Policy reform and productivity change in Chinese agriculture:

A distance function approach

Bernhard Brümmer, Thomas Glauben and Wencong Lu

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Contact:

Bernhard Brümmer
Agricultural Economics
University of Göttingen
D-37073 Göttingen
Germany
bbruemm@gwdg.de

Thomas Glauben
Institute of Food Economics
University of Kiel
D-24098 Kiel
Germany
tglauben@food-econ.uni-kiel.de

Wencong Lu
Department of Agricultural Economics
Zhejiang University
310029 Hangzhou, Zhejiang
China
wenclu@zju.edu.cn

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Abstract

Agricultural policy reform has been an important source of change in the Chinese agricultural sector. The reforms led to productivity growth and helped China in pursuing its self-sufficiency goal especially in the grain sector. To analyse whether observable productivity growth stems from technologically induced components, or from the market induced parts, a multi-input-multi-output model is derived using an econometric distance function framework. A decomposition allows to distinguish allocative effects, scale effects, technological change, and technical efficiency change. Data on farms in Zhejiang from 1986 to 1999 are used to analyse the impact of policy reform.

Keywords: Productivity growth, China, Policy reform, Distance function.

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Introduction

On November 10, 2001, the WTO's Ministerial Conference approved the text of the agreement for China's entry into the World Trade Organization. Several issues are involved that are expected to play a key role in the future development of agricultural world markets. The most immediate impact on world markets will probably come from the fact that China committed itself "…not [to] maintain or introduce any export subsidies on agricultural products" (WTO, 2001). However, the impact of such commitments will strongly depend on China's net trade position. The agricultural trade balance, in turn, will also depend on the structural development of the domestic sector. While an upper bound on domestic support has been agreed upon (8,5 % of the value of total farm output), the policy implementation of the remaining domestic support will be of crucial importance for China's success in rural economic reform and thus for rural economic growth and structural change. Increasing productivity will be a decisive factor in determining China's rural development over the next decades, hence it seems to be useful to examine in which way rural reforms did affect the sector's productivity in the past.

Several studies address the impact of reform policies on productivity growth in China. McMillan, Whalley, and Zhu (1989) study the impact of the household responsibility system on agricultural production. Stavis (1991) examines the market reforms and changes in agricultural productivity during the first reform period. The annual growth rate of total factor productivity was 3.7 % during 1980-84, and dropped to 2.2 % per annum in the year 1985-89. Lin (1992) reports that productivity growth during 1978-84 explained about 50 % of output growth. He also found that 96 % of the change in productivity was attributable to the institutional change to the household responsibility system. Furthermore, Huang (1992) and Nguyen and Wu (1993) report that the growth rate of the farm sector declined in the second half of the 1980's because productive resources were shifted out of the farming sec tor.

More recently, several authors begun to decompose productivity change in Chinese agriculture into technical and allocative efficiency, and technical progress. Fan (1990) estimates land, labor and total factor productivity at both the national and regional level. He argues that 70 % of the observable productivity growth over the period 1965-86 could be explained by an increase in input use. The remaining part stems in equal shares from technical efficiency change and technical change. Wu (1992) covers the period 1985-91 and found, that over 70% of total factor productivity (TFP) growth was due to technical change, but the contribution of technical efficiency declined or even became negative in the late 1980's. Kalirajan, Obwona, and Zhao (1996) estimated a varying coefficient production frontier and found that TFP growth in the reform periods was positive in most provinces. Carter and Estrin (2001) estimate a multiple-output stochastic production frontier using aggregate data from 1986 to 1995. They argue that grain self-sufficiency policies and incomplete market reforms in the 1980s and 1990s led to allocative inefficiency. Further, agricultural disinvestments led to inward movements of the production frontier, and fragmentation of land holdings reduced technical efficiency.

This study is devoted to the identification and measurement of the components of productivity development in Chinese farming sector during the 1980s and 1990s reform periods. To control for productivity adjustments related to changes in technical and allocative efficiency, economies of scale, and technical progress, we decompose the traditional index of *TFP* growth into these components. Since, disagreement about the (relative) importance of technical versus allocative efficiency remains in the literature (Carter and Estrin, 2001), we focus on the efficiency impact of the rural reforms. The consideration of allocative effects regarding the outputs necessitates the modelling of a multi-output technology. Thus, we use an output distance function approach. A parametric output distance function is estimated using individual farm household data over the period 1986-2000 from several regions in the province Zhejiang.

We extend the literature along the following main lines. First, in contrast to Carter and Estrin (2001) we use individual household data to estimate the multi-output technologies in Chinese agriculture. Second, the distance function approach does not require behavioral assumptions (cost minimization or profit maximization) to provide a valid representation of the underlying production technology. This might be advantageous for the Chinese farming sector because at least in the beginning of the observation period numerous restrictions still hindered the functioning of markets. On the other hand the policy reforms over the observation period induce drastic changes in market conditions which renders the assumption of maximizing behavior questionable. Theses problems have been recognized by Wang, Wailes and Cramer (1996) who extend the standard dual profit function approach by means of shadow prices, thus allowing for allocative efficiency. Finally, some authors (Chen, Davis and Wang, 1997; Carter and Estrin, 2001) suggest that small farm size and land fragmentation prevent households from realizing scale economies and thus in turn lead to technical inefficiency. In the spirit of nonparametric decomposition procedures, our approach allows the to separate scale inefficiency from technical inefficiency which are theoretically distinct concepts (see section 'Theoretical framework'). Therefore, we explicitly distinguish between these two sources of productivity growth and separate scale effects from technical efficiency in the decomposition of total factor productivity change.

The plan of the paper is as follows. The following section gives an overview of the different policy reforms in China over the last two decades. The next section presents the theoretical framework before data and empirical specification are discussed. The empirical results are presented and analyzed in the subsequent section, followed by the last section concludes with the main findings of the study.

Agricultural policy reform in China

Agricultural reform in the past twenty years can be roughly divided into five periods. The first period, 1979 to 1984, coincides with the introduction of the household responsibility system (HRS) and adjustments in the state purchase price for agricultural products (Wu, 1997). Although these quota price adjustments exhibited no unique direction in each year, the overall development of the terms of trade for grain and oilseeds showed an overall improvement. Together with the price increase, the procurement quota for grain and oil crops was successively decreased. Local free markets and fairs were gradually given permission to re-open as an outlet for farm surpluses. That is, after the fulfillment of the state procurement quotas, most products could be exchanged in relatively deregulated local markets at prices higher than the quota price. Before economic reform, state commercial enterprises and marketing co-operatives had the exclusive entitlement to purchase grain and oil crops. By 1984, the share of state marketing dropped down to 91 percent for the 12 most important crops and livestock products. The overall agricultural output, in particular grain and oil crops, increased significantly.

In the beginning of the second reform period (1985 – 1989), a program was introduced to further enhance the functioning of rural markets, i.e., prices and quantities were to be determined – at least partially – by market mechanisms (e.g. Yao, 1994). However, over this relative long period the issue of policy reform was in the focus of policy discussions, and frequent adjustments of agricultural policies occurred – sometimes in favor of market liberalization but sometimes also adversely affecting previous achievements. The debate was particularly intense in the second half of the 1980s when the rate of growth of agricultural production fell. It was further acerbated in the beginning of the 1990s when increases in agricultural prices affected inflation, thereby causing macroeconomic problems.

In particular, in 1985 the marketing of many products, including animal products, fruit and vegetables, was deregulated, and a voluntary procurement contract for rice, wheat and maize was introduced. The procurements quickly lost its voluntary character following a decrease in grain production so that contracts were mandatory again in 1986. A significant share of key commodities such as grain, oil crops, cotton remained subject to state price controls and obligatory contract purchase or procurement quota rules. Later in 1986, the procurement quota for grain was partly reduced. In addition, a new subsidy system for fertilizer and fuel was introduced for the cultivation of grain and oil crops to encourage higher production of these crops. The introduction of the rural market program led to stagnating agricultural production stagnated and decreasing grain production. This observation might be partially explained by the fact that – contrary to the first reform period – labor mobility was allowed for, hence a labor outflow from agriculture took place.

Following criticisms of the impact of the rural market program, the government introduced a set of adjustment policies, the third regime, starting in 1990 (OECD, 1995). Apart from constraints put on the development of rural industry, the government implemented further reform in the grain sector, aimed at phasing out the old centrally planned 'purchase and supply' system in favor of more market oriented solutions. For example, purchase and selling grain prices were equated, i.e., grain and oilseed price subsidies to urban dwellers were eliminated. Further, interregional grain transfers which had been previously arranged by the central government were now replaced by a contract system between provincial governments. The government reformed the input supply system by removing subsidies and allowing private firms to supply inputs to producers. Also, the system of in-kind-supplies of fertilizers and fuel for deliveries of grain and oil crops to the state agencies was converted to monetary payments. These policy measures aim at partially substituting governmental interference in markets by functioning market forces, thus to avoid government failure due to information problems. However, market reform in agriculture remained incomplete, reflected by the different degrees of price and quantity controls in different sub-sectors (grain, cotton and oil corps vs. livestock and vegetables), by the segmentation of regional agricultural markets, and by the isolation of domestic markets from international markets.

Policy developments in 1994 initiated the fourth reform period (1994-1998). The direction of reform in this period is more unambiguous. Most reforms aimed at a rebirth of self-sufficiency policies, not only at the national level but also at the regional level (i.e., by province) (OECD, 1995). In particular, it was not allowed that relatively developed regions (e.g. Zhejiang) purchased grain from other regions. Furthermore, private grain traders were not allowed to buy grain from farmers before the latter had fulfilled their respective state purchase contract. To promote regional self-sufficiency, the so-called "Governor's' responsibility system" was introduced in 1995, holding the provincial leadership ultimate responsible for maintaining the overall balance of grain supply and demand. Admissible policy instruments included stabilization of planting area, output, and stocks, as well as the installation of local reserves to directly regulate grain markets and stabilize prices. Not surprisingly, some local governments have reintroduced command purchase and others have set barriers to regional grain trade. In effect, the rural market reforms for grain, oil crops and cotton were largely reversed. Some progress, however, was still made with respect to grain and cotton procurement policy. First, state procurement prices for grain and cotton increased substantially, in line with other market price changes (Huang, 1998). Both the state procurement prices for grain and cotton doubled between 1993 and 1996. Thus, the gap between the regulated quota procurement prices and market prices (for grain) narrowed substantially. In 1997, market prices even fell below the quota prices, first in the spring for corn and later in the year also for wheat and rice. In order to protect the interest of grain producers and to meet food security goals, the central government launched a price support policy and set a support price level for all grains (grain support program). In addition, subsidies were provided to the state grain marketing enterprises.

In order to reduce the financial burden of the grain support program, the central government planned to deepen the reform in the grain marketing area. In May 1998, the "new" grain reform was officially announced, marking the end of the fourth reform period. The new policy was summarized as "four separations and one improvement". The four separations set for grain marketing include separating: "government policy from commercial business functions"; "central grain reserves from local commercial reserves"; "central and local responsibilities on grain marketing" and "new debts from old debts". The one improvement means that quota procurement prices are determined by the prevailing market price.

At the beginning of this actual reform period, the original idea of the reform was to introduce a transition period before total liberalization of the grain sector. However, the huge government debt caused the direction of the grain marketing reform to make a surprising change. The central government announced a means of simultaneously recovering the huge government debts, and raising market prices over state procurement prices. This involves tightening up the country's grain marketing system and returning it to government monopolistic control. Currently, only state grain enterprises are allowed to procure grain from farmers, with private dealers only permitted to retail grain that is purchased from the government grain marketing agencies.

Theoretical framework

The analysis of productivity growth under various policy measures requires a detailed modelling of the underlying production technology. As outlined above, the policy reforms were quite different for the sub-sectors within agriculture. To capture the distinct effects for different outputs, the modelling approach should allow for multiple outputs. Further, to identify and measure the sources of productivity change during the 1980s and 1990s reform periods, we decompose the traditional index of total factor productivity growth into technical and allocative efficiency, a scale effect and technical change.

To achieve these requirements we start from the output distance function (Shephard, 1970; Färe, 1988). The output distance function treats inputs as given and expands output vectors as long as the expanded vectors are still technologically feasible. In terms of the output correspondence, which maps each possible vector x^t to an output set $P^t(x^t)$ (see Färe and Primont, 1995, p. 11), the output distance function is given by $D_O^t\left(x^t, y^t\right) = \inf_{\phi}\left\{\phi > 0 : y^t/\phi \in P^t\left(x^t\right)\right\}$ for all $x^t \in \Re_+^K$, where $D_o^t\left(x^t, y^t\right)$ is non-decreasing, convex, and linearly homogeneous in outputs, and non-increasing and quasi-concave in inputs (see Färe and Primont). It gives the reciprocal of the maximum proportional expansion of the output vector y^t, given inputs x^t, and characterizes the technology completely. $D_o^t\left(x^t, y^t\right)$ will take a value which is less than or equal to one. Figure 1 illustrates the distance function in output space for the case of two outputs.

Figure 1 about here

The output set *P(x)* in Figure 1 is bounded by the production possibility curve which describes the technically efficient points of production for each output combination, given the factor endowment *x*. To obtain the value of the distance function, each observed point of production is scaled radially towards the boundary of the output set.

Based on a particular representation of the production technology, it is possible to derive various decompositions of productivity growth (e.g., Kumbhakar and Lovell, 2000; Carter and Estrin, 2001; Brümmer, Glauben and Thijssen, 2002). The decomposition in the framework of an output distance function utilizes the fact that the reciprocal of the distance function has been proposed as a measure of technical efficiency (Farrell, 1957). In particular, the reciprocal of the output distance function is equal to the Farrell-type output orientated measure of technical efficiency (*TE*) as: $D_O^t(x^t, y^t) = 1/TE \Leftrightarrow \ln D_O^t(x^t, y^t) + \ln TE = 0$. Replacing the output measure of technical efficiency *TE* with an exponential non-negative error term u and totally differentiating leads to $\sum_{m=1}^{M}\frac{\partial \ln D_O}{\partial \ln y_m}\dot{y}_m + \sum_{k=1}^{K}\frac{\partial \ln D_O}{\partial \ln x_k}\dot{x}_k + \frac{\partial \ln D_O}{\partial t} + \frac{\partial u}{\partial t} = 0$, where a dot over a variable indicates the respective growth rate. Defining $\frac{\partial \ln D_O}{\partial \ln y_m} = \mu_m$ and $\frac{\partial \ln D_O}{\partial \ln x_m} = -\lambda_k RTS$, where RTS denotes returns to scale[1], and considering the conventional divisia index for TFP growth $T\dot{F}P = \sum_{m=1}^{M} R_m \dot{y}_m - \sum_{k=1}^{K} S_k \dot{x}_k$[2], we get, after some manipulations, the decomposition formula of productivity growth for multiple outputs:

$$T\dot{F}P = \sum_{m=1}^{M}(R_m - \mu_m)\dot{y}_m + \sum_{k=1}^{K}(\lambda_k - S_k)\dot{x}_k + (RTS-1)\sum_{k=1}^{K}\lambda_k \dot{x}_k - \frac{\partial \ln D_o(.)}{\partial t} - \frac{\partial u}{\partial t} \qquad (1)$$

The relationship in equation (1) decomposes observable factor productivity growth into an output price effect $\left(\sum_{m=1}^{M}(R_m - \mu_m)\dot{y}_m\right)$, an input price effect $\left(\sum_{k=1}^{K}(\lambda_k - S_k)\dot{x}_k\right)$, a scale effect $\left([RTS-1]\sum_{k=1}^{K}\lambda_k \dot{x}_k\right)$, a technical change effect $\left(-\frac{\partial \ln D_O}{\partial t}\right)$, and a technical inefficiency change effect $\left(-\frac{\partial u}{\partial t}\right)$.[3]

Figure 2 illustrates last two components (technical change and change in technical efficiency) for the case of two outputs and constant factor endowment x. From period t to $t+1$ a proportional output growth is observed. The instantaneous rate of output growth can be measured by the ratio $\ln\frac{OC}{OA}$. Technical change leads to a change in the output set from $P^t(x)$

[1] Returns to scale (*RTS*) are defined as in Färe and Primont.
[2] Here, R_m is the revenue share of output y_m and S_k is the cost share of input x_k.
[3] In order to decompose *TFP* growth according to equation (1), we require knowledge on the growth rates of inputs and outputs, and the observed revenue (R_m) and cost shares (S_k). These measures are directly calculated from the data. Furthermore, we need the elasticities of the distance function with respect to inputs and outputs, and time. These are required for the calculation of the parameters μ_m, λ_k, *RTS,* and technical change. The calculation is then based on the coefficients that result from the estimation of the econometric model. According to their definitions, each of these quantities is derived from the corresponding distance function elasticity. Returns to scale are then calculated as the negative sum of distance elasticities with respect to the inputs[3].

to $P^{t+1}(x)$. The related change in the distance function is represented by a change from $D^t_o(x,y^{t+1})$ to $D_o^{t+1}(x,y^{t+1})$.[4] In the figure, the instantaneous rate of technical change is represented by $\ln\frac{OD}{OB}$. Efficiency change measures the producer capacity to improve technical efficiency from period t to period $t+1$, and is represented by a change from $D^t_o(x,y^t)$ to $D_o^{t+1}(x,y^{t+1})$. We can evaluate the instantaneous rate of output-oriented technical efficiency change by $\ln\frac{OD/OC}{OB/OA}$. Technical change minus technical efficiency change yields then again the rate of output growth.

Figure 2 about here

The price effects are caused by the violation of the first order conditions (f.o.c.'s) for profit maximization[5] (Kumbhakar and Lovell, 2000, Brümmer, Glauben, and Thijssen, 2002). These allocative effects might occur if market imperfections exist (e.g. transaction costs, risk, quantitative restrictions, incomplete information, or mark-ups) or if the implied assumption of profit maximization behavior is inadequate. The allocative components account for

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Finally, the change in technical efficiency is obtained as the difference in the individual technical efficiency estimates from year to year.

[4] Alternatively, technical change could also be evaluated at y^t. In Figure 2, this makes no difference; however, if the output growth is not proportional, the two approaches will generally yield different results. In the Malmqvist productivity index literature, a geometric mean is usually used as the preferred indicator of technical change.

[5] To clarify the allocative effects for outputs ($R_m - \mu_m \neq 0$) and inputs ($\lambda_k - S_k \neq 0$) in equation (1), we can derive the stationary solutions of the following simple profit maximisation approach: $\max \sum_m p_m y_m - \sum_k w_k x_k$ subject to $D_O(x,y) = 1$. The resulting $M+N+1$ first order conditions from the corresponding Lagrangian are $0 = p_m - \theta \frac{\partial D_O}{\partial y_m}$ (i); $0 = -w_k - \theta \frac{\partial D_O}{\partial x_k}$ (ii); and $0 = D_O - 1$ (iii). Summing up the first M equations in (i), and utilising Euler's theorem and linear homogeneity in outputs of the distance function, we see that total revenue must be equal to the Lagrange multiplier θ: $\sum_m p_m y_m = \theta \sum_m \frac{\partial D_O}{\partial y_m} y_m = \theta$. Using this latter identity, we can express the output share R_m in terms of the logarithmic derivative of the distance function: $R_m = p_m y_m \big/ \sum_m p_m y_m = \theta \frac{\partial D_O}{\partial y_m} y_m \frac{1}{\theta} = \frac{\partial \ln D_O}{\partial \ln y_m} \equiv \mu_m$. We can apply a similar procedure to the K first order conditions for the inputs (ii). Summing up these K equations and considering the definition of returns to scale (RTS) leads to the identity $\sum_k w_k x_k = -\theta \sum_k \frac{\partial D_o(.)}{\partial x_k} x_k = \theta \cdot RTS$. The cost share S_k has to be equal to the

differences between the observed revenue and cost shares of outputs and inputs which determine the conventional *TFP* divisia index, and their corresponding shadow shares, as derived from the distance function elasticities. Hence, these allocative effects represent the part of TFP change that is not determined technologically. Although they are caused by market or behavioral conditions, these components are elements of a technological productivity measure. To summarize, the following is true for the allocative effects regarding output m and input k in the decomposition formula given in (1):

$$\left.\begin{matrix} R_m - \mu_m \\ S_k - \lambda_k \end{matrix}\right\} =: \begin{cases} = 0 & no \;\; f.o.c. \;\; violation \\ \neq 0 & f.o.c. \;\; violation \end{cases}.$$

From the above, it is obvious that under profit maximization the slope of the distance function at the observed output mix must be equal to the price ratio of the output prices. Figure 3 depicts an example where the assumption of profit maximization is violated at time t and time $t+1$.

Figure 3 about here

Here the price ratios (P_1/P_2) do not coincide with the slope of the frontier function at the observed output vector in both periods, and thus the output mix in each period is allocatively inefficient.

Data and empirical specification

Measuring and decomposing productivity growth during Chinas different reform phases in the last fifteen years requires farm-specific data which are observed over a relatively long period of time, thus a panel with a strong longitudinal component is necessary. We use accounting data from the period 1986-2000 from the province Zhejiang, with the years 1992 and 1994 missing. Furthermore, the identification system changed in 1992, making it impossible to assign a specific farm ID in the first period to its corresponding ID after 1992. This implies

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negative of the corresponding logarithmic derivative of the distance function divided through by *RTS*, to fulfil that we must treat the farms as two distinct sub-panels which are both balanced. The first panel (1986-1991) comprises 233 farms per year, while the second panel (1993, 1995-2000) consists of 74 farms per year. An overview of the main sample characteristics is given in Table 1.

Table 1 about here

There are conspicuous developments of inputs and outputs over time. In particular, the output structure has changed in favor of ‘other outputs’, underlining the diversification of the farm households toward other revenue-making activities. This might be caused by the instable and often changing market conditions for agricultural products, and might reflect the increasing integration of the farm households with the rest of the rural economy. Similarly, capital and particularly intermediate inputs show large gains in value, although input subsidies are removed in the late 1980s but probably because the government allows private firms to supply inputs to producers. Labor and land remain virtually constant. It should be noted, however, that these changes occur to the most part between 1990 and 1995 – the start and the end of the observation period show the key variables evolving at a more moderate pace.

We estimate a translog distance function with three outputs and four inputs, augmented by a trend variable to account for technical change in the first sub-sample (1986-1991), and by a generalized index model for technical change[6] (Baltagi and Griffin, 1988) in the second sub-sample (1993-2000). The output variables are defined as the total revenue from crop production, animal husbandry, and other production activities, respectively. Using an output price index for agricultural outputs, the monetary values are converted to constant 1989 prices for the first sample period. In the second sub-sample, 1997 is used as base year for the deflation of all monetary variables. The input variables are labor, defined as total hours

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the first-order conditions for the inputs: $-\frac{\partial \ln D_O}{\partial \ln x_k} \Big/ RTS \equiv \lambda_k$.

[6] Initially, we applied the linear trend model for technical change in the second period as well. However, explorative estimations indicated that the estimates for technical change were responsive

spent on farm work, and capital, defined as the deflated replacement value of farm equipment and machinery. The total area allocated to the different crops defines the land variable, and intermediate inputs are measured by the deflated value of direct expenses. The resulting specification is given in equation (2):

$$\begin{aligned}\ln D_{it}^{O} &= \alpha_0 + \sum_{m=1}^{3} \beta_m \ln y_{mit} + \sum_{k=1}^{4} \gamma_k \ln x_{kit} + \alpha_T A(t) \\ &+ \frac{1}{2}\sum_{j=1}^{3}\sum_{k=1}^{3} \beta_{jk} \ln y_{jit} \ln y_{kit} + \frac{1}{2}\sum_{j=1}^{4}\sum_{k=1}^{4} \gamma_{jk} \ln x_{jit} \ln x_{kit} + \sum_{j=1}^{3}\sum_{k=1}^{4} \delta_{jk} \ln y_{mit} \ln x_{kit} \\ &+ \sum_{m=1}^{3} \beta_{Tm} A(t) \ln y_{mit} + \sum_{k=1}^{4} \gamma_{Tk} A(t) \ln x_{kit} + I_1 \delta_{TT} t^2\end{aligned} \tag{2}$$

Here, y_m denotes crop, livestock, and other production for m=1..3, and x_k denotes labor, capital, land, and intermediate inputs for k=1..4. $A(t)$ reflects a linear trend variable in sub-sample 1, and an index of technical change in sub-sample 2, where I_1 is a binary variable with value 1 for observations in the first sub-sample[7] and value 0 otherwise. α, β, γ, and δ are parameters to be estimated. The index of technical change in sub-sample 2 is estimated by a set of time dummy variables TD_t with corresponding parameters ζ_t, $t = 1987..1991$: $A(t) = \sum_{i=1987}^{t} \zeta_i TD_i$. For identification, additional restrictions have to be imposed as described in Baltagi and Griffin (1988, p.27).[8] Further, D^O denotes the unobservable value of the distance function.

Using linear homogeneity of the output distance function in outputs, equation (2) can be transformed in order to obtain an observable variable on the right hand side (Coelli and Perelman, 2000). We use crop output y_1 as denominator for the outputs. Finally, substituting $\ln D^O$ with u and adding an additional error term v to account for random noise, we end up with an estimating equation (3) which has the same composed error structure as a standard stochastic production frontier model.

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[7] In the first sub-sample, the model is hence augmented by a quadratic trend variable.
[8] No dummy for 1986 enters the model because we have a constant term in our specification. This implies a notation that slightly differs from Baltagi and Griffin, however, the essentials of the model remain unchanged.

$$\ln y_{1it} = -\Bigg(\alpha_0 + \sum_{m=1}^{2} \beta_m \ln \frac{y_{mit}}{y_{1it}} + \sum_{k=1}^{4} \gamma_k \ln x_{kit} + \alpha_T A(t)$$
$$+ \frac{1}{2}\sum_{j=1}^{2}\sum_{k=1}^{2} \beta_{jk} \ln \frac{y_{jit}}{y_{1it}} \ln \frac{y_{kit}}{y_{1it}} + \frac{1}{2}\sum_{j=1}^{4}\sum_{k=1}^{4} \gamma_{jk} \ln x_{jit} \ln x_{kit} + \sum_{j=1}^{2}\sum_{k=1}^{4} \delta_{jk} \ln \frac{y_{jit}}{y_{1it}} \ln x_{kit} \qquad (3)$$
$$+ \sum_{m=1}^{2} \beta_{Tm} A(t) \ln \frac{y_{mit}}{y_{1it}} + \sum_{k=1}^{4} \gamma_{Tk} A(t) \ln x_{kit} + I_1 \delta_{TT} t^2 \Bigg) - u_{it} + v_{it}$$

where v is i.i.d. $N(0,\sigma_v)$ and u is i.i.d. $N(\mu_{it},\sigma_u)$ truncated at zero from below to ensure non-negative values.

The specification of the parameter μ_{it} can be used to further analyze the impact of certain variables on the degree of technical efficiency (Battese and Coelli, 1995). Here, we have chosen the following parsimonious specification of this parameter to control for diversification, climate, regional differences, and in particular policy reforms.

$$\mu_{it} = \theta_0 + \eta_1 H_{it} + \eta_2 \ln Z_t + \sum \theta_j VD_{ij} + \sum \varphi_k TD_t + \phi_{1/2} PD_{1/2} \qquad (4)$$

where, H_{it} measures output farm diversification by means of a Herfindahl index $\left(H_i = \sum_{m=1}^{M} R_m^2\right)$ over the different revenue-generating activities. Z_t is defined as the area in hectares that has been affected by adverse weather conditions (flooding or draught) in each period, *VD* (*TD*) is a set of appropriately defined regional (time) dummies. In the first sub-sample period, we additionally introduce a policy dummy (PD_1) that takes a value of one in the years after 1989 to capture the impact of the change in the policy regime after 1989. The associated parameter is denoted by ϕ_1. The second period covers also different policy regimes. ϕ_2 takes a value of one for the years 1995 to 1998. For the estimation by maximum likelihood, all variables are normalized by their respective sample means.[9]

Note that no regime dummies enter the deterministic kernel of the distance frontier. Thus, we maintain the assumption that the different policy regimes do not directly affect the production technology. Furthermore, the attempt to distinguish between both policy and time

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[9] All estimations were carried out using Ox 3.20 (Doornik, 1998).

dummies seems futile. Since we focus on the identification and measurement of the components of productivity growth, in particular technical and allocative efficiency, during Chinas several reform phases, the linkage between the level of technical efficiency and the different policy regimes is of particular interest.

Results

Before we describe and interpret the main results, namely, the level of technical efficiency and the development of TFP growth and its components, we give an overview of the estimated coefficients and the distance elasticities.

Parameter estimates and distance elasticities

The model seems acceptable in terms of the share of significant parameters given that we estimate single equation models (see Appendix Table A 1). Further, the test of the one-sided error, which is also a test for the significance of the efficiency component, gives high mixed χ^2-statistics (292.99 and 192.93, respectively), thus indicating that the modelling of inefficiency is appropriate for this setting. However, the overall role of the efficiency component is limited: The total variance of the composed error stems to the largest part from the unsystematic error term. The model is monotonic increasing in the outputs and non-increasing in the inputs, thus the theoretical requirements are not violated in this regard.

The development of the distance elasticities (see Appendix Table A 2) for the outputs reflects the changes in the output composition. With regard to the input side, the higher distance elasticities for intermediate inputs and capital in absolutes values for the second sub-sample might reflect the increasing relative cost shares of this variables in the 1990s. Similarly, the distance elasticity for labor decreases around 50 percent in absolute values, indicating a lower relative use of labor in production during the 1990s. Summing up the negative of these input distance elasticities gives a measure of the scale elasticity of 0.93 in the first period, indicating decreasing returns to scale. In the second period, constant returns to scale prevail at the sample mean. Given the small size of the farms, the low estimate of the scale elasticity in the first period might reflect the impediments to growth. In particular, input markets were heavily regulated in most years of the first observation period. The increase in the scale elasticity in the second sub-sample would then reflect deregulation on factor markets during the 1990s.

Technical efficiency

The average yearly degree of technical efficiency is documented in Table 2. As in most other studies (Fan, 2000, Carter and Estrin, 2001), the point estimates indicate a moderate level of technical efficiency in most years.

Table 2 *about here*

For the period 1986-1991, we find similarly to Fan (2000) that technical efficiency was relatively low in the first two years of the observation period, while inefficiency has virtually vanished in 1989. These results support the hypothesis that the effects of the household responsibility system were largely exhausted by end of the 1980s. The pattern of technical efficiency for the second sub-sample starts from a only mediocre level in 1993, and remain virtually unchanged over time. This might connected to the relative extensive redistributions of land property rights in most villages during the 1990s (Ding, 2000). As some authors suggest (Wen, 1995; Yao, 1995), the uncertainty in land tenure weakens farmers' investment incentive in land, especially with regard to long term land-saving investments. Li, Rozelle and Brandt (1998) provide additional evidence that land tenure and associated property rights might be one of the major factors affecting production efficiency in rural China. Furthermore, Kalirajan, Obwona, and Zao (1996) argue that an observed drop in technical efficiency in the beginning of the 1990s could also stem from structural shifts in the labor force. In particular, an outflow of educated and younger farmers from agriculture to other activities could lead to a decline in technical efficiency.

The parameter estimates (see Appendix Table A 1) for the determinants of technical efficiency in equation (4) measure the direct impact of the different policy regimes on the level of technical efficiency. The negative coefficient estimate for the first regime dummy (PD_1) of the period 1989-1991[10] documents a significant positive impact of policy measures on efficiency in the period. However, the policy dummy (PD_2) defined for the years 1995-98 does not signal any impact of this policy regime on the level of technical efficiency. Hence, the changes around 1998 seem to have no effect on the level of technical efficiency. This is not particularly surprising since the rebirth of self-sufficiency policies and the phasing out of the old centrally planned system mainly induce changes in market conditions and thus influence primarily allocative efficiency.

The significant positive estimates for the Herfindahl index for the second sub-sample indicate efficiency gains from diversification, and several of the regional and time dummies are significant. However, the overall role of the efficiency component is limited, since the total variance of the composed error stems to the largest part from the unsystematic error term. The efficiency differences between the farms in each year are negligible, while between years we find larger differences. This is in line with Fan (2000) who found only small regional differences in technical efficiency.

Components of TFP Change

As outlined above, the development total factor productivity during Chinas reform periods can be decomposed into several sources namely technical and allocative efficiency, scale effects and technical progress. According to equation (1) table 3 contains the average results per annum for the decomposition of TFP change within the distinguished policy regimes (see section ‘Agricultural policy reform’). Differences between the periods might indicate the impact of policy measures on productivity growth and its sources. Allocative effects on the input side are ignored because of the lack of consistent input price information over the whole observation period, as well as the numerous restrictions on the input markets which were in force over the different years of the sample.

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[10] As mentioned above (‘Data and empirical specification’), the identification system change in 1992 implying we must treat the observations as two distinct sub-panels. Thus, we can only set dummies for the years 1989-

Table 3 *about here*

The most rapid change in productivity growth was realized in Chinas second reform period (1985-1989) of around 23% (0.235) per annum. This tremendous increase is mainly caused by the high gains in technical efficiency (0.213) and a slight technical progress (0.036). Although the production possibility frontier shifts outwards as indicated by the rate of technical change, farmers are able to catch up quickly and maintain the high level of efficiency throughout the late 1980s. Changes in allocative and scale effects only have a negligible impact in aggregate on TFP growth. However, behind the overall value of nearly zero (the three effects nearly offset each other), we find moderate efficiency changes regarding the allocation of crops (-0.072) and other outputs (0.075), while livestock kept virtually constant (-0.009).

This tremendous increase in factor productivity and technical efficiency during the second half of the 1980s slows down in the 1990s. While in the third reform phase (1990-1993) factor productivity still increases strongly with rates of nearly 6% (0.054) per annum, it nearly stagnates with only 1.3% (0.013) growth per annum within the fourth period (1994-1998). The differences in TFP change between these two periods seem to be mainly caused by remarkably different developments in technical efficiency. In the third reform phase we still find improvements in technical efficiency albeit of small magnitude with 0.3% (0.028) per annum. Over the fourth period, technical efficiency decreases with a rate of -1.5%. Technical progress is distinctly different between the two reform periods. We find high growth rates between of 4% (0.041) per annum for the third reform period. For the fourth policy regime (1994-1998), technical change stagnates at a rate of 0.7% per annum. In contrast to the 1980s, farmers are not able to catch up to the frontier although there are no further outward shifts of the production possibility curve. This might be a result of the deterioration of extension services and land infrastructure, particularly with regard to the existing water conservation

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1991 to control for the impact of the policy changes in the third reform period.

systems, thus keeping farmers from applying the best practice production techniques (Carter, Zhong and Cai, 1996; Kalirajan, Obwona, and Zao 1996).

Similar to the Chinas second reform phase (1985-1989) the single allocative effects nearly offset each other under the third policy regime (1990-1993). Within the following period (1994-1998) we find a moderate impact of the aggregated allocative effects on observed productivity development, dominated by the nearly 4% (0.040) change per annum of other output allocation. In particular, the negligible productivity impact of changes in crop allocation (0.002) might reflect the tightening of supply controls in this period. As mentioned above, local governments have reintroduced command purchase and set barriers to regional grain trade, whereby the central governments set support price levels for all grains. In consequence, the crop output virtually remained constant over the years 1994 to 1998. Thus, although the restrictions on crop markets jointly with price controls presumably increased allocative inefficiency for crop outputs, these do not show up in the productivity growth measure because of the little changes in the level of crop output. Furthermore, as in the second reform period, scale effects have a negligible impact on productivity change during the third and the fourth reform phases.

In the end of the 1990s, the beginning of Chinas current reform period, we find a further flattening of total factor productivity growth with 0.9% (0.009) per annum. It stems from high technical regress (-0.060) enforced by increasing technical inefficiency (-0.019), while the scale effects are (0.003) negligible. These negative components are neutralized by the allocative effects, indicating that deviations between observed and shadow revenue shares are mitigated by output growth especially for the other outputs. Nevertheless, the strong technological regress for these two years remains striking.

Concluding remarks

The study contributes to the on-going debate over the development of productivity change and its sources in Chinese agriculture during the last fifteen years. In particular, it focuses on the productivity and efficiency impact of Chinas several rural reforms, which can roughly divided into five periods since 1979. Over this relatively long period frequent adjustments of agricultural policies occurred – sometimes in favor of market liberalization but sometimes the reforms aimed at phasing out the old centrally planned system. To control for productivity adjustments related to changes in technical and allocative efficiency, economies of scale, and technical progress, we decompose the standard measure productivity growth into these components. Considering the allocative effects regarding the outputs, we employ a multi-output distance function approach. A parametric output distance function is estimated using individual farm household data from the province Zhejiang over the period 1986-2000.

Our results clearly show, that most the rapid change in productivity growth was realized in Chinas second reform period (1985-1989). The tremendous increase of around 23% per annum is mainly caused by high gains in technical efficiency and a moderate technical progress. In contrast, allocative efficiency remains virtually constant during this period. Hence, the allocative effects only have a negligible impact in productivity growth. This strong increase in factor productivity an technical efficiency slows down in the 1990s. While in the third reform phase (1990-1993) factor productivity still increase with rates close to 6% per annum, it nearly stagnates with only 1.3% growth per annum within the fourth period (1994-1998). The differences in productivity development between the two reform periods are manly cause by remarkably different developments in technical efficiency. While we find slight improvements in technical efficiency in the third reform phase, it decreases over the fourth period. Similar to the second reform phase allocative efficiency remain constant in the third period, but we find a moderate impact of the allocative effects over the years 1994 to 1998. With the beginning of the current (fifth) reform period in the end of the 1990s, we find high rates of technical regress as well as an increasing technical inefficiency.

In terms of policy implications, the result of the decomposition procedure advice specific measure to evaluate possible impacts of Chinas different agricultural policy regimes on productivity and efficiency changes – at least for the province Zhejiang in the southeast. In particular, the results indicate that the more, but incomplete, market oriented reforms in the mid 1980s likely increased productivity growth and technical efficiency, but does not lead to remarkable improvements in allocative efficiency. However, TFP growth and technical efficiency successively slow in the 1990s, when more anti-market reforms took place. Obviously, farmers are not able to catch up the production frontier although there were no remarkable technological progress in the last decade. This might be a result of the deterioration of extension services and land infrastructure as well as the relative extensive redistributions of land property rights in the 1990s keeping farmers from applying the best practice production techniques. The uncertainty in land tenure weakens farmers' investment incentives in land. Further, the outflow of educated and younger farmers from agriculture could led to the decline in technical efficiency. The negligible changes in allocative efficiency during the whole observation period might be caused by the frequent adjustments of the market conditions, and the missing land transfer rights. These unstable and uncertain conditions, respectively lead to increasing adjustment cost, which in turn might hinder farmers to "find" allocative efficient production plans.

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Figures

Figure 1: Output distance function for two outputs

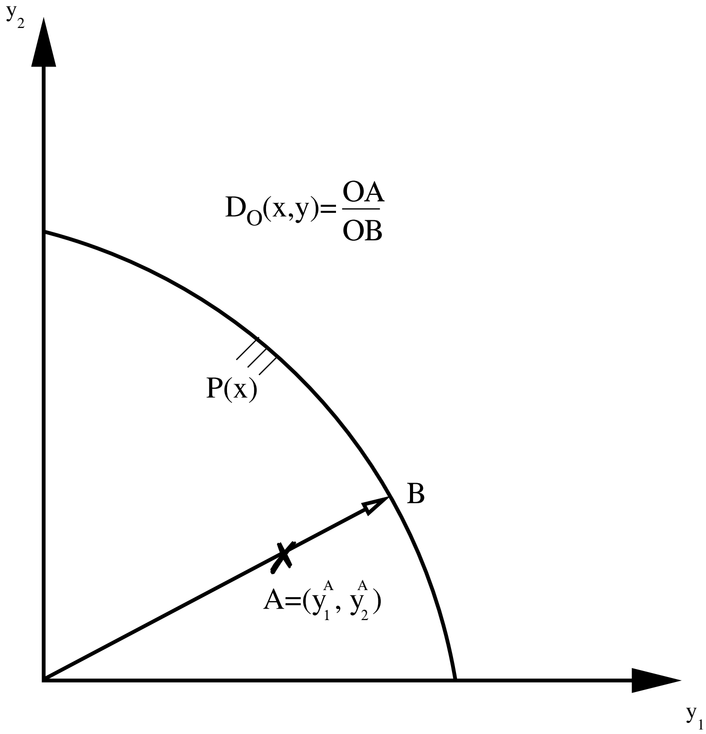


Figure 2: Output growth in a distance function framework

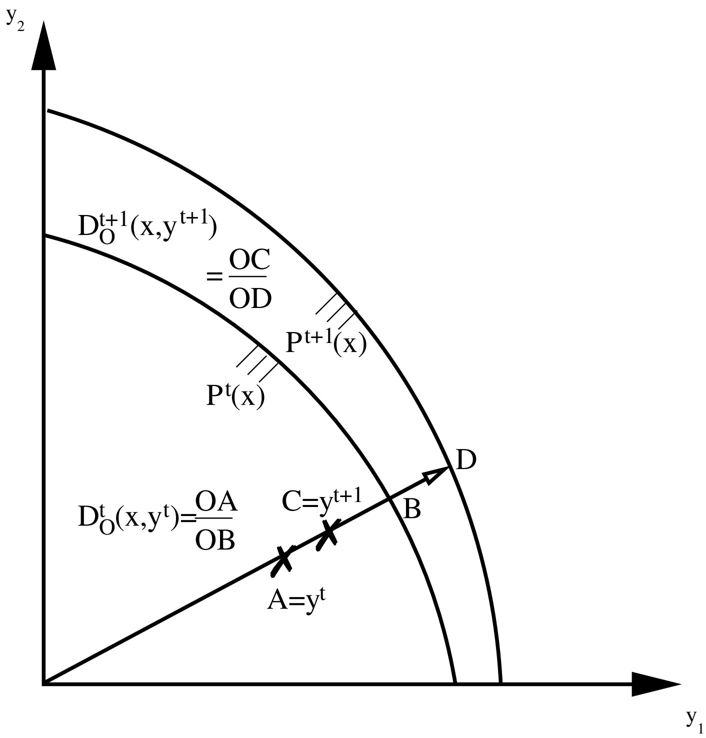
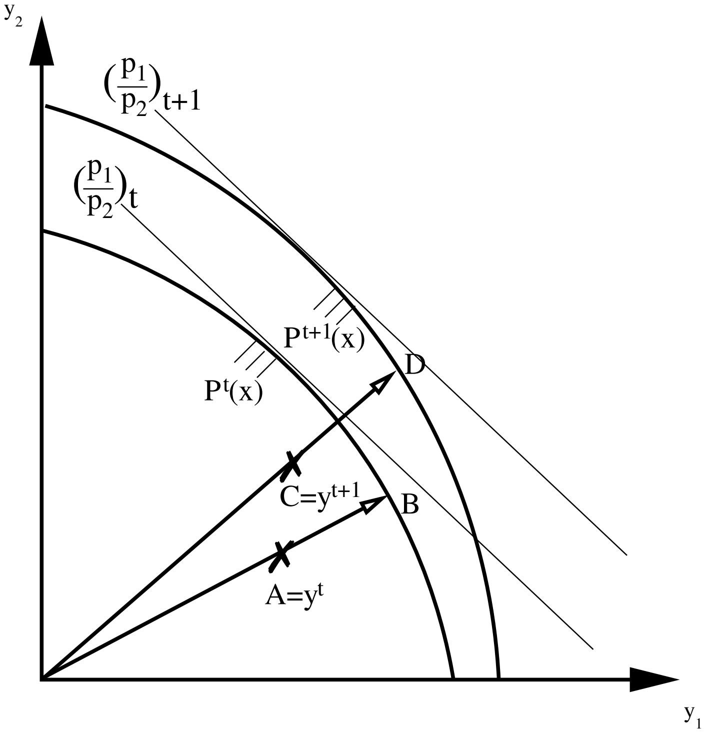


Figure 3: Price effects in the decomposition of total productivity growth



Tables

Table 1: Descriptive statistics of the samples

Variable	Unit	Minimum	Mean	Maximum	Standard-deviation
		First sub-sample 1986-1991 (n=1308)			
Crops	Yuan	34.6	1267.8	6681.7	878.2
Livestock	Yuan	3.2	1313.3	11469.0	1238.3
Other Output	Yuan	6.4	3828.3	108370.0	6342.7
Labor	Man days	25.0	493.2	1436.0	218.5
Capital	Yuan	19.2	2319.4	62136.0	4241.1
Land	Mu	0.3	3.2	53.5	2.2
Intermediate Input	Yuan	13.5	2697.7	107960.0	5218.4
		Second sub-sample 1986-1991 (n=518)			
Crops	Yuan	10.4	1701.3	24598.1	1707.3
Livestock	Yuan	5.1	1452.3	31536.5	2290.8
Other Output	Yuan	4.7	14291.7	668051.6	41868.0
Labor	Man days	102	524.58	2004	259.08
Capital	Yuan	64.9	5154.0	53368.7	7587.1
Land	Mu	0.4	2.7581	23.5	1.8406
Intermediate Input	Yuan	371.2	14787.5	1003911.6	53463.0

All monetary values in constant 1989 prices.

Table 2: Level of technical efficiency over the observation period

1986	1987	1988	1989	1990	1991	1992
0.572	0.684	0.889	0.986	0.998	0.990	/

1993	1994	1995	1996	1997	1998	1999	2000
0.773	/	0.753	0.746	0.756	0.729	0.730	0.705

Remark: "/" indicate that no observations were available in this period.

Table 3: Decomposition of productivity growth by policy reform periods

Reform Period	TFP Change	Allocative Effects Crops	Allocative Effects Livestock	Allocative Effects Others	Scale Effects	Technical Change	Technical Efficiency Change
Second (86-89)	0.235	-0.072	-0.009	0.075	-0.009	0.036	0.213
Third (90-93)	0.054	-0.022	0.004	0.028	-0.001	0.041	0.003
Fourth (94-98)	0.013	0.002	-0.013	0.040	-0.008	0.007	-0.015
Fifth (99-00)	0.009	0.027	0.015	0.042	0.003	-0.060	-0.019

Remark: Calculated values for the third reform period based on the years, 1990, 1991, 1993 and for the fourth period on the years 1994, since data for 1992 and 1994 are missing.

Appendix

Appendix Table A 1: Parameter estimates

1986-91	Estimates	robust-SE	93-2000	Estimates	robust-SE
α_0	0.1353*	0.0227	α_0	-0.0795	0.0952
β_1	0.2609*	0.0192	β_1	0.2316*	0.0653
β_2	0.2996*	0.0146	β_2	0.3441*	0.0415
γ_1	-0.4642*	0.0304	γ_1	-0.2716*	0.1282
γ_2	-0.0352*	0.0121	γ_2	-0.0112	0.0455
γ_3	-0.1179*	0.0231	γ_3	-0.2649*	0.0926
γ_4	-0.2682*	0.0205	γ_4	-0.4611*	0.0510
α_T	-0.0438	0.0227			
β_{11}	0.1332*	0.0174	β_{11}	0.0742*	0.0190
β_{22}	0.0538*	0.0067	β_{22}	0.0552*	0.0095
γ_{11}	0.1816*	0.0882	γ_{11}	0.0830	0.1527
γ_{22}	0.0088	0.0129	γ_{22}	-0.0123	0.0190
γ_{33}	0.1905*	0.0575	γ_{33}	-0.0814	0.0801
γ_{44}	-0.0928*	0.0252	γ_{44}	-0.0833*	0.0244
δ_{TT}	-0.0032	0.0174			
β_{12}	-0.0282*	0.0073	β_{12}	-0.0003	0.0104
δ_{11}	-0.0853*	0.0294	δ_{11}	-0.0735	0.0501
δ_{12}	-0.0292*	0.0124	δ_{12}	0.0467*	0.0178
δ_{13}	0.0468	0.0306	δ_{13}	-0.0499	0.0442
δ_{14}	0.0147	0.0166	δ_{14}	-0.0281	0.0154
β_{T1}	0.0122	0.0087			
δ_{21}	0.0213	0.0164	δ_{21}	0.0063	0.0298
δ_{22}	-0.0055	0.0056	δ_{22}	-0.0283*	0.0099
δ_{23}	-0.0242	0.0136	δ_{23}	-0.0312	0.0273
δ_{24}	0.0624*	0.0107	δ_{24}	0.0497*	0.0141
β_{T2}	-0.0091	0.0054			
γ_{12}	-0.0083	0.0246	γ_{12}	0.0156	0.0341
γ_{13}	-0.1635*	0.0603	γ_{13}	-0.0145	0.0911
γ_{14}	-0.0288	0.0325	γ_{14}	-0.0090	0.0401
γ_{T1}	-0.0100	0.0177			
γ_{23}	0.0012	0.0230	γ_{23}	-0.0088	0.0291
γ_{24}	0.025*	0.0123	γ_{24}	0.0072	0.0116
γ_{T2}	-0.0097	0.0061			
γ_{34}	0.0791*	0.0339	γ_{34}	0.0410	0.0360
γ_{T3}	0.0046	0.0150			
γ_{T4}	0.0065	0.0108			
			ζ_{1995}	0.6020*	0.0844
			ζ_{1996}	0.6711*	0.0743
			ζ_{1997}	0.6771*	0.0676
			ζ_{1998}	0.5883*	0.0648
			ζ_{1999}	0.4469*	0.0634
			ζ_{2000}	0.4081*	0.0646
			The remainder set of cross terms between time dummies and variables has been omitted for saving space and is available upon request		
$\ln\{\sigma_v\}$	-1.6804*	0.0276	$\ln\{\sigma_v\}$	-1.6048*	0.0390
$\ln\{\sigma_u\}$	-3.5581*	1.0900	$\ln\{\sigma_u\}$	-4.5475*	1.2340
θ_0	0.186*	0.0924	θ_0	-0.3550*	0.1209
η_1	-0.0952	0.1103	η_1	0.8721*	0.1567
η_2	-0.6456*	0.1982			
θ_1	0.3601*	0.0505			
θ_2	0.2958*	0.0752	θ_2	0.3507*	0.0328
θ_3	0.1140	0.1048			
ϕ_1	-0.5344*	0.0757			
φ_3	-0.2112*	0.0365			

Appendix Table A 2: Distance elasticities: Average values of the sample

Sample	Crop	Livestock	Other Output	Time	Labor	Capital	Land	Interm. Input
1986-91	0.5030	0.2608	0.2362	-0.0385	-0.4339	-0.04397	-0.1697	-0.2814
93-2000	0.3702	0.3051	0.3247	-0.0666	-0.2333	-0.1134	-0.2219	-0.4273