The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

Productivity of Mongolian Grain Farming: 1976-89[1]

by

T. Bayarsaihan, G. E. Battese and T. J. Coelli

Centre for Efficiency and Productivity Analysis
University of New England
Armidale, NSW 2351.
Ph: (067) 73 3563, Fax: (067) 73 3607
Email: tbayarsa@metz.une.edu.au

ABSTRACT

This paper uses stochastic frontier production function models applied to farm level input-output data to attempt to measure and explain efficiency, technological change and productivity changes in Mongolian grain farms during the pre-reform period (1976-89). The results obtained point towards a 13.6 percent decline in efficiency, a 6.4 percent decline in technology and an 18.3 percent overall decline in TFP over the 14 year study period. However, it is observed that in the final nine years of the study period TFP went against this trend with a 56 percent growth in TFP. This suggests that the shift away from policies encouraging increased input usage (prevalent in the 1970's) towards the "intensive" technology and incentive reform policies of the 1980's was beginning to achieve considerable success.

Results also indicated that farm efficiency levels were significantly and positively correlated with vocational technical education, experience of the farmers, levels of Russian technical advice and the incentive systems used on the farms. We also found evidence constant or mildly increasing returns to scale, suggesting that the current economic reform of splitting the original State Farms into smaller units may not justified on the grounds of scale economies.

---

[1] Paper presented to 41st Australian Agricultural and Resource Economics Society Conference, Gold Coast, 20-25 January, 1997.

1. Introduction

Mongolia is a central Asian country with an agricultural-based economy. The land area is approximately half the size of India (1.6 million sq. km) and the population is estimated to be 2.4 million, as of 1996. Agriculture and its related industries employ about 40 per cent of work force and generates 30 per cent of national income. Animal husbandry is the principal sector, producing about three quarters of total agricultural output.

Arable farming is a non-traditional sector, which has been significantly expanded over the last four decades. Mongolian arable farming is characterised by low productivity and high risk due to high altitude, harsh climatic conditions and the absence of domestic production of such important agricultural inputs as machinery, fertiliser and chemicals. The principal crops are grain (85 % wheat, with the remainder barley and oats), potato and vegetables. Among them grain is the single most important agricultural commodity.

Despite the above mentioned technical and economic limitations, the Government has allocated substantial resources into the arable sector in order to boost agricultural production during the last two decades. As a result, in the second half of the 1980s, self-sufficiency in grain production was achieved and a substantial part of the total vegetable and potato requirements were supplied domestically.

The dramatic political, social and economic reforms of the former centrally-planned economies (including Mongolia) that began in the early 1990s have since had a substantial effect upon Mongolian agriculture. Mongolia began a new market-driven economic system in 1991. This involved major macro-economic reforms, including the floating of exchange rate, liberalization of foreign trade and prices and global privatisation. Furthermore, a variety of agricultural subsidies were also removed.

As a result of the privatisation process, the Former State Farms, which were primarily involved in crop production, have been broken up into smaller share-holding companies with their workers becoming the shareholders. The new competitive market environment, to which the individual companies have been exposed, has put enormous pressure onto farmers. The enhancement of the productivity of grain farming has become a vitally important issue, both to the farmers themselves and to a government concerned about declining grain production levels.

The principle aim of this paper is to analyse the productivity of Mongolian grain farming. The analysis will utilise data on 48 State Farms over the 14 year period from 1976 to 1989. We focus on the immediate pre-reform period (instead of the post-reform period) for three reasons. Firstly, post-reform farm data is likely to be very costly and difficult to collect. Secondly, this data is likely to be of a very poor quality given the disruptions to record keeping resulting from the reform process, and thirdly, any analysis of post-reform data is likely to be heavily influenced by disruptions to input markets during the reform process. That is, 1992-1996 data is more likely to reflect the costs of the reform *process* rather than the benefits of a market economy.

Furthermore, we have observed that following privatisation, most grain farms continue to function in a similar way to the old State Farms in the terms of structure and technology, but with reduced sizes of units. Hence our analysis of pre-reform data is likely to provide information which will be particularly useful to the government in the formulation of development strategies for the grain sector.

The analysis conducted in this study is the first attempt at a rigorous analysis of the total factor productivity (TFP) of Mongolian crop farming. We look not only at TFP differentials across farms and through time, but also consider the decomposition of TFP change into technical change and technical efficiency change components. We furthermore obtain measures of scale economies and also investigate a range of factors (such as farmer education, experience etc.) as possible explanators of efficiency differences.

The remainder of this paper is organised into sections. In the following section we provide a brief description of Mongolian grain production. In Section 3 we discuss the stochastic frontier production function methodology which is used in this paper and in Section 4 we describe the data used. Results and discussion is provided in Section 5 and some brief concluding comments are made in the final section.

2. Mongolian Grain Production

The centrally-planned development initiatives of the Mongolian agricultural sector were accelerated in the mid 1970s and continued until the end of the 1980s. In general, the development initiatives were implemented in three different ways: (i) increased use of conventional inputs, (ii) the development and importation of new technology and (iii) a series of policy reforms aimed at improving farm efficiency. Although all three elements of the development effort were present at every stage of the development, the emphasis shifted more in favour of the last two components particularly towards the end of the 1980s.

Until the mid- 1980s, the development mostly occurred by way of further expansion of new marginal agricultural land, increased use of labour, new investment into building, machinery and irrigation, and increased application of modern inputs, such as fertiliser, chemicals and new seeds (Ulziihutag, 1992).

In the early 1980s, it became increasingly difficult to achieve output growth by increasing conventional inputs (due to resource shortages). Hence the Government began shifting its policy from so called "extensive" into "intensive" growth strategy. The emphasis of the new approach was the increased role of new technology, the development of workers education and skills, and the introduction of economic reforms with the aim of providing incentives for workers to achieve more efficient production.

During the past three decades a total of 20 new grain varieties were introduced into production (Ulziihutag, 1992). Also a comprehensive agronomic analysis was conducted on 400 000 ha of arable land. (Ulziihutag, 1992). New comprehensive soil protection technology was introduced on 10,300 ha of land , and wind breaks were introduced on 100 000 ha of land (Economic and Social Development, MPR, 1988). As part of the policy of introducing new technology, in 1986 the Government introduced a so called "intensive technology package" into production. The official report states that an average yield from land using intensive technology was 30-90 per cent higher than the national yield (Ministry of Agriculture, 1991). All these efforts demonstrate the importance that the Government attached to the development of new technology.

Much of the Government official documents of that period including The Reports of Implementation of 6th and 7th Five-Year Plan (Unen, 1981 and 1986) emphasised the importance of efficiency improvement and technology development. In the ten years between 1975 and 1986, the number of farm staff with high school education increased 380 per cent, the number with University Degrees increased 190 per cent and Technical College Graduates increased by 160 per cent (Ministry of Agriculture, 1986).

In addition to the investment into new technology and human resources development, the Government undertook a series of incentive reforms in an attempt to improve farm efficiency and performance. Two distinctive stages of this reform in State Farm sector can be observed prior to 1990, the first began in the mid-1970s, the second in the mid-1980s. This reform was primarily aimed at increasing output and productivity by way of introducing an improved incentive system and bringing output prices to the level of real production costs. In the second stage of the reform (1986-1989) the tight planning process was gradually relaxed and farms exercised more and more autonomies in terms of resource allocation and actual production management (Coleman, 1989). During this period (1986-1989), several new forms of farm incentive systems were experimented with within the State Farm structure including Simple-, and Tenancy Contracts. (Ministry of Agriculture, 1990)

One of the principal aims of the present study is to shed some light upon the actual impacts of the various Government technological and reform policies on farm performance in terms of efficiency and productivity.

The analysis of Mongolian agricultural productivity may also make a small contribution to the wider debate surrounding the reasons behind the economic failure of Centrally Planned Agriculture. Only a few studies related to agricultural productivity and efficiency issues have been carried out for the former centrally planned economies except for China[2]. These studies often had controversial findings and frequently pointed against the prevailing course of development (Carter and Zhang, 1994; Johnson et al. 1994; Brada and King 1993; Koopman 1989). Moreover, the majority of these analyses have looked at agricultural efficiency issues from the aggregated national/international level. Hence our analysis of farm-level data may provide valuable insights that may have been masked by aggregation effects in previous studies.

A number of papers have suggested that a productivity slowdown was one of the major reasons for the deterioration of the overall communist economic system (Moroney and Lovell, 1991; Bergson 1983, 1992; Levine 1982). A thorough analysis of Mongolian grain farming using farm level data would contribute to the existing knowledge on this area. Given the fact that Mongolian grain farms were almost exact prototypes of Soviet Sovkhoz farms in terms of structure and functioning and also that there has been a striking similarity in policy change patterns in Mongolian and Soviet Agriculture, this analysis of Mongolian farm-level data may provide valuable insights into the characteristics of pre-reform Soviet-style agricultural enterprises.

---

[2]It should be noted here that due to political and ideological confrontations existed between China and the rest of the former socialist countries since early 1960s, the economic developments of the two groups followed quite different patterns.

3. Analytical framework

Previous analyses of agricultural productivity have used a variety of economic models including production, cost and profit functions. The choice of an analytical framework in this study is limited by the nature of the centrally planned economic system. The basic assumptions underlying the market based models such as competitive input and output markets, and cost-minimising or profit maximising firm behaviour, are not relevant in this case. Output maximising behaviour is believed to be more in line with the output target system present in the centrally planned system. For this reason, most of the empirical studies involving the former centrally planned economies have opted for the use of production functions in preference to cost or profit functions. So is the case for this study.

Stochastic Frontier Production Function (SFPF) models (see Lovell, 1993 and Coelli, 1995) are used in this analysis. They were chosen for several reasons. Firstly, as noted by Coelli (1995), the SFPF approach is well suited to the analysis of production efficiency in industries in which data noise is likely to be a particular problem. Mongolian arable farming experiences large variability in yields as a consequence of a hostile and volatile climate.[3]

A second reason for the choice of SFPF methods is that when applied to panel data, SFPF models are capable of capturing both efficiency change and technological change as components of productivity change. This is in contrast to conventional productivity measurement methods, such as index numbers or aggregate production analyses, which ignore efficiency effects, resulting in potential biases (Grosskopf 1993). This decomposition of productivity change introduces an additional dimension to the analysis from the policy perspective, as both elements, efficiency and technical changes, often entail different policy recommendations (Nishimizu and Page 1982; Perelman, 1995).

A further advantage of the SFPF method is that it can be used to explain efficiency variation in terms of potential explanatory variables. To the knowledge of the authors, thus far, no one study on centrally planned economic system has attempted to this. Therefore, the application of the recently developed SFPF model for inefficiency effects model (see Kumbhakar et al., 1991 and Battese and Coelli, 1995) to the centrally planned agriculture case should provide some valuable information on factors influencing the efficiency of centrally planned economic systems.

A SFPF differs from a conventional ordinary least squares (OLS) production function in the structure of the error term. The error term is divided into two elements: a symmetric part reflecting stochastic elements and a non-symmetric non-negative part representing inefficiencies.

A stochastic frontier production function for panel data may be defined as:

$$Y_{it} = f(X_{it};\beta)\exp(V_{it} - U_{it}), \qquad i = 1.....N,\ t = 1.....T, \tag{1}$$

where

Y_{it} denotes the production level for the i-th farm in the t-th year;

[3] Data envelopment analysis (DEA) can also be used the measure efficiency in production. However this linear programming method is not well suited to noisy data because it assumes no noise is present.

X_{it} is a vector of inputs associated with the production of the i-th firm in the t-th period of observation,

f(.) is a suitable function describing the production technology (such as the translog discussed below);

V_{it} are assumed to be independent and identically distributed random errors which have normal distribution with mean zero and variance σ_v^2,

U_{it} are non-negative random variables associated with the technical inefficiency of production, and

β is a vector of unknown parameters to be estimated.

Two different SFPF panel data models are considered in this paper. The first model assumes that the technical inefficiency effect (U_{it}) of a firm is the product of a random variable and an exponential time trend (Battese and Coelli, 1992). This model is applied to all 14 years of data and is used to obtain information on technical efficiency and technological change. The second model we consider assumes that the inefficiency effect is a function of a vector of explanatory variables and a random variable (Battese and Coelli, 1995). This model is applied to the final three years of data only, because our data on the explanatory variables are limited to these last three years. This latter model provides valuable information on the possible causes of efficiency differentials between farms. The structure of these two alternative models is outlined below.

Model 1: SFPF with Time-varying Inefficiency Effects

The technical inefficiency effects in the SFPF with time varying inefficiencies are modelled as (Battese and Coelli, 1992):

$$U_{it} = \eta_{it}U_i = \{\exp[-\eta(t-T)]\}U_i, \; t \in \tau(i), \qquad (2)$$

where

η is an unknown parameter to be estimated; and

U_i are independent and identically distributed non-negative random variables, obtained by truncation (at zero) of the normal distribution with unknown mean μ and variance σ^2.

We observe that when $\eta > 0$, U_{it} decreases as t increases; when $\eta < 0$, U_{it} increases; and when $\eta = 0$, U_{it} is constant through time.

Model 2: SFPF with a Model for the Inefficiency Effects

The second model is that proposed by Battese and Coelli (1995) where the inefficiency effects are influenced by a function of farm-specific explanatory variables:

$$U_{it} = z_{it}\delta + W_{it} \qquad (3)$$

where

z_{it} is a vector of explanatory variables associated with the technical inefficiency effects;

δ is a vector of unknown parameters to be estimated; and

the W_{it}'s are unobservable random variables, which are assumed to be independently distributed, obtained by truncation of the normal distribution with mean zero and variance, σ^2, such that U_{it} is non-negative (i.e., $W_{it} \geq -z_{it}\delta$). [One could equivalently say that the inefficiency effects, U_{it}, are assumed to be independent non-negative truncations of the normal distribution with mean, $z_{it}\delta$ and variance, σ^2.]

The maximum likelihood method is used to estimate the unknown parameters in each of the models. This was done using the computer program, FRONTIER, version 4.1 (see Coelli, 1994). In the case of Model 2, the parameters of both the stochastic frontier and inefficiency effects model are estimated simultaneously, thus avoiding the statistical biases inherent two-stage estimation methods (Battese and Coelli, 1995).

The technical efficiency (TE) of the i-th farm in the t-th year is equal to the ratio of the observed output level to the output level predicted by the SFPF (and hence will take a value in the 0-1 interval). This can be shown to be equivalent to $\exp(U_{it})$. As done in Battese and Coelli (1992, 1995), we use the expectation of U_{it}, conditional upon $E_{it}=V_{it}-U_{it}$ to predict the (unobservable) U_{it}, and hence to predict $TE_{it}=\exp(-U_{it})$.

4. Data Sources and Variable Definitions

Concerns regarding data from centrally planned economies have traditionally been related to their availability and reliability. Prior to the recent reforms, most of the data made available to the public were disguised and kept in highly aggregated form mainly for propaganda or ideological reasons. The enormous quantity of data used for decision making, planning and control were not disclosed and hidden away from wider public use. It was only after the radical reform of 1991, that micro-level data has become available to the public. It is data such as this which is used in the current study.

Farm level input and output data on 48 farms over the 14 year period, 1976-1989 were obtained from the individual annual farm financial reports kept at the Ministry of Agriculture. Data on some farms in some years were not available. Hence a total of 507 observations were collected. Additional data on farm-specific characteristics for the final three years of the study period, 1987-1989, were obtained from separate sources for the 48 farms. These sources included Farm Human Resources Reports (Ministry of Agriculture) and the Statistical Yearbooks of the State Statistical Board.

In selecting the adequate variables for the production function, the preferences were given to physical measures rather than monetary values (where ever possible) to avoid any biases resulting from price distortions. In those cases where the variables were expressed in value terms, these values are deflated by the official price changes (Whole-sale Price Reform, 1986).

The two stochastic frontier models employed here used essentially the same dependent and explanatory variables with a few differences as stated below. Firstly, because the farm characteristics data were available only for the last three years (1987-1989) of the study period, the model involving these variable was estimated only for this period. Secondly, in the Model 2, we have included an additional variable, the index of natural conditions, to capture and separate the effects of the differences in natural conditions on the production levels and the efficiency levels of individual farms.

The variables used in the Stochastic Frontier Production Function analyses are:

- Grain output (in tonnes)

- Cultivated land (in hectares)
- Labour (in mandays)
- Capital (depreciation and machinery service costs in tgs)
- Fertiliser (in tgs)
- Other costs, including bags, and materials for harvest (in tgs)
- Time as a proxy for technical change
- Index of Natural Conditions.[4]

The detailed data on farm specific characteristics (which are used as explanatory variables for the inefficiencies) were available only by 13 provinces (not by individual farms) over the three year period, 1987-1989. This provincial level data were assigned to individual farms depending on which province each individual farm belonged to. In other words, the farms belonging to the same province would have the same values for a given year.

Farm-Specific Explanatory Variables used in Model 2 are:

- The percentage of the Graduates of Vocational Technical School in total number of grain workers
- The percentage of workers with more than 6 years experience.
- Index of Natural Conditions[5]
- Time as proxy for omitted factors
- Dummy Variable 1 (Russian built/assisted farms=1, otherwise=0)
- Dummy Variable 2 (Farms introduced economic remuneration system=1, otherwise=0)

5. Results and discussion

Summary statistics on the input and output variables are listed in Table A1 in the Appendix. It is interesting to note that the mean values of all variables, except for sown area, increased over the study period with the highest rate of increase observed in *Other Cost* (a 3.5 times increase). We also note that as the mean of production increased so too did the standard deviation. This may suggest a less than even distribution of resources between farms or perhaps greater variation in efficiencies.

Model 1: SFPF with Time-varying Inefficiency Effects

In this study, the translogarithmic functional form is used for the SFPF.

---

[4] This is an aggregate index reflecting three different variables: soil quality (% of soil organic matter), long-term average precipitation (mm) and long-term average temperature. This variable was constructed by Ekh-amgalan and Myagmarjav (1993).

[5] This variable was included both in the frontier function as well as inefficiency effects function in order to establish explicitly the influence of natural conditions upon efficiency levels of the farms. The hypothesis being that poor natural conditions will not only directly reduce land productivity but will also have an indirect effect on efficiency through reduced worker motivation resulting from the unfavourable conditions.

$$\ln Y_{it} = \beta_0 + \sum_{j=1}^{5}\beta_j \ln x_{jit} + \sum_{j=1}^{5}\sum_{k=1}^{5}\beta_{jk} \ln x_{jit} \ln x_{kit} + \sum_{j=1}^{5}\beta_{tj} t.\ln x_{jit}$$

$$+\beta_t t + \beta_{tt} t^2 + V_{it} - U_{it}, \qquad i = 1.....N, t = 1.....T, \qquad (4)$$

where the subscripts i and t represent the i-th farm and the t-th year of observation respectively. Simpler forms such as the Cobb-Douglas where considered and subsequently rejected on the basis of likelihood ratio tests (see below).

Model 1 was estimated for the overall period (1976-1989) as well as for three different sub-periods (1976-1980; 1981-1985; 1986-1989), reflecting different policy benchmarks of each of the five-year plans. Some of the key parameter estimates are listed in Table 1. To conserve space we have omitted the estimates of the second-order parameters since these are not of vital interest. The full set of results are available from the authors.

Table 1

Maximum-likelihood estimates for the parameters of the stochastic frontier production functions with time-varying effects for the Mongolian grain farmers

Variables	Parameter	Model 1.0 1976-1980	Model 2.0 1981-1985	Model 3.0 1986-1989	Model 4.0 1976-1989
Constant		0.39	0.042	0.33	0.050
		(0.12)	(0.068)	(0.18)	(0.041)
Land	β_1	0.217	0.35	0.353	0.326
		(0.106)	(0.11)	(0.090)	(0.064)
Labour	β_2	0.063	0.424	0.234	0.211
		(0.052)	(0.077)	(0.059)	(0.040)
Fertiliser	β_3	0.096	-0.065	0.077	0.043
		(0.039)	(0.053)	(0.041)	(0.030)
Capital	β_4	0.625	0.342	0.395	0.474
		(0.101)	(0.096)	(0.075)	(0.053)
Other cost	β_5	0.010	0.077	0.056	0.076
		(0.031)	(0.041)	(0.027)	(0.022)
Time	β_6	-0.030	0.125	0.009	0.0257
		(0.061)	(0.030)	(0.056)	(0.0074)
[second order terms omitted for brevity]					
	$\sigma^2_s = \sigma^2_v + \sigma^2$	0.238	0.51	0.052	0.75
		(0.104)	(0.18)	(0.014)	(0.29)
	$\gamma = \sigma^2/\sigma^2_s$	0.72	0.778	0.28	0.824
		(0.13)	(0.092)	(0.17)	(0.070)
	μ	0.66	-1.26	0.24	-0.16
		(0.38)	(0.52)	(0.16)	(0.41)
	η	-0.48	-1.26	0.14	-0.009
		(0.13)	(0.52)	(0.14)	(0.022)
Return-to-Scale		1.011	1.133	1.115	1.131
Log-Likelihood		-37.7	-75.0	11.54	-240.1

[1] The estimated standard errors are presented below the corresponding parameter estimates.

The models are estimated in terms of the transformed variance parameters $\sigma_s^2=\sigma^2+\sigma_v^2$ and $\gamma=\sigma^2/\sigma_s^2$. This is done for computational reasons (see Coelli, 1994). The parameter γ can take a value between 0 and 1. A value of 0 implies that the technical inefficiency is not present (and hence that the traditional average response function is an adequate representation of production technology) while a value of 1 implies that there is no noise present. If the parameter μ is zero, then the U_i have a half-normal distribution rather than the more general truncated normal distribution. The generalised likelihood-ratio test[6] was used to test a variety of hypotheses regarding functional forms and error distributions. The results of these tests are listed in Tables 2 to 5 and are discussed below.

<u>**Panel 1: 1976-80**</u>

As shown in Table 2, given the specification of the time-varying inefficiency model (4), the null hypothesis that all second order terms are not significantly different from zero was strongly rejected. (Model 1.1). Thus, the Translog functional form was preferred to Cobb-Douglas functional form. Also, the null hypothesis of no technical change is rejected (Model 1.2). Hence, technical change is present in the model. The null hypothesis that γ is zero rejected, implying that the traditional average response function in which farms fully inefficient is not an adequate representation of the data. So, the stochastic frontier production function is preferred to average response function in describing production technology. The null hypothesis that technical efficiency is time-invariant is rejected (Model 1.4). Hence, the negative value of η suggests that the efficiency levels of farms were decreasing over time. In the final Model 1.5, the null hypothesis that the half-normal distribution for the inefficiency term was preferred to more general representation was accepted.

Table 2

Generalised-likelihood Ratio Tests of Hypotheses for Parameters of the SFPF Models for Grain Farmers in Mongolia for Panel 1: (1976-1980)

Assumptions	Null Hypothesis	Log-Likelihood	χ^2-statistic	Value of statistic	Decision
Model 1.0		-37.709			
Model 1.1	H_0: $\beta_{ii}=\beta_{ij}=\beta_{it}=0$, i,j=1,...,5.	-68.58	$\chi^2_{21,0.95}=32.67$	61.74	H_0: Reject
Model 1.2	H_0: $\beta_{tt}=\beta_t=\beta_{it}=0$ j=1,...,5.	-63.99	$\chi^2_{7,0.95}=14.07$	52.56	H_0: Reject
Model 1.3	H_0: $\gamma=0$	-51.33	$\chi^2_{3,0.95}=7.82$	27.23	H_0: Reject
Model 1.4	H_0: $\eta=0$	-46.03	$\chi^2_{1,0.95}=3.84$	16.6	H_0: Reject
Model 1.5	H_0: $\mu=0$	-38.50	$\chi^2_{1,0.95}=3.84$	1.58	H_0: Accept

<u>**Panel 2: 1981-85**</u>

The same battery of hypothesis tests are applied to the second panel. The test results listed in Table 3 indicate that the same conclusions are made on all tests with the one

[6] The likelihood-ratio test statistic is calculated as $\lambda=-2\{\log[\text{Likelihood}(H_0)]-\text{Likelihood}(H_1)\}$. It has chi-square distribution, with parameter equal to the number of parameters assumed to be zero in the hull hypothesis, H_0, provided H_0 is true.

exception that the null hypothesis that technical efficiency is time-invariant is not rejected in this instance. Thus, even though the negative sign on the η estimate suggests that efficiency was decreasing over time, the test result indicates that this is not statistically significant.

Table 3

Generalised-likelihood Ratio Tests of Hypotheses for Parameters of the SFPF Models for Grain Farmers in Mongolia for Panel 2: (1981-1985)

Assumptions	Null Hypothesis	Log-likelihood	χ^2-statistic	Value of statistic	Decision
Model 2.0		-75.026			
Model 2.1	H_0: $\beta_{ij}=\beta_{it}=\beta_{tt}=0$, i,j=1,...,5.	-107.29	$\chi^2_{21,0.95}=32.67$	64.52	H_0: Reject
Model 2.2	H_0: $\beta_{it}=\beta_t=\beta_{tt}=0$ j=1,...,5.	-86.16	$\chi^2_{7,0.95}=14.07$	22.27	H_0: Reject
Model 2.3	H_0: $\gamma=0$	-80.94	$\chi^2_{3,0.95}=7.82$	11.82	H_0: Reject
Model 2.4	H_0: $\eta=0$	-76.20	$\chi^2_{1,0.95}=3.84$	2.35	H_0: Accept
Model 2.5	H_0: $\mu=0$	-76.19	$\chi^2_{1,0.95}=3.84$	2.33	H_0: Accept

<u>Panel 3: 1986-89</u>

Table 4 contains the test results for the third panel. The conclusions made on all tests are identical to the conclusions for the first panel. We note however that the positive sign on the η estimate indicates that efficiency was increasing over time.

Table 4

Generalised-likelihood Ratio Tests of Hypotheses for Parameters of the SFPF Models for Grain Farmers in Mongolia for Panel 2: (1986-1989)

Assumptions	Null hypothesis	Log-likelihood	χ^2-statistic	Value of statistic	Decision
Model 3.0		11.539			
Model 3.1	H_0: $\beta_{ij}=\beta_{it}=\beta_{tt}=0$, i,j=1,...,5.	-11.21	$\chi^2_{21,0.95}=32.67$	45.51	H_0: Reject
Model 3.2	H_0: $\beta_{it}=\beta_t=\beta_{tt}=0$ j=1,...,5.	3.04	$\chi^2_{7,0.95}=14.07$	17.01	H_0: Reject
Model 3.3	H_0: $\gamma=0$	3.64	$\chi^2_{3,0.95}=7.82$	49.73	H_0: Reject
Model 3.4	H_0: $\eta=0$	9.33	$\chi^2_{1,0.95}=3.84$	4.42	H_0: Reject
Model 3.5	H_0: $\mu=0$	11.01	$\chi^2_{1,0.95}=3.84$	1.06	H_0: Accept

<u>Total Panel : 1976-89</u>

Table 5 contains the test results for the full panel. The conclusions made on all tests are identical to the conclusions for the second panel. The conclusion that technical inefficiency is time-invariant is not surprising given that the results for the three sub-panels suggested a period of decreasing efficiency, followed by a stagnant period, then a period of increasing efficiency.

A likelihood ratio test was used to test the null hypothesis that the values of the parameters of the SFPF were identical across the three sub-periods versus the alternative hypothesis that they were different (a Chow test). The test statistic was calculated to be 682.60. This exceeds the $\chi^2_{64,\,0.95}$ critical value of 83.5, hence we reject the null hypothesis and conclude that the results from the models estimated for the three sub-panels should be the focus of our attention.

Table 5

Generalised-likelihood Ratio Tests of Hypotheses for Parameters of the SFPF Models for Grain Farmers in Mongolia for the Full Panel: (1976-1989)

Assumptions	Null Hypothesis	Log-likelihood	χ^2-statistic	Value of statistic	Decision
Model 4.0		-240.10			
Model 4.1	H_0: $\beta_{ii}=\beta_{ij}=\beta_{it}=0$, i,j=1,...,5.	-370.95	$\chi^2_{21,0.95}=32.67$	261.69	H_0: Reject
Model 4.2	H_0: $\beta_{tj}=\beta_t=\beta_{tt}=0$ j=1,...,5.	-268.30	$\chi^2_{7,0.95}=14.07$	56.40	H_0: Reject
Model 4.3	H_0: $\gamma=0$	-263.65	$\chi^2_{3,0.95}=7.82$	47.09	H_0: Reject
Model 4.4	H_0: $\eta=0$	-240.18	$\chi^2_{1,0.95}=3.84$	0.16	H_0: Accept
Model 4.5	H_0: $\mu=0$	-242.34	$\chi^2_{1,0.95}=3.84$	2.24	H_0: Accept

To conclude, the three separate sub-panels divided according to five year plans have been statistically preferred option against a single overall panel. In terms of the inefficiency trends, the inefficiency increased in the first panel (1976-80), and was stagnant in the second panel (1981-1985) and declined in the third panel (1986-89) suggesting some efficiency improvement towards the end of study period.

The first order parameter estimates (listed in Table 1) associated with the input variables may be directly interpreted as partial elasticities of the output with respect to individual inputs, evaluated at the sample means of the data.[7] Furthermore, the parameter estimates associated with the time trend, t, may be interpreted as the annual percentage change in output due to technological change, evaluated at the sample means of the data. Given this, the technical change at the mean of data was not significantly different from zero in Panels 1 and 3 and positive and significant in Panel 2. Furthermore, in most models the input elasticities have the expected signs and are significantly different from zero. The one regular exception is the fertiliser elasticity which is often insignificant, and is in one instance incorrectly signed. These fertiliser results are consistent with some earlier studies (Ulziihutag, 1992; World Bank 1995) who suggest that some wastage may have resulted from inappropriate fertiliser application.

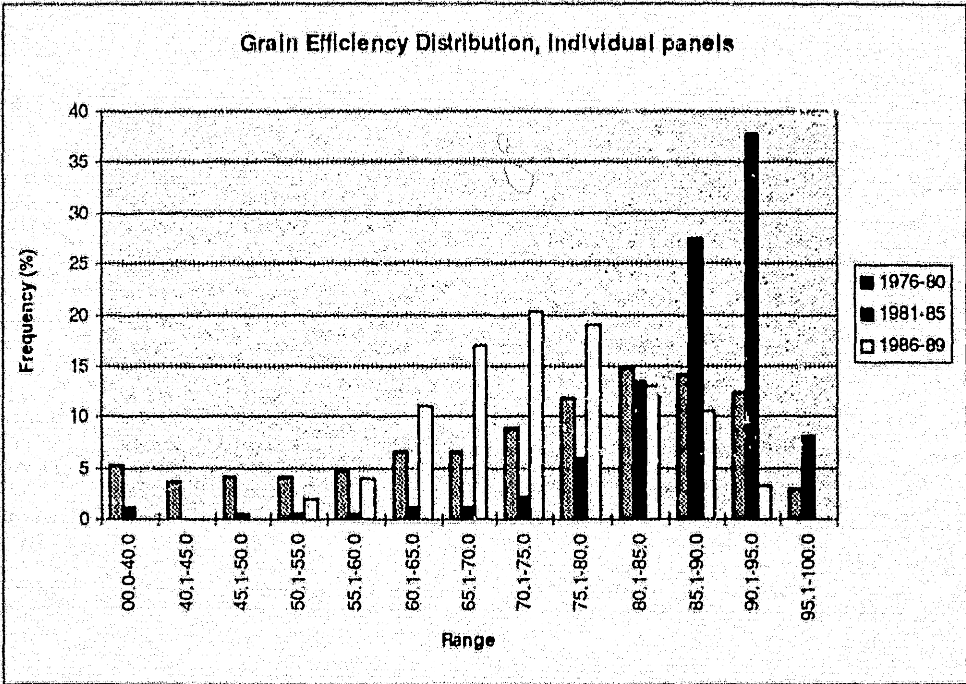
The scale elasticity is obtained as the sum of the five partial input elasticities. These sums are observed to be 1.011, 1.133 and 1.131, in Panels 1, 2 and 3, respectively. This indicates that the farms are operating at either constant or mildly increasing returns to scale during this period. This result suggests that the present post-reform

[7] This is because mean-corrected data was used in estimation.

policy of splitting these State Farms into smaller farms cannot be justified with a scale economies argument.

The distribution of technical efficiencies of farms in the individual panels are illustrated in Figure 1. The efficiency distribution of farms in Panel 1 and 3 have a similar shape, where the majority of farms are in the middle range of efficiency intervals suggesting considerable room for efficiency improvement. However, in Panel 2, most of farms are in the higher range of efficiency distribution suggesting the majority of farms were functioning close to their frontier during that period.

Figure 1



Following a similar approach to that used in Nishimizu and Page (1982), we combine information on technical efficiency and technological change to obtain an overall measure of TFP change. The influence of these factors are summarised by the indices listed in Table 6 and plotted in Figure 2.[8] We observe that over the 14 year period there was a 13 percent decline in technical efficiency and a 7 percent technological regress, resulting in an overall decline in TFP of 18 percent. The news is not all bad though, as we can see in Figure 2 that the largest fall in TFP occurred during the first five years at a time when the Government was pursuing a program of increasing production by increasing input usage. The final nine years of the period are, however,

[8] The technological change measures for the breaks between the panels 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.

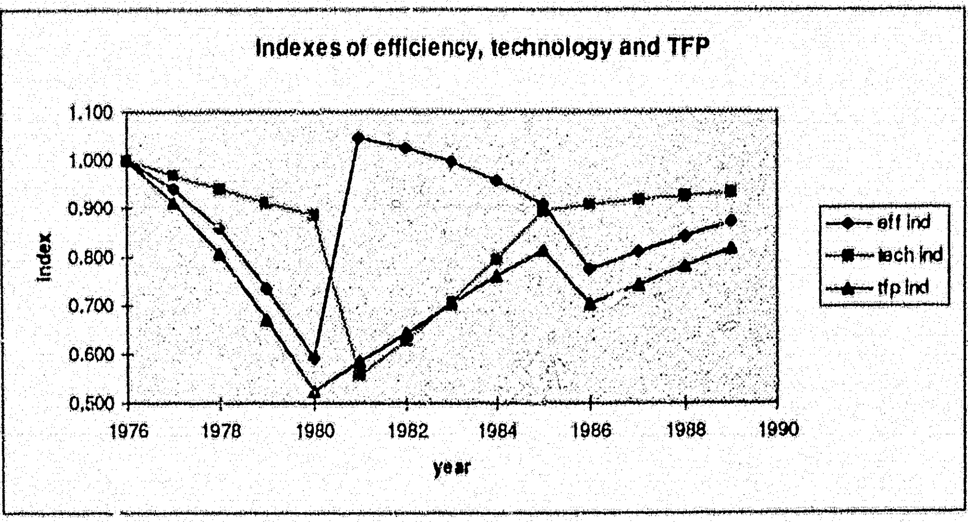
characterised by improving TFP levels, with the TFP index rising from 0.523 in 1980 to 0.817 in 1989, which equates to a 56 percent growth in TFP. This indicates that the "intensive" technology and incentive reform policies of the 1980's had some impressive success.

Table 6

Indexes of Efficiency, Technology and TFP of Mongolian Grain Farms

Year	Efficiency	Technology	TFP
1976	1.000	1.000	1.000
1977	0.[illegible]39	0.970	0.911
1978	0.858	0.941	0.807
1979	0.736	0.913	0.671
1980	0.591	0.885	0.523
1981	1.048	0.558	0.584
1982	1.026	0.627	0.643
1983	0.996	0.706	0.703
1984	0.958	0.794	0.761
1985	0.909	0.893	0.812
1986	0.773	0.909	0.703
1987	0.808	0.918	0.741
1988	0.841	0.926	0.779
1989	0.874	0.934	0.817

Figure 2



Model 2: SFPF with a Model for the Inefficiency Effects

Model 2 is estimated using the final three years of the data period (1987-1989). This is because the data on farm characteristics was only available for this period. The ML estimates are presented in Table 7. Again the second order terms are omitted to save space. We observe that many of the reported parameter estimates are similar to those obtained in Model 1. A battery of tests regarding functional form etc., similar to those tests conducted for Model 1, where also conducted for this model. The results of these tests were similar to that found for Model 1. Hence they are not reported here.

The one test which is of particular interest in Model 2, is the test of the null hypothesis that the inefficiency effects are not functions of vocation technical graduates, experience, time, Russian management, incentive system and differences in natural conditions. That is, H_0: $\delta_1=...=\delta_6=0$. The calculated value of the likelihood ratio test statistic was found to be 14.52, which is greater that the table value $\chi^2_{6,0.95}=12.53$. Hence the null is rejected, indicating that these factors do have a significant influence upon technical efficiencies.

Table 7

Maximum-likelihood estimates for the parameters of the stochastic frontier production functions with Inefficiency Effects Model, 1987-1989[1]

Variables	Parameter	Estimate
Constant	β_0	-0.75
		(0.21)
Land	β_1	0.61
		(0.24)
Labour	β_2	0.35
		(0.12)
Fertiliser	β_3	0.156
		(0.086)
Capital	β_4	0.25
		(0.14)
Other cost	β_5	0.045
		(0.036)
Natural Cond.	β_6	0.0050
		(0.0018)
Time	β_7	0.53
		(0.21)
[second order terms are omitted for brevity]		
Inefficiency Model		
Constant	δ_0	0.51
		(0.80)
Vocational Tech. Grad	δ_1	-0.0132
		(0.0039)
Experience	δ_2	-0.0087
		(0.0089)
Time	δ_3	0.19
		(0.11)
D-Russian-built	δ_4	-0.34
		(0.13)
D-Incentive	δ_5	-0.23
		(0.13)
Natural Cond.	δ_6	0.0052
		(0.0053)
	$\sigma^2_s=\sigma^2_v+\sigma^2$	0.140
		(0.025)
	$\gamma=\sigma^2/\sigma^2_s$	0.99999
		(0.00014)
Log-Likelihood		34.544

[1] The estimated standard errors are presented below the corresponding parameter estimates

The primary purpose of estimating this model was to establish the main causes of efficiency variation among the farms. The signs on the estimates of the δ parameters agree with our initial expectations. The negative estimate associated with *Vocational Technical Graduates* suggests that those farms with better educated workers achieved higher efficiency levels. The negative sign associated with *Experience* suggests that those farms with workers with higher levels of experience performed better. However, due to a large standard error, the relationship was found to be weak.

The first dummy variable, *D-Russian-built*, representing those farms built and assisted by Soviet Experts had a negative parameter estimate. This suggests that, those farms built and advised by Russian experts were performing at a higher efficiency level than the rest. The second dummy variable, *D-incentive* is also negative. This indicates that those farms which had a higher degree of autonomy in terms of finance and management through an Incentive Promotion Scheme performed with higher efficiency levels than those not involved in the Scheme. However a large standard error suggests a weak relationship being present.

The parameter estimate associated with the variable, *Natural Condition*, was found to have negative sign, but with a large standard error. This sign suggests, that those farms located on better natural conditions performed slightly better in terms of efficiency performance. One possible explanation for this result is that the workers who were forced to farm marginal cropping lands (i.e., land which was not very well suited to growing crops) often lacked motivation because of frequent crop failures.[9]

Finally, the parameter estimate associated with *Time* is found to be positive. This parameter is difficult to interpret since it as been included to proxy omitted factors which may vary systematically through time. However, a large standard error suggests that this variable is not overly important.

6. Conclusions

Technical efficiency, technological change and TFP of Mongolian grain farming were investigated for the period ,1976-1989, using two different SFPF models. A SFPF Model With Time-Varying Inefficiencies was applied to three different sub-panels, reflecting different policy hallmarks (five-year plans). Farm efficiencies were found to be decreasing in the first sub-period, stagnant in the second sub-period and increasing in the third sub-period. This suggests that the policy initiatives taken in the last sub-period (1986-1989), in the form of greater farm autonomy and various innovative work re-organisations, such as tenancy contracts, had a positive influence upon farm efficiencies. However, we observe that a wide distribution of technical efficiencies between farmers suggests that there is still a lot of room for improvement.

The measures of technical change obtained for the three sub-panels also agree with our expectations. We observe that technological change was essentially absent in the first and third periods. This can be rationalised by recalling that the policy emphasis in the first period was upon expansion of input use and that in the third period was upon efficiency improvement. We also observe that technological progress was quite strong

[9] A number of the newer farms were established on such land. This was a consequence of the Governments desire to achieve self-sufficiency in grain supplies.

in the second period, most likely a consequence of the intensive technology reforms introduced during that period.

Indices of technical efficiency, technology and TFP were calculated and plotted for the 14 year study period. From 1976 to 1989 we observe a 13.6 percent decline in efficiency, a 6.4 percent decline in technology and an 18.3 percent overall decline in TFP. These declining figures are in accord with productivity measures obtained in other centrally planned economies. However, there is some good news hidden amongst these poor results. During the final nine years of the study period we observe improving TFP levels, with the TFP index rising from 0.523 in 1980 to 0.817 in 1989, which equates to a 56 percent growth in TFP. This indicates that the "intensive" technology and incentive reform policies of the 1980's was beginning to achieve considerable success.

One additional result of particular interest is that the farms were observed to be operating in an area of constant or mildly increasing returns-to-scale. This suggests that the current policy of reducing farm sizes cannot be justified using scale economies arguments.

A second SFPF was estimated in which the inefficiency effects were modelled as an explicit function of a vector of farm-specific characteristics. The results of this model suggested that the efficiency levels of farms were positively related to the levels of technical education and experience of farm workers, the degree of management autonomy and the amount of Russian technical assistance. These results indicate that policies aimed at improving education levels and retaining experienced workers will pay dividends in terms of technical efficiencies. They also suggest that the present reform process of giving farmers complete management autonomy (ownership) should improve efficiencies, however they also suggest that we should not hastily throw out all aspects of the Russian technical systems as they appear to have had a positive influence upon farm efficiencies in the past.

The results presented in this paper will form part of the PhD thesis of the senior author. Further work will include a repeat of the analysis using alternative methodologies, such as data envelopment analysis (DEA) and index numbers, so as to test the robustness of these results to choice of methodology. We shall also consider the influence of permitting more flexible technological change structures in the SFPF models and we also plan to investigate the impact of including climatic data into our models.

References

Battese, G.E. and T.J. Coelli (1992), "Frontier Production Functions, Technical Efficiency and Panel Data: With Application to Paddy Farmers in India", *Journal of Productivity Analysis*, 3, 153-169.

Battese, G.E. and T.J. Coelli (1995), "A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data", *Empirical Economics*, 20, 325-332.

Bergson, A. (1983), "Technological Progress", in Abram Bergson and Herbert Levine (Eds). *The Soviet Economy Toward the Year 2000.* London: Allen & Unwin.

Bergson, A. (1992), "Communist Economic Efficiency Revisited", *American Economic Review*, 82, Papers and Proceedings, 27-30.

Brada, J. C. and A. E. King (1993), " Is Private Farming More Efficient than Socialized Agriculture?", *Economica*, 60, pp. 41-56.

Carter, A. and Zhang, B.(1994), "Agricultural Efficiency Gains in Centrally Planned Economies", *Journal of Comparative Economics*, 18, 314-328.

Coelli, T.J. (1992), "A Computer Program for Frontier Production Function Estimation: FRONTIER, Version 2.0", *Economics Letters*, 39, 29-32.

Coelli, T.J. (1994), *A Guide to FRONTIER Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation*, mimeo, Department of Econometrics, University of New England, Armidale, pp. 32.

Coelli, T.J. (1995), "Recent Developments in Frontier Estimation and Efficiency Measurement", *Australian Journal of Agricultural Economics*, 39, 3, pp. 219-245.

Coleman, G. (1989), "An Agricultural Information System for Mongolia", *Strengthening Enterprise Management and Monitioring of Agricultural Cooperatives*" FAO TCP/MON/8852, Norwich, UK.

Enkhamgalan, A. and Myagmarjav, B. (1993) " Economic Evaluation of Agricultural Land in Mongolia", *Final Research Report*, Institute of Agricultural Economics, Ulaanbaatar, Mongolia.

Grosskopf, S. (1993), "Efficiency and Productivity", in Fried, H.O., C.A.K. Lovell and S.S. Schmidt (Eds), *The Measurement of Productive Efficiency Techniques and Applications*, Oxford University Press, New York, 160-194.

Johnson, S.R., A. Bouzaher, A. Carriquiry, H. Jensen, and P.G. Lakshminarayan (1994), Production Efficiency and Agricultural Reform in Ukraine, *American Journal of Agricultural Economics*, 76, 629-635.

Koopman, R. B. (1989), " Efficiency and Growth in Agriculture: A Comparative Study of the Soviet Union, United States, Canada and Finland", *Staff Report No. AGES 89-54*, Agriculture and Trade Analysis Division, Economic Research Service, U.S. Department of Agriculture.

Kumbhakar, S. C., S. Gosh and J. T. McGuckin (1991), "Generalized Production Frontier Approach for Estimating Determinants of Inefficiency in U.S. Dairy Farms", *Journal of Business and Economic Statistics*, 9, 279-286.

Levine, H. S. (1982), "The Centralized Planning of Supply in Soviet Industry" in *Comparison of the United States and Soviet Economics*, U.S. Congress, JEC, 153-168.

Lovell, C.A.K. (1993), "Production Frontiers and Productive Efficiency", in Fried, H.O., C.A.K. Lovell and S.S. Schmidt (Eds), *The Measurement of Productive Efficiency Techniques and Applications*, Oxford Univ. Press, New York, 3-67.

Ministry of Agriculture (1986), *"Report on the Human Resources in Agricultural Sector"*, Ulaanbaatar, Mongolia.

Ministry of Agriculture (1990), "The Status of Tenancy Contracts in Agriculture", Ulaanbaatar, Mongolia.

Ministry of Agriculture (1991), *"Report on the Introduction of New Technology"*, Ulaanbaatar, Mongolia.

Moroney, J.K., and C.A.K. Lovell (1991), "The Performance of Market and Planned Economies Revisited", Working Paper, Department of Economics, University of North Carolina, Chapel Hill, N.C.

Nishimizu, M., and M. Page Jr. (1982), "Total Factor Productivity Growth, Technological Progress and Technical Efficiency Change: Dimensions of Productivity Change in Yugoslavia, 1965-78", *The Economic Journal*, 92, 920-936.

Perelman, S. (1995), "R & D, Technological Progress and Efficiency Change in Industrial Activities", Review of Income and Wealth, 41, 3, 349-366.

State Statistical Office (1988) "Economic and Social Development, Mongolian People's Republic", Ulaanbaatar, Mongolia.

Ulziibat, S. (1992) The Analysis of Intensification of Grain Production in Mongolia- Case of Forest-Steppe Region, Candidate of Science Dissertation, Mongolian Agricultural University, Ulaanbaatar, Mongolia

Unen (1981), *"Reports on the Implementation of 5th Five-Year Plan of National Economy"*, Government Printhouse, Ulaa baatar, Mongolia.

Unen (1986), *"Reports on the Implementation of 6th Five-Year Plan of National Economy"*, Government Printhouse, Ulaanbaatar, Mongolia.

Whole-Sale Price Reform (1986), State Committee for Prices, Ulaanbaatar, Mongolia.

Appendix

Table A1

Summary Statistics on Input and Output Data

Variable	Mean	Std. Dev.	Max. value	Min value
Output (tn)				
1976-1980	7941.7	6347.5	28548.7	150.0
1981-1985	11515.8	9297.8	47848.0	171.7
1986-1989	13438.9	9962.8	65863.5	5.1
1976-1989	**9977.1**	**8304.7**	**65863.**	**5.1**
Sown area (ha)				
1976-1980	11717.5	7568.7	32577.0	500.0
1981-1985	11380.8	6942.7	29010.0	200.0
1986-1989	11318.0	6766.0	29517.0	50.0
1976-1989	**10680.6**	**7486.6**	**32577.0**	**50.0**
Labour (mandays)				
1976-1980	27867.0	27790.6	210672.0	
1981-1985	33179.8	23040.6	111645.0	1386.0
1986-1989	34348.6	24147.1	189183.0	88.0
1976-1989	**31958.4**	**25338.3**	**210672.0**	**20.1**
Fertiliser (000 tgs)				
1976-1980	237.4	200.9	959.9	0.7
1981-1985	347.3	277.4	2095.6	1.1
1986-1989	472.2	344.2	1426.3	1.1
1976-1989	**293.2**	**245.1**	**2095.6**	**0.7**
Capital (000 tgs)				
1976-1980	1801.0	1283.9	5950.5	64.5
1981-1985	2272.6	2149.6	22989.4	34.9
1986-1989	2750.5	1872.7	7589.2	3.1
1976-1989	**2116.3**	**1730.7**	**22989.4**	**3.1**
Other Cost (000 tgs)				
1976-1980	179.8	186.2	1104.5	0.3
1981-1985	396.3	360.5	1967.4	0.4
1986-1989	632.2	716.8	4156.7	1.1
1976-1989	**366.1**	**444.9**	**3701.4**	**0.3**