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**EFFECTS OF TECHNOLOGICAL CHANGE AND INSTITUTIONAL REFORM ON PRODUCTION GROWTH IN CHINESE AGRICULTURE**

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From 1949 to 1986 agricultural production grew 4% a year in China (Fan). This growth was the most rapid among all the socialist countries (Wong) and even more rapid than growth in most developing countries (Hayami and Ruttan). Contributing to the rapid production growth was a series of technological and institutional changes, and rapid increase of modern inputs. Since 1979 efforts have been made to improve incentives and stimulate production by decentralizing authority and responsibility for production decision to family units. Substantial improvement in productive efficiency has resulted.

Using a traditional accounting approach initiated by Solow, Perkins and Yusuf, and Wiens measured the total factor productivity in Chinese agriculture; however, the sources of productivity growth in their studies were not identified. Recently, some studies have measured the effects of institutional change on production and productivity growth. Lin (1987) attributed the rapid growth in agricultural production from 1980 to 1984 to the household production responsibility system. He found that 20% of productivity growth or 60% of agricultural production growth was attributed to the institutional change. However, he ignored the effects of technological

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change on production and productivity growth. McMillan, Whalley and Zhu used the accounting approach to capture the effects of reforms in prices and incentive systems on total productivity growth. Their results suggest that 22% of the increase in productivity in China's agriculture between 1978 and 1984 was due to higher prices and 78% to change in the incentive system. They also ignored the effects of technological change.

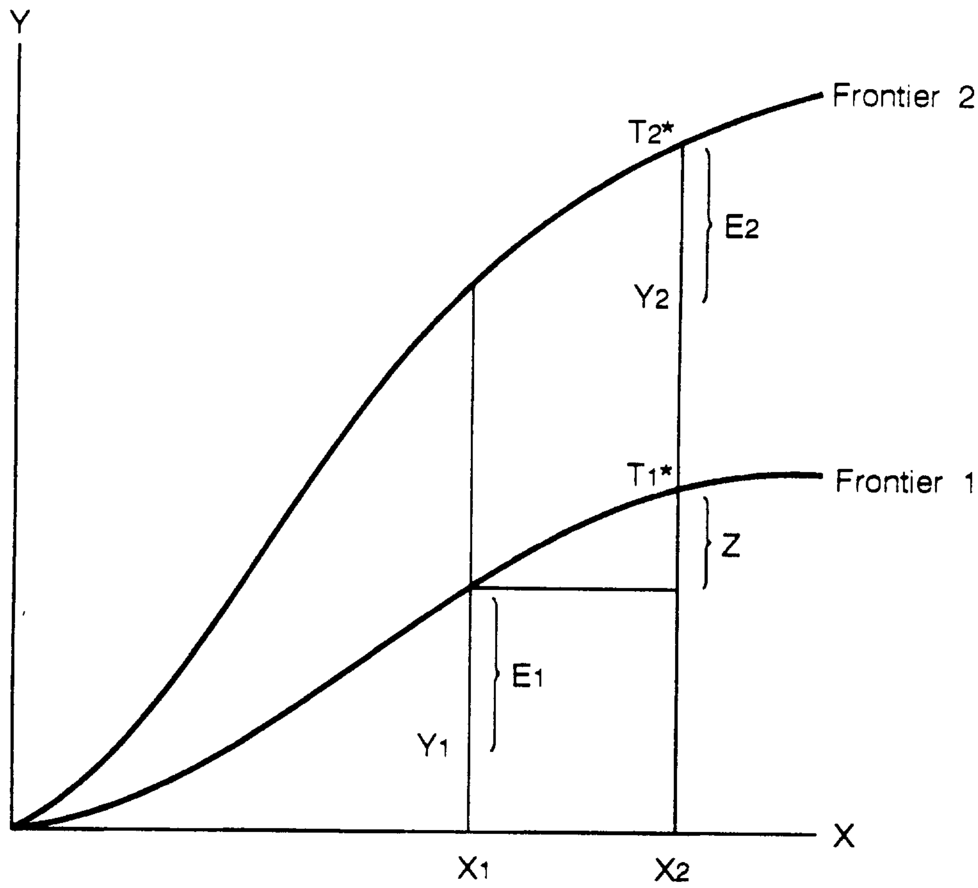
The purposes of this study are to develop a new approach to capture the relative contributions of input growth, technological change and organizational reforms to growth of agricultural production and to apply the approach to the major agricultural production regions of China. During the 1950s, the Chinese government divided the country into six administrative regions. This division is inappropriate for an analysis of agricultural productivity. However, formulating regional land on differences in land use is not feasible because of data limitations. Therefore, in this study the country is divided into seven regions that take into account the availability of the agricultural data, the geographical features, and the current social and cultural conditions. These regions adhere closely to the administrative division and are as follows: (1) Northeast (N.E.): Heilongjiang, Liaoning, and Jilin provinces. (2) North (N.): Municipalities of Beijing and Tianjin; Hebei, Henan, Shandong, Shanxi, Shaanxi, and Gansu provinces. (3) Northwest (N.W.): Autonomous regions of Nei Monggol, Ningxia, Xinjiang, and Tibet; Qinghai province. (4) Central (C.): Jiangxi, Hunan, and Hubei provinces. (5) Southeast: (S.E.): Shanghai municipality; Jiangsu, Zhejiang, and Anhui provinces. (6) Southwest (S.W.): Sichuan, Guizhou, and Yunnan provinces. (7) South (S.): Guangxi autonomous region; Fujian and Guangdong provinces.[1]

## Effects of Input Growth, Technological Change, and Efficiency Improvement

In traditional productivity theory, total production growth consists of movements along the production function (an increase of total inputs) and shifts of the production function (technological change), assuming that the firm is perfectly efficient in production. The growth rate of total factor productivity is the growth rate of total output minus the growth rate of total input; hence, technological change is considered the unique source of productivity growth and the effects of efficiency improvement on productivity growth are ignored. The assumption of perfect efficiency in production is unrealistic. Differences among firms between realized output and potential output are caused by differences in the capacity to use new technological knowledge and in the motivations of farmers. If this assumption is relaxed, total production growth can be attributed to efficiency improvement as well as to increased inputs and technological change. Different policy inferences may be drawn consequently, inasmuch as technological change and efficiency improvement represent fundamentally different sources of growth in production. Therefore, new approach will be developed to capture all three effects on production growth in this study.

In this study technological change is defined as a shift of the frontier production function. Efficiency improvement is defined as the decrease in the distance between the firm's realized output and its potential output (or frontier). The different sources of production growth are shown in Figure 1. At times 1 and 2 the producer faces production frontiers 1 and 2 respectively. If production were perfectly efficient, output would be $T_1^*$ at time 1 and $T_2^*$ at time 2. However, the producer's realized output is $Y_1$ at time 1 and $Y_2$ at time 2 owing to production inefficiency. Technological change is measured by

Figure 1. Effects on Production Growth of Input Increase, Technological Change, and Efficiency Improvement.



the distance between frontier 2 and frontier 1, i.e., $T_2^* - T_1^*$. Inefficiency is measured as the distance between the frontier and the output realized by the producer, i.e., $E_1$ at time 1 and $E_2$ at time 2. Hence the improvement of efficiency over time is the difference between $E_1$ and $E_2$. The contribution of input change is measured as Z. Therefore, the total production growth can be decomposed to three effects: input growth, technological change, and efficiency improvement.

$$Y_2 - Y_1 = Z + (T_2^* - T_1^*) + (E_1 - E_2).$$

Prior to the introduction of household production responsibility system to Chinese agriculture, production was organized by production teams or state farms. A farmer's income was not closely related to his production effort. After the reform, when producers became responsible for their plots, they worked harder, allocated resources more efficiently, and produced more output with the same input and technology. Thus if only technological change is considered as the source of production and productivity growth, the effects of technological change will be overestimated by ignoring institutional change. Therefore, the efficiency improvement is used in this study to capture the effect of institutional change on production and productivity growth.

## Frontier Production Function

The frontier production function approach, initiated by Farrell in 1957, has been expanded by various methods of measuring and computing production functions and efficiency (Lovell and Schmidt). The main approaches include pure programming, modified programming, the deterministic statistical frontier and the stochastic frontier. Pitt and Lee indicated that the programming approach and the deterministic frontier approach do not allow for random shocks in the production process; as a result a few extreme observations can determine the frontier and exaggerate the maximum possible output. In this study, the stochastic frontier approach is employed to avoid this problem.

Consider the following production function:

$$(1) \qquad Y_{it} = f(x_{it}, b)e^{v_{it}} e^{u_{it}},$$

$$\text{or} \quad \ln Y_{it} = \ln f(x_{it}, b) + v_{it} + u_{it}$$

where i denotes the $i^{th}$ firm or region, and t denotes time t. $Y_{it}$ is output, $x_{it}$ is 1×k rows of inputs, $f(x_{it}, b)$ is potential output, $v_{it}$ is a stochastic variable representing uncontrolled random shocks in production, and $u_{it}$ is one-sided distribution, $u \le 0$, which represents technical inefficiency. $f(x_{it}, b)e^{v_{it}}$ is the stochastic frontier, given that $v_{it}$ consists of random factors outside the firm's control. The nonpositive disturbance u indicates that output must lie on or below the frontier $f(x_{it}, b)e^{v_{it}}$, because $e^{u_{it}}$ has a value between zero and one. It is assumed that for $t \neq t'$, $E(u_{it}u_{it}') = 0$ for all i, and $E(u_{it}u_{it}') = 0$ for all $i \neq j$. In this specification, the firm's inefficiency may change over time by learning from experience. We also assume u is truncated normal with variance $\sigma_u^2$, v is normal with mean zero and variance $\sigma_v^2$, and $E(u_{it}v_{it}') = 0$.

The efficiency for a firm or region i at time t, then, is defined as:

$$\frac{Y_{it}}{f(x_{it}, b)e^{v_{it}}}$$

Based on the conditional distribution of $u_{it}$, given the distribution $v_{it} + u_{it}$, the efficiency of a specific firm or region at a given time can be measured as (Kalirajan and Flinn)

$$(2) \qquad E\left\{\exp\left(\frac{u_{it}}{u_{it} + v_{it}}\right)\right\} = \exp\left[-\left(\frac{\sigma_u \sigma_v}{\sigma}\right)\left(\frac{f(.)}{1-F(.)} - \frac{\varepsilon_{it}}{\sigma}\frac{\sqrt{\lambda}}{1-\lambda}\right)\right]$$

where $\varepsilon_{it} = v_{it} + u_{it}$, $\sigma$ is standard error of $\varepsilon_{it}$, $\lambda = \frac{\sigma_u^2}{\sigma^2}$, and $f(.)$ and $F(.)$ are the values of the standard normal density function and standard normal distribution function evaluated at

$$\frac{\varepsilon_{it}\sqrt{\lambda}}{\sigma \; 1-\lambda} .$$

The next step of the specification is to choose an appropriate functional form. Consider a production process that uses n inputs to produce one output represented by the production function

$$(3) \qquad Y = f(x_1, \ldots\ldots, \ldots x_n, T),$$

where Y is output, $x_i$ is $i^{th}$ input and T is used to catch technical progress (time trend). The unrestricted translog form can be use to represent production function (3). However, the translog form needs a lot of data and has many variables which may lead multicollinearity problem. Consider a restriction that all inputs are separable from each other but each input cannot be separated from technical progress:

$$(4) \qquad Y = f\{g_1(x_1, T), \ldots g_n(x_n, T)\}$$

The theoretical background of this form comes from the fact that every input changes over time while the effects among inputs are indirect through time. Then the following production function form can be used to represent (4):

$$(5) \qquad \ln(Y) = a_0 + a_t t + \sum_i a_i \ln(x_i) + \sum_i a_{it} \ln(x_{it}) \times t + a_{tt} t^2$$

If we consider all inputs and time as separable, the production function can be expressed as

$$(6) \qquad Y = f\{g_1(x_1), \ldots, \ldots g_n(x_n), T\}$$

The Cobb-Douglas production function can be used to represent (6)

$$(7) \qquad \ln(Y) = a_0 + \sum_i a_i \ln(x_i) + a_t t$$

Owing to the serious multicollinearity problem of the translog form and the constancies of production elasticities in the Cobb-Douglas form, functional form (5) has been used for the estimations. The Cobb-Douglas form and average production functions are also estimated for comparison purposes.[2]

## Estimation of Production Functions and Efficiency

Panel data from 29 provinces, municipalities, and autonomous regions in 1965, 1970, 1975, 1976......through 1986 are used in the estimations. Gross agricultural production value serves as the aggregate total output, using 1980 constant prices. The sub-aggregates are (a) crop production, (b) forestry, (c) animal husbandry, (d) sideline industries, and (e) fisheries. Rural industry at all levels (including town, village, and teams) is excluded from agricultural production.[3]

Labor input in agriculture is measured by the numbers of employed persons at year end.[4] The sum of sown areas and pasture is used to measure land input because the arable land data are inaccurate. Pasture areas are calculated in sown land area equivalence for output value, i.e., one unit of pasture equals .0124 of a unit of sown land (in 1985).[5] Chemical fertilizer input is measures by pure nutrients, using the following percentage: 20% for ammonium sulfate, 18.7% for super phosphate, and 40% for potassium sulfate.[6] Machinery input is measured by total horsepower at year end.[7]

Manurial fertilizer, which always has been very important in China, include animal, human, and crop wastes; green manures; and water plants. In this study, manurial fertilizer is measured from the agricultural population (i.e., human waste) and numbers of domestic animals.[8] Draft animals are measured at year end in units of heads which are used for agricultural activities and rural transportation. They include water buffaloes, cattle, horses, asses, mules, and camels.[9] Irrigation input is measured as irrigated areas.

The results of production function estimation for the different specifications are shown in Table 1. The ordinary least square technique is used for the average production function estimation and the maximum likelihood technique for the frontier production function. The Cobb-Douglas form is used for regressions 1 and 2. Time trend (T) measures neutral technological change over time. Except for machinery and irrigation, the coefficients of regressions 1 and 2 are very significant considering the crudeness of the data. However, the negative coefficients of draft animals are unrealistic. The sum of production elasticities of traditional inputs (except for draft animals) is more than .75, which implies that traditional inputs still dominate China's agricultural production. Chemical fertilizer

Table 1. Estimates of Production Functions

| Regression No: | R1 (Average) | R2 (Frontier) | R3 (Average) | R4 (Frontier) | R5 (Average) | R6 (Frontier) |
|---|---|---|---|---|---|---|
| Constant | -2.81 | -2.70 | -2.81 | -3.19 | -2.92 | -2.82 |
| | (-10.72) | (-11.27) | (-5.23) | (-6.13) | (-6.24) | (-6.14) |
| LABOR | .278* | .266* | .420* | .417* | .438* | .428* |
| | (7.19) | (6.14) | (5.16 ) | (4.66) | (5.40) | (4.94) |
| LAND | .356* | .379* | .243* | .331* | .246* | .261* |
| | (7.88) | (9.39) | (2.40) | (3.99) | (2.78) | (3.60) |
| C. FERT | .235* | .236* | .140* | .089*** | .132* | .132* |
| | (8.71) | (9.29) | (2.70) | (1.66) | (2.57) | (2.61) |
| MACHINERY | .055** | .051** | .078*** | .123* | .075*** | .068*** |
| | (1.77) | (1.82) | (1.39) | (2.52) | (1.35) | (1.30) |
| M. FERT | .185* | .178* | .227* | .266* | .241* | .241* |
| | (5.30) | (5.67) | (2.99) | (3.27) | (4.18) | (3.40) |
| ANIMALS | -.132* | -.133* | .002 | -.026 | | |
| | (-5.13) | (-4.94) | (.037) | (-.301) | | |
| IRRIGATION | .059** | .055** | .009 | -.037 | | |
| | (1.81) | (1.66) | (.145) | (-.537) | | |
| T | .0123* | .0125* | .0014 | .0420 | .0496 | .0505*** |
| | (2.41) | (2.17) | (.364) | (.980) | (1.28) | (1.33) |
| LABORT | | | -.0097** | -.0109** | -.0111* | -.0108** |
| | | | (-1.822) | (-1.79) | (-2.07) | (-1.83) |
| LANDT | | | -.0024 | -.0065 | -.0073 | -.0077*** |
| | | | (-.368) | (-1.20) | (-1.25) | (-1.64) |

(Continued)

| Regression NO: | R1 (Average) | R2 (Frontier) | R3 (Average) | R4 (Frontier) | R5 (Average) | R6 (Frontier) |
|---|---|---|---|---|---|---|
| C.FERTT | | | .0068** | .0087* | .0083* | .0081* |
| | | | (1.83) | (2.41) | (2.23) | (2.30) |
| MACHINERYT | | | .0080** | .0083* | .0092* | .0098* |
| | | | (1.93) | (2.08) | (2.33) | (2.56) |
| M. FERTT | | | -.00006 | -.0014 | -.0050 | -.0051 |
| | | | (-.013) | (-.273) | (-1.27) | (-1.13) |
| ANIMALST | | | -.006 | -.0041 | | |
| | | | (-1.51) | (-.725) | | |
| IRRIGATIONT | | | -.0003 | .0006 | | |
| | | | (-.064) | (.118) | | |
| $T^2$ | | | .00147* | .0013* | .0012** | .0011*** |
| | | | (2.23) | (2.30) | (1.80) | (1.58) |
| $\lambda$ | | .822* | | 1.278* | | .821*** |
| | | (2.17) | | (3.23) | | (1.56) |
| $\sigma$ | | .288* | | .266* | | .254* |
| | | (9.38) | | (10.99) | | (6.84) |
| Observations | 406 | 406 | 406 | 406 | 406 | 406 |
| $R^2$ | .940 | .932 | .957 | .942 | .954 | .959 |

Notes: 1. Numbers in parentheses are t test values. Single asterisk indicates significant at 5% level; double asterisk indicates significant at 10% level; triple asterisk indicates significant at 20% level.

2. C. FERT: Chemical fertilizer; M. FERT: Manurial fertilizer; T: Time Trend, T=1 for 1965, T=6 for 1970,...T=22 for 1986; LABORT: cross term of labor and time trend; LANDT: cross term of land and time trend ......; IRRIGATIONT: cross term of irrigated areas and time trends.

input plays an important role in production. The significant and positive time trend coefficient strongly suggests that total factor productivity in Chinese agriculture has increased through neutral technological change.

Functional form (5) is used for regressions 3, 4, 5, and 6. Production elasticity for input i in this production functional form is $\partial \ln Y / \partial \ln x_i = a_i + a_{it} t$. Thus if $a_{it} > 0$, production elasticity of input i is increasing; if $a_{it} < 0$, production elasticity of input i is decreasing.

Regressions 3 and 4 use the same input variables as regressions 1 and 2. In addition, the cross-term of each input and time trend captures the relative changes of each input in total input over time. The greater significance of the coefficients in regression 4 relative to those in regression 3 implies that the frontier production function for estimation improved the results. Labor, land, draft animals, and manurial fertilizer play a decreasing role in production whereas production elasticities of chemical fertilizer and machinery increase over time.

Because the coefficients of draft animals are negative and the irrigation coefficients are not significant in regressions 1 through 4, these two variables are omitted in regressions 5 and 6. Some effects of draft animals on production are reflected by manurial fertilizer. The improvement in irrigation in China mainly occurs through increased irrigation power rather than an expansion in the size of irrigated areas. Therefore, these omissions do not greatly affect the estimation. Furthermore, these omissions avoid the collinearity among draft animals, manurial fertilizer, and land input. Most of the estimators in regressions 5 and 6 are significant. The omissions of draft animals and irrigation did not cause changes in other coefficients. Again, the frontier estimation is superior to the average estimation.

Table 2 shows that production elasticities (calculated using regression 6) of traditional inputs--land, labor, and manurial fertilizer--are

Table 2. Production Elasticities for Different Inputs from 1965 to 1985

| | Labor | Land | Chemical Fertilizer | Machinery | Manurial Fertilizer |
|---|---|---|---|---|---|
| 1965 | .417 | .253 | .140 | .078 | .235 |
| 1970 | .363 | .215 | .181 | .127 | .210 |
| 1975 | .309 | .176 | .221 | .176 | .185 |
| 1976 | .298 | .168 | .229 | .186 | .180 |
| 1977 | .287 | .161 | .237 | .195 | .174 |
| 1978 | .276 | .153 | .246 | .205 | .169 |
| 1979 | .265 | .145 | .254 | .215 | .164 |
| 1980 | .254 | .138 | .262 | .225 | .159 |
| 1981 | .244 | .130 | .270 | .234 | .154 |
| 1982 | .233 | .122 | .278 | .244 | .149 |
| 1983 | .222 | .114 | .286 | .254 | .144 |
| 1984 | .211 | .107 | .294 | .264 | .139 |
| 1985 | .200 | .099 | .303 | .274 | .134 |

decreasing: labor by 3.6% per year; land, 4.6%; and manurial fertilizer, 3.1%. The annual rates of increase of production elasticities for modern inputs--machinery, 6.5%; chemical fertilizer, 3.9%--are greater than the rates of decrease for traditional inputs.

The results in Table 2 can be compared to those of other studies. For example, Ma, Calkins and Johnson estimated the production elasticities (using 1984 data) for Shuyang county, Jiangsu province. The ranges in value for their elasticities were as follows: labor, .25 to .36; land, .17 to .20; chemical fertilizer, .17 to .23; manurial fertilizer, .08 to .11; and other inputs, .22 to .29. The elasticities vary depending on crops. Wong's estimation of the production functions (using 1960-80 data) for nine socialist countries resulted in the following production elasticities: labor, .223; land, .143; chemical fertilizer, .177; machinery, .122; and livestock, .233. Comparing those to the production elasticities in Table 2, we observe that the elasticities of land and labor in China are greater than those in the Socialist countries, indicating that Chinese agriculture uses more traditional inputs than other socialist countries.

The level and variability of technical efficiency for each region are calculated in Table 3, using (2) and the results of the frontier production function from regression 6. During the 1960s and 1970s, technical efficiency was about 70%. Efficiency has improved significantly since the institutional change in 1979. The institutional change has three effects. (a) Farmers' incomes and efforts have been linked through improved incentive systems. (b) Farmers may leave agriculture to engage in nonagricultural activities (mainly rural industry), thus improving the land/labor ratio. (c) Farmers may allocate their time and resources to produce high-profit crops, which has improved allocative efficiency and the full use of regional comparative

Table 3. Level and Variability in Technical Efficiency of Seven Regions for Selected Years

| Year \ Region | N.E | N. | N.W. | C. | S.E. | S.W. | S. | National Average | C.V.[a] |
|---|---|---|---|---|---|---|---|---|---|
| 1965 | .868 | .433 | .698 | .728 | .679 | .681 | .644 | .646 | .191 |
| 1970 | .853 | .561 | .844 | .844 | .847 | .731 | .846 | .772 | .138 |
| 1975 | .887 | .581 | .808 | .881 | .866 | .652 | .812 | .761 | .127 |
| Average 65-79 | .892 | .574 | .758 | .850 | .817 | .713 | .789 | .737 | |
| Rank | 1 | 7 | 5 | 2 | 3 | 6 | 4 | | |
| C.V. 65-79 | .033 | .117 | .103 | .069 | .084 | .061 | .087 | .132 | |
| Rank | 1 | 7 | 6 | 3 | 4 | 2 | 5 | | |
| 1980 | .917 | .625 | .692 | .826 | .802 | .781 | .756 | .753 | .122 |
| 1981 | .911 | .630 | .774 | .858 | .851 | .791 | .758 | .768 | .114 |
| 1982 | .911 | .645 | .777 | .885 | .863 | .851 | .810 | .788 | .109 |
| 1983 | .939 | .681 | .751 | .863 | .847 | .858 | .795 | .791 | .103 |
| 1984 | .934 | .726 | .799 | .908 | .900 | .894 | .831 | .831 | .070 |
| 1985 | .891 | .725 | .829 | .909 | .906 | .891 | .870 | .843 | .076 |
| Δ 70s-85[b] | .001 | .151 | .071 | .059 | .089 | .178 | .081 | .106 | |
| Rank | 1 | 6 | 2 | 3 | 5 | 7 | 4 | | |
| Δ 65-85 | .023 | .292 | .131 | .181 | .227 | .210 | .226 | .197 | |
| Rank | 1 | 7 | 2 | 3 | 6 | 4 | 5 | | |
| Average 65-85 | .898 | .616 | .766 | .863 | .844 | .771 | .807 | .772 | |
| Rank | 1 | 7 | 6 | 2 | 3 | 5 | 4 | | |
| C.V. 65-85 | .033 | .123 | .081 | .056 | .073 | .105 | .081 | .130 | |
| Rank | 1 | 7 | 5 | 2 | 3 | 6 | 4 | | |

Notes: a: C.V.: Coefficient of Variation.

b: Δ 70s-85 indicates the absolute improvement of technical efficiency between 1965-79 average and 1985.

advantages.

It is widely accepted that the introduction of the household production responsibility system enlarged the differences in income among regions (Jiang and Luo). However, there is no evidence that the differences in productive efficiency have increased--the coefficient of variation in productive efficiency has decreased since the reform (see the last column of Table 3). The disparity between the production efficiency improvement and income growth among regions suggests that the substantial improvement in production efficiency in poor regions owing to the recent institutional reform did not result in a corresponding increase in income. One reason for this lack of response is the distorted prices in agriculture. Despite the substantial increase in prices in the last ten years, the agricultural product prices still are not reflected by supply and demand. Further reform in prices is needed to give farmers more incentives to promote further production growth. Another reason is the uneven development of rural industry. The low level of income per capita especially in the Southwest is due to the underdevelopment of rural industry.

## Accounting for Total Production Growth

In this part we develop and use an empirical approach to separate the effects on production growth of an increase in inputs, technological change and institutional reform. Using functional form (5), the production function can be expressed as

$$(8) \quad LnY(t) = a_0 + \sum_i a_i \ln x_i(t) + \sum_i a_{it}(\ln x_i(t)) \times t + a_t t + a_{tt} t^2 + \ln(e^{u(t)}) + v(t).$$

$$(9) \qquad = \ln A_0(t) + \sum_i a_i(t) \ln x_i(t) + \ln E(t).$$

where $\ln A_0(t) = a_0 + a_t t + a_{tt} t^2 + v(t)$; $a_i(t) = a_i + a_{it} t$; and $E(t) = e^{u(t)}$.

Taking the first derivative of (9) with respect to time t, the growth rate of total production can be accounted for as

$$(10) \qquad \partial \ln Y(t)/\partial t = \partial \ln A_0(t)/\partial t + \sum_i a_i(t) \times \partial \ln x_i(t)/\partial t + \sum_i \ln x_i(t) \times \partial a_i(t)/\partial t + \partial \ln E(t)/\partial t.$$

The first term in (10) measures neutral technological change. The second term captures the effect of input change on production growth; it is the sum of growth rates in inputs weighted by the relevant production elasticities. The third term measures the the effects of biased technological change on production growth; if it is positive, output has increased through biased technological change (using abundant resources to substitute for scarce resources). The last term reflects the effect of institutional change (or efficiency improvement) on production growth.

Using (10), the accounting for the sources of total production growth is presented in Table 4. Neutral and biased technological change are considered as total technological change in the accounting and treated as the residual. For the whole country, total production growth rate was 5.04% per year from 1965 to 1985; 57.7% of the growth is explained by increased use of total input and 42.3%, by growth in total factor productivity. About 63% of productivity change is attributed to institutional change (or efficiency improvement) and about 37%, to technological change. The increase of labor still explains

Table 4. Accounting for Growth of Total Agricultural Production in Terms of Annual Growth Rates, 1965 to 1985

| | N.E. | N. | N.W. | C. | S.E. | S.W. | S. | National |
|---|---|---|---|---|---|---|---|---|
| **Total Production Growth** | | | | | | | | |
| | 5.09 | 5.88 | 3.70 | 4.40 | 5.50 | 4.40 | 4.50 | 5.04 |
| | (100) | (100) | (100) | (100) | (100) | (100) | (100) | (100) |
| **Total Input Growth** | | | | | | | | |
| | 3.10 | 3.10 | 2.72 | 2.71 | 2.80 | 3.66 | 2.55 | 2.91 |
| | (60.9) | (52.7) | (73.5) | (61.6) | (50.9) | (83.2) | (56.7) | (57.7) |
| Labor | .23 | .24 | .45 | .43 | .25 | .67 | .49 | .39 |
| | (4.5) | (4.1) | (12.2) | (9.8) | (4.5) | (15.2) | (10.9) | (7.7) |
| Land | .04 | -.05 | -.07 | -.01 | .06 | .11 | 0 | .002 |
| | (.8) | (-.9) | (-1.9) | (-.2) | (1.1) | (2.5) | (0) | (.04) |
| C. Fert. | 1.73 | 1.61 | 1.51 | 1.22 | 1.29 | 1.45 | .79 | 1.32 |
| | (34.0) | (27.4) | (40.8) | (27.7) | (23.5) | (33.0) | (17.3) | (26.2) |
| M. Fert. | .20 | .35 | .18 | .13 | .04 | .36 | .31 | .25 |
| | (3.9) | (6.0) | (4.9) | (3.0) | (7.3) | (8.2) | (6.9) | (5.0) |
| Machinery | .90 | .95 | .65 | .94 | 1.16 | 1.07 | .96 | .95 |
| | (17.7) | (16.2) | (17.6) | (21.4) | (21.1) | (24.3) | (21.3) | (18.8) |
| **Total Productivity Growth** | | | | | | | | |
| | 1.99 | 2.78 | .98 | 1.69 | 2.70 | .74 | 1.95 | 2.13 |
| | (39.1) | (47.3) | (26.5) | (38.4) | (49.1) | (16.8) | (43.3) | (42.3) |
| Institutional Change | | | | | | | | |
| | .13 | 2.61 | .86 | 1.11 | 1.45 | .82 | 1.52 | 1.34 |
| | (2.5) | (44.4) | (23.2) | (25.2) | (26.4) | (18.6) | (33.8) | (26.6) |
| Technological Change | | | | | | | | |
| | 1.86 | .17 | .12 | .58 | 1.25 | -.08 | .43 | .79 |
| | (36.5) | (2.9) | (3.2) | (13.2) | (22.7) | (-1.8) | (9.6) | (15.7) |

Note: (10) is employed for the accounting.

about 7.7% of total production growth. The change of land input had the least effect, because acreage used for agriculture remained nearly constant. Among all inputs, increased chemical fertilizer input contributed most significantly to production growth (26.2%), while manurial fertilizer explained 5% of total production growth. The increase in machinery use is the second most important factor in total production increase.

The differences in sources of production growth among regions are substantial due to the differences in the resource endowments and total factor productivity growth. Growth in total agricultural production varied from 3.70% in the Northwest to 5.88% in the North region. The contribution of total input growth to production growth varies from 50.9% in Southeast to 83.2% in Southwest. The differences in modern input (chemical fertilizer and machinery) growth explains most of the differences in total input growth. Among modern inputs, chemical fertilizer has the largest effects. The differences in traditional input growth are small.

The differences of the effects of institutional change on production growth explain the largest share of the differences in total production growth, ranging from 2.5% in Northeast to 44.4% in North.

The contribution of technological change to production growth also has varied substantially among regions. Total factor productivity growth in the Northeast is mainly explained by technological change. Technological change contributed more than 45% of the total factor productivity in the Southeast. However, technological change in the North, Northwest, and Southwest contributed little to total factor productivity and total production growth.

## Concluding Comments

The major findings of this study are summarized as follows: The estimates of the frontier production functions for China's agriculture indicate that traditional inputs are still important to China's agriculture. However, the importance of the traditional inputs of land, labor, and manurial fertilizer is decreasing rapidly. In contrast, the coefficients of modern inputs, e.g., chemical fertilizer and machinery inputs, were small in 1965 but have since increased rapidly. By 1985, the modern inputs were as important as the traditional inputs.

Efficiency measurements indicate that the household production responsibility system has contributed significantly to production growth. However, the regional differences in performance are large. In general, land-scarce regions gained more from the reform.

The accounting for production growth showed that a significant share of total production growth still can be attributed to increases in traditional inputs. Among all inputs, increased chemical fertilizer use was the most important source of production growth. Increased machinery input ranked second in importance. Total input growth explains 57.7% of total production growth. The residual, the proxy for technological change and efficiency improvement, accounts for 42.3% of total production growth. Institutional change has had greater effects on productivity and production growth than has technological change.

These findings have important policy implications in promoting further production growth and smoothing regional inequalities. China's population reached 1065.29 million in 1987. The population growth rate from 1949 to 1987 was 1.84%, although it declined to 1.29% in last decade. Further decreases in population growth will not be easy in the next decade because the base population is large and those born in the 1960s are entering the reproductive age. Thus the demand for food will continue to grow even apart from income effects. The demand for cash crops is increasing with the development of industrialization. How to meet the future demand for rapid increases in food and in industrial materials is an urgent problem.

Increased Input Use. The quickest solution for China is to increase the use of inputs, such as land, labor, chemical fertilizer, machinery, and others. However, the total land input is likely to decline in the future (Sun). Without an increase in land areas, an increase in labor will have only a limited effect on total production. Increased use of modern inputs, especially chemical fertilizer, likely has the greatest potential for increasing total production. Although fertilizer input per unit of land in China is higher than in most developing countries, the output increase from greater fertilizer use is still potentially large in some regions (see Table 4), particularly in the Northeast, Northwest, North, and Southwest. Increased machinery input will have little effect on production unless it increases land productivity. Thus, a top priority in mechanization involves increased land productivity (e.g., mechanization of irrigation).

Technological Change. The results of this study indicate that technological change accounts for 15.7% of total agricultural production growth in China. Compared to other countries, this proportion is very small. In Japan, from 1960 to 1980, 47.4% of total production growth stemmed from technical change, and technical change accounted for 84.2% of the growth in U.S. total output (Hayami and Ruttan).[11] Underinvestment in agriculture may explain the slow technological change in China. In 1985, the agricultural sector produced 28.1% of total national output and 41.1% of national income, although the agricultural investment was only 3.4% of total investment.[12] The underinvestment in agriculture has resulted in poor rural infrastructure and insufficient agricultural research. An increase in agricultural investment, especially in research and development, is needed to stimulate technological change.

Institutional Change. Recent institutional changes have improved agricultural production efficiency greatly; 26.6% of production growth has been contributed by institutional change. The new strategy should focus on greater regional specialization, based on comparative advantages.
The self-sufficiency policy both at the national level and local levels should be discarded. Crops should be grown where soil and climate provide the most favorable conditions. Although rural labor has more opportunities to work outside agriculture, labor immobility will become a major source of inefficiency. The pattern of land holdings (in terms of size distribution of farm), land tenure and other contractual arrangements in agriculture should be adjusted appropriately to gain more efficiency. The recent introduction of factor and product markets in agriculture has contributed to more efficient allocation of resources; however, instability of input and output prices and the insufficient supplies of modern inputs will continue constrain agricultural production.

Smoothing Regional Inequalities. Differential growth rates in agricultural development among regions of a country represent a persistent challenge to policy makers. Smoothing the differences in technological and institutional changes among regions is needed to reduce the differences in production and income growth. A well-integrated and extensive physical infrastructure, and a strong regional agricultural research capacity adapted to the needs of the regional agricultural economy are important in contributing to develop new comparative advantages in technology in the regions disadvantaged by resource endowments and stimulate more even rates of technological change across regions.

New agricultural policies and institutional changes should create more geographically even growth in agricultural production and income. For example, crop prices should be raised in order to narrow the income differences between the regions with advantage of crop production but with disadvantage of rural industry, and the regions with the well-developed rural industry.

## Endnotes

1. Hainan was not separated from Guangdong province.

2. The traditional estimation of a production function assumes that every firm is technically efficient, resulting in the average production function, i.e., $Y_{it} = f(x_{it}, b)e^{\varepsilon it}$, where $\varepsilon it$ has normal distribution, $N(0, \sigma^2)$.

3. The time series of provincial monetary value of total production (measured in 1980 constant prices) before 1985 is reported in *Collection of Statistical Materials in National Income, 1945-1985*, State Statistical Bureau, Beijing: China's Statistical Publishing House, 1987. The data after 1985 are reported in *China's Statistical Yearbooks*, 1986, 1987, State Statistical Bureau.

4. The provincial data of labor before 1980 are calculated from the provincial agricultural population. $L_{it} = P_{it} \times \frac{r_{i,80}}{r_{n,80}} \times r_{n,t}$, where $L_{it}$ denotes $i^{th}$ region's labor input in year t; $P_{it}$, $i^{th}$ region's population in year t; $r_{i,80}$, $i^{th}$ region's ratio of labor to population in year of 1980; $r_{n,80}$, national ratio of labor to population in year 1980. $r_{n,t}$, national ratio of labor to population in year t. The data for agricultural population before 1980 are taken from *National Agricultural Statistical Materials for 30 Years (1949-1979)*, State Statistical Bureau, March 1980. The data of agricultural labor after 1980 are taken from various issues of China's Statistical Yearbooks.

5. The data for sown areas and pasture are taken from *National Agricultural Statistical Materials for 30 Years (1949-1979)*, State Statistical Bureau, March, 1980.

6. The data before 1980 are reported in *National Agricultural Statistical Materials for 30 years (1949 - 1979)*. The data after 1980 are taken from various issues of China's statistical Yearbooks.

7. The horsepower of 1965 and 1970 is interpolated based on the numbers of hand tractors and other tractors. The horsepower from 1970 to 1975 is taken from the *National Agricultural Statistical Materials for 30 Years (1949-1979)*. The horsepower after 1980 is taken from various issues of the Statistical Yearbooks.

8. The FAO estimated that one animal (horse unit) produces about 4 tons of manure per year and a person produces .25 ton per year. Manure contains 2.2% pure nutrient, and the manure availability is about 75% of total use. Therefore, manurial resources are estimated as follows:

Annual manurial resources (tons)

$$= ((.25 \times \text{Rural population} + 4 \times \text{numbers of livestock}) \times 2.2\%) \times 75\%$$

The results of this estimation are not significantly different from that of Stone (Tang and Stone).

9. The numbers of draft animals before 1980 are taken from the *National Agricultural Statistical Materials for 30 Years (1949-1979)*. The numbers after 1980 are taken from various issues of Statistical Yearbooks after 1980.

10. The data of irrigated areas before 1980 are reported in *National Agricultural Statistical Materials for 30 Years (1949 - 1979)*. Those after 1980 are published in the various issues of Statistical Yearbooks.

11. See Table 7.2, Hayami and Ruttan (1985). Total output growth is 1.9% a year in Japan from 1960 to 1980; and total productivity growth (the contribution of technical change to output growth), .9%. Thus the relative contribution of technical change to total output growth is 47.4%. Using the same calculation, the relative contribution of technical change to total output growth is 84.2% in the United States.

12. *China's Statistical Yearbook, 1986*. Beijing: China's Statistical Publishing House.

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