Policy Reform and Productivity Change in Chinese Agriculture: A Distance Function Approach

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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.

Introduction

On November 10, 2001, the WTO's Ministerial Conference approved the text of the agreement for China's entry into the WTO. The negotiations preceding this formal act had already been concluded in September. Several issues are involved that are expected to play a key role in the future development of agricultural world markets, and which are hence of utmost importance also for the development of the Common Agricultural Policy (CAP). 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). On the other hand, exclusive state trading for cereals will be continued. 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 structural change.

This paper addresses these issues by focusing on the impact of agricultural policies on the productivity of the sector. Increasing productivity will be a decisive factor in determining the role of China on the agricultural world markets over the next decades, hence it is useful to examine in which way certain policies did affect the sector's productivity in the past. Several studies are related to the impact that reform policies have on productivity growth in China. McMillan et al. (1989) study the impact on agricultural production of the household responsibility system. 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 sector.

More recently, several authors begun to decompose productivity change in Chinese agriculture into technical and allocative efficiency, and technical progress. Fan (1990) estimates land, labour 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 et al. (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 analyses the impact of the various policy reforms during both the 1980s and 1990s on the productivity growth in the Chinese farming sector. To control for reform-induced adjustments of productivity growth related to changes in technical and allocative efficiency, economies of scale or technical process, we decompose the traditional index of TFP growth into these components. In particular, the consideration of allocative effects regarding the outputs necessitates the explicit 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 1985-1999 from several regions in the province Zhejiang.

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

Agricultural policy reform

Agricultural reform in the past twenty years can roughly divided into four periods. The first period, 1979 to 1985, 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 fulfilment of the state procurement quotas, most products could be exchanged in relatively deregulated local markets at a higher price than the quota price. Before economic reform, only 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 dramatically.

In the beginning of the second reform period (1985 – 1993/94), a program was introduced to further enhance the functioning of rural markets which partially allowed prices and quantities to be determined by markets (e.g. Yao, 1994). However, over this relatively long period the issue of policy reform was in the focus of policy discussions, and frequent adjustments of agricultural policies occurred – sometimes in favour of market liberalisation but adversely effecting 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. 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 the 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 fertiliser and fuel was introduced for delivery of grain and oil crops to encourage peasants to produce more of these crops. The introduction of the rural market program lead 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 – labour mobility was allowed for, hence a labour outflow from agriculture took place.

Following criticisms of the impact of the rural market program, the government introduced a set of adjustment policies, starting in 1989 (OECD, 1995). Apart from constraints put on the development of rural industry, the government implemented further reform in the grain sector, aiming to phase out the old centrally planned ‘purchase and supply’ system in favour 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, inter-regional 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 supplying of fertilisers 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 subsectors (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 third 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) to 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 stabilisation of planting area, output, and stocks, as well as the installation of local reserves to directly regulate grain markets and stabilise prices. Not surprisingly, some local governments have re-introduced 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 state set 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 programme). In addition, subsidies were provided to the state grain marketing enterprises.

In order to reduce the financial burden of the grain support programme, 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 third reform period. The new policy was summarised 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 liberalisation 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 framers, with private dealers only permitted to retail grain that is purchased from the government grain marketing agencies.

Modelling framework

The analysis of productivity and its response to various policy measures requires a detailed modelling of the underlying technology of the farms in the sample. As outlined above, the policy reforms were quite different for the subsectors within agriculture. To capture the distinct effects for different outputs, the modelling approach must allow for multiple outputs. Furthermore, different measures may affect the components of productivity growth in a distinct manner, hence, we are not only interested in measuring total observable productivity growth but in decomposing it into its several components. In particular, it might be very interesting to look at the development of technical and allocative efficiency. One possible framework to achieve these requirements start from the 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[1]. 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

$$D_O^t\left(x^t, y^t\right) = \inf_{\phi}\left\{\phi > 0 : y^t/\phi \in P^t\left(x^t\right)\right\} \text{ for all } x^t \in \Re_+^K \qquad (1)$$

$D_o^t\left(x^t, y^t\right)$ 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.

Using this representation of technology, we are able to derive four different components of (observable) productivity change: technical change, change in technical and allocative efficiency, and scale effect. The most useful property of the distance function for our purposes is the fact that the reciprocal of the distance function has been proposed as a measure of technical efficiency (Farrell, 1957). The reciprocal of the output distance function is equal to the Farrell-type output orientated measure of technical efficiency (*TE*) as: $D_O(t,x,y) = 1/TE \Leftrightarrow \ln D_O(t,x,y) + TE = 0$. Replacing the output measure of technical

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[1] Formally, the distance function can be defined in terms of the output correspondence. For each input vector $x^t \in \Re_+^K$ at time t, let $P^t\left(x^t\right)$ be the set of feasible output vectors $y^t \in \Re_+^M$, the output correspondence is $P^t\left(x^t\right) = \left\{y^t : \left(x^t, y^t\right) \in S^t\right\}$, where S^t is the technology set at time t.

efficiency TE with an exponential non-negative error term u it yields $D_o(x,y)\exp(u) = 1 \Leftrightarrow \ln D_o(x,y) + u = 0$.

Totally differentiating the last expression 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. Substituting $\frac{\partial \ln D_o(.)}{\partial \ln y_m} = \mu_m$ and $\frac{\partial \ln D_o(.)}{\partial \ln x_k} = -\lambda_k RTS$, where RTS denotes returns to scale[2], and multiplying by minus one results in:

$$-\sum_{m=1}^{M} \mu_m \dot{y}_m + RTS \sum_{k=1}^{K} \lambda_k \dot{x}_k - \frac{\partial \ln D_o(.)}{\partial t} - \frac{\partial u}{\partial t} = 0 \tag{2}$$

Equation (2) can serve as the core for the decomposition of productivity growth. Usually, total factor productivity growth is measured as the difference between the growth rate of an output quantity index and of an input quantity index. Consider the conventional divisia index, which is defined as $\dot{TFP} = \sum_{m=1}^{M} R_m \dot{y}_m - \sum_{k=1}^{K} S_k \dot{x}_k$ for a multi-output, multi-input setting. Here, $R_m = \frac{p_m y_m}{\sum_m p_m y_m}$ denotes the observed revenue share of output y_m, $S_k = \frac{w_k x_k}{\sum_k w_k x_k}$ is the observed cost share of input x_k, and $p = (p_1, \ldots, p_M)$, $w = (w_1, \ldots, w_K)$ are the price vectors for outputs and inputs, respectively.

Summing up equation (2) and the TFP growth divisia index leads to the decomposition formula of productivity growth for multiple outputs:

$$\begin{aligned} \dot{TFP} &= \sum_{m=1}^{M} (R_m - \mu_m)\dot{y}_m + \sum_{k=1}^{K} (RTS\lambda_k - S_k)\dot{x}_k - \frac{\partial \ln D_o(.)}{\partial t} - \frac{\partial u}{\partial t} \\ &= \sum_{m=1}^{M} (R_m - \mu_m)\dot{y}_m + \sum_{k=1}^{K} (\lambda_k - S_k)\dot{x}_k + (RTS-1)\sum_{k=1}^{K} \lambda_k \dot{x}_k - \frac{\partial \ln D_o(.)}{\partial t} - \frac{\partial u}{\partial t} \end{aligned} \tag{3}$$

The relationship in equation (3) 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 effect $\left(-\frac{\partial u}{\partial t}\right)$.[3]

In Figure 1 the components introduced above are illustrated for the case of two outputs. Technical change leads to a change in the output set from $P^t(x^{t+1})$ to $P^{t+1}(x^{t+1})$. The related change in the distance function is represented by a change from $D^t_o(x^{t+1},y^{t+1})$ to $D_o^{t+1}(x^{t+1},y^{t+1})$. Efficiency change measures the producer capacity to improve technical efficiency from period t to period $t+1$, and is represented by a change from $D^t_o(x^t,y^t)$ to $D_o^{t+1}(x^{t+1},y^{t+1})$. In Figure 1 there are locally varying returns to scale because an increase of x^t to x^{t+1} does not lead to an equi-proportionate shift in the isoquant.

Figure 1: Decomposition of productivity change in a distance function framework

[2] Returns to scale (*RTS*) are defined as in Färe and Primont.
[3] In the case of only one output, equation (3) is essentially the same as the decomposition given by Kumbhakar and Lovell (2000) in the context of a production function.

Furthermore, allocative components are caused by the violation of the first order conditions (f.o.c.'s) for the profit maximisation approach[4]. That is, the following is true for the allocative effects regarding output m and input k in the decomposition formula given in (2):

$$\left(R_m - \mu_m\right), \left(S_k - \lambda_k\right) \begin{cases} = 0 \text{ if no f.o.c. violation for output } m \text{ / input } k; \\ \neq 0 \text{ if f.o.c. violation for output } m \text{ / input } k. \end{cases}$$

These violations 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 maximisation behaviour is inadequate. The allocative components account for the differences between observed value shares of outputs and inputs which determine the conventional *TFP* Divisia index, and their corresponding shadow shares, as derived from the distance function elasticities. From the above, it is obvious that the slope of the distance function at the observed output mix must be equal to the price ratio of the output prices (under profit maximisation). In the example depicted in Figure 1 the assumption of profit maximisation is violated at time t and time $t+1$. Thus, this output mix is allocatively inefficient.

Hence, these allocative effects represent the part of TFP change that is not determined technologically. Although they are caused by market or behavioural conditions, these components are elements of a technological productivity measure. Therefore, we explicitly distinguish between the allocative components as the "connected to market" part of *TFP* change and the other three components (technical change, change in technical efficiency, and scale component) as the "connected to technology" part of *TFP* change.

In order to decompose *TFP* growth according to equation (2), 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

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[4] To clarify the allocative effects for outputs (R_m - $\mu_m \neq 0$) and inputs (λ_k - $S_k \neq 0$) in equation (3), 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: $R_m = \frac{p_m y_m}{\sum_m p_m y_m} = \theta \frac{\partial D_O}{\partial y_m} y_m \frac{1}{\theta} = \frac{\partial \ln D_O}{\partial \ln y_m} \equiv \mu_m$. 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 negative of the corresponding logarithmic derivative of the distance function divided through by *RTS*, to fulfil the first-order conditions for the inputs: $-\frac{\partial \ln D_O}{\partial \ln x_k} \Big/ RTS \equiv \lambda_k$.

respect to the inputs[5]. Finally, the change in technical efficiency is obtained as the difference in the individual technical efficiency estimates from year to year.

Data and empirical specification

The identification of the impact of policy changes over time 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 1986-1999 from the province Zheijang, 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 that we must treat the farms as two distinct subpanels which are both balanced. The first panel comprises 233 farms per year, while the second panel consists of 79 farms per year. An overview of the descriptive statistics is given in Table 1.

Table 1: Descriptive statistics of the samples

	Minimum	Mean	Maximum	Std.dev.
	1986-1991 (n=1398)			
Crops	75.81	1499.8	6298	823.09
Livestock	7.02	1495.8	12031	1209.6
Other Output	8.29	4387.5	84978	6166.8
Labour	26	499.17	1634	219.97
Capital	25.38	2702	70944	4334.9
Land	0.3	3.2273	53.5	2.1537
Intermediate inputs	28.31	2904.5	75910	4169.8
	1993,1995-1999 (n=474)			
Crops	195.10	1697.2	15201	2917.9
Livestock	4.53	1414.2	25247	4662.8
Other Output	5.28	10633.4	336883	61005
Labour	81	512.13	2004	251.64
Capital	134.67	4538.5	59628	15186
Land	0.4	2.7494	23	1.6662
Intermediate inputs	178.06	7565.0	276148	50724

All monetary values in constant 1989 prices.

The development of the different input and output variables over time is very interesting. As can be seen from Table 1, output of the farms has nearly doubled. The rise in the share of the other output underlines in first place the diversification of the farm households toward other revenue-making activities, thus reflecting the increasing integration of the farm households with the rest of the rural economy. On the input side, capital and intermediate inputs show the largest gains in value while labour 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.

Code de champ modifié

Given the above data availability, we estimate a translog distance function with three outputs and four inputs, augmented by a trend variable to account for technical change. The output variables are defined as the total revenue from crop production, animal husbandry, and

[5] The decomposition holds exactly for continuous data. Since we have discrete observations, the parameters μ and λ, and the revenue and cost shares have to be approximated. We choose the common approximation to use the arithmetic mean between two subsequent periods.

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 subsample, 1997 is used as base year for the deflation of all monetary variables. The input variables are labour, defined as total hours 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 (4).

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

where y_m denotes crop, livestock, and other production for m=1..3, x_k denotes labour, capital, land, and intermediate inputs for k=1..4, t denotes a trend variable, and α, β, γ, and δ are parameters to be estimated. D^O denotes the unobservable value of the distance function. Using linear homogeneity of the output distance function in outputs, equation (4) can be transformed in order to obtain an observable variable on the right hand side (Coelli and Perelman, 2000). We use 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 (5) which is similar in structure to standard stochastic production frontier model with composed error.

$$\begin{aligned} \ln y_{1it} = -\Bigg(& \alpha_0 + \sum_{m=1}^{2} \beta_m \ln \frac{y_{mit}}{y_{1it}} + \sum_{k=1}^{4} \gamma_k \ln x_{kit} + \alpha_T t \\ &+ \frac{1}{2}\sum_{j=1}^{2}\sum_{k=1}^{2} \beta_{jk} \ln \frac{y_{jit}}{y_{1it}} \ln \frac{y_{kit}}{y_{1it}} + \frac{1}{2}\sum_{j=1}^{4}\sum_{k=1}^{4} \gamma_{jk} \ln x_{jit} \ln x_{kit} + \sum_{j=1}^{2}\sum_{k=1}^{4} \delta_{jk} \ln \frac{y_{jit}}{y_{1it}} \ln x_{kit} \\ &+ \delta_{TT} t^2 + \sum_{m=1}^{2} \beta_{Tm} t \ln \frac{y_{mit}}{y_{1it}} + \sum_{k=1}^{4} \gamma_{Tk} t \ln x_{kit} \Bigg) - u_{it} + v_{it} \end{aligned} \tag{5}$$

where v is i.i.d. $N(0,\sigma_v)$ and u is i.i.d. $N(\mu_{it},\sigma_u)$ truncated from below to ensure non-negative values. The specification of the parameter μ_{it} of the distribution of u can be used to further analyse the impact of certain variables on the level of technical efficiency (Battese and Coelli, 1995). Here, we have chosen a parsimonious specification of this parameter to control for regional differences and for the impact of climate: $\mu_{it} = \theta_0 + \theta_1 \ln Z_t + \sum_{j=2}^{5} \theta_j RD_{ij}$ where Z_t is defined as the area in hectares that has been affected by adverse weather conditions (flooding, or draught) in each period, and RD is a set of appropriately defined regional dummies. In the first sample period, we additionally introduce a dummy 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 three different policy regimes, hence, two dummies are introduced, one for the year 1993 with coefficient ϕ_2, and one for the year 1998 and 1999 (coefficient ϕ_3). For the estimation by maximum likelihood, all variables are normalised by their respective sample means.[6]

Results

The estimation results of the two different models show several interesting characteristics. The model seems acceptable in terms of significant parameters, at least as indicated by the

[6] All estimations were carried out using Ox 2.30 (Doornik, 1998).

relatively large share of significant variables (given that we estimate single equation models). Furthermore, 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 test of the one-sided error, which is also a test for the significance of the efficiency component, gives high mixed χ^2-statistics (255.49 and 126.99, respectively), thus indicating that the modelling of inefficiency is appropriate for this specific setting. The regional dummies are jointly significant in the first period.

With regard to the reform dummy variables, only the variable in the first period and the dummy for 1991 in the second period play a role. In both cases, the positive value of the estimate signals that efficiency is lower in the years indicated by the dummies. 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. This in turn raises doubt whether the model is fully specified. Nevertheless, the magnitude of the parameter estimates deserve some more discussion.

Technology

The interpretation of the parameter estimates[7] can be facilitated by looking at the corresponding distance elasticities. In Table 2, the average values of the elasticities are shown for the two subperiods.

Table 2: Distance elasticities: Average values of the sample

	crop	**livestock**	**other output**	**time**
86-91	0.5008	0.2782	0.221	-0.08093
93-99	0.2942	0.3489	0.3569	0.1022
	labour	**capital**	**land**	**intermediate input**
86-91	-0.4081	-0.05769	-0.215	-0.2643
93-99	-0.4013	-0.1009	-0.1909	-0.3297

The development of the distance elasticities of the outputs reflects the changes in the output composition, with the remarkable exception of the output from animal production. The revenue share of this category decreases over time, however, the distance elasticity indicates that the technological development favoured even further expansion of this subsector. This might be a direct consequence of the different policy regimes in different subsectors. The change in the distance attributable to technical change is given in the last column of the top rows. Here, the difference between the two periods is especially large. We found strong technical progress in the first period while in the second period, the data revealed technical regress. The possible reasons for this characteristic will be discussed below.

With regard to the input elasticities, the low magnitude of the capital elasticity is surprising, although its value doubles from the first to the second subperiod. The labour elasticity remains virtually unchanged, which is surprising because over the observation period, a large outflow of labour from agriculture took place. Summing up the negative of these input distance elasticities gives a measure of the scale elasticity of .94 in the first period, indicating decreasing returns to scale. This picture changes in the second subperiod: Now, on average increasing returns to scale prevail in the sample.

[7] The full set of parameter estimates is given in Appendix Tables 1 and 2.

Technical efficiency

The level of technical efficiency gives a first idea of the potential for improvements in rural agriculture in China. On average, the point estimates for technical efficiency indicate a moderate to substantial degree of technical efficiency (Table 3).

Table 3: Level of technical efficiency over the observation period

1986	*1987*	*1988*	*1989*	*1990*	*1991*
0.715	0.678	0.652	0.575	0.534	0.580
1993	*1995*	*1996*	*1997*	*1998*	*1999*
0.588	0.690	0.697	0.688	0.709	0.710

Initially, the level of technical efficiency is relatively high. The figures then worsen, to minimum of technical efficiency in the year 1990 with only 53 %. Subsequently, the efficiency scores increase again so that in the last year of the observation period the initial efficiency level is regained.

Productivity change

The evolution of technical efficiency tells only the first part of the story. As outlined above, it is possible (and probable, in particular for China) that allocative efficiency effects, scale effects and the impact of technical change outweigh the technical efficiency component. shows the composition of efficiency change according to equation (3). Note that we ignore allocative effects on the input side because of the lack of consistent input price information over the whole period.

Table 4: Decomposition of productivity growth in the observation period

	1986-91	1993, 1995-1999
TFP Chg.	0.072	-0.064
Allocative effects	0.020	0.006
Scale effects	-0.001	0.007
Technical Chg.	0.080	-0.102
TE Chg.	-0.027	0.024

The result for the two periods are quite different. While the overall TFP growth in the first period is substantial, all the gains seem to get lost again in the second period. Among the components, technical change and technical efficiency change are the most important factors. The allocative effects are have at least some impact in the first period. In the second period, they are negligible, as are the scale effects in both periods.

These aggregate figures can only give a first impression of the development of productivity growth in China. For a more detailed analysis, a look at the changes from year to year is necessary. Table 5 shows the annual changes of the decomposition.

Table 5: Decomposition of productivity growth by years

	86/87	*87/88*	*88/89*	*89/90*	*90/91*
TFP Chg.	0.1119	0.1608	0.035	0.0181	0.0349
Allocative effects	0.0735	0.1101	0.0225	-0.0154	-0.0899
Scale effects	-0.0167	-0.0022	0.0171	-0.0027	0.0007
Technical Chg.	0.0922	0.0785	0.0732	0.0774	0.0774
TE Chg.	-0.0371	-0.0255	-0.0778	-0.041	0.0467
	93/95	*95/96*	*96/97*	*97/98*	*98/99*
TFP Chg.	-0.0105	-0.1572	0.1082	-0.1492	-0.1133

Allocative effects	0.0101	-0.0569	0.1858	-0.061	-0.0495
Scale effects	-0.0146	-0.0029	0.0348	-0.0117	0.0314
Technical Chg.	-0.1076	-0.105	-0.1026	-0.0981	-0.0966
TE Chg.	0.1014	0.0076	-0.0098	0.0215	0.0013

The upper part of Table 5 describes the development in the first period, 1986-91. Several characteristics are noticeable. First of all, the magnitude of technical change is impressively high (7 %) over all years. The technical efficiency change is negative in all but the last period and partially offsets the gains from technical change. This is not surprising: With rapid technical progress, it is difficult for the majority of the small farmers to catch up with respect to the upward moving frontier. Furthermore, the partial reduction of the impact of the household responsibility system could contribute to these decreases in efficiency as well. The relatively large magnitude of the allocative effects is surprising at the first glance. The signs of these output effects are not uniquely determined by over- or underemployment of a single output since they do not only depend on the difference between shadow and observed revenue shares but also on the direction of output adjustment. Hence, only the aggregate magnitude should be interpreted. Here, it is clear that at the beginning and at the end of the period large effects prevail, possibly indicating strong adjustments in output ratios in the presence of a divergence between shadow and observed revenue share. The rapid and heterogeneous output price adjustments, and the changing regimes with regard to supply controls in these years are also supportive for these figures.

The figures in the lower part of Table 5 show a less clear picture. In particular, the high rate of technical regress needs further explanation. Also, the large magnitude of the allocative effects in 1996/97 is interesting. These effects are not connected to the crop production but stem to equal parts from livestock and from other outputs. The tightening of supply controls in this specific years is probably reflected in these figures. The efficiency changes are only modestly positive which indicates that even in this period of inward contractions of the output set, small scale farmers are not able to effectively catch up to the frontier function

Concluding remarks

The productivity change in Chinese agriculture is analysed by decomposing it into four basic components. Using a distance function framework, individual data from the province Zhejiang provide the empirical foundation for the years 1986-1999. Technical change, accounting for shifts of the production possibilities frontier over time, is found to be dominant in both analysed subperiods. The second most important component is the change in technical efficiency. The third group of components, comprising the allocative effects, is related to violations of the profit maximizing conditions which implicitly confound the standard measure of productivity growth. Their relative importance in both periods points at the impact of distinct policy regimes that prevailed in China over time.

The observable TFP growth shows a positive rate of change in the first period. This picture reverses in the second sample period. While the standard TFP growth index presents a clear message for these two periods, the decomposition shows a more detailed but also more heterogeneous pattern. In particular, the allocative effects are of special importance because they reflect the impact of price and supply controls on the optimising behaviour of the farm household. Given this important role of the output allocative effects, the incorporation of allocative effects on the input side should be the next step.

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Appendix

Appendix Table 1: Parameter estimates subperiod 1: 1986-1991

	Coefficient	***robust-SE***	***t-value***	***t-prob***
α_0	0.569325	0.03979	14.3	0.000
β_1	0.179677	0.01658	10.8	0.000
β_2	0.305476	0.01244	24.6	0.000
γ_1	-0.372140	0.02611	-14.3	0.000
γ_2	-0.0353567	0.01177	-3.00	0.003
γ_3	-0.207046	0.02242	-9.24	0.000
γ_4	-0.281244	0.01962	-14.3	0.000
α_T	-0.0686543	0.008864	-7.75	0.000
β_{11}	0.124450	0.01914	6.50	0.000
β_{22}	0.0598677	0.005672	10.6	0.000
γ_{11}	0.136731	0.08859	1.54	0.123
γ_{22}	-0.000424512	0.01274	-0.0333	0.973
γ_{33}	0.162542	0.06071	2.68	0.008
γ_{44}	-0.0363521	0.03215	-1.13	0.258
δ_{TT}	0.0529049	0.006427	8.23	0.000
β_{12}	-0.0405230	0.007844	-5.17	0.000
δ_{11}	-0.0583084	0.02860	-2.04	0.042
δ_{12}	-0.0431083	0.01323	-3.26	0.001
δ_{13}	0.0315364	0.03330	0.947	0.344
δ_{14}	0.0264919	0.01786	1.48	0.138
β_{T1}	-0.0111177	0.006499	-1.71	0.087
δ_{21}	0.0284494	0.01726	1.65	0.100
δ_{22}	-0.00619385	0.005656	-1.10	0.274
δ_{23}	-0.0271122	0.01394	-1.95	0.052
δ_{24}	0.0350371	0.01149	3.05	0.002
β_{T2}	0.0104804	0.003048	3.44	0.001
γ_{12}	0.0416166	0.02166	1.92	0.055
γ_{13}	-0.110512	0.06126	-1.80	0.071
γ_{14}	-0.0661145	0.03237	-2.04	0.041
γ_{T1}	-0.0195613	0.01215	-1.61	0.108
γ_{23}	-0.0179918	0.02231	-0.807	0.420
γ_{24}	0.0251134	0.01218	2.06	0.039
γ_{T2}	-0.00445816	0.004693	-0.950	0.342
γ_{34}	0.0719528	0.04225	1.70	0.089
γ_{T3}	0.0103033	0.01251	0.824	0.410
γ_{T4}	-0.0190418	0.007851	-2.43	0.015
$\ln\{\sigma_v\}$	-1.68275	0.02568	-65.5	0.000
$\ln\{\sigma_u\}$	-3.80761	0.02943	-129.	0.000
θ_0	0.217719	0.02263	9.62	0.000
θ_1	0.185071	0.03953	4.68	0.000
θ_2	0.283906	0.02436	11.7	0.000
θ_3	-0.000375621	0.06058	-0.00620	0.995
θ_4	0.292842	0.02988	9.80	0.000
θ_5	0.243363	0.03636	6.69	0.000
ϕ_1	0.157292	0.02137	7.36	0.000

Appendix Table 2: Parameter estimates subperiod 2: 1993,1995-1999

	Coefficient	***robust-SE***	***t-value***	***t-prob***
α_0	0.358451	0.1960	1.83	0.068
β_1	0.265713	0.06898	3.85	0.000
β_2	0.388796	0.03214	12.1	0.000
γ_1	-0.279104	0.07391	-3.78	0.000
γ_2	-0.0598855	0.03585	-1.67	0.096
γ_3	-0.298019	0.07492	-3.98	0.000
γ_4	-0.327278	0.05538	-5.91	0.000
α_T	0.0830256	0.02584	3.21	0.001
β_{11}	0.0716783	0.03843	1.87	0.063
β_{22}	0.0680688	0.01249	5.45	0.000
γ_{11}	0.145611	0.2438	0.597	0.551
γ_{22}	-0.0311657	0.03999	-0.779	0.436
γ_{33}	-0.179616	0.06574	-2.73	0.007
γ_{44}	-0.0818617	0.05255	-1.56	0.120
δ_{TT}	-0.00542832	0.02751	-0.197	0.844
β_{12}	-0.0117559	0.02252	-0.522	0.602
δ_{11}	-0.0980946	0.08960	-1.09	0.274
δ_{12}	-0.00369237	0.04554	-0.0811	0.935
δ_{13}	-0.0145901	0.08764	-0.166	0.868
δ_{14}	0.0263032	0.03464	0.759	0.448
β_{T1}	0.0157931	0.01853	0.852	0.395
δ_{21}	0.0505238	0.05328	0.948	0.344
δ_{22}	-0.0193652	0.01349	-1.44	0.152
δ_{23}	-0.0572788	0.04248	-1.35	0.178
δ_{24}	0.0357919	0.03414	1.05	0.295
β_{T2}	0.0103369	0.01007	1.03	0.305
γ_{12}	0.0352783	0.06572	0.537	0.592
γ_{13}	-0.00931599	0.1564	-0.0596	0.953
γ_{14}	-0.0324826	0.08783	-0.370	0.712
γ_{T1}	-0.0292438	0.04396	-0.665	0.506
γ_{23}	0.00106613	0.05074	0.0210	0.983
γ_{24}	0.00558560	0.03207	0.174	0.862
γ_{T2}	0.0144731	0.008790	1.65	0.100
γ_{34}	0.0693149	0.07441	0.932	0.352
γ_{T3}	0.0183930	0.03256	0.565	0.572
γ_{T4}	-0.00710478	0.02491	-0.285	0.776
$\ln\{\sigma_v\}$	-1.60369	0.07994	-20.1	0.000
$\ln\{\sigma_u\}$	-9.73457	0.06096	-160.	0.000
θ_0	0.328632	0.2233	1.47	0.142
θ_1	0.0363817	0.1299	0.280	0.780
θ_2	-0.0568853	0.1131	-0.503	0.615
θ_3	0.175785	0.1028	1.71	0.088
θ_4	-0.305503	0.1402	-2.18	0.030
θ_5	-0.0733159	0.1266	-0.579	0.563
ϕ_2	0.164434	0.06885	2.39	0.017
ϕ_3	-0.0212872	0.1427	-0.149	0.882