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Productivity growth in pre-1990 Mongolian agriculture: spiralling disaster or emerging success?

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Received 21 August 2001; received in revised form 19 April 2002; accepted 6 May 2002

Abstract

The reasons for the spectacular collapse of so many centrally-planned economies are a source of ongoing debate. In this paper, we use detailed farm-level data to measure total factor productivity (TFP) changes in Mongolian grain and potato farming during the 14-year period immediately preceding the 1990 economic reforms. We measure TFP growth using stochastic frontier analysis (SFA) and data envelopment analysis (DEA) methods. Our results indicate quite poor overall performance, with an average annual TFP change of -1.7% in grain and 0.8% in potatoes, over the 14-year period. However, the pattern of TFP growth changed substantially during this period, with TFP growth exceeding 7% per year in the latter half of this period. This suggests that the new policies of improved education, greater management autonomy, and improved incentives, which were introduced in final two planning periods in the 1980s, were beginning to have a significant influence upon the performance of Mongolian crop farming.

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JEL classification: C23; D24; O13; P27

Keywords: Mongolia; Centrally-planned economies; Total factor productivity; Incentive reform

1. Introduction

In the past decade, the world has witnessed the collapse of many centrally-planned economies. The reasons for these failures are not always clear and continue to be a source of considerable debate (Ofer, 1987; Bergson, 1987, 1992; Easterly and Fischer, 1995). Some commentators have suggested that a lack of incentives in the centrally-planned systems may have played a major role in the decline. For example, Kornai (1990) argues that the soft-budget constraints applied to many firms in centrally-planned economies had a

detrimental effect on incentives. The measurement of low levels of efficiency and slow technical change in a number of centrally-planned countries (e.g. Bergson, 1987; Moroney and Lovell, 1991), could be seen as evidence of incorrect incentive structures.

A number of studies have looked at agricultural productivity change in former centrally-planned economies (e.g. Gemma, 1991; Brada and King, 1993; Carter and Zhang, 1994). However, these studies have all used aggregated national- or regional-level data, which can often be of questionable quality in centrally-planned countries (Ofer, 1987). This may partly explain the wide-ranging results obtained in these studies. A limited number of analyses of farm-level data have also been conducted (e.g. Tran et al., 1993;

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Johnson et al., 1994; and Brock, 1996). However, these analyses have only involved data from a short period of time and hence provide little information on productivity change over time. Thus, a study that can provide accurate measures of productivity change in a former centrally-planned economy, along with analysis of the factors contributing to this decline, would be a valuable contribution to this literature.

In this study, we have an excellent opportunity to address some of the many unanswered questions, at least for the case of Mongolia. We have gained access to a source of very detailed data on Mongolian State farms. Information on the inputs and outputs of each of the 48 State farms producing grain and potatoes was collected from the original hand-written farm records by the senior author.¹ We have used this information to construct an annual data series for each farm for the 14-year period from 1976 to 1989.

This 14-year period covers the last three planning periods of pre-1990 Mongolia, a period that was characterised by quite substantial changes in sector policies.² These policy adjustments mirrored the changing Soviet views on central planning, which eventually culminated in the major “Perestroika” reforms of 1990. During the first sub-period (1976–1980) of our 14-year study period, the policy focus for Mongolian State farms was on encouraging output growth through increased use of inputs. However, during the second (1981–1985) and third (1986–1989) sub-periods, the Government began shifting its policy away from a so-called ‘extensive’ to an ‘intensive’ growth strategy (Ulziibat, 1992). The emphasis of the new approach was the increased role of new technology (Unen, 1981), investment in human resources (through technical education) and the introduction of new incentive systems (Unen, 1986), with the aim

of improving farm productivity levels. In particular, during the last 4 years (1986–1989) of the centrally-planned economic regime, several new forms of farm incentive systems aimed at improving farm performance were experimented with within the State farm structure (Ministry of Food and Agriculture, 1990a,b). This was a reflection of the new wave of Gorbachev’s economic reforms, which were gaining momentum throughout the Eastern Block.

The end of the central-planning system in Mongolia in 1991, resulted in widespread changes in Mongolian agriculture. A number of studies were commissioned to assess the state of Mongolian agriculture. However, these studies expressed conflicting views of the health of Mongolian crop farming prior to 1990. Some studies concluded that existing technology in crop farming was obsolete and inadequate. Ulziibat (1992) questioned the standard and adequacy of Russian technology used in the crop sector, and Ulrich (1994) reported that the existing technology in the crop sector was well below Western standards. However, other authors stated that the main problem facing the crop sector was poor management and organisational and incentive problems within the farm (Dixon, 1989; United Nations Development Programme, 1992).

Given the conflicting conclusions in these reports, it is a little surprising that no detailed analysis of total factor productivity (TFP) in Mongolian crop farming has yet been conducted. Hence, the effects of the successive economic reforms in Mongolian crop farming, that took place in the 1970s and 1980s, are yet to be quantified. The main aim of this study is to look at this question.

In this paper, we measure the TFP of Mongolian State farms using stochastic frontier analysis (SFA) and data envelopment analysis (DEA) methods.³ We construct the TFP change indices for each farm in the sample, and decompose these into measures of technical change and technical efficiency change. SFA is chosen as the principal method of analysis, because of its ability to accommodate data noise and traditional hypothesis tests. However, the DEA method is also used as a check to see if our results are robust to alternative methodologies.

¹ We believe that this micro data is much more reliable than the aggregate data that was publicly reported by government agencies. It was not uncommon for the latter data to be adjusted for propaganda purposes. However, we have no reason to suspect that the farm-level data was manipulated in any way.

² The current study covers the fifth (1976–1980), sixth (1981–1985) and seventh (1986–1989) 5-year plan periods of the national economy of Mongolia. These are referred to here as the first, second and third sub-periods, respectively. The seventh plan period was meant to be 1986–1990 but was shortened to 1989 by the 1990 reforms.

³ See, Färe et al. (1994) and Coelli et al. (1998) for information on these methods.

The panel data methods used in this paper have particular advantages over the more traditional approach to TFP measurement, which involves the use of Tornqvist index numbers.⁴ In particular, we avoid the need to use price information, which are often of questionable quality in a centrally-planned economy. Furthermore, we avoid the need to assume that these farms maximise revenue and minimise costs, which would be a brave assumption indeed. Moreover, the DEA method does not impose any functional restrictions on production technology. In addition, our methods allow us to decompose TFP change into technical efficiency change and technical change components, which may help shed some light on the relative importance of poor technology versus poor incentives in explaining Mongolian agricultural performance.

Overall, this paper is designed as an exercise in empirical economic history. We are attempting to address a number of important questions, such as:

1. What actually happened to agricultural productivity under the communist government?
2. Were there significant scale diseconomies in these large farms?
3. What was the effect of the reform process on agricultural productivity? In particular, did incentive reforms have a positive effect?

We believe that questions such as these must be asked, so that economists and historians can try to identify the main reasons for the demise of communism. We do know that communism did not work. However, it is important to know why it failed. The empirical analysis in this paper is designed to provide us with a small piece of empirical evidence, along the road to learning more about the factors behind the failure of communism.

The remainder of this paper is organised into sections. In Section 2, we provide a brief discussion of Mongolian agriculture. In Section 3, we describe the SFA and DEA methods which are utilised in the study. In Section 4, we describe the data that is used, while in Section 5 we present and discuss our empirical results. Some brief concluding comments and policy discussion are provided in the final section.

2. Mongolian State farms

Compared to livestock farming (the largest sector in Mongolian agriculture), crop farming is not traditional, although grain, potatoes and other vegetables have long been the essential elements in the diet of Mongolians (Chalmers, 1993). The principal crops are grain (85% of which is wheat; the balance in barley and oats), potatoes and other vegetables. In terms of revenue, crop production provided 30% of total agricultural production in Mongolia in 1989. Of this crop production, grains provided 72% and potatoes 19% (National Statistical Office, 1998). Hence, in this study we focus on an analysis of grain and potato production.

State farms were developed under communism. The structure and functioning of State farms followed that of Soviet Sovkhozy (Chalmers, 1993). They accounted for about 81% of total national crop land and were the main producers of crops in the country. State farms were large relative to most Western farms (Sloane, 1990; Chalmers, 1993). For the period 1981–1989, an average State farm had 15,931 ha of crop land and 213 workers, and produced 9467 tonnes of cereal, 1425 tonnes of potatoes and 501 tonnes of vegetables. In 1989, the 48 State farms produced a total of 839,000, 148,000 and 54,900 tonnes of grain, potatoes and vegetables, respectively.

As outlined in Section 1, a number of development initiatives were introduced in Mongolian crop farming in the two decades leading up to 1990 (Ulziibat, 1992). In the crop sector, these initiatives basically fell into three categories: (i) increased use of conventional inputs such as land, labour, machinery and fertilisers; (ii) the development and importation of new technology and increased emphasis on education and skills; (iii) a series of policy reforms aimed at improving farm efficiency, through greater management autonomy and incentives.

The last set of reforms represented a radical change in policy. Prior to these reforms, the management and decision-making processes at the farm-level were highly restricted and regulated by production plans and output targets determined from the national headquarters. The production plan for each State farm, regarding what and how much it was to produce, and where it was to sell, was decided at the Ministry of Food and Agriculture (Coleman, 1989). The

⁴ See, Caves et al. (1982) and Coelli et al. (1998) for information on these methods.

allocation of most material inputs, such as machinery, fertiliser and capital investment, to individual farms was done by the Ministry of Food and Agriculture. All the profits, if any were made, were transferred back to the Ministry (Sloane, 1990).

Some small incentive reforms began in the early 1980s. An incentive-based wages system for farm workers was introduced, and the tight planning process was gradually relaxed, with farm managers exercising more and more autonomy in terms of resource allocation and actual production management (Coleman, 1989). Farms were also allowed to retain a certain amount of their profits for later investment in farm expansion and machinery replacement.

Then during the 1986–1989 period, several new forms of farm incentive systems, based on contracts, were tried within the State farm structure (Sloane, 1990). Under these contract arrangements, the central management in the farm signed contracts with individual production units within the farm. Two types of contracts—*simple* and *tenancy*—were available. The difference between simple and tenancy contracts was in the degree of autonomy given to individual units and the length of contract terms (Ministry of Food and Agriculture, 1990a,b). A simple contract was quite tight in terms of the types, quantity and quality of output and input levels and remuneration in the form of wages, and was usually signed on an annual basis. However, under a tenancy contract arrangement, a group of farm members signed contracts with the management of the State farm, basically on resource use, such as land, machinery and buildings on a longer term basis (e.g. 5–10 years). These tenancy groups were obliged to supply the government with a certain share of output, and received the right to sell the remainder at market price to local or national markets. The tenancy groups would pay a resource use fee derived from farm asset values along with a surcharge for farm overall management. Under this arrangement, production units exercised greater autonomy in terms of management and resource allocation (Ministry of Food and Agriculture, 1990b). By 1990, 86.5% of all workers in crop production were engaged under either simple or tenancy contracts. Of these workers, 42.9% were engaged in simple contracts and 57.1% in tenancy contracts (Ministry of Food and Agriculture, 1990a,b).

Despite the introduction of the above mentioned reforms, and some reported improvements in farm

productivity (Ministry of Food and Agriculture, 1990b, 1991), the substantial economic reforms, which were implemented across much of the communist world in 1990, were also introduced in Mongolian crop farming. The large State farms were split up into smaller farms and privatised. All these events were followed by dramatic reductions in output, the abandonment of large amounts of cropping land and the flight of a significant number of technical staff to the cities.⁵ The empirical analysis in this paper may shed some light on the appropriateness of these policies. Some questions of particular interest are: (i) Were there substantial diseconomies of scale in these farms? (ii) Were the management and incentive reforms of the final planning period ineffective?

3. Methodology

TFP is measured in this study using the Malmquist TFP index defined in Caves et al. (1982) and Färe et al. (1994). In these two papers, the TFP index is defined using distance functions. This allows one to consider multi-output, multi-input technologies. In this study, we only require a single-output technology. Nevertheless, we will continue to use the distance function notation so as to remain consistent with the notation in the literature. However, we will not formally define the distance function in this paper. We simply note that, in the case of a single-output technology, the (output-orientated) distance function is equivalent to the ratio of the observed output to the predicted frontier output for the observed input vector (i.e. the distance measure is equal to the traditional technical efficiency measure).

The Malmquist TFP index measures the TFP change between two data points (e.g. those of a particular firm in two adjacent time periods) by calculating the ratio of the distances of each data point relative to a common technology. Following Färe et al. (1994), the Malmquist (output-orientated) TFP change index between period s (the base period) and period t is given by:

$$m_o(y_s, x_s, y_t, x_t) = \left[\frac{d_o^s(y_t, x_t)}{d_o^s(y_s, x_s)} \times \frac{d_o^t(y_t, x_t)}{d_o^t(y_s, x_s)} \right]^{1/2}, \quad (1)$$

⁵ The removal of Soviet funded subsidies from the Mongolian economy also contributed to these events.

where the notation $d_o^s(x_t, y_t)$ represents the distance from the period t observation to the period s technology. A value of m_o greater than 1 will indicate positive TFP growth from periods s to t while a value less than 1 indicates a TFP decline. Note that Eq. (1) is, in fact, the geometric mean of two TFP indices. The first is evaluated with respect to period s technology and the second with respect to period t technology.

An equivalent way of writing this productivity index is:

$$m_o(y_s, x_s, y_t, x_t) = \frac{d_o^t(y_t, x_t)}{d_o^s(y_s, x_s)} \left[\frac{d_o^s(y_t, x_t)}{d_o^t(y_t, x_t)} \times \frac{d_o^s(y_s, x_s)}{d_o^t(y_s, x_s)} \right]^{1/2}, \quad (2)$$

where the ratio outside the square brackets measures the change in the output-oriented measure of technical efficiency between periods s and t . That is, the efficiency change is equivalent to the ratio of the technical efficiency in period t to the technical efficiency in period s . The remaining part of the index in Eq. (2) is a measure of technical change. It is the geometric mean of the shift in technology between the two periods, evaluated at x_t and also at x_s . Thus, the two terms in Eq. (2) are:

$$\text{Efficiency change} = \frac{d_o^t(y_t, x_t)}{d_o^s(y_s, x_s)}, \quad (3)$$

and

$$\text{Technical change} = \left[\frac{d_o^s(y_t, x_t)}{d_o^t(y_t, x_t)} \times \frac{d_o^s(y_s, x_s)}{d_o^t(y_s, x_s)} \right]^{1/2}. \quad (4)$$

In this study, we estimate the production functions (distance functions) using both stochastic frontier analysis and data envelopment analysis methods. SFA is chosen as the principal method of analysis, because of its ability to accommodate data noise and traditional hypothesis tests. The DEA method is also used as a check to see if the results are robust to alternative methodologies. These methods are used to obtain estimates of technical efficiency for each farm in each of the 14 years considered. Information on technical change, production elasticities and returns to scale are also obtained. The information on technical efficiencies and technical change is combined to obtain measures of total factor productivity change.

3.1. Stochastic frontier methods

The distance measures required for the Malmquist TFP index calculations can be measured relative to a parametric technology. There are many different ways in which one could approach this. In this paper we consider a stochastic production frontier defined as follows:

$$\ln(y_{it}) = f(x_{it}, t, \beta) + v_{it} - u_{it}, \\ i = 1, 2, \dots, N, \quad t = 1, 2, \dots, T, \quad (7)$$

where y_{it} is the output of the i th farm in the t th year; x_{it} a $(1 \times K)$ vector of inputs; $f(\cdot)$ the translog functional form; t a time trend representing technical change; β a vector of unknown parameters to be estimated; v_{it} the random errors, assumed to be i.i.d. and have $N(0, \sigma_v^2)$ -distribution, independent of the u_{it} , the technical inefficiency effects.

The model used in this paper accommodates time-varying technical efficiency. It is specified such that the technical inefficiency effect for a given farm in a particular time period is the product of a random variable associated with that farm and an exponential time trend (Battese and Coelli, 1992). That is:

$$u_{it} = \eta_i u_i = \{\exp[-\eta(t - T)]\} u_i, \quad (7a)$$

where η is an unknown parameter to be estimated; and the u_i are independent and identically distributed random variables, having half-normal distribution with unknown variance σ^2 .⁶

The method of maximum likelihood is used to estimate the unknown parameters in each of the models. This was done using the computer program, FRON-TIER, Version 4.1 (see Coelli, 1994).

The technical efficiencies of each firm in each year can be predicted using the conditional expectation of $\exp(-u_{it})$, given the value of $e_{it} = v_{it} - u_{it}$. Since u_{it} is a non-negative random variable, these technical efficiency predictions are between 0 and 1 with a value of 1 indicating full technical efficiency.

In this parametric case, we can use the measures of technical efficiency and technical change to calculate

⁶ The more general case in which the u_i were non-negative truncations of the $N(\mu, \sigma^2)$ distribution where μ was unknown, was estimated for our data. However, the μ estimates were not significantly different from zero, so the half-normal distribution is assumed for the inefficiency effects, u_i .

the Malmquist TFP index via Eqs. (2)–(4). The technical efficiency measures,

$$TE_{it} = E(\exp(-u_{it})|e_{it}), \quad (8)$$

where $e_{it} = v_{it} - u_{it}$, can be used to calculate the efficiency change component. That is, by observing that $d_o^t(x_{it}, y_{it}) = TE_{it}$ and $d_o^s(x_{is}, y_{is}) = TE_{is}$ we calculate efficiency change as:

$$\text{Efficiency change} = \frac{TE_{it}}{TE_{is}}. \quad (9)$$

This measure can be compared directly to Eq. (3).

The technical change index between periods s and t for the i th firm is calculated directly from the estimated parameters by evaluating the partial derivative of the production function with respect to time (at a particular data point). Because technical change is non-neutral in our model, this technical change index may vary for different input vectors. Hence, we use a geometric mean to estimate the technical change index between adjacent periods s and t . That is,

$$\text{Technical change} = \left\{ \left[1 + \frac{\partial f(x_{is}, s, \beta)}{\partial s} \right] \times \left[1 + \frac{\partial f(x_{it}, t, \beta)}{\partial t} \right] \right\}^{0.5}. \quad (10)$$

This measure may be compared directly with Eq. (4). The indices of technical efficiency change and technical change obtained using Eqs. (9) and (10) may then be multiplied together to obtain a Malmquist TFP index, as defined in Eq. (2).⁷

Note that we could have estimated all the required distance measures directly (they would simply be ratios of observed output to predicted output for the two different input vectors for the periods s and t technologies), as is done in the DEA approach discussed below. However, we believe that the technical change measures are most easily obtained in the above manner.

3.2. DEA methods

Following Färe et al. (1994), and given that suitable panel data are available, we can also calculate the required distance measures for the Malmquist TFP index using DEA-like linear programs. For the i th firm, we must calculate four distance functions to measure the TFP change between two periods, s and t . This requires the solving of four linear programming (LP) problems. Färe et al. (1994) assume a constant returns to scale (CRS) technology in their analysis.

First we define some notation. y_{it} is a $M \times 1$ vector of output quantities for the i th farm in the t th year;⁸ x_{it} a $K \times 1$ vector of input quantities for the i th farm in the t th year; Y_t is a $N \times M$ matrix of output quantities for all N farms in the t th year; X_t is a $N \times K$ matrix of input quantities for all N farms in the t th year; λ is a $N \times 1$ vector of weights; and ϕ is a scalar, reflecting the degree to which the output vector can be expanded (or contracted).

The required LPs are:

$$[d_o^t(y_t, x_t)]^{-1} = \max_{\phi, \lambda} \phi, \quad \text{s.t.} \quad -\phi y_{it} + Y_t \lambda \geq 0, \\ x_{it} - X_t \lambda \geq 0, \quad \lambda \geq 0, \quad (11)$$

$$[d_o^s(y_s, x_s)]^{-1} = \max_{\phi, \lambda} \phi, \quad \text{s.t.} \quad -\phi y_{is} + Y_s \lambda \geq 0, \\ x_{is} - X_s \lambda \geq 0, \quad \lambda \geq 0, \quad (12)$$

$$[d_o^t(y_s, x_s)]^{-1} = \max_{\phi, \lambda} \phi, \quad \text{s.t.} \quad -\phi y_{is} + Y_t \lambda \geq 0, \\ x_{is} - X_t \lambda \geq 0, \quad \lambda \geq 0, \quad (13)$$

and

$$[d_o^s(y_t, x_t)]^{-1} = \max_{\phi, \lambda} \phi, \quad \text{s.t.} \quad -\phi y_{it} + Y_s \lambda \geq 0, \\ x_{it} - X_s \lambda \geq 0, \quad \lambda \geq 0. \quad (14)$$

These four LP's must be solved for each farm, for each pair of adjacent years for the two crops. With 48 farms and 14 years of annual data, this equates to $2((48 \times 14 \times 3) - 2) = 4028$ LP's. The DEAP computer program (Coelli, 1996) was used to carry out these calculations in this study.

⁸ In the application in this study, we have only one output. Hence, $M = 1$.

⁷ Note that we have not imposed constant returns to scale upon the estimated production frontiers. This will mean that any scale related productivity changes will not be captured by our SFA TFP indices. However, given that we find scale economies very close to one in our empirical work, we expect that any scale effects would be minimal.

4. Data

The farm-level recording and reporting system developed for agriculture in the centrally-planned economies was perhaps one of the most detailed and comprehensive data recording systems ever created (Sloane, 1990; Asian Development Bank, 1992). This is simply due to the fact that the farms were owned by the State and were controlled and managed by it from the top (Coleman, 1989). For this the central authorities needed to obtain all the production and financial data at the top level and instructed farms to supply them with this information. As a result, an enormous amount of data related to all aspects of production and finance was gathered over the years. However, these data have only been analysed in terms of simple statistics and comparisons (Coleman, 1989; Asian Development Bank, 1992).

Farm-level unbalanced panel data⁹ on 48 State farms over the period 1976–1989 were obtained from the original (hand-written) annual farm financial reports of individual State farms kept by the Ministry of Food and Agriculture. Many of these State farms produced grain, potatoes, vegetables and livestock products. However, these various enterprises were managed quite separate from each other. They had separate land areas, labour forces and management teams. The inputs used by each of these enterprises were presented in detail on the State farm annual reports. The present study considers the grain and potato enterprises because these were, by far, the most important outputs. All State farms producing grain and potatoes for human consumption are included in the analysis.

In selecting adequate variables for the analysis, preference was given to physical rather than value variables (wherever possible) to avoid any biases resulting from price distortions. In those cases where the variables were expressed in value terms, the price deflation indices of the *Whole-Sale Price Revision* were used (State Committee for Prices, 1986).

Outputs of grain and potatoes are measured in tonnes. Five input variables are included in the analysis: sown area (hectares); labour (man days);

depreciation and machinery service costs as a proxy for capital (Tgs);¹⁰ fertiliser (Tgs); other costs (Tgs).

Note that the sown area is used as the land measure (as opposed to total crop land) because the ratios of cultivated land to fallow land differed between the crop regions depending on their long-term rainfall levels and soil qualities, which determine the fallow required. Since this ratio was kept constant for each farm over time, sown area was seen as the best measure of land input (see, for example, Wyzan, 1981; Koopman, 1989).

Some other input variables were initially considered, including seed and overhead costs (management), but were found to be not statistically significant at the 5% level and were consequently dropped from the analysis. The reason why the seed and management variables were found insignificant is perhaps due to fact that both of them were used on the farms according to norms per hectare and thus could be multi-collinear with sown area.

5. Results and discussion

Empirical results are presented as follows. We begin with a presentation of the SFA grain results, followed by the discussion of the SFA potato results. We then quickly summarise the DEA grain and potato results, before making comparisons between the SFA and DEA results.

5.1. SFA grain results

Stochastic frontier production functions, as defined in Eq. (7), were estimated using the data described in the previous section. A number of hypothesis tests were conducted, regarding: (i) the consistency of parameter values across the three sub-periods; (ii) the functional form; (iii) the presence of technical change; and (iv) the form of the composed error terms. The results of these likelihood ratio (LR) tests are presented in Table 1.

The first LR test in Table 1 is a test to see if it is valid to pool the data from the three sub-periods. The model defined in Eq. (7) was estimated for the 14-year

⁹ Unbalanced panel data refers to time series data based on panel observations where some observations are missing

¹⁰ The abbreviation “Tgs” stands for Tugrigns, the Mongolian currency. The official exchange rate of Tugrigns against US dollar was fixed until 1989 to the rate 1 US\$ = 3.1 Tgs.

Table 1

Tests of hypotheses for parameters of the SPPF models for grain farms

Null hypothesis	$\ln[L(H_1)]$ (unrestricted model)	$\ln[L(H_0)]$ (restricted model)	λ -statistic	Critical value	Decision
A. H_0 : parameters are identical across the three sub-panels	–125.30 (–35.40 – 76.49 – 13.41)	–237.97	278.98	79.08	Reject H_0
B. H_0 : Cobb–Douglas is preferred ($\beta_{ij} = \beta_{it} = \beta_{tt} = 0, i, j = 1, \dots, 5$)					
1976–1980	–35.40	–67.16	63.51	32.67	Reject H_0
1981–1985	–76.49	–107.04	61.11	32.67	Reject H_0
1986–1989	13.41	–9.84	46.48	32.67	Reject H_0
C. H_0 : no technical change ($\beta_{ij} = \beta_t = \beta_{tt} = 0, j = 1, \dots, 5$)					
1976–1980	–35.40	–57.25	43.68	14.07	Reject H_0
1981–1985	–76.49	–87.14	21.30	14.07	Reject H_0
1986–1989	13.41	9.81	7.18	14.07	Accept H_0
D. H_0 : no trend in technical inefficiency ($\eta = 0$)					
1976–1980	–35.40	–44.25	17.69	3.84	Reject H_0
1981–1985	–76.49	–77.68	2.39	3.84	Accept H_0
1986–1989	9.81	5.65	8.32	3.84	Reject H_0
E. H_0 : no technical inefficiency ($\gamma = \eta = \mu = 0$)					
1976–1980	–35.40	–49.20	27.58	7.05	Reject H_0
1981–1985	–76.49	–81.85	10.73	7.05	Reject H_0
1986–1989	9.81	–5.87	31.36	7.05	Reject H_0

period (1976–1989) and also for each of the three sub-periods (1976–1980, 1981–1985 and 1986–1989). The LR test result indicates that there was a significant difference in the parameters between the three sub-periods. Hence the remaining tests are conducted upon separate models in each of the three sub-periods.

The next three LR tests reported in Table 1 are tests of the Cobb–Douglas functional form versus the translog functional form. The results indicate that the more flexible translog form was favoured in all three sub-periods.¹¹ The following set of three LR test results relate to tests for the existence of significant technical change. These results indicate significant technical change in all but the final sub-period. The next set of results reported in Table 1 are tests for the

significance of technical inefficiency trends, reflected in significant estimates of the η -parameter. The test results indicate significant technical inefficiency trends in all but the second sub-period. The final set of test results reported in Table 1 report tests for the existence of technical inefficiencies. These tests identify significant inefficiencies in all three sub-periods.

Thus, our preferred models for these three sub-periods are: (i) as is defined in Eq. (7) for sub-period 1, (ii) Eq. (7) with η set to zero in sub-period 2, and (iii) Eq. (7) with technical change parameters set to zero in sub-period 3. Parameter estimates for these three models are presented in Table 2. The first-order coefficient estimates may be interpreted as production elasticities at the sample mean because the data was mean-corrected prior to estimation. The second-order terms have not been reported so as to conserve space. Complete results are reported in Bayarsaihan (1998).

The parameter estimates presented in Table 2 have expected signs, with the one exception of the coefficient of fertiliser in the second sub-period, which is negative, but insignificant. The extent of technical change over the study period was found to be rather disappointing. At the mean of the data, technical regress of 6% per annum was observed in the first

¹¹ Note that many past analyses of agricultural productivity change in former centrally-planned economies (e.g. Gemma, 1991; Brada and King, 1993; Carter and Zhang, 1994) have used the restrictive Cobb–Douglas functional form, while the present study uses the more flexible translog functional form. This may be of some importance. For example, Weitzman (1970) seriously questioned the earlier research findings on Soviet growth that were based on Cobb–Douglas functions, and provided alternative explanations for growth in the Soviet Union using a more flexible functional form.

Table 2
Maximum-likelihood estimates of translog models for grain production

Variables	1976–1980	1981–1985	1986–1989
Constant (β_0)	0.323 (0.065) ^a	0.111 (0.078)	0.233 (0.045)
Land (β_1)	0.194 (0.099)	0.36 (0.12)	0.278 (0.072)
Labour (β_2)	0.062 (0.049)	0.421 (0.079)	0.190 (0.056)
Fertiliser (β_3)	0.096 (0.038)	–0.060 (0.055)	0.075 (0.039)
Capital (β_4)	0.627 (0.097)	0.341 (0.099)	0.452 (0.071)
Other costs (β_5)	0.016 (0.029)	0.074 (0.042)	0.068 (0.026)
Time (β_6)	–0.062 (0.031)	0.090 (0.021)	–
Estimates of second-order parameters omitted to conserve space			
$\sigma_s^2 = \sigma_v^2 + \sigma^2$	0.51 (0.17)	0.184 (0.033)	0.072 (0.017)
$\gamma = \sigma^2 / \sigma_s^2$	0.871 (0.05)	0.35 (0.13)	0.47 (0.14)
η	–0.51 (0.12)	–	0.201 (0.073)

^a Estimated standard errors are presented below the corresponding parameter estimates.

sub-period, while technical progress of 9% per annum was observed in the second sub-period, followed by zero technical change in the final sub-period. The technical regress observed in the first sub-period coincides with the period of ‘extensive’ growth policy (1976–1980), when the emphasis was put on increased input use rather than productivity enhancement to ensure higher output. The significant technical progress that occurred in the second sub-period (1981–1985) coincides with substantial government investment to new seeds, machinery and human resources and agricultural research in the crop sector. The absence of technical change in the third sub-period (1986–1989) is, at first a little surprising. However, as we discuss shortly, the improved incentive systems appear to have had a substantial influence upon technical efficiency.

The returns to scale measures (the sum of β_1 to β_5) indicate that, in all three sub-periods, the grain farms were operating in the range of either constant (0.99 in the first sub-period) or mildly increasing returns to scale (1.14 and 1.06 in the second and third sub-periods, respectively). This observation does not support the claim of scale problems in the large-scale farms. This may explain why the large farms in the post-reform period were reluctant to split into smaller units and why recent government action has tried to reverse this fragmentation.

Grain farms in the period 1976–1989 operated, it would seem, significantly under their potential. They operated at estimated average efficiency levels of 0.804, 0.829 and 0.824 in the first, second and third sub-periods, respectively. From the estimates of the

η -parameter reported in Table 1, we see that technical efficiency decreased in the first sub-period, remained constant in the second sub-period and increased in the third sub-period. The overall trend of efficiency change seems to be in line with the initial expectation. The initial decline in farm efficiency falls in the ‘extensive’ growth policy period (1976–1980) when little attention was given to farm incentives. The ‘intensive’ growth policy, which began in the early 1980s, did not result in any significant change of farm efficiency in the second sub-period (1981–1985), most likely because the farms were busy learning the new technologies. However, in the last sub-period (1986–1989), when significant farm reorganisation occurred, we observe a marked upward trend in farm efficiency. During this period, various forms of tenancy systems were introduced to give the workers greater incentives and the farm managers a higher degree of autonomy.

Based on the information on changes in efficiency and technology obtained from the SFA model, the TFP of grain farms over the period 1976–1989 was calculated using the methods outlined in Section 3.¹² The

¹² Note that the technological change measures for the breaks between the three periods were calculated as follows. In the case of the 1980/1981, we predicted mean production in 1980 using mean input data from 1980 and then predicted mean production in 1981 using the 1980 data. The ratio of these two predictions provides a measure of technological change. We repeated the process using 1981 input data and then used the geometric mean of these two technological change measures as our final measure. The same procedure was used for the 1985/1986 break period.

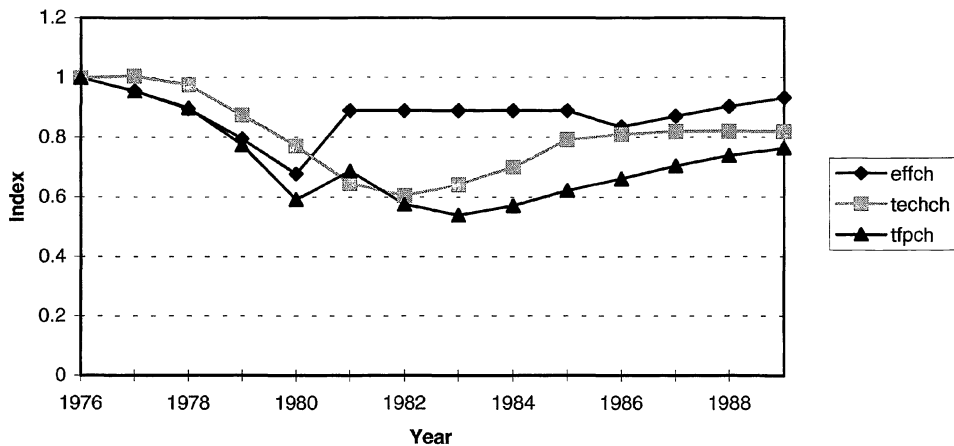


Fig. 1. SFA cumulative indices of changes in efficiency, technology and TFP of grain production, 1976–1989.

TFP results are plotted in Fig. 1 and indicate that the overall TFP change in Mongolian grain farms was rather disappointing. Over the 14-year period there was an overall 23.6% decline in TFP.

However, a closer look at the changing pattern of TFP reveals some interesting trends. The initial fall in TFP during the first 5 years of the study period was replaced by a significant improvement

towards the end of the study period (i.e. during the last 6 years, 1983–1989). During the latter period a total 41.7% increase in TFP is observed (which equates to a 7% increase per year). This suggests that the ‘intensive’ technology and incentive reform policies of the second half of the 1980s had begun to turn around the worrying slide in agricultural performance.

Table 3
Tests of hypotheses for parameters of the SFPF models for potato farms

Null hypothesis	$\ln[L(H_1)]$ (unrestricted model)	$\ln[L(H_0)]$ (restricted model)	λ -statistic	Critical value	Decision
A. H_0 : parameters are identical across the three sub-panels	–433.84 (–157.40 –160.84 – 115.60)	–502.45	137.21	79.08	Reject H_0
B. H_0 : Cobb–Douglas is preferred ($\beta_{ij} = \beta_{it} = \beta_{tt} = 0, i, j = 1, \dots, 5$)					
1976–1980	–157.40	–182.72	50.66	32.67	Reject H_0
1981–1985	–160.84	–171.10	20.51	62.67	Accept H_0
1986–1989	–115.60	133.62	36.03	32.67	Reject H_0
C. H_0 : no technical change ($\beta_{ij} = \beta_t = \beta_{tt} = 0, j = 1, \dots, 5$)					
1976–1980	–157.40	–162.93	11.06	14.07	Accept H_0
1981–1985	–171.10	–171.24	0.28	14.07	Accept H_0
1986–1989	–115.60	–121.11	11.02	14.07	Accept H_0
D. H_0 : no trend in technical inefficiency ($\eta = 0$)					
1976–1980	–162.93	–171.20	16.54	3.84	Reject H_0
1981–1985	–171.23	181.68	20.90	3.84	Reject H_0
1986–1989	–121.11	–125.49	8.76	3.84	Reject H_0
E. H_0 : no technical inefficiency ($\gamma = \eta = \mu = 0$)					
1976–1980	–162.93	–173.87	21.88	7.05	Reject H_0
1981–1985	–171.23	–189.02	35.58	7.05	Reject H_0
1986–1989	–121.11	–127.20	12.18	7.05	Reject H_0

Table 4
Maximum-likelihood estimates of translog models of potato production

Variables	1976–1980	1981–1985 ^a	1986–1989
Constant (β_0)	0.37 (0.14) ^b	0.374 (0.074)	0.32 (0.13)
Land (β_1)	0.79 (0.69)	0.694 (0.081)	0.621 (0.085)
Labour (β_2)	0.184 (0.058)	0.255 (0.060)	0.191 (0.066)
Fertiliser (β_3)	0.053 (0.049)	0.006 (0.033)	0.069 (0.042)
Capital (β_4)	0.177 (0.059)	0.177 (0.042)	0.157 (0.073)
Other costs (β_5)	0.109 (0.041)	0.033 (0.029)	0.083 (0.029)
Time (β_6)	–	–	–
Estimates of second-order parameters omitted to conserve space			
$\sigma_s^2 = \sigma_v^2 + \sigma^2$	0.90 (0.24)	0.321 (0.046)	0.253 (0.047)
$\gamma = \sigma^2/\sigma_s^2$	0.662 (0.102)	0.170 (0.103)	0.27 (0.15)
η	–0.34 (0.12)	0.316 (0.085)	0.32 (0.13)

^a Cobb–Douglas functional form used in second sub-period (i.e. second-order terms in translog set to zero).

^b Estimated standard errors are presented below the corresponding parameter estimates.

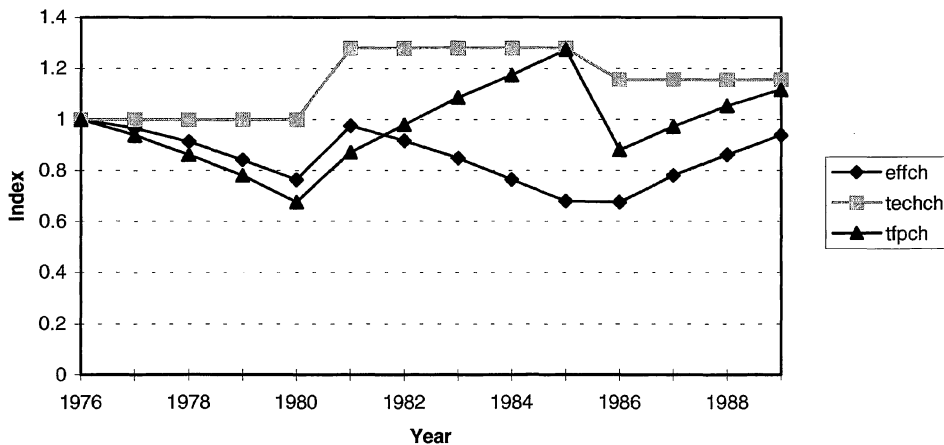


Fig. 2. SFA cumulative indices of changes in efficiency, technology and TFP of potato production, 1976–1989.

5.2. SFA potato results

Our discussion of the potato results will be brief because the same procedures as outlined for grain production were followed for potato production. Using the same battery of LR tests (see Table 3) discussed above, we found that there was a significant difference in the parameters between the three sub-periods. Furthermore, we found that the translog functional form was favoured over the Cobb–Douglas form in all sub-periods, except for sub-period 2. Tests for technical change could find no significant technical change in any sub-period. Tests for technical inefficiency trends (η) found significant trends in all

sub-periods, and tests for the existence of technical inefficiencies also found significant inefficiencies in all three sub-periods.

Parameter estimates for our preferred models for these three sub-periods are presented in Table 4.¹³ The signs of the parameter estimates conform with our expectations. Mean technical efficiencies are 0.734, 0.723 and 0.752, for sub-periods 1, 2 and 3, respectively. Increasing technical efficiency levels towards the end of the sample period conforms our

¹³ The second-order terms have again not been reported to conserve space. Complete results are reported in Bayarsaihan (1998).

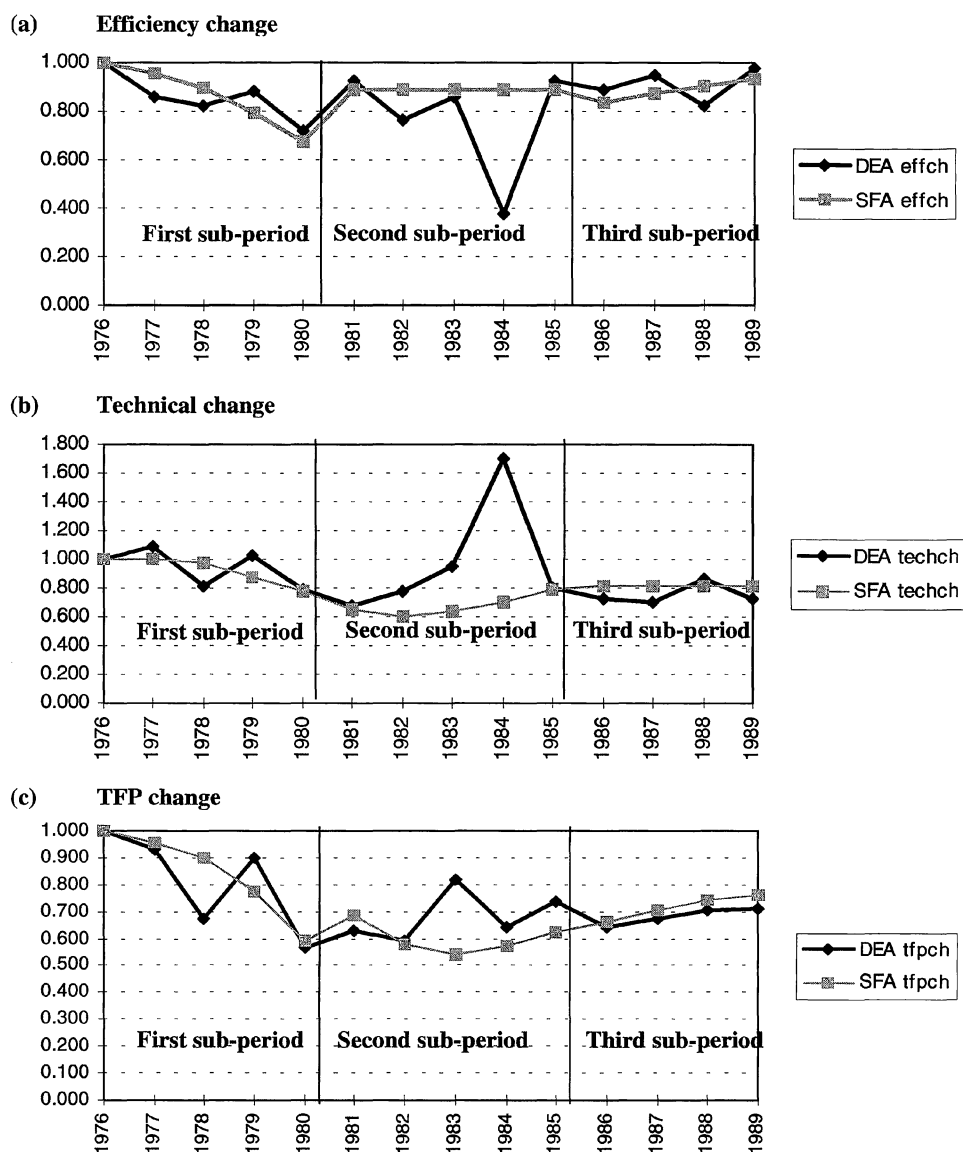


Fig. 3. Comparison of the trends in TFP and its components between DEA and SFA approaches: grain farms, 1976–1989.

earlier observations of the effects of reforms upon grain production.

Based on the information on changes in efficiency and technology obtained from the SFA model, the TFP of potato production over the period 1976–1989 was calculated using the methods outlined in Section 3. The TFP results are plotted in Fig. 2 and indicate that the overall TFP change in Mongolian potato production was better than for grain production, but still

quite low. Over the 14-year period there was an overall 11.6% increase in TFP. This was primarily due to a 15.5% shift in technology (technical progress), which was moderated by a 3.4% efficiency decline.¹⁴ Again,

¹⁴ These results at first appear to contradict the SFA results, where we found no significant technical change but significant technical efficiency change. However, these results were for *within* each sub-period. It is the changes *between* the sub-periods which have the greatest influence upon the results reported in Fig. 3.

a similar pattern of TFP change over time is observed here, as was observed in the case of grain. After a sharp decline in TFP from 1976 to 1980, TFP then increases by an impressive 65.1% in the latter part of the 14-year period.

5.3. DEA results

As mentioned earlier, the primary purpose of using DEA was to investigate the robustness of the SFA results, which are the core analyses of the current

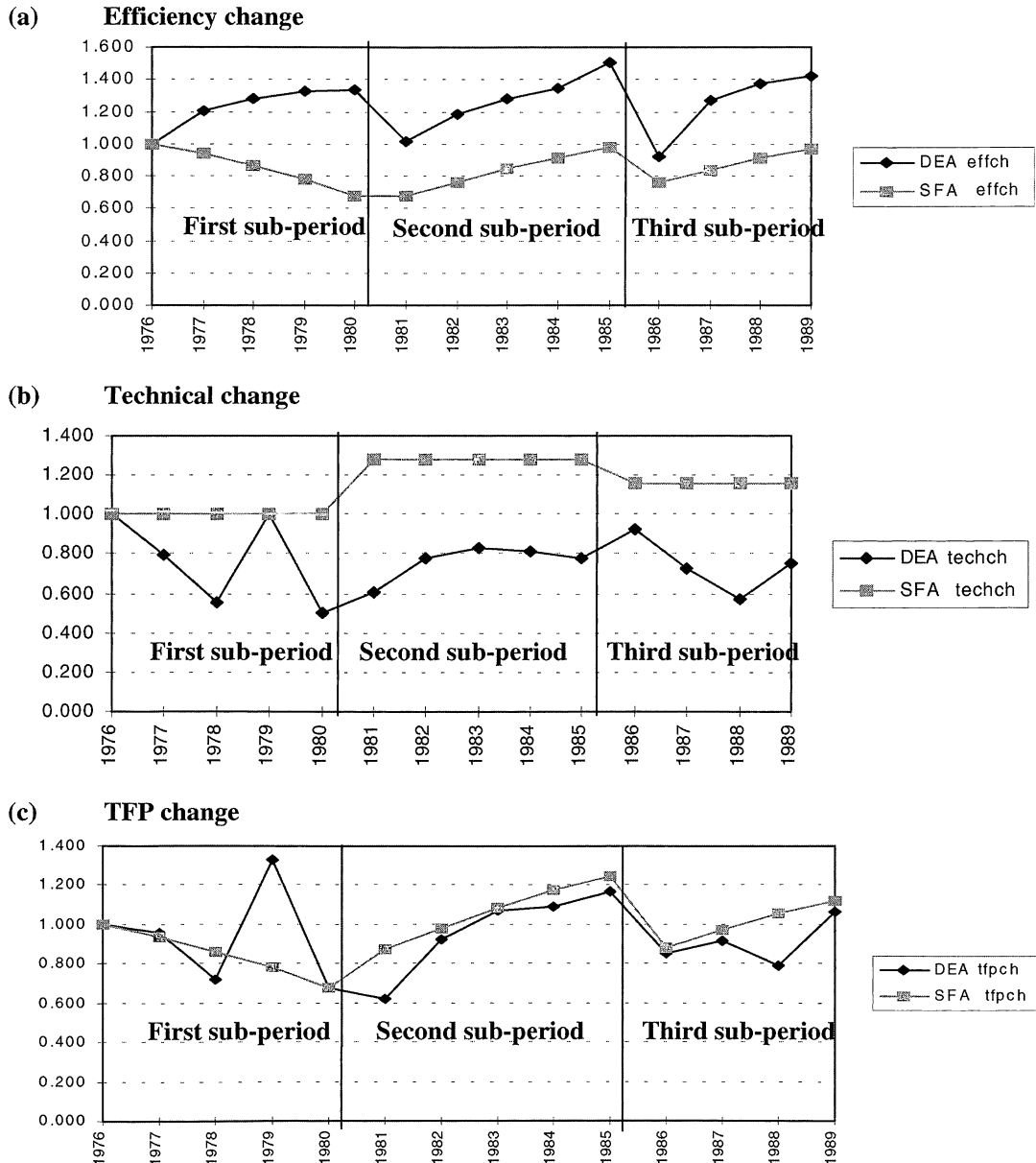


Fig. 4. Comparison of the trends in TFP and its components between DEA and SFA approaches: potato farms, 1976–1989.

Table 5

Comparison of mean efficiency scores between DEA and SFA results in grain and potato production

Period	Grain		Potato	
	DEA	SFA	DEA	SFA
1976–1980	0.804	0.804	0.797	0.734
1981–1985	0.815	0.829	0.803	0.723
1986–1989	0.852	0.824	0.852	0.752

study. In Table 5, we compare the average efficiency scores using DEA and SFA. In the grain case, the average efficiency scores of the individual sub-periods under alternative models were very similar (in the first sub-period, the efficiency scores were identical), whereas in the potato case, the average efficiency scores under the DEA models were slightly higher than those obtained using the SFA models. This is perhaps due to the fact that DEA models can envelope the observations in a more flexible way (hence yielding higher efficiency scores) than the SFA models.

In Table 6, we compare the annual changes in TFP obtained using the DEA and SFA methods, for both grain and potato production. In the grain case, the changes in TFP and its components were found to be quite similar across the two methods. In the potato case, however, the two approaches produced a comparable TFP change (0.5 and 0.8% increase per annum from DEA and SFA, respectively), but the components differed substantially from one another. The DEA results suggest that the efficiency change is most important, while the SFA results suggest that technical change makes the largest contribution.

Finally, Figs. 3 and 4 compare for grain and potato production, respectively, the trend patterns of TFP

change and its components under the DEA and SFA approaches. In both the grain and potato production cases, the trend patterns of efficiency change, technical change and TFP change were found to be similar for the two approaches, despite more year-to-year fluctuations in the DEA results. The overall similarity in the changing patterns of TFP under the two different model specifications (DEA and SFA) suggests that our results are fairly robust to the choice of methodology.

6. Conclusions and policy discussion

The empirical results obtained in this study confirm the expectation that the performance of Mongolian State farms was poor in the 14-year period prior to the 1990 reforms. The results for grain production provide evidence of significant inefficiency, with mean technical efficiency of the order of 80%. Technical efficiency declined over the study period by 6.7%, while technical change also declined by 18.1%. This provides an overall decline of 23.6% in TFP for Mongolian grain farms. However, it is noted that the majority of the decline in TFP occurred in the first half of the study period. In fact, TFP growth of 41.7%, or 7% per year, is observed over the final 6 years. This sudden change in direction of TFP appears to coincide with a notable shift in policy, away from policies encouraging increased input usage, towards policies promoting improved education, management autonomy and incentives.

For the case of potato production, the average technical efficiency level was lower, at approximately 74%. In contrast to grain production, TFP in potato production actually grew by 11.6% over the 14-year period. This comprised a 15.5% increase in technical change and a small 3.4% decline in technical efficiency. This TFP result is obviously better than that for grain, but is still poor in comparison to that achieved in most developed countries (e.g. see Koopman, 1989). In terms of the TFP trend over time, the TFP of potato production followed a similar pattern to that seen for grain. After an initial decline in the 1970s, it also achieved impressive TFP growth of 7% per year over the latter half of the study period.

Our analyses of grain and potato farming were repeated using DEA methods, the results of which

Table 6

Comparison of annual average rates of TFP change and its components between DEA and SFA results in grain and potato production, 1976–1989

Measure	Grain		Potato	
	DEA	SFA	DEA	SFA
Efficiency change	−0.2	−0.5	2.8	−0.2
Technical change	−1.9	−1.3	−2.2	1.1
TFP change	−2.0	−1.7	0.5	0.8

confirmed the general findings we obtained using SFA analysis. What is clear from all our empirical results is that there was a substantial turn around in the performance of Mongolian crop farming in the early to mid 1980s. This appears to coincide with a significant change in the agricultural policy, away from production growth through input growth, towards improved education, greater management autonomy and improved incentives. Thus, our results suggest that the absence of these factors may be one of the main reasons for the poor state of Mongolian agriculture prior to these reforms.¹⁵

It is also interesting to note that our empirical results indicate that the majority of the measured TFP change was due to technical change. Some past studies have suggested that poor technical change is most likely the result of a lack of investment in technology, while low technical efficiency is generally due to management and incentive problems (Gregory and Stuart, 1981; Brooks et al., 1991, p. 152). However, caution needs to be exercised in the interpretation of the empirical results in this study. Even though we do find that technical change (frontier shift) is the main contributor to TFP change (both to the initial decline and to the subsequent rally), it should be noted that the total shift in the frontier between the first year and the last year of the study period is negative in the case of grain, and only marginally positive in the case of potatoes. Hence, if one begins from the logical position that technical knowledge cannot be ‘lost’, one must conclude that the measured ‘technical regress’ and subsequent ‘technical progress’ during the study period is primarily due to uniform reductions and subsequent increases in technical efficiency across all farms. Thus, from our empirical results, we conclude that the decline and subsequent improvement in productivity in Mongolian crop production is most likely a result of problems with management and incentive structures, rather than any initial ‘loss’ and subsequent ‘rediscovery’ of agricultural technology.

However, given that there is little or no net technical progress over the period, one may also conclude that technology was not improving very much during this period.¹⁶

Finally, even though the data used in this study does not extend into the 1990s, our empirical results may suggest that some of the policy reforms implemented in Mongolia in the early 1990s may not have been optimal, in retrospect. In particular, two conclusions of some relevance are that: (i) the splitting up of the large State farms could not be justified on the basis of scale economies, since we could find no evidence of decreasing returns to scale, and (ii) the management and incentive reforms that had been implemented in the 1980s were clearly reaping dividends, and hence that the rush to privatisation (and subsequent damaging flight of skilled labour and abandonment of land) could perhaps have been avoided by a more orderly implementation of co-operative structures, at least during a transition period.¹⁷ This observation tends to support the recent discussion of the negative aspects of the *shock therapy* approach to economic transition. A number of commentators now acknowledge that, given the initial absence of the institutions necessary for a market economy, the transition process in many countries may have been more successful if one had utilised the existing organisational and institutional capital, and undertaken reforms in more measured ways (Stiglitz, 1999).

However, we must keep in mind that the empirical evidence in this paper is confined to the case of Mongolian agriculture. Additional analyses of firm-level panel data in other countries may help shed further light on these important questions, which are fundamental to providing a better understanding of the reasons for the demise of communism.

¹⁵ We should note that this study is an analysis of pre-1990 data in Mongolia, with the primary aim of measuring and explaining past problems. We do not have access to recent data and hence we do not attempt to address current agricultural policy issues in Mongolia. This is not to say that such issues are not important. An analysis of current issues such as food self-sufficiency, water shortages, and market structure would be particularly beneficial, if suitable data were available.

¹⁶ Two additional points are worth noting here. First, part of the measured technical regress could have been due to declining quality of natural resources, such as soil and water. Unfortunately, we have no data available to us to test this hypothesis. Second, we are confined to Mongolian data, hence we are unable to make definitive comments regarding the relative quality of the agricultural technology used in Mongolia versus the rest of the world. Additional data from a western country with similar climatic and soil conditions (perhaps parts of Canada) would be required before we could look more closely at this issue.

¹⁷ However, some of these problems would have been unavoidable, given the reduction in Soviet funded subsidies.

Acknowledgements

This paper is derived from the unpublished Ph.D. Thesis of T. Bayarsaihan, *An Analysis of Efficiency and Productivity in Mongolian Crop Farming*, Faculty of Economics, Business and Law, University of New England, Armidale. The views expressed in this paper are those of the authors and not necessarily those of the Asian Development Bank. The authors thank the late John Dillon for many helpful comments. The authors bear responsibility for any errors that may remain.

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