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Abstract

We examine regional total factor productivity growth in post-reform (1980-95) Chinese agriculture using nonparametric Malmquist procedures. The results indicate that average productivity growth was 2.8% annually for the country as a whole. Technical innovation contributed to productivity growth by 3.0%, while the poor efficiency performance reduced productivity growth by 0.2%. We found evidence of profound productivity growth divergence among regions during this economic transition period. The divergence of technical change rather than efficiency change among regions seems to be the major contributing factor. The lagging Northwest showed neither a systematic trend for technical change nor propensity to increase efficiency and fell further behind the leading South in productivity.

Keywords: total factor productivity, Chinese agricultural reform, productivity convergence, and Malmquist index.

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Since 1977, China has embarked on a great economic transformation - the transition to a market-oriented economy. Remarkable economic growth and substantial improvement in the standard of living have resulted from institutional and economic reforms. An accompaniment of the economic growth in China has been the growing economic disparity among regions as characterized by: (a) inequality in per capita income has widened (the ratio between the lowest and highest province is 6:1); (b) most of the people who are below the poverty line live in the deep-interior area; © the coastal region attracts the most foreign investment and is more export-oriented than the inland and deep-interior regions; (d) provincial differences in arable land per capita are 10:1; and (e) the high degree of regional isolation in trade and flows of production inputs arises from regional regulations and high transportation costs due to poor infrastructure and the vastness of the country (Yoshitomi, 1996).

This disparity has resulted in a variety of economic and political distress as "survival of the fittest" has become the norm. These tensions have recently received increasing attention from policymakers, researchers, and the public. Growing economic inequality among regions is a serious concern because a widening gap of regional development causes regional fragmentation politically and economically (Yabuki, 1995, p.86; Ding, 1995, p.15; Bell et al., 1993, p.48). Probable explanations for regional economic disparity range from location advantages, such as easier access of coastal regions to foreign investors, to preferential government policies, such as the shift in investment and development from the interior to coastal areas (e.g., Bell et al., 1993; Tuan, 1993, among others).

In this paper, we analyze the regional economic disparity by investigating total factor productivity (TFP) growth in a single but fundamental industry - agriculture - in the post-reform

(1980-95) China. The specific objective of this paper is to estimate and explain changes in agricultural productivity among regions by using nonparametric Malmquist index procedures. We test the hypothesis that agricultural TFP differentials among regions have converged in post-reform China. The productivity convergence hypothesis suggests that as a country advances economically, regional productivities and living standards increasingly become more alike (Baumol et al., 1994). In this study, the 30 provincial-level units in China were grouped into seven regions: Northeast, North, Northwest, Central, East, South, and Southwest.[1]

This study focuses on the regional TFP growth in Chinese agriculture over the 15-year economic transition period, which provides an ideal case for studying economic disparity for the following reasons. First, in spite of remarkable progress in industrialization, China is still an agricultural country with 80% of its population in rural areas. Agriculture continues to be the backbone or foundation of the Chinese economy. Accordingly, regional agricultural TFP disparity should reflect the differences in economic achievements and in turn the extent of inequality among regions. There are 65-million people in China who are still living below the government poverty line. As Baumol et al. (1994) pointed out, productivity convergence has substantial implications for the welfare of the nation and for alleviating poverty in the country. An analysis of the degree and reasons for regional disparity would help policymakers to understand the nature of the problems and design policies to balance the economic growth.

Second, China is not an integrated economy. Rather, it is a collection of provincial or regional economies with widely differing endowments of climate, topography, natural resources, production inputs, and technologies (Garnaut and Huang, 1995). The analysis of regional productivity change in such a vast country will shed light on the sources for regional disparity and on recommendations for appropriate remedial measures. Third, few contemporary studies have focused on the degree of productivity convergence in developing countries, particularly in transitional economies like China. The analysis of this study on Chinese regional growth disparity will provide valuable information for other transitional economies (e.g., India, Eastern Europe, and republics of the former Soviet Union) which are currently undertaking economic reforms. Finally, our study differs from earlier studies on economic disparity in China in that we use data covering the longer post-reform era. The method used here allows us to explain changes in productivity over time by separating catching-up to the frontier (efficiency change resulting from the institutional reforms) from shifts in the frontier (innovation arising from technological progress). In addition, the approach allows regions to have different underlying production functions without requiring that particular functional forms be specified in the analysis.

For the spatial aggregation used in this study, we found no evidence of TFP convergence among regions during this post-reform period. Rather, we observed that the gap in regional productivity has been widening with only a couple of regions pulling ahead. The leader, the southern region, consistently augmented its productivity and technology during the post-reform period. The lagged, the northwestern region, showed only a very slight gain in average annual productivity. This region was not able to progress more from its backwardness partially because of its inability to adopt technology and organization of production from the leading regions or foreign countries. The cause of growth disparity among regions was technical change rather than efficiency change. Future policies should promote regional specialization, development of local market infrastructure, and interregional movement of resources to improve efficiency and technological development, agricultural research, and investment in rural areas to augment technical change. Greater integration and cooperation between the leaders and the laggards to promote technical change and efficiency change would enhance productivity convergence.

The organization of this paper is as follows. The next section reviews previous studies on economic disparity in China. Section III discusses the analytical procedures used in this study. The fourth section describes the data used in this study and presents the estimated results of productivity and its components for Chinese agriculture. The final section provides a summary and chief conclusions of this study.

2. Past Studies on Chinese Economic Disparity

Since the very beginning of economic reforms, China has adopted a development strategy of allowing some selected regions to open for more foreign investment and to advance at a faster rate than the others (Bell et al, 1993, p.10). Geographically, reforms advanced more dramatically in the southern and eastern regions, where only a moderate number of large state-owned enterprises were subject to central or state planning. The results of such policies led to the emergence of the coastal provinces as the focal point of many of the reform efforts. For instance, special economic zones and 14 cities open to foreign direct investments and technologies are all located in the coastal region. Resources generated by foreign trade were allowed to be retained by the coastal region. The fast growth in town and village enterprises occurred primarily in the coastal provinces when restrictions on nonfarm activities in rural areas were eliminated. The inflow of foreign direct investment and state capital were heavily concentrated in the coastal provinces. For example, the Guangdong province absorbed about one-third of total foreign investment from 1985 to 1987, while one of the poorest provinces, Guizhou, literally received no foreign investment until 1988 (Kueh and Ash, 1996, p.172). In 1982, about 46% of the state capital was invested in the East, 18% in the Central, and 18% in the West, but in 1992 these investment allocations changed to 55%, 25%, and 16%, respectively (Ding, 1995, p.16).

The emergence of coastal regions as leaders in the reform process has helped to advance their economies more rapidly than the inland and deep-interior regions. Consequently, the coastal region has benefited more from the economic reforms and plays an increasingly vital role in the country's economy. In 1990, for example, 12 coastal provinces with about 14% of total territory and 41% of total population accounted for 54% of GNP, 63% of industry output, 81% of export values, and 87% of foreign direct investment. In contrast, nine deep-interior provinces with 56% of total land area and 23% of population accounted for only 16% of GNP, 12% of industry output, 6.1% of export values, and 6.1% of foreign direct investment (Yabuki, 1995).

As the above statistics suggest, the economic reform has also brought a greater disparity in income among regions. Per capita GNP in 1990 was 1,959, 1,258, and 1,079 yuan, respectively, in the coastal, inland, and deep-interior regions, yielding a ratio of 1:0.64:0.55 (Yabuki, 1995, p.180). Tuan (1993) reported that per capita farm income in the coastal region increased from 242 yuan in 1980 to 968 yuan in 1990. Over the same period, however, per capita farm income increased from 189 yuan to 649 yuan in the inland region and from 165 yuan to 552 yuan in the deep-interior region. Consequently, the ratios of per capita farm income in these three regions widened from 1:0.78:0.68 in 1980 to 1:0.67:0.57 in 1990. Tuan concluded that rural economic achievement has widened between regions after two decades of reforms. To maintain sustainable rural economic growth, he suggested that the pricing and foreign trade systems should be further liberalized to enhance regional specialization.

Carter and Zhong (1991) found that policy regulations in China affected regional specialization which was measured by the cotton/grain yield ratio and cotton/grain sown area ratio. Correlation between these two ratios was high and positive during 1980-1984 when farmers had more freedom in production decisions because of policy deregulations, which led to greater regional specialization in cotton. Correlation between these two ratios, however, was low and negative during 1984/85-1987/88 when the government imposed the lower cotton purchasing quotas in 1985.

Fan (1991) examined regional-level farm production growth over the period 1965-85.[2] Using a parametric approach and slightly differing regional demarcation from this study, he observed substantial differences in TFP growth among regions: 1.99% in the Northeast, 2.78% in the North, 0.98% in the Northwest, 1.69% in the Central, 2.7% in the Southeast, 0.74% in the Southwest, and 1.95% in the South, respectively, with the national average of 2.13%. His results showed that the contribution from institutional (efficiency) change to growth ranged from a minimum of 6.5% in the Northeast to a maximum of 94% in the North. Technical progress was the major contributor to the TFP growth in the Northeast, but not in the North, Northwest, and Southwest.

Fan and Pardey (1992) estimated that the contribution of agricultural research to productivity growth was unequal among regions with 35% in the Southeast and 8.6% in the North. They also reported that the regions with low land productivity neither caught up with the regions with more productive land nor closed the gap in regional labor productivity differentials. This lack of convergence in regional labor productivities resulted from "the regional rather than national characteristics of the labor market and intersectoral rigidities in the national labor markets."

These studies highlight growing economic disparity and unbalanced development among regions in China, which is also evident from the ever widening gap in productivity growth, standard of living, and economic conditions among regions. This review also reveals a need for a rigorous test and explanation of growth differentials among regions. We will examine these issues at a more disaggregated regional-level than previous studies by using nonparametric

Malmquist index procedures which are discussed in the next section.

3. The Analytical Procedures

When an output is attributed to a single input, productivity can be measured by the ratio of output over input (e.g., yield per acre). Such a measure, land productivity, is a partial assessment since all the other contributing factors to productivity are not considered. A comprehensive measure of productivity is total factor productivity (TFP) which is based on aggregate output and aggregate input use. TFP changes are often measured based on econometric estimation or an index number approach. Common to most index approaches is to require a cost/revenue share for aggregation and/or to impose structure on the underlying technology by specifying an aggregate production function. A recent development in the measurement and explanation of productivity changes formulates a productivity index by using distance functions calculated with nonparametric programming techniques. This index is termed the Malmquist productivity index by Caves et al. (1982) and popularized recently by Färe and Grosskopf and others. This index, unlike others, neither imposes structure on the underlying technology nor requires a cost (revenue) share for aggregating outputs and inputs. The distance function provides a natural means for such aggregation.

The distance function is a representation of technology, which is the reciprocal of maximum proportional expansion of all outputs for a given level of inputs. For example, Shephard (1970) defined the *within-period* and *mixed-period* output distance functions as:

(1) $$D^t(x^t,\ y^t) = \left[max\{\theta : (x^t,\ \theta y^t) \in I^t(x^t),\ \theta \geq 0\}\right]^{-1},\ t=1,\ ...,\ T$$

(2) $$D^{t+1}(x^t,\ y^t) = \left[max\{\theta : (x^t,\ \theta y^t) \in I^{t+1}(x^t),\ \theta \geq 0\}\right]^{-1}$$

where $x^t \in R^n_+$ and $y^t \in R^s_+$ denote the input vector and an output vector at time t, θ is a scalar variable, and $I^t(x^t)$ is the production technology in period t which defines the transformation of inputs into outputs, i.e., $I^t(x^t) = \{x^t,\ y^t):\ x^t\ can\ produce\ y^t\}\ t=1,\ ...,\ T$. Here, $I^t(x^t)$ is assumed to satisfy certain axiomatic properties defined by Shephard in 1970 (also see Färe, 1988). The *within-period* output distance function, $D^t(x^t,\ y^t)$, measures how far year t output lies from the best-practice frontier or maximum output defined by year t technology. The *mixed-period* output distance function, $D^{t+1}(x^t,\ y^t)$, uses production observations from one period (t) and measures the distance to the best-practice frontier defined by technology from an adjacent period (t+1).

Empirical applications (e.g., Jaenicke and Lengnick, 1997; Price and Weyman-Jones, 1996; Qiu et al., 1996; and Färe et al., 1994) have shown the merits of the nonparametric Malmquist procedures. This approach does not require the maintained hypothesis of cost minimization or profit maximization. Since such a hypothesis often does not hold in regulated industries or imperfect markets as in China, the Malmquist index is most suitable in measuring the TFP in Chinese agriculture. Also, this approach does not require data on prices which are not readily available or do not reflect opportunity costs in the developing countries.

Using the ratio of distance functions from two periods, Caves et al. (1982) defined the Malmquist index with reference to old technology (period t) as $M^t = \frac{D^t(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)}$ and with reference to new technology (period t+1) as $M^{t+1} = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)}$. The productivity change can be measured with respect to old technology (M^t) or new technology (M^{t+1}). To avoid having to choose an arbitrary reference, Färe and Grosskopf (1994) defined the output-based Malmquist productivity change index, $M(x^t, y^t, x^{t+1}, y^{t+1})$ or $M(\bullet)$ for short, between year t and t+1 as the geometric mean of two Malmquist productivity indexes.

(3) $$M\left(x^{t}, y^{t}, x^{t+1}, y^{t+1}\right) = \left[\frac{D^{t+1}(x^{t}, y^{t})}{D^{t}(x^{t}, y^{t})}\frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t}, y^{t})}\right]^{\frac{1}{2}}$$

Further, they decomposed productivity change multiplicatively into the efficiency change (*EC*) and technical change (*TC*) components:[3]

(4) $$M\left(x^{t}, y^{t}, x^{t+1}, y^{t+1}\right) = \left[\frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t}(x^{t}, y^{t})}\right]\left[\frac{D^{t}(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})}\frac{D^{t}(x^{t}, y^{t})}{D^{t+1}(x^{t}, y^{t})}\right]^{\frac{1}{2}} = EC*TC$$

The *EC* is measured by the ratio of *within period* distance functions from two separate periods, which captures whether the observation in each period moves closer or farther from the best-practice frontier between years t and $t+1$. The *TC* is the geometric mean of two measures of the shift in the best-practice frontier: one shift is measured using actual inputs and outputs in period t along with distance function with reference to old and new technologies and the other using observed inputs and outputs in period $t+1$ and distance functions representing old and new technologies. The productivity increases (decreases) from period t to $t+1$ if the value of $M(\bullet)$ is greater (less) than one and shows no change if the value of $M(\bullet)$ is one. The same interpretation applies to the technical change and efficiency change components.

The *EC* component in (4) can be further decomposed into scale efficiency change (*SC*) and pure efficiency change (*PC*),

(5) $$EC = SC*PC = \left[\frac{\dfrac{D^{t}\left(x^{t}, y^{t}|_{VRTS}\right)}{D^{t}\left(x^{t}, y^{t}|_{CRTS}\right)}}{\dfrac{D^{t+1}\left(x^{t+1}, y^{t+1}|_{VRTS}\right)}{D^{t+1}\left(x^{t+1}, y^{t+1}|_{CRTS}\right)}}\right]\left[\frac{D^{t+1}\left(x^{t+1}, y^{t+1}|_{VRTS}\right)}{D^{t}\left(x^{t}, y^{t}|_{VRTS}\right)}\right]$$

where CRTS (VRTS) stands for constant (variable) returns to scale. The scale efficiency change captures the relative deviations between the CRTS and VRTS technologies, while the pure efficiency change measures the relative efficiency as the ratio of two distance functions under the VRTS technology. Similarly, the *TC* component can also be partitioned into output bias (*OB*), input bias (*IB*), and a magnitude component (*MC*) (Färe and Grosskopf, 1996).

$$(6)\quad TC = OB * IB * MC = \left[\frac{D^{t}(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})}\frac{D^{t+1}(x^{t+1}, y^{t})}{D^{t}(x^{t+1}, y^{t})}\right]^{\frac{1}{2}}\left[\frac{D^{t+1}(x^{t}, y^{t})}{D^{t}(x^{t}, y^{t})}\frac{D^{t}(x^{t+1}, y^{t})}{D^{t+1}(x^{t+1}, y^{t})}\right]^{\frac{1}{2}}\left[\frac{D^{t}(x^{t}, y^{t})}{D^{t+1}(x^{t}, y^{t})}\right]$$

The *OB* technical change captures the effect of the change in output mixes.[4] The *IB* technical change captures the effect of the change in input mix. It is measured by the geometric mean of two measures of the frontier shift: one is the shift in technology between period t+1 and t evaluated at the input-output vector observed at time t and the other is the shift in technology between period t and t+1 evaluated at the input level observed at time t+1 and at the output level observed at time t. Technical change is Hicks output (input) neutral if *OB* (*IB*) is equal to one and output (input) biased if *OB* (*IB*) is not equal to one. Under joint neutrality (*OB*=*IB*=1), the magnitude component equals technical change.

Computation of the fully-decomposed, output-based Malmquist index measures (equations 3 through 6) requires estimation of various *within* and *mixed*-period distance functions: $D^t(x^t, y^t)$, $D^{t+1}(x^{t+1}, y^{t+1})$, $D^{t+1}(x^t, y^t)$, $D^t(x^{t+1}, y^{t+1})$, $D^t(x^{t+1}, y^t)$, and $D^{t+1}(x^{t+1}, y^t)$ under CRTS as well as $D^t(x^t, y^t)$ and $D^{t+1}(x^{t+1}, y^{t+1})$ under VRTS. The value of output distance functions is determined from the reciprocal of Farrell's measure of technical efficiency which is derived through nonparametric data envelopment analysis (DEA). Consider k regions, each produces s outputs using n inputs in period t. Let X^t and Y^t be the input and output matrices in period t; x_i^t and y_i^t be the input and output column vectors of the ith region in period t; and z^t be the column vector of intensity variables to be estimated in period t. Then,

$$X^t = [x_1^t \; x_2^t \ldots x_i^t \ldots x_k^t] = \begin{bmatrix} x_{11}^t & x_{12}^t & \cdots & x_{1i}^t & \cdots & x_{1k}^t \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ x_{n1}^t & x_{n2}^t & \cdots & x_{ni}^t & \cdots & x_{nk}^t \end{bmatrix} \quad Y^t = [y_1^t \; y_2^t \ldots y_i^t \ldots y_k^t] = \begin{bmatrix} y_{11}^t & y_{12}^t & \cdots & y_{1i}^t & \cdots & y_{1k}^t \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ y_{s1}^t & y_{s2}^t & \cdots & y_{si}^t & \cdots & y_{sk}^t \end{bmatrix} \quad z^t = \begin{bmatrix} z_1^t \\ \cdot \\ \cdot \\ \cdot \\ z_k^t \end{bmatrix}$$

The value of distance function $D^t(x_i^t, y_i^t)$ for region I can be derived from the solution of the following linear programming problem that maximizes the efficiency index (θ):

$$\begin{aligned} \left[D^t(x_i^t, y_i^t)\right]^{-1} &= \max_{(\theta, z)} \theta_i \\ s.t. \; Y^t z^t - \theta_i y_i^t &\geq 0 \\ X^t z^t - x_i^t &\leq 0 \\ z^t &\geq 0. \end{aligned} \tag{7}$$

The first matrix equation is a set of constraints on outputs. In this application there is one output (the value of agricultural production) and thus there is one output constraint equation for period t: $y_1 z_1 + \ldots + y_7 z_7 \geq \theta_i y_i$. This constraint requires that the maximum potential output of region i must be less than or equal to the theoretically efficient output that is a weighted sum of all regions' outputs. The solution seeks to maximize θ and thus also seeks large z values to satisfy this constraint. The second matrix equation is a set of constraints on inputs. In this application there are six input constraints like the following for period t: $x_{1n} z_1 + \ldots + x_{7n} z_7 \leq x_{in}$. Here, x_{in} denotes the use of the nth input by region i. This constraint requires that to produce observed output in the ith region at period t, the actual use of input n for region i be greater than or equal to the theoretically efficient input usage that is a weighted sum of input n use for all regions. The values for the weights for each region are the same as in the output constraint and some may be zero. The solution seeks small values for z to satisfy the second constraint set. This constraint set inhibits the tendency for large zs in the first constraint and bounds the solution.

CRTS was imposed in (7) by allowing the elements of z^t to take any nonnegative values. The solution for this distance function and all others was obtained with General Algebraic Modeling System or GAMS (Brooke et al., 1988). The weights z_i selected are larger for the more efficient regions where x_i tends to be small and y_i tends to be large relative to the other regions. For inefficient regions z_i can be zero. In this way the solution z_is determine a best practice frontier and the solution also determines a scalar radial output expansion factor θ for region i to reach the frontier. The product $\theta_i * y_i$ is the maximum output possible for region i under current technology if it efficiently uses its inputs. The reciprocal of θ_i is the value of the distance function. The value of $D^{t+1}(x_i^{t+1}, y_i^{t+1})$ was computed using (7) with the superscript t was replaced by t+1.

Computation of the value of $D^{t+1}(x_i^t, y_i^t)$ involved observations from periods t and t+1.

(8)
$$\begin{aligned} \left[D^{t+1}(x_i^t, y_i^t\right]^{-1} &= \max_{(\theta, z)} \theta_i \\ s.t.\ Y^{t+1}z^{t+1} - \theta_i y_i^t &\geq 0 \\ X^{t+1}z^{t+1} - x_i^t &\leq 0 \\ z^{t+1} &\geq 0 \end{aligned}$$

The first constraint in (8) states that given the actual amount of inputs used by the ith region in period t, the maximum output in period t should be less than or equal to the theoretically efficient output produced by all regions at time t+1. The second constraint provides that to produce the observed level of output y in the ith region at period t, the actual level of input used by the ith region in period t should be greater than or equal to the theoretically efficient input use at time t+1. The value of $D^t(x_i^{t+1}, y_i^{t+1})$ was estimated using (8) with superscripts t+1 and t was interchanged.

The values of $D^t(x_i^t, y_i^t)$ and $D^{t+1}(x_i^{t+1}, y_i^{t+1})$ under the VRTS technology were computed using (7) except that CRTS constraint was replaced by the constraint which restricts the sum of the elements in the intensity vector z^t to be equal to one.

The values of $D_i^t(x_i^{t+1}, y_i^t)$ and $D_i^{t+1}(x_i^{t+1}, y_i^t)$ were calculated using (9) and (10).

$$\text{(9)}\quad \begin{aligned} \left[D^t(x_i^{t+1}, y_i^t)\right]^{-1} &= \max_{(\theta, z)} \theta_i \\ s.t.\ Y^t z^t - \theta_i y_i^t &\geq 0 \\ X^t z^t - x_i^{t+1} &\leq 0 \\ z^t &\geq 0 \end{aligned}$$

$$\text{(10)}\quad \begin{aligned} \left[D^{t+1}(x_i^{t+1}, y_i^t)\right]^{-1} &= \max_{(\theta, z)} \theta_i \\ s.t.\ Y^{t+1} z^{t+1} - \theta_i y_i^t &\geq 0 \\ X^{t+1} z^{t+1} - x_i^{t+1} &\leq 0 \\ z^{t+1} &\geq 0 \end{aligned}$$

In (9) the reference technology is from period t, the observed level of output from period t, and the observed level of inputs from period t+1. The output constraint in (9) is same as in (7). The second constraint in (9) states that the actual level of input used by the ith region at time t+1 should be greater than or equal to the theoretically efficient input use at time t. In (10), the input constraint, the second equation, is same as in (7) except that t is replaced by t+1. However, the maximum output produced by the ith region at time t should be less than or equal to the theoretically efficient output produced by all regions at time t+1.

4. Empirical Analysis

In this section, we define production regions for Chinese agriculture, describe the data used in this study, and present the estimates of productivity growth from the Malmquist index and its components. Various groupings have been used to delineate regions in China. For instance, China has been identified as "seven great joint industrial regions", "ten great economic regions", and "six central regions" (Yabuki, 1995). The other common groupings used recently are East, Central, and West regions; and coastal, emerging inland, and deep-interior regions. Yabuki (1995, p.180) used "seven market economic zones (Bohai rim, Yangtze delta, South China, Yangtze river basin, Northeast, Yellow river basin, and Deep interior)" as regional units for his analysis. Fan (1991) divided China into "seven regions" that adhere closely to the administrative divisions (see endnote 2). We divided China into seven regions: Northeast, North, Northwest, East, Central, South, and Southwest, for which agricultural output and input data are available (see endnote 1).

The first block in table 1 displays regional differences in selected variables. Precipitation is abundant but distributed unequally among regions, ranging from about 76 inches in the South to 12 inches in the Northwest. In spite of its vast areas and because of dense population, arable land is a scare resource in China, averaging only 0.4 hectares per worker. This number is far below that in the United States (63 hectares per worker) and even below that in South Asia (0.8 hectares per worker). The northern region, the main grain and cotton producing area, is the most populated and it contains only about 7.2% of the country's areas. The northwester region, with concentrated plateaus and vast deserts, is the least populated, which comprises of about 43.8% of the country's areas.

The production frontier estimation in this study was based on one output (gross value of agricultural outputs measured in constant 1980 prices, excluding rural industrial outputs) and six agricultural inputs (irrigated area, farm machinery power, manure fertilizer, chemical fertilizer, sown area under all crops, and labor force).[5] Sources for the data used in this study were

Agricultural Statistics of the People's Republic of China, 1949-90 (Colby et al., 1992) and various issues of *China Rural Statistical Yearbook* and *China Statistical Yearbook.*

The second and third blocks in table 1 present, respectively, the means and the growth rates of output and six input variables over the period 1980-1995. The North ranked first and the Northwest last in gross value of agricultural outputs. On average, total agricultural output was valued at 83,308 and 28,989 million yuan in the North and Northwest, respectively, which accounted for about 25% and 8.5% of the country's agricultural output. For the nation as a whole, gross value of agricultural output grew at 6.9% per year with the highest average growth of 8.3% in the South and the lowest growth of 5.8% in the Central region. Among inputs, chemical fertilizer use grew the fastest, followed by farm machinery use, which highlights the modernization of agricultural production in China. The growth rate of chemical fertilizer use averaged 7.5% annually with a growth rate of 11% in the Northwest and 6.1% in the East. The growth rate of farm machinery use was higher in the North and South than in the other regions. The least growth occurred for area sown under all crops, followed by irrigated area. Because of limited agricultural land availability, the growth rate of area sown under all crops averaged only 0.1% annually with an increase of 1% in the Southwest and a decrease of 0.4% in the East.

The Malmquist productivity index and its components were calculated for each of the seven regions and over the period from 1980 to 1995. We present these results in terms of annual percentage changes, average annual percentage change, and cumulative percentage change (or growth). The percentage change for each year in each region was computed by taking the natural logarithm of the annual Malmquist productivity index and its components to express growth as a continuous rate. For example, the annual percentage change in the catching-up effect was approximated by $Ln(EC)$ where $EC = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t}(x^{t}, y^{t})}$. The average annual change in the

Malmquist productivity index and its components for each region over the study period was calculated using the values of distance functions for the beginning year (1980) and final year (1995). For example, the average annual change in the catching-up effect was equal to *Ln(EC)* where $EC = \left[\frac{D^{1995}(x^{1995}, y^{1995})}{D^{1980}(x^{1980}, y^{1980})}\right]^{\frac{1}{15}}$. The cumulative percentage change was computed by letting *t* be the base period 1980 and *t*+1 be 1981, 1982, ..., 1995 so that equations (7) through (10) could be computed for each year from 1981 to 1995. Finally, we investigated the timing of the structural change in regional agriculture by regressing the natural logarithm of the cumulative Malmquist productivity change index on time and the structural-break variable.

4.1. Annual Percentage Changes in the Malmquist Index and its Components: The first block in table 2 displays the percentage change in the catching-up effect. From a total of 105 values for all regions and years, we found increases in efficiency in only 10 cases, no change in 81 cases, and decrease in 14 cases. Most regions in this post-reform period were efficient; their *within-period* distance functions were equal to one. A slight increase in the efficiency performance was observed in the southern region until 1984/85. The North had more years (9 out of a total of 15 years) of efficiency deterioration, indicating that the provinces in this region were falling behind the frontier. The efficiency change in this region ranged from an increase of 7.9% in 1986/87 to a decrease of 11% in 1994/95 implying that this region fell further behind the frontier by 11%. In the northwestern region, efficiency was unchanged until 1990/91 and then deteriorated.

As reported in the second and third blocks in table 2, there was no pure efficiency change and all of the efficiency performance was captured by the scale efficiency change. As a result, these regional variations in the catching-up performance were mainly due to deviations from constant returns to scale technology, i.e., the scale efficiency change.

The fourth block in table 2 displays the percentage change in the best-practice technology.

For all regions and years, 78 cases showed progress in the best-practice technology and 27 cases showed regression. Progressive technical change occurred for all regions in 1981/82, 1983/84, and 1991/92. Regressive technical change was the most frequent in the mid 1980s. For instance, average technical change decreased by 0.7% between 1985/86 and 1988/89 for the nation as a whole, while it increased by 4.0% between 1980/81 and 1984/85 and by 4.2% after 1989.[6] Economic incentives and policies were less favorable to the farming sector in the mid 1980s. For example, the prices of inputs such as chemical fertilizers and plastic sheeting increased much faster than grain prices; agricultural investment as a proportion of total state capital construction outlays fell to only 3% over the period 1986-1988; and farm savings were not reinvested in agriculture but were diverted to other sectors (Ash, 1993, pp.33-35).

Growth in output due to technical innovation varied considerably among regions and years, ranging from an increase of 17% in 1982/83 in the Northeast to a decrease of 14% in 1988/89 also in the Northeast, which resulted from substantial variation in grain production and in turn gross value of agricultural outputs. For instance, grain production in the Northeast increased sharply from 33 million tons in 1982 to 45 million tons in 1983, a growth of 37%, and gross value of agricultural output grew at 21%. In contrast, grain production decreased from 46 million tons in 1988 to 39 million tons in 1989, a drop of 16%, and gross value of agricultural output declined by 8.2%. The southern provinces experienced progress in the best-practice frontier during the entire study period, while the provinces in the Northwest and Southwest showed progressive technical change in only 9 years.

The economic reforms have brought considerable change in input price and mix. Use of modern agricultural inputs (chemical fertilizers, machinery power) have increased significantly in this post-reform period as shown in the third block of table 1. This was also revealed by the increase in input bias, as displayed in the fifth block in table 2. That is, progress in the best-practice technology resulted essentially from input-biased technical change. In total, we found increases in input bias in 99 cases and decreases only in 6 cases. Five of the 6 cases with decrease in input-biased technical change were observed in the northern region. Percentage change in the input bias component among regions varied from an increase of 11% in the Northeast in 1989/90 to a decrease of 0.9% in the North in 1990/91.

The final block in table 2 presents annual percentage changes in the calculated Malmquist indices. Since no change in efficiency implies that productivity growth is identical to technical change, percentage changes in productivity for the regions were similar to the values for technical change, ranging from an increase of 17% in 1982/83 to a decrease of 14% in 1988/89 in the Northeast. Over all years for all regions, we found 73 cases with productivity growth and 32 cases with regression. Progressive productivity growth was observed for all regions in the period 1981/82 and 1983/84. The southern region experienced productivity growth in all periods, while the northwestern region had only 7 years with productivity growth. TFP regression occurred most frequently in the mid 1980s, a decrease of 0.5% between 1985/86 and 1988/89 for the country as a whole (see endnote 6). In contrast, average Malmquist index measures for the whole country increased by 4.0% between 1980/81 and 1984/85 and by 3.6% after 1989. The decline in productivity growth in the second half of the 1980s was caused by a slowdown in technological change, a decrease in real annual expenditures on agricultural research, the unfavorable effects of price policies on the farm sector, and environmental degradation as indicated by Lin (1992), Sicular (1995), Huang et al. (1995), Huamg and Rozelle (1995), and Lin et al. (1996).

In all, the productivity measures showed that production efficiency was common in post-reform Chinese agriculture. Differences in productivity growth among regions resulted primarily from the heterogenous technical change. New technology has been and will continue to be the engine of Chinese agricultural economic growth (also see Stone, 1988; Huang et al., 1995). To balance agricultural productivity among regions, policymakers need to focus on the measures of promoting technological development and adoption in the northwestern and southwestern regions. Achieving this goal would require greater investment in agricultural research, rural infrastructures, and education in these lagging regions along with technological transfer from the leaders (South and East).

4.2. Average Annual Changes: Average annual index value between 1980 and 1995 showed that productivity grew at 2.8% per year for the country as a whole (Table 3). The innovation effect augmented productivity growth by 3.0% per year, while the deteriorating efficiency performance reduced productivity by 0.2% per year. The greatest efficiency regression came from the North and Northwest, where efficiency decreased 0.8% annually.

The average annual rates of productivity change varied substantially among regions. The South, the most dynamic region in China, experienced the highest growth in productivity at 4.6% per year on average. This growth was due to progress in the best-practice frontier (4.5%) and moving closer to the frontier (0.1%). In contrast, the northwestern region, the most lagging inland area, showed a very slight gain in average annual productivity, only 0.5%. This resulted from technology boosting potential production by 1.3% annually. This was the smallest gain in potential output from technology of all the regions. Interestingly, this region did not maintain its efficiency level even with this small gain in productivity from technical progress. If this region had maintained its actual output at the same proportion of potential output (efficiency unchanged), the change in TFP would equal 1.3% per year, all due to progress in the best-practice technology. But, actually this region suffered a decrease in efficiency of 0.81%

annually. Therefore, the northwestern region fell further behind its potential and TFP grew at just 0.5% annually. This put the interregional comparison in productivity change between the leader (South) and the laggard (Northwest) at a ratio of about 9:1. Variations in average annual changes were much smaller than changes calculated for each year, because as Färe et al. (1990) noted, variations across years within the same region offset each other (also true for variations across regions within the same period).

<u>4.3. Cumulative Changes</u>: Figures 1 through 4 reveal that between 1980 and 1995 substantial productivity growth occurred in all regions except for the Northwest. The cumulative Malmquist productivity index measures indicate that TFP from 1980 to 1995 rose by 101% in the South, 86% in the East, 59% in the Northeast, 52% in the North, 46% in the Central, 38% in the Southwest, and only 7.7% in the Northwest (Figure 1). The cumulative changes due to shifts of the best-practice frontier in these regions were 98%, 86%, 59%, 72%, 46%, 38%, and 22%, respectively (Figure 2). The cumulative growth in the input bias component in the corresponding regions were 58%, 51%, 54%, 57%, 43%, 51%, and 59% (Figure 3). The cumulative efficiency changes among the regions above were 1.5%, 0%, 0%, -11%, 0%, 0%, and -11%, respectively (Figure 4). These results suggest that technological innovation rather than efficiency change was the driving force for the TFP growth in post-reform Chinese agriculture.

Let us take a closer look at regional productivity growth in figure 1. The southern region experienced the fastest growth in agricultural productivity, followed by the eastern region. The dynamic South was the leader in productivity and technological progress for the past 15 years except for 1981. The East had a slightly higher growth rate than the South in 1981 and since then it has been a close second to the South. The higher growth in the South and East resulted from an ideal geographic location for absorbing foreign investment, technology and managerial skills. The northwestern region lagged behind the other regions in productivity growth because of its backwardness, poor rural infrastructures, and inability to absorb investment and technology from more productive regions and foreign firms. Productivity growth did occur in the other regions over the period but growth did not occur in every year. In this post-reform period, the leader, the southern region, showed a systematic growth in productivity.[7] The laggard, the northwestern region, did not show a systematic trend for productivity growth. Growth in productivity was observed in all other regions although the growth was not sustained over all years.

It is evident from figure 1 that the gap or difference in productivity growth between the leader (South) and the laggard (Northwest) has been widening over time. For instance, the disparity in the cumulative Malmquist index between the leader and the laggard in 1982 were at a ratio of about 5:1. This ratio between the leader and the laggard widened to about 7:1 in 1985, about 11:1 in 1991, and 13:1 in 1995, respectively. This alarmingly widening gap occurred because the laggard has experienced roughly flat productivity while the leading region has shown phenomenal growth over the same period. Further, a divergence in growth of productivity also occurred between the leader and other regions. For instance, the comparison in cumulative Malmquist index measures between the South and the Northeastern region was about 1:1 in 1983 and widened to about 2:1 in 1995. In the base year of our study period, productivity in the South was greater than in other regions as evidenced by the value of output per hectare: 1,541, 1,246, and 861 yuan per hectare for the South, Northeast and Northwest, respectively. These results suggest divergence rather than convergence in agricultural productivity growth across regions in China over this time period.

The pace of TFP growth has not been steady over the past 15 years. In most regions productivity growth was rapid in the first half of the 1980s and slow in the mid 1980s. After 1989, productivity growth accelerated in all regions. The accelerating growth was most marked in the South and East and was slowest in the Northwest and Southwest. The resurgence of growth after 1989 was mainly due to reform measures favorable to the agricultural sector. Examples of these measures include raising grain prices, increasing investment in agricultural capital construction, and reducing the government procurement quota levels.

A substantial variation in productivity over this period was observed in the Northeast, ranging from an increase of 17% in 1982/83 to a decrease of 14% in 1988/89. This results from greater uncertainty in grain production in this region partly due to the weather vagaries. Over the last 15 years, for instance, the cultivated area in this region suffering serious damage from natural disaster ranged from a low of 1.3 million acres in 1983 to a high of 6.1 million acres in 1989. Accordingly, policies designed for this region should focus on reducing the adverse impact of natural calamities (e.g., better flood control and more timely harvest equipment).

4.4. Structural Change: Economic growth has been accompanied by major changes in economic structure. The timing of structural change during this post-reform period was investigated by regressing the natural logarithm of the cumulative Malmquist productivity change index on time and a structural-change dummy variable (Price and Weyman-Jones, 1996). We expressed the Malmquist index as a function of time and a structural-change dummy variable:

$$M_t = M_0 e^{(\alpha_1 + \alpha_2 D_t)t} \tag{11}$$

where M_t stands for the cumulative Malmquist productivity index, t is the time variable, D_t is a structural break dummy variable in period t. Sequential Chow tests (F-tests) were used to determine if there is a statistically significant change in the slope coefficient, i.e., a departure from a steady trend rate of growth. The sequential test was carried out by setting the dummy variable equal to zero before the break and equal to one thereafter and varying the period at which the break was believed to occur. The null hypothesis is that there is no structural break in the trend rate of Malmquist productivity growth in Chinese agricultural regions or H_0: $\alpha_2 = 0$.

The calculated *F*-values in table 4 showed that there were more changes in the underlying production structure in the South than in the followers and the laggard. This illustrates that the southern region maintained its leading position in productivity and technology with several periods of accelerating growth over the post-reform period. The northwestern region had only one structural change in 1991, which occurred much later than in any other region. This suggests that this region not only did not experience many accelerating growth periods but also showed a delayed response to economic reforms. Five regions out of the seven experienced structural change in 1986, which was one year after China started the price and urban economic reforms.

5. Conclusions

In spite of phenomenal growth in the overall economy, growing economic disparity among regions in China is a serious concern because of its significance to the welfare of the nation and political stability of the country. In this study, we analyze the regional economic disparity by examining total factor productivity (TFP) growth in Chinese agriculture during the economic transition period (1980-1995) using nonparametric Malmquist index procedures.

The results of this study show that the average growth in productivity during this post-reform period was 2.8% annually for the country as a whole. Technical progress or innovation advanced the growth by 3.0%, while the poor efficiency or catching-up performance reduced TFP growth by 0.2%. Substantial productivity growth was observed in all regions except in the Northwest. The dynamic South has played the leading role in productivity and technology for the past 15 years by changing its economic structure and absorbing investments, technologies, and modern managerial skills. The Northwest has lagged behind other regions with negligible growth in productivity. This region showed neither an upward trend from technical change nor a propensity to catch up with more productivity regions.

Evidence in this study suggests productivity divergence rather than convergence across regions in China during this post reform period. The leader South outstripped the other regions in TFP growth following reforms with an average annual increase in productivity of 4.6%. The laggard Northwest with a nearly flat 0.5% annual TFP growth apparently benefited less from reforms. Divergence in innovation rather than in efficiency seems to be the major factor for growing regional disparity in the agricultural sector. It is possible that this divergence might be an initial transitory part of a long-term productivity convergence process. Initially after reforms, some regions might catch up with world leaders more rapidly than other regions. These fast-growing regions are converging with the rest of the world. Eventually, the fast regions' growth might slow and the laggards could catch up. This might eventually result in convergence within China's regions. It would be interesting to test this hypothesis in future research. In any event, the divergence, while it exists, will have negative impacts for the welfare of the nation and for alleviating poverty in the country and cause regional political and economic fragmentation. Therefore, in the future agricultural policies and remedial measures should be more geographically oriented to address this disparity.

In the lagging Northwest and Southwest regions, measures such as adopting locally suitable technologies and organization from more productive regions and improving their resource allocations should be promoted. However, substantial catching up requires greater effort be sustained over a long period to build up human capital and rural infrastructures.

Consequently, policies should also encourage more domestic and foreign capital investment toward education and infrastructural development.

The results also indicate that, among the followers, particularly in the North, efficiency-enhancing practices should be promoted. The northeastern provinces, a very important grain producing region, should focus on reducing uncertainty in agricultural production by mitigating the adverse impacts of natural calamities. Application of modern agricultural inputs should be encouraged particularly in the central provinces because this region has made the least progress in input-biased technical change.

Market cooperation, economic integration, and technology transfer between the leading regions (South and East) and the laggards (Northwest and Southwest) should be stimulated. This is because the leading regions are relatively short in natural resources and are export-oriented. They are experiencing higher labor costs and strong pressure to transform production with capital-intensive methods. In contrast, the lagging regions are relatively rich in natural resources but lag in technology. Excessive delay in technology dissemination will handicap the welfare of the nation by widening economic inequality. However, this transfer should not impede the growth of the leading regions by undermining the economic incentives for their development.

The TFP growth disparity among regions indicates that production patterns should be adjusted in accordance with regional comparative advantage. Efficiency-enhancing measures such as regional specialization, interregional trade liberalization, and development of local market infrastructure should be promoted in all regions. Technological progress has been and will continue to be the key component of Chinese agricultural growth. Shifts in the best-practice frontier require developing new technologies, increasing investment in agricultural research, and improving agricultural infrastructure. Regional economic disparity, associated with the reforms in China, should be reduced in the process of economic development so that the welfare of all the people in the nation can be improved. This is possible only through marketization and increasing regional economic integration and cooperation.

Endnotes

1. The provinces that come under these seven regional classifications are as follows: Heilongjiang, Jilin, and Liaoning provinces in the Northeast; Shandong, Hebei, Henan, and Shanxi provinces and Beijing and Tianjin municipalities in the North; Shaanxi, Gansu, Nei Monggol, Ningxia, Xinjiang, and Qinghai provinces in the Northwest; Zhejiang, Jiangsu, and Anhui provinces and Shanghai municipality in the East; Hubei, Hunan, and Jiangxi provinces in Central; Guangdong, Guangxi, Fujian, and Hainan provinces in the South; and Sichuan, Guizhou, Yunnan, and Xizang provinces in the Southwest.

2. Regional delineation used by Fan (1991) differs slightly from this study in that Fan included Shaanxi and Xizang in the North and called the East as the Southeast. Additionally, he obtained the measure of productivity growth for each region by estimating a production function over the shorter-reform period (1965-85), while we obtained an index measure of productivity change for each region by not relying on a specific production function and using the data for the longer-reform period (1980-95).

3. See Färe and Grosskopf (1994) for more information about calculation of the indirect output-based and direct and indirect input-based Malmquist productivity indexes.
4. There was only one output in this study, thus, the output bias term is equal to one (see Färe and Grosskopf, 1996).

5. Irrigation input was measured by irrigated area with complete set of irrigation equipment to move adequate water to the fields under normal condition. Farm machinery (e.g., cultivators, plows, tractors, etc.) was measured by total kilowatts at the end of year. Manure fertilizer was computed using the number of farm animals and rural population by following Fan's procedure (footnote 8 in Fan, 1991). Chemical fertilizer referred the gross weight of nitrogen, phosphate, and potash fertilizers on an effective nutrient weight basis. Land input represented area sown under all crops. Labor input referred to the number of workers in the agricultural sector. Regional labor input before 1987 was derived using the procedure in Fan (footnote 4, 1991). Labor data for the period 1987-1995 was obtained from Eric Wailes and Cheng Fang.

6. Average technical change for all the regions and each of three subperiods (1980/81-1984/85, 1985/85-1988/89, and 1989/95) was computed using data in the fourth block in table 2. Average growth in the productivity for all the regions and each subperiod was calculated using data in the final block in table 2.

7. A trend analysis that regressed the natural logarithm of the cumulative Malmquist productivity index against the time variable was run for each region. The results showed that the slope coefficients (or the rate of growth) for all regions except for the Northwest were statistically different from zero at the 1% significance level.

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Table 1. Physical Characteristics, Means, and the Growth Rates of Agricultural Output and Inputs: 1980-95

	Variable	Northeast	North	Northwest	East	Central	South	Southwest	Country
Regional Features in 1993	Temperature (^{0}C)	7.4	12.8	8.4	15.8	16.7	22.1	16.1	14.2
	Precipitation (inches)	20.7	17.4	12.3	55.8	68.9	75.7	40.2	41.6
	Area sown per worker (ha.)	1.01	0.45	0.64	0.43	0.44	0.35	0.30	0.44
	Total land (mil. ha.)	78.5	66.8	405.6	33.9	55.4	57.5	227.9	925.7
	(%)	8.5	7.2	43.8	3.7	6.0	6.2	24.6	100.0
	Population (million)	104.4	289.8	105.9	184.8	159.3	149.0	186.3	1,177.4
	(%)	8.9	24.6	9.0	15.7	13.5	12.6	15.8	100.0
Mean Level of Output and Inputs during 1980-95	GVAP (million yuan)	33,960	83,308	28,989	59,709	46,990	40,901	46,743	340,600
	LABR (1,000)	15,556	73,870	25,424	47,182	44,286	38,780	65,364	310,462
	MACH (1,000 kilowatts)	24,489	87,974	24,979	41,846	26,150	23,985	19,492	248,915
	SAWN (1,000 hectares)	16,304	36,431	17,408	21,498	20,769	13,800	20,162	146,372
	IRRI (1,000 hectares)	2,539	13,507	6,509	7,901	6,724	4,244	4,550	45,974
	CHEM (1,000 tons)	2,075	6,118	1,609	4,224	3,130	2,844	2,568	22,568
	MANU (1,000 tons)	630	2,092	1,008	877	998	1,061	1,554	8,220
Average Annual Growth (%)	GVAP	6.67	7.02	7.66	6.84	5.84	8.28	6.01	6.90
	LABR	1.26	1.59	2.12	0.95	1.54	1.16	1.83	1.49
	MACH	4.11	7.36	5.19	5.83	4.78	7.24	6.55	5.86
	SAWN	-0.14	0.14	0.07	-0.35	-0.12	0.36	1.02	0.14
	IRRI	2.88	0.79	1.05	0.65	0.34	-0.66	0.55	0.80
	CHEM	6.34	7.95	10.74	6.10	7.58	7.09	6.44	7.46
	MANU	2.19	3.52	2.09	1.12	1.76	2.75	2.27	2.24

Source: *China Statistical Yearbook: 1994.* Beijing: China Statistical Publishing House. 1995.
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Socioeconomic Data and Application Center. ftp://ftpserver.ciesin.org/pub/data/china/adm-bnd/CTSAR90.bnd90/

[a]Temporatures and precipitations are yearly averages for major cities in each region; GVAP=gross value of agriculture output in constant 1980 price, excluding nonagricultural outputs; AGWK=the number of workers in the agricultural sector; MACH=farm machinery power; ASWN=area sown for all crops; IRRI=irrigated area; CHEM=chemical fertilizer; and MANU=manure fertilizer

Table 2. Percent Changes (%) in the Malmquist Productivity Index and Its Component Measures between Years *t* and *t*+1[a]

Region	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94	94/95	G[b]	R[b]
Percent Change in EC (Efficiency Change)																	
Northeast	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
North	-1.1	-3.3	3.0	-1.0	2.1	-4.0	7.9	-2.8	3.2	-3.0	2.2	-4.5	-3.1	3.8	-11.4	6	9
Northwest	0	0	0	0	0	0	0	0	0	0	-1.5	-4.2	1.1	-4.8	-2.7	1	4
East	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Central	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
South	0.1	1.4	0	-0.4	0.4	0	0	0	0	0	0	0	0	0	0	3	1
Southwest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G[b]	1	1	1	0	2	0	1	0	1	0	1	0	1	1	0	10	-
R[b]	1	1	0	2	0	1	0	1	0	1	1	2	1	1	2	-	14
Percent Change in SC (Scale Efficiency Change)																	
Northeast	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
North	-1.1	-3.3	3.0	-1.0	2.1	-4.0	7.9	-2.8	3.2	-3.0	2.2	-4.5	-3.1	3.8	-11.4	6	9
Northwest	0	0	0	0	0	0	0	0	0	0	-1.5	-4.2	1.1	-4.8	-2.7	1	4
East	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Central	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
South	0.1	1.4	0	-0.4	0.4	0	0	0	0	0	0	0	0	0	0	3	1
Southwest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G	1	1	1	0	2	0	1	0	1	0	1	0	1	1	0	10	-
R	1	1	0	2	0	1	0	1	0	1	1	2	1	1	2	-	14
Percent Change in PC (Pure Efficiency Change)																	
Northeast	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
North	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northwest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
East	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Central	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 2 (continuous)

Region	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94	94/95	G	R
Percent Change in PC (Pure Efficiency Change)																	
South	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Southwest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Percent Change in TC (Technical Change)																	
Northeast	-5.6	6.5	17.0	0.5	-9.3	4.2	0.4	6.5	-14.0	9.1	9.2	5.6	6.4	8.0	-4.3	11	4
North	4.4	4.6	4.8	9.2	1.4	0.1	1.3	2.1	-5.7	2.7	5.8	5.8	7.5	8.3	6.4	13	2
Northwest	5.3	1.4	-5.0	0.8	3.9	-2.6	1.4	-0.6	-10.7	-0.3	2.9	2.4	0.8	1.7	-3.9	9	6
East	6.3	6.9	-0.1	13.0	2.4	2.0	-0.2	1.1	-1.2	1.1	-0.8	11.6	8.5	7.3	6.9	11	4
Central	3.0	4.8	-2.2	8.6	1.2	-4.9	-0.3	-4.6	1.7	3.1	7.5	5.5	4.5	4.1	-1.4	10	5
South	6.2	11.3	3.6	8.6	9.0	0.8	6.5	1.0	2.9	2.7	6.5	7.8	6.1	6.3	7.9	15	0
Southwest	1.5	8.0	1.1	5.9	0.1	-3.2	2.2	-1.2	-3.6	-1.1	11.5	0.5	-1.9	-9.0	7.9	9	6
G	6	7	4	7	6	3	5	4	2	5	6	7	6	6	4	78	-
R	1	0	3	0	1	4	2	3	5	2	1	0	1	1	3	-	27
Percent Change in IB (Input Bias)																	
Northeast	8.0	6.1	7.0	6.8	4.8	4.5	3.2	2.4	3.9	11.3	4.0	2.2	2.7	5.3	2.8	15	0
North	0.1	-0.1	-0.8	0.5	0.1	0.1	0.1	-0.3	0.7	-0.6	-0.9	0.1	1.5	0.1	1.9	10	5
Northwest	1.7	4.9	4.5	2.0	1.2	2.2	1.4	2.5	2.9	2.9	0.8	0.1	0.2	0.1	-0.1	14	1
East	3.5	5.0	3.1	3.1	2.5	4.0	3.2	4.1	2.0	2.6	0.9	1.7	2.8	3.1	3.0	15	0
Central	1.7	4.9	1.8	1.9	1.4	2.3	1.1	0.5	0.2	1.7	0.8	0.8	1.2	1.9	3.0	15	0
South	1.5	1.5	1.9	0.9	2.2	2.7	5.0	3.6	3.0	1.7	2.5	2.6	3.8	2.8	4.1	15	0
Southwest	2.8	2.2	6.4	4.0	4.0	7.1	5.6	3.8	5.1	4.6	4.6	1.2	3.5	1.8	0.9	15	0
G	7	6	6	7	7	7	7	6	7	6	6	7	7	7	6	99	-
R	0	1	1	0	0	0	0	1	0	1	1	0	0	0	1	-	6

Table 2 (continuous)

Region	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94	94/95	G	R
Percent Change in MC (Magnitude Component)																	
Northeast	-13.6	0.5	10.0	-6.3	-14.0	-0.3	-2.9	4.1	-17.9	-2.1	5.2	3.4	3.7	2.8	-7.0	7	8
North	4.2	4.6	5.5	8.7	1.3	-0.1	1.2	2.4	-5.9	3.3	6.7	5.7	6.0	8.2	4.5	13	2
Northwest	3.6	-3.5	-9.5	-1.2	2.7	-4.8	-0.1	-3.1	-13.6	-3.1	2.1	2.3	0.6	1.6	-3.8	6	9
East	2.8	1.9	-3.2	9.9	0.1	-2.1	-3.4	-3.0	-3.2	-1.4	-1.6	9.9	5.7	4.3	3.9	7	8
Central	1.3	-0.2	-4.0	6.7	-0.3	-7.3	-1.4	-5.1	1.5	1.4	6.7	4.7	3.2	2.2	-4.5	8	7
South	4.6	9.8	1.6	7.8	6.8	-2.0	1.4	-2.7	-0.1	1.0	4.0	5.3	2.3	3.4	3.9	12	3
Southwest	-1.3	5.8	-5.3	2.0	-4.0	-10.2	-3.6	-5.0	-8.7	-5.8	7.0	-0.8	-5.4	-10.7	7.0	4	11
G	5	5	3	5	3	0	2	2	1	3	6	6	6	6	4	57	-
R	2	2	4	2	4	7	5	5	6	4	1	1	1	1	3	-	48
Percent Change in M(•) (Malmquist Productivity Change Index)																	
Northeast	-5.6	6.5	17.0	0.5	-9.3	4.2	0.4	6.5	-14.0	9.1	9.2	5.6	6.4	8.0	-4.3	11	4
North	3.2	1.3	7.8	8.2	3.4	-4.0	9.2	-0.7	-2.0	-0.3	8.0	1.2	4.4	12.1	-5.0	10	5
Northwest	5.3	1.4	-5.0	0.8	3.9	-2.6	1.4	-0.6	-10.7	-0.3	1.4	-1.8	1.9	-3.1	-6.6	7	8
East	6.3	6.9	-0.1	13.0	2.4	2.0	-0.2	1.1	-1.2	1.1	-0.8	11.6	8.5	7.3	6.9	11	4
Central	3.0	4.8	-2.2	8.6	1.2	-4.9	-0.3	-4.6	1.7	3.1	7.5	5.5	4.5	4.1	-1.4	10	5
South	6.2	12.7	3.6	8.2	9.4	0.8	6.5	1.0	2.9	2.7	6.5	7.8	6.1	6.3	7.9	15	0
Southwest	1.5	8.0	1.1	5.9	0.1	-3.2	2.2	-1.2	-3.6	-1.1	11.5	0.5	-1.9	-9.0	7.9	9	6
G	6	7	4	7	6	3	5	3	2	4	6	6	6	5	3	73	-
R	1	0	3	0	1	4	2	4	5	3	1	1	1	2	4	-	32

[a]Changes in the Malmquist productivity index and its component measures between years t and t+1 were calculated from $Ln(M(\bullet)) = Ln(EC) + Ln(TC)$, $Ln(EC) = Ln(SC) + Ln(PC)$, and $Ln(TC) = Ln(IB) + Ln(MC)$, respectively.

[b]G = the total number of positive changes in each region across time period (or in each time period across all regions) and R = the total number of negative change sin each region across time period (or in each time period across all regions)

Table 3. Average Annual Change in Productivity Growth and its Components: 1980-95

Region	EC	SC	PC	TC	IB	MC	M(•)
	--			(%)	--		
Northeast	0.00	0.00	0.00	3.07	2.88	0.20	3.07
North	-0.81	-0.81	0.00	3.60	3.00	0.60	2.79
Northwest	-0.81	-0.81	0.00	1.30	3.09	-1.78	0.50
East	0.00	0.00	0.00	4.12	2.75	1.37	4.12
Central	0.00	0.00	0.00	2.54	2.37	0.17	2.54
South	0.10	0.10	0.00	4.54	3.06	1.48	4.64
Southwest	0.00	0.00	0.00	2.13	2.75	-0.62	2.13
Average	-0.22	-0.22	0.00	3.04	2.84	0.20	2.83

Note: EC = efficiency change, SC = scale efficiency change, PC = pure efficiency change, TC = technical efficiency change, IB = input-biased technical change, MB = magnitude component change, and M(•) = change in the Malmquist productivity index.

The average annual changes were calculated from $Ln(M(\bullet)) = Ln(EC) + Ln(TC)$, $Ln(EC) = Ln(SC) + Ln(PC)$, and $Ln(TC) = Ln(IB) + Ln(MC)$ where the Malmquist productivity index and its component measures were computed using the data from 1980 and 1995. For instance,

$$EC = \left[\frac{D^{1995}\left(x^{1995}, y^{1995}\right)}{D^{1980}\left(x^{1980}, y^{1980}\right)}\right]^{\frac{1}{15}} \quad and \quad TC = \left[\left(\frac{D^{1980}\left(x^{1995}, y^{1995}\right)}{D^{1995}\left(x^{1995}, y^{1995}\right)}\,\frac{D^{1980}\left(x^{1980}, y^{1980}\right)}{D^{1995}\left(x^{1980}, y^{1980}\right)}\right)^{\frac{1}{2}}\right]^{\frac{1}{15}}$$

Table 4. Structural Change Test for Chinese Agricultural Regions: 1980-1995
(Calculated F-values in the Table, critical $F_{0.05, 1, 13} = 4.67$)

Break in	Northeast	North	Northwest	East	Central	South	Southwest
1981	0.011	0.445	0.625	1.696	0.605	6.164	1.229
1982	1.931	0.909	0.319	1.499	0.788	12.119	3.368
1983	1.506	3.375	4.266	0.324	0.014	1.427	0.596
1984	1.108	0.110	0.518	0.334	0.281	0.177	0.147
1985	8.291	1.386	0.072	1.482	1.268	0.636	1.375
1986	3.254	6.262	0.996	8.727	7.339	6.920	4.912
1987	1.731	0.568	0.291	15.870	3.446	10.525	5.407
1988	0.623	0.828	0.451	11.094	3.402	22.335	3.322
1989	0.475	0.688	0.357	4.632	1.590	9.107	0.739
1990	1.103	0.038	1.238	0.535	0.014	2.950	0.002
1991	2.411	0.295	8.364	0.187	3.272	0.525	0.637
1992	1.994	0.055	4.505	1.672	1.730	0.541	0.033
1993	1.167	0.238	2.697	2.318	0.368	0.936	0.870
1994	0.466	0.295	0.713	1.696	0.028	0.919	2.359
1995	0.004	4.201	0.162	0.439	0.041	0.034	0.003

Note: The F-test (Chow test) was used to determine if there is a statistically significant change in the slope coefficient:

$$F = \frac{RSS_r - RSS_u}{RSS_u/(n-3)},$$

where RSS_r and RSS_u are the residual sums of squares for the restricted and unrestricted cases, respectively.

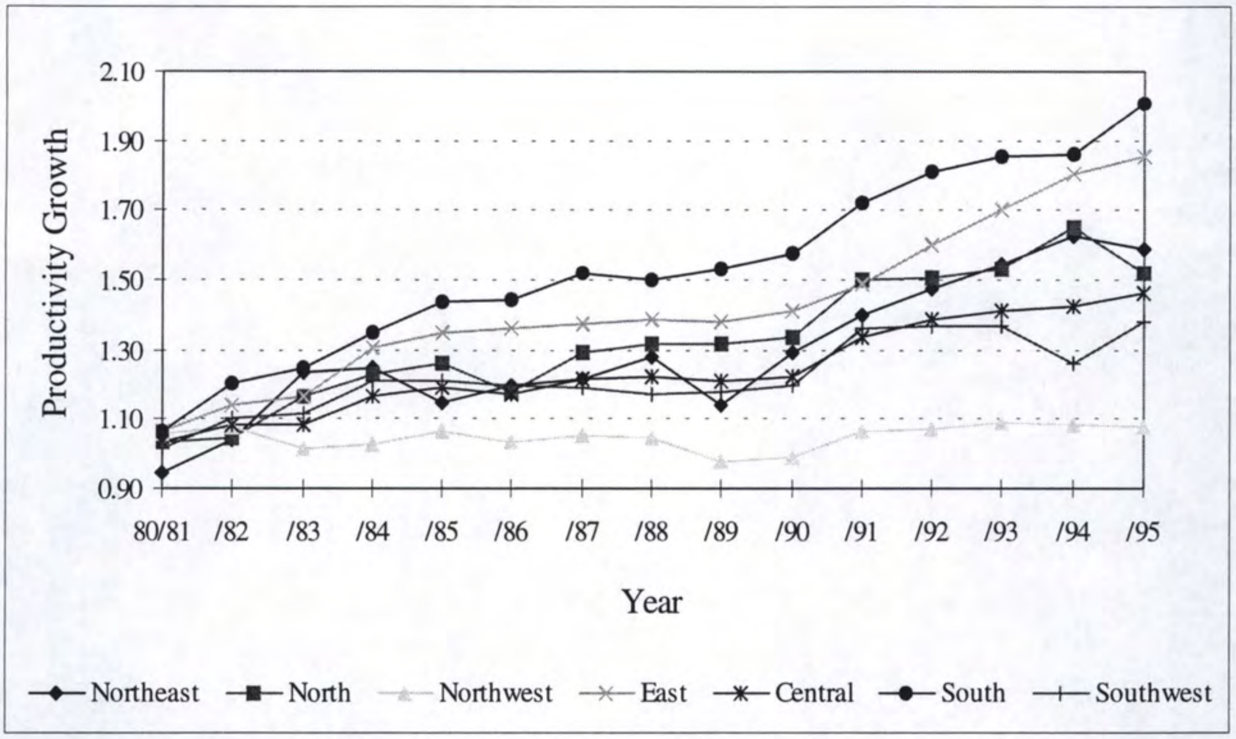

Figure 1. Cumulative Productivity Growth among Regions

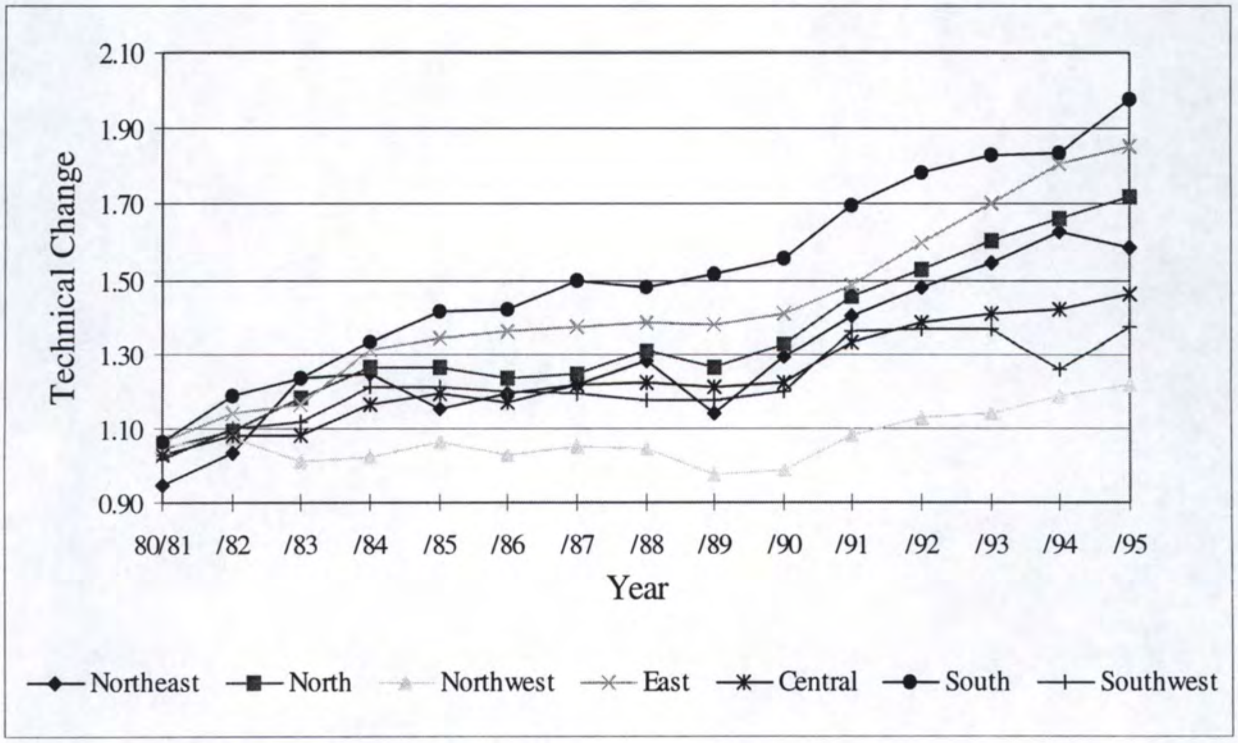

Figure 2. Cumulative Technical Change among Regions

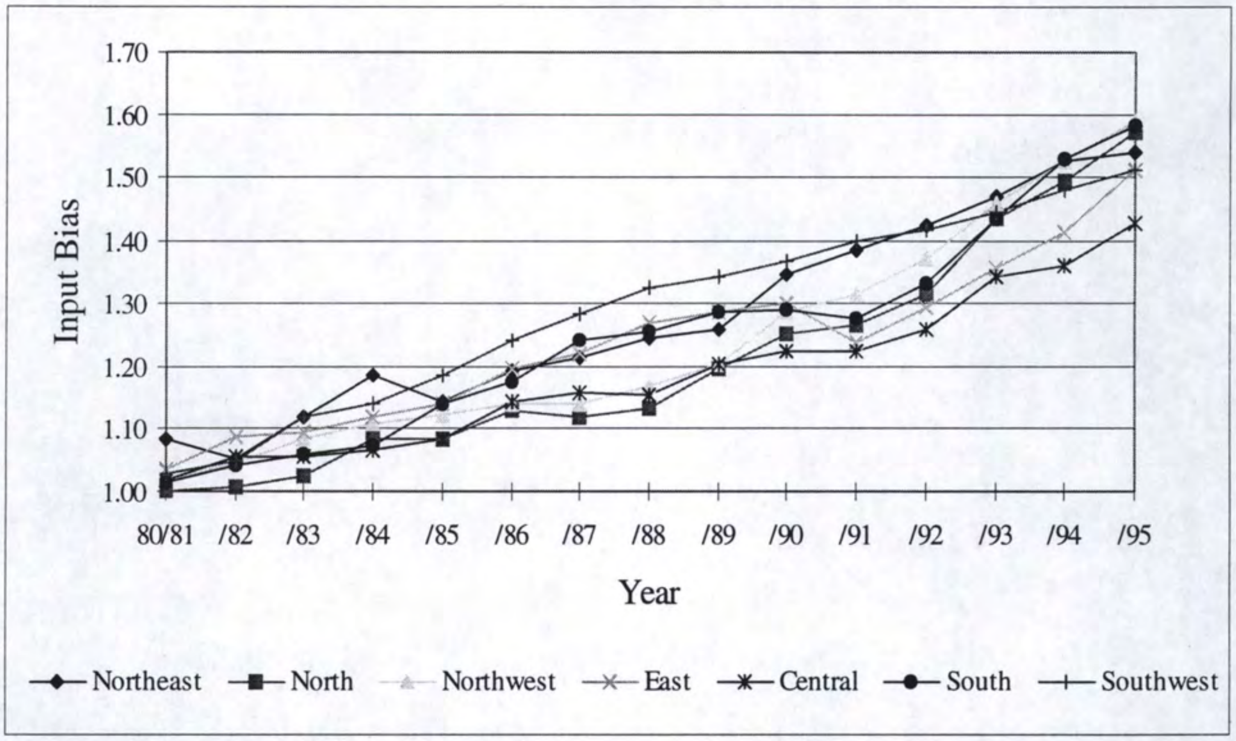

Figure 3. Cumulative Input Biased Technical Change among Regions

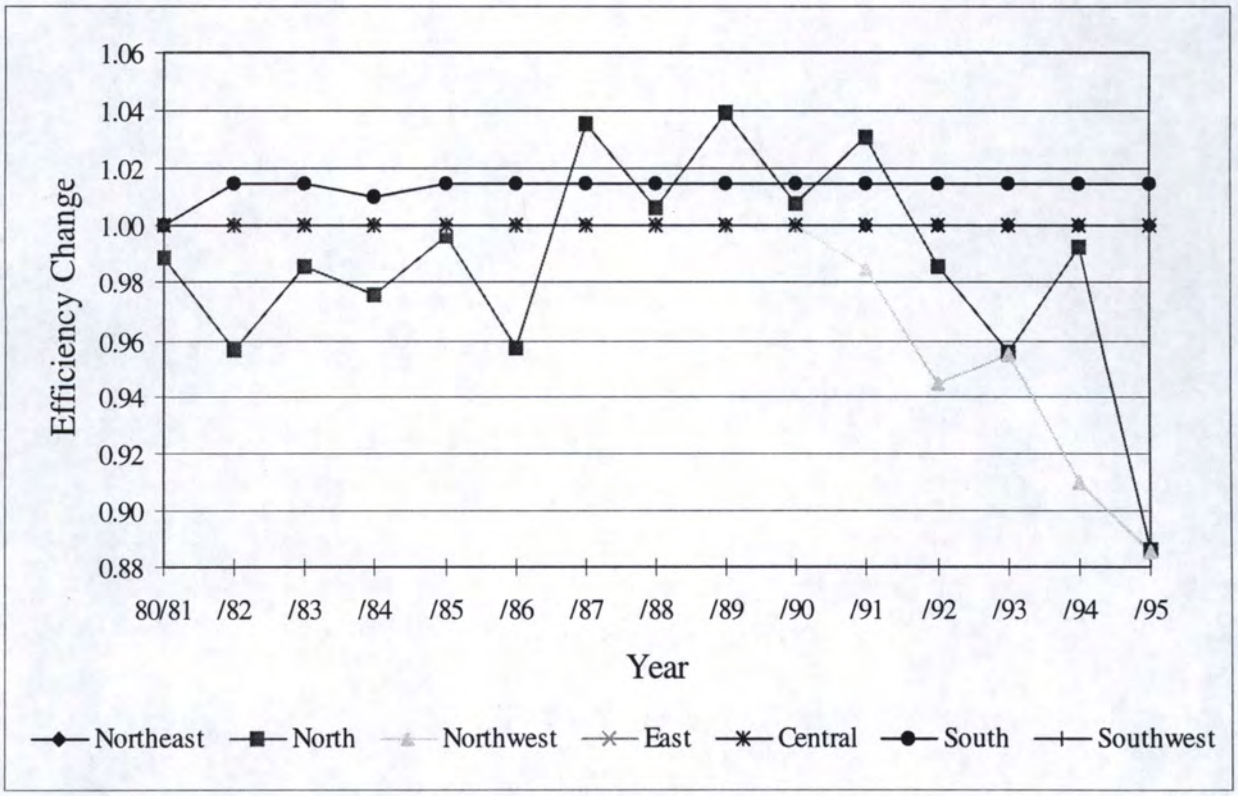

Figure 4. Cumulative Efficiency Change among Regions