's monopsony procurement system until recently, have a significant supply effect in boosting agricultural productivity, while natural disasters are a significant explanatory factor in provincial-level efficiency changes. Finally, provinces along the coast, which are typically more open to trade and reform, have significantly higher rates of growth.

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Table 1. Gross value of output per hectare, output shares, irrigated acreage as percent of sown land, and input usage per hectare, 1979-1995 provincial averages.

	Malmquist Index	Output Value/ hectare	Output Shares Grain	Cash Crops	Animal	Other Ag
Fujian	7.77	2496	0.29	0.22	0.20	0.29
Xinjiang	7.74	1580	0.32	0.38	0.22	0.08
Jiangsu	7.32	2624	0.41	0.23	0.24	0.12
Zhejiang	6.69	2231	0.33	0.23	0.21	0.23
Hainan	6.34	1892	0.22	0.17	0.17	0.44
Liaoning	6.18	2362	0.39	0.20	0.26	0.16
Shandong	4.97	2221	0.37	0.29	0.21	0.12
Heilongjiang	3.86	1216	0.59	0.15	0.19	0.08
Tibet	3.67	1960	0.33	0.06	0.51	0.09
Jilin	3.55	1593	0.56	0.15	0.21	0.08
Guangdong	2.93	1862	0.25	0.26	0.22	0.27
Hebei	1.99	1592	0.41	0.30	0.21	0.08
Qinghai	1.01	1240	0.38	0.09	0.44	0.08
Gansu	0.86	789	0.48	0.21	0.22	0.08
Hubei	0.30	1856	0.40	0.25	0.21	0.14
Sichuan	0.30	1342	0.41	0.20	0.30	0.09
Guizhou	-0.08	690	0.37	0.23	0.25	0.16
Jiangxi	-0.15	1684	0.39	0.19	0.23	0.19
Hunan	-0.31	1484	0.39	0.21	0.27	0.13
Henan	-0.70	1506	0.47	0.25	0.18	0.09
Shanxi	-0.95	864	0.49	0.21	0.20	0.10
Anhui	-1.00	1366	0.45	0.25	0.20	0.10
Shaanxi	-1.00	1054	0.47	0.20	0.18	0.14
Guangxi	-1.16	1166	0.31	0.24	0.29	0.16
Yunnan	-1.70	919	0.36	0.25	0.24	0.15
Ningxia	-3.16	525	0.54	0.19	0.20	0.08
Inner Mongolia	-3.85	1006	0.39	0.18	0.31	0.12

Table 1 (continued)

	Inputs per hectare				
	Irrigated proportion	Labor	Draft Animals	Fertilizer	Power
Fujian	0.71	2.18	0.26	0.19	13.95
Xinjiang	0.87	0.67	0.50	0.08	11.10
Jiangsu	0.79	1.77	0.07	0.19	17.66
Zhejiang	0.85	2.06	0.08	0.13	15.81
Hainan	0.35	1.04	0.43	0.07	7.99
Liaoning	0.25	1.27	0.45	0.16	18.60
Shandong	0.65	1.78	0.34	0.16	18.72
Heilongjiang	0.10	0.40	0.18	0.06	9.40
Tibet	0.57	2.30	3.08	0.03	10.97
Jilin	0.20	0.82	0.35	0.12	9.49
Guangdong	0.65	1.45	0.32	0.13	10.96
Hebei	0.56	1.72	0.36	0.13	23.77
Qinghai	0.29	1.33	0.69	0.05	12.63
Gansu	0.25	1.04	0.53	0.05	8.44
Hubei	0.64	1.54	0.27	0.13	10.84
Sichuan	0.45	1.84	0.20	0.08	5.00
Guizhou	0.28	1.29	0.45	0.04	2.62
Jiangxi	0.75	1.63	0.34	0.10	8.07
Hunan	0.79	1.78	0.24	0.10	8.91
Henan	0.50	1.79	0.47	0.12	12.86
Shanxi	0.30	0.94	0.30	0.07	13.75
Anhui	0.56	1.61	0.31	0.11	9.69
Shaanxi	0.35	1.28	0.26	0.08	8.38
Guangxi	0.55	1.76	0.51	0.08	7.59
Yunnan	0.36	1.56	0.50	0.06	6.03
Ningxia	0.31	0.57	0.26	0.04	7.55
Inner Mongolia	0.24	0.71	0.36	0.04	9.39

Table 2: Annual Growth Rates of Agricultural Outputs, Inputs, and Productivity

	1970 -1978	1979 -1984	1985 -1989	1990 -1992	1993 -1995	1979 -1995
Deflated Outputs:						
Grain	2.7	5.0	0.0	2.8	1.8	2.5
Other Farming	1.6	10.7	3.2	6.6	10.2	7.6
Animal Husbandry	2.9	9.6	8.7	8.2	14.1	9.9
Other Agriculture	4.2	10.5	11.0	8.3	13.6	10.8
Weighted Index of Outputs:	2.7	7.8	3.9	5.4	7.6	6.2
Input Quantities:						
Cultivated Land	-0.2	-0.3	-0.5	-0.1	-0.2	-0.3
Multicropping Ratio	0.7	-0.4	0.8	0.6	0.4	0.3
Irrigated Ratio	2.1	0.1	0.7	2.7	0.6	0.8
Labor	0.1	1.8	0.5	1.6	-1.7	0.8
Draft Animals	0.2	4.1	3.0	1.4	4.3	3.4
Fertilizer Content	10.8	11.9	6.3	7.5	7.0	8.6
Machinery Power	18.3	8.8	7.6	2.6	6.0	6.8
Weighted Index of Inputs:	4.1	3.5	2.4	3.1	1.7	2.8
Divisia MFP Index	-1.4	4.2	1.4	2.3	5.8	3.3

Table 3. Average annual percentage changes in the Malmquist MFP measure, technical change, efficiency change, and the crude Divisia Index, Chinese provincial data, 1979-1995.

Province	Malmquist Index	Technical Change	Efficiency Change	Divisia MFP Index
Hebei	1.9	1.1	0.9	3.3
Shanxi	-0.9	-0.6	0.3	2.8
Inner Mongolia	-3.6	-3.1	-0.5	-1.6
Liaoning	5.8	5.8	0.0	4.1
Jilin	3.3	3.3	0.0	2.0
Heilongjiang	3.6	3.6	0.0	2.6
Jiangsu	6.9	6.9	0.0	5.3
Zhejiang	6.3	6.3	0.0	3.3
Anhui	-0.9	-0.5	-0.5	2.2
Fujian	7.3	7.3	0.0	3.3
Jiangxi	-0.1	-0.1	0.0	2.4
Shandong	4.7	3.8	1.1	4.1
Henan	-0.7	1.1	-1.6	1.9
Hubei	0.3	0.3	0.0	2.5
Hunan	-0.3	-0.5	0.3	2.6
Guangdong	2.8	4.0	-1.1	2.8
Guangxi	-1.1	-0.8	-0.1	2.3
Hainan	6.0	6.0	0.0	5.1
Sichuan	0.3	0.3	0.0	2.5
Guizhou	-0.1	-0.7	0.7	0.6
Yunnan	-1.6	-0.9	-0.5	0.6
Tibet	3.5	3.5	0.0	1.4
Shaanxi	-0.9	1.0	-1.6	0.3
Gansu	0.8	-0.5	1.5	2.1
Qinghai	1.0	1.0	0.0	-0.5
Ningxia	-3.0	-2.8	0.6	1.6
Xinjiang	7.3	7.3	0.0	2.7

Table 4. Average annual growth rates (percentages) of Malmquist productivity index, selected periods.

	1979-1984	1985-1989	1990-1992	1993-1995
Hebei	5.2	-0.6	-0.9	3.9
Shanxi	-0.2	-1.7	-2.5	0.6
Inner Mongolia	-9.1	-2.4	0.6	-2.0
Liaoning	8.5	2.3	4.8	10.2
Jilin	5.8	-2.4	8.4	4.9
Heilongjiang	4.7	-1.0	5.5	8.8
Jiangsu	6.3	3.9	10.2	11.8
Zhejiang	3.1	5.2	6.6	15.4
Anhui	-1.7	-2.0	-0.5	1.4
Fujian	2.6	5.4	5.8	22.2
Jiangxi	-2.8	-3.2	2.8	6.5
Shandong	8.6	-0.8	1.2	12.3
Henan	0.4	-2.4	-1.3	0.8
Hubei	-1.2	-1.7	4.0	2.5
Hunan	2.0	-3.0	-1.2	1.3
Guangdong	1.6	1.6	6.4	3.9
Guangxi	-1.1	-3.3	-1.2	2.6
Hainan	7.9	-0.3	3.0	18.1
Sichuan	0.3	-0.3	0.7	1.0
Guizhou	5.3	-4.3	1.3	-3.4
Yunnan	-0.5	-1.8	-0.2	-4.9
Tibet	-8.6	3.2	1.0	27.7
Shaanxi	-4.7	-2.7	3.6	3.3
Gansu	-2.0	-1.9	1.6	9.5
Qinghai	-0.5	1.7	1.9	1.5
Ningxia	2.8	-8.1	-4.6	-3.4
Xinjiang	7.7	8.3	9.8	4.8

Table 5. Panel data estimation results for 27 provinces over the 16 years 1980-1995 (t-statistics in parentheses).

	Malmquist MFP Measure	Technical Change	Efficiency Change	
Coast Dummy	0.0353	0.0334	0.0008	
	(2.9444)	(2.8429)	(0.1304)	
HRS	0.0583	0.0843	-0.0279	
	(3.3977)	(5.3071)	(-2.9303)	
Δ Industry	-0.3565	-0.2213	-0.1242	
	(-2.6762)	(-1.7909)	(-1.6862)	
Δ Relative Grain	14.4055	19.7966	-3.6920	
Prices	(1.9971)	(2.9656)	(-0.9209)	
Δ Disaster Acres			-0.9656	-0.9731
			(-5.2961)	(-5.2223)
Constant	0.9572	0.9326	1.0282	1.0005
	(54.6397)	(56.7669)	(107.893)	(364.748)
R^2	0.0993	0.1373	0.08910	0.0597