4. Method of Analysis

4.1 Introduction

This study is designed to identify and analyse productivity in the Mongolian extensive livestock industry in the socialist period by estimating a production function. Because of the industry's absolute dependence on a harsh natural environment, specific attention is paid to the influence of weather on the performance of the industry. The production function analysis of productivity in the present study consists of two stages. In the first stage, a weather-yield model is estimated and a weather index is derived. The second stage involves the estimation of a production function that incorporates the weather index derived in the first stage.

4.2. General approach to model specification

The general approach to model specification in this study is that, under Mongolian conditions, productivity gains can be achieved more readily by decreasing the mortality rate and increasing the birth rate of animals, rather than by trying to increase yield of products per animal. Since the concept of productivity in animal production is often associated with increased yield per animal by improving its quality, this approach needs some explanation.

4.2.1 Animal productivity measures

Per head productivity in year t can be measured as a ratio of the total output to the number of animals at the beginning of year t.

$$P = \frac{O}{Ao} = \frac{A*Y}{Ao} \tag{4.1}$$

where P=per head productivity

O=output

A=the total number of animals from which output was obtained

Y=yield per animal

Ao=the number of animals at the beginning of the year

Here yield represents output of several products, such as meat, wool, hides and milk. As (4.1) shows, per head productivity for a given number of animals at the beginning of year t can be increased as a result of (i) increased yield per animal (ii) increased number of animals which produce output. Increased yield per animal is achieved by improving its quality, usually through breeding. An increased number of output-producing animals in year t can be achieved by either increasing their birth rate or decreasing their mortality rate. Using this approach, Y in (4.1) is referred to as the biological per head productivity and P is referred to as the economic per head productivity.

The approach specified above has been chosen on the following grounds:

1. Maximisation of livestock numbers was the dominant behaviour of herders over the whole period under investigation.
2. Yield of wool, milk and meat from an individual animal was basically constant over the period under investigation. A standard dependent variable in a production function is 'total output' which, in the case of animal production, is derived as *animals* times *per head productivity*. It follows that if per head productivity is constant then *output* is proportional to *animals*.
3. The dramatic changes, which occured as a result of the transition to a market oriented economy, made the studies of post-socialist agriculture generally incomparable with that of its socialist counterpart. With respect to productivity of the industry, however, these changes mainly affected areas such as harvesting, storage, transportation and marketing of livestock products, while production decision-making at the herd level, aimed at maximising livestock numbers, remained much the same. Therefore, the relevance of the present study, which focuses on the socialist period, can be improved if it deals with the variable that was less affected by the transitional changes.
4. The use of growth rate, rather than harvested products, as a dependent variable avoids the errors associated with the discrepancy between total production and harvested production of meat - the main output of the industry. This discrepancy, which is unduly ignored in some productivity studies, occurs because of the specific feature of animals as being both output and capital assets of production. For example,

in unfavourable years, it often happens that the harvested production of meat exceeds its total production. This happens because harvested animals include not only those that correspond to the meat production in a given year, but some of those that are produced in previous years, this is the case of a shrinking herd. On the other hand, in favourable years only a part of produced meat is harvested leading to herd expansion. It is clear that in both shrinking and expanding herd cases the volume of harvested meat does not represent real production of meat in a given year, hence, it should not be used as a dependent variable in the production function.

In the present study, the natural growth rate, expressed as percentage growth in animal numbers per 100 livestock at the beginning of year, is used as the basic indicator of performance of extensive livestock production, where per head yield of harvested products is generally constant. The natural growth rate is defined as the difference between the birth rate and the mortality rate.

It is assumed that an increase in the growth rate of animals took place mainly as a result of an increased use of technological inputs and technical change, while the impact of other sources of productivity growth such as economies of scale and the degree of production efficiency are assumed to be insignificant.

The productivity analysis in the present study is conducted separately for two kinds of animals- cattle and small stock. These constitute the bulk of the extensive livestock industry in Mongolia in terms of their contribution to both domestic supply and exports of livestock products. Sheep and goat have been integrated into the 'small stock' category due to two factors. First, as they are grazed together, forming the same herd, it was not possible to separate expenditures of economic inputs between them. Second, the fact that they are grazed together indicates that they use generally the same type of pasture, hence, their attitude to the natural environment is similar to some degree. So, their aggregation into a single term has been considered an acceptable simplification.

4.2.2 The two-stage estimation procedure

The productivity analysis in the present study consists of two stages. This two-stage estimation procedure was demanded by the need to deal with weather-the main determinant of output in livestock production in Mongolia.

The first stage is designed to estimate weather-yield models. The weather-yield models are used to test the hypotheses 1 and develop a general weather pattern in Mongolia in terms two species of animals, cattle and small stock. It is believed that agricultural development efforts can be improved if the weather restraints are properly identified and development programs are focused on "removing" them.

In the second stage, the production function is used to test hypotheses 2, 3, 4 and 5.

4.3. Weather-Yield Model

4.3.1 General assumptions

The introduction of weather variables in the productivity analysis of the extensive livestock industry in Mongolia is necessary because of two factors. First, it seemed simply impossible to ignore weather when the variability in the industry's output is overwhelmingly determined by weather variability. As noted by Shaw (1964), the validity of the estimates of the production function in agriculture without account of the weather is questionable, as the latter significantly contributes to output growth. Second, omitting weather may bias the coefficient on the trend variable. One possibility for this to happen is a trend-like change in weather patterns (Offutt *et al.* 1987). Although it can be argued that the time span under investigation in productivity analyses is usually short enough so that changes in weather patterns do not pose a serious problem, it is the duty of an analyst to explicitly state any 'canger' that may erode the model's validity. Another possibility, no less serious than the first is the possibility for weather to show a cyclical behaviour. In Mongolia there is evidence of a short cycle (4-5 years) and a medium cycle (11-13 years) in weather patterns. Among these, a twelve-year cycle which corresponds to the lunar calendar has been said to be better evidenced. Certainly, to test for the existence of weather cycles is beyond the scope of the present study. However, to the best of the author's knowledge, there is no strong basis to reject the existence of cyclical weather behaviour. If this is the case, and the time span under investigation coincides with either the downward or upward slope of a larger weather cycle, then the omission of weather in the anlaysis will unavoidably lead to biased estimates of technical change, as approximated by the coefficient of a time trend.

Figure 4.1 illustrates the situation when weather shows a trend-like pattern leading to biased estimates of technical change. The horizontal axis represents a time period and the vertical axis represents the suitability of weather to agricultural production. The shape of a weather function is only for illustration purposes. If weather was improving, as indicated by a time span OA, then omitting weather might unduly attribute the growth of agricultural output, that resulted from 'improved' weather, to technical change (upward bias). Similarly, if the time span under investigation falls on AB, then we would obtain the downward biased estimate of technical change.

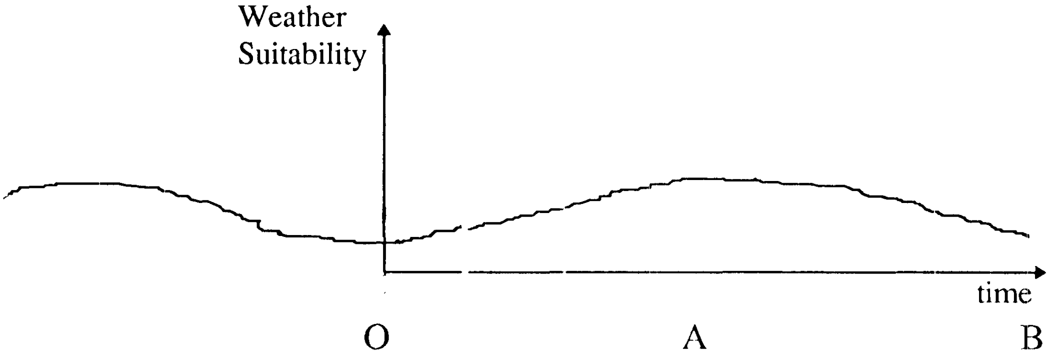

Figure 4.1: Biased estimates of technical change due to trend-like patterns in the behaviour of weather

As it can be seen, the shorter the time period the greater the probability for it to fall on one of the slopes in the weather pattern.

Referring to weather variables, a reasonable hypothesis is that the relationship between agricultural yield and an individual meteorological factor is a bell-shaped curve. For example, the snow cover provides a drink for animals during cold seasons, however, if it is too much, it becomes a negative factor preventing animals from normal grazing. Unfortunately, with the limited number of time-series observations the use of any non-linear functions becomes impossible. For example, quadratic functions in a multiple regression model will double the number of independent variables, reducing drastically the available degrees of freedom. Thus for simplification, it was assumed that the relevant range is only the rising (or falling) part of the curve which can be approximated by a straight line. While the specification of weather factors adopted in this study may be criticised as over-simplified, it is believed to provide reasonable quantitative estimates of the influence of weather on the animals' performance, as indicated by the NGR.

4.3.2 Weather variables

In the empirical analysis presented here, the natural growth rate of animals is assumed to be a function of a time trend and of four monthly and eight annual weather variables. The monthly variables are:

- the severity index for cold months (October to April)
- average temperature (°C)
- average precipitation (mm)
- average wind velocity (m/sec)

The annual variables are:

- the number of days with blowing snow storms
- the number of days with ordinary snow storms
- the number of days with a continuos slight rain
- the number of days with electric storms
- the number of days with storm winds (above 15 m/sec)
- the number of hot days (above 30°C)
- snow depth (cm)
- the duration of snow cover

Variables other than precipitation and temperature have been included mostly due to their direct effect on the animals' performance. While being the main determinants of pasture yield, precipitation and temperature have also significant direct effect on animals. For example, continuos cold rains in late spring and early summer have been observed to have an important negative impact on animals, especially calves, lambs and kids.

To better capture the impact of weather variability on the animal's performance, 36 districts have been chosen where meteorological stations exist and necessary weather variables are available. 20 years time-series data from 1969 to 1990 (data for 1975 and 1979 are missing) include the above specified four monthly and eight annual variables. The location of the meteorological stations is shown in Figure 4.2 and their allocation between the agro-ecological regions and sub-regions is provided in Appendix 1.

The only composite weather variable is the severity index. The rest are elementary single variables which do not need further explanation. The severity index, supposed to indicate the severity of weather during cold seasons, was calculated for seven months with subzero temperatures, from October to April (Namhaijantsan, 1992). The formula used to derive the severity index is:

$$S=[(1-0.04\,t)*(1+0.272\,v)]*0.67 \qquad (4.2)$$

where S=the severity index

t=monthly average temperature (°C)

v= monthly average wind velocity (m/sec)

All data were collected from the Ministry of Nature and Environment.

4.3.3 Agro-ecolological regions

Because of the highly variable temporal and spatial ecological conditions in Mongolia, the agro-ecological zonation scheme developed by Shirnen *et al.* (1991) was used to facilitate the weather-yield modelling procedure. Based on the characteristics of topography, climate, soil and natural vegetation types, this zonation scheme divided Mongolia into 5 regions consisting of 18 sub-regions (Figure 4.2 and Appendix 1).

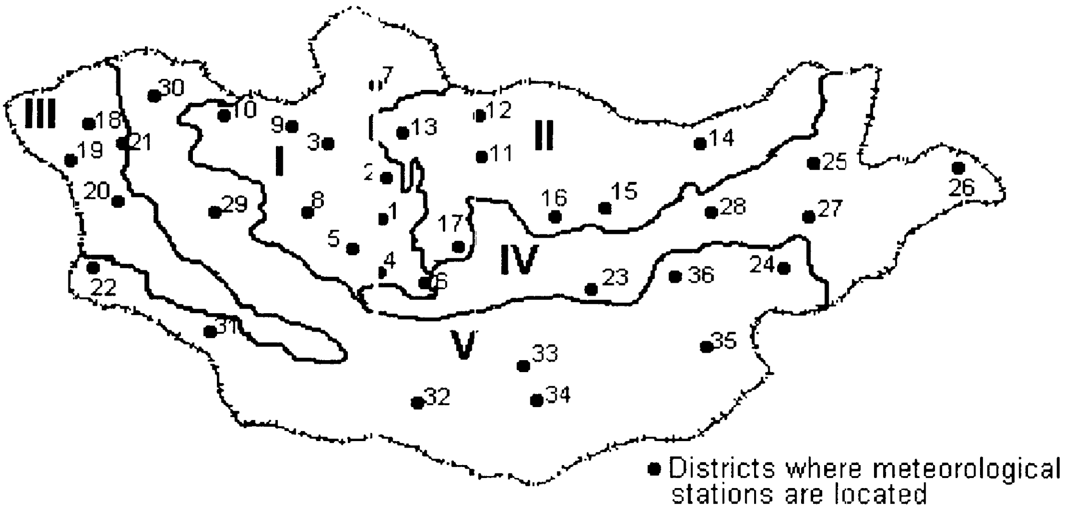

Figure 4.2: The agro-ecological regions in Mongolia

Source: Shirnen *et al.* (1991)

Legend to Figure 4.2

Ecological Regions and Dominant Farming Activities	*Bio-climatic Potential**	*Average Annual Yield of Pasture 100 kg/ha*
I. Hangai-Huvsgul Mountainous Meadow and Forest Steppe Region; Cattle mainly yaks, sheep, early ripening fodder crops;	0.55-0.82	350
II. Orhon-Selenge Forest-Steppe Region; Rainfed crop production, cattle, sheep	0.82-1.10	460
III. Altai Mountainous Steppe Region; Sheep, goat and cattle	0.27-0.55	230
IV. Steppe Region; Sheep, goat, cattle	0.55-0.82	350
V. Gobi-Desert Region; Goat, sheep, camel	0.27 and less	180

*Bio-climatic potential is, in essence, a weather index that takes account of both moisture and thermal factors. It is calculated using the formula:

BCP=M*T/1000

where BCP=bio-climatic potential

M=moisture index

T=the sum of temperatures above 10°C

1000=the minimum of T required for the growth of plants outdoors

Moisture index, M, is calculated as a ratio of the sum of rainfalls during the vegetation period to the sum of daily deficiencies of the air moisture (Shirnen and Bazargur, 1987)

The meteorological stations are numbered in the same order as in Appendix 1.

As shown in Appendix 1, the agro-ecological regions are represented by 5 to 8 weather-reporting districts. The sub-regions are represented by 2 to 5 weather-reporting districts, except for Southern Altai, Bulnai, Hentii and Herlen-Huh Nuur which are represented by only one.

There are a total of around 330 districts in Mongolia with the average size of 300 000 ha of pasture land with 100 000 livestock and 600-1200 herding families. One agro-ecological region covers 60 to 70 districts and 36 000 to 84 000 herding families. One sub-region has 15 to 20 districts and 9 000 to 24 000 herding families. Comparing these pictures one might argue that the sample data are not a good representation of the population. However, considering the fact that one district is an average of 600 to 1200 herding families, the errors associated with the seemingly poor representation are assumed to be not serious.

4.3.4 The model and estimation

Keeping in mind the assumptions described above, the weather-yield model was estimated as follows.

The stepwise regression method was used to select the appropriate weather regressors from 51 candidates, specified above. Because of the strong heterogeneity of ecological conditions the stepwise method was used separately for each district. The possibility of selecting the weather-yield model at levels of the agro-ecological regions and sub-regions was tested.

The regressor selection approach used here can be regarded as a combination of two approaches: *prior* reasoning and statistical techniques. It is '*prior* reasoning' in the sense that the candidates for the weather regressors were initially selected on the basis of the certain knowledge about the weather-animal relationships. However, a *prior* reasoning is still a crude approximation to reality as the net impact of weather on animals is the result of the complex interaction of all weather variables and each of them has some importance in determining the animal's performance. In essence, the use of the stepwise technique was demanded by the complexity of the weather-animal relationship. The stepwise technique was carried out as a compromise between the minimisation of the number of regressors and the maximisation of the adjusted R-squared. Since the number of time-series observations is 20, a maximum number of the weather regressors was limited to 11.

The model for each cross-sectional unit was defined as:

$$G_t = a + \sum_{k=1}^{m} \gamma_k z_{kt} + \alpha T + u_t \qquad (4.3)$$

where G_t = the NGR in year t (t=1 2,..., 20)

a = the intercept term

z_{kt} = weather variables (k=1,2,...,m)

u_t = the error term

γ_k and α = the slope coefficients to be estimated

T = a time trend

The weather index was derived using the approach employed by Orlan, B. and Lin, W. (1969), Doll (1967), and Desai (1986). The main idea of this approach is that the influence of weather on yield can be calculated by comparing the yields predicted for actual and average weather. The predicted yields are calculated by the use of the response coefficients from the weather-yield models. As described in section 2.2, the weather index is derived in two slightly different ways. Orlan, B. and Lin, W. (1969) and Doll (1967) calculated the weather index as a ratio of the yield predicted for actual weather to the yield predicted for average weather. Desai (1986) first calculated the weather variability of yield by subtracting the yield predicted for actual weather from the yield predicted for average weather. Then weather-adjusted yield was derived by subtracting the estimated weather variability of yield from actual yield. The weather index in this case can be calculated as a ratio of actual yield to weather-adjusted yield. Since, the weather variability of yield is of interest in the present study, the weather index and weather adjusted yield were calculated by the method suggested by Desai (1986).

Thus, the weather variability of NGR is:

$$V_t = G_{pt} - \overline{G} \qquad (4.4)$$

where V_t = weather variability of NGR in year t

G_{pt}= NGR predicted for actual weather

$\overline{G}$ = NGR predicted for average weather

Weather-adjusted NGR is:

$$G^a = G_t - V_t \qquad (4.5)$$

where G^a =weather adjusted NGR in year t

G_t = actual NGR in year t

The weather index is:

$$W_t = \frac{G_t}{G^a} \qquad (4.6)$$

where W_t= the weather index

It is noteworthy that to capture the 'net impact' of weather, the predicted values of NGR are calculated using only the response coefficients of weather variables in the model 4.3, excluding those of the time trend and the intercept.

The final step involves the estimation of the aggregate weather-yield model which was defined as:

$$\ln G_{nt} = \sum_{k=1}^{5} C_k D_{knt} + \omega \ln V_{nt} + \alpha_1 T + \alpha_2 T^2 + u_{nt} \qquad (4.7)$$

where G = Natural Growth Rate of Animals

n = districts (n=1, 2,...,36)

t = an individual year (t=1,2,3, ..., 20)

k= agro-ecological regions (k=1,2,...,5)

W = weather index

u = the disturbance term

D = dummies for agro-ecological regions

C, ω, α=the coefficients to be estimated

T = time trend as a proxy for omitted variables which have systematic effects on the natural growth rate of animals.

Specification of the weather index in the logarithmic form implies that if weather was average, as indicated by unitary weather index, then its effect is zero ($log 1=0$).

The dummy variable model is selected over the error components model because the 'firm-specific' effects are assumed to be correlated with the technological inputs that are approximated by the time trend. Moreover, there is basis to believe that the 'firm-specific' effects are generally fixed. This is because, when the effects of weather have been removed, the 'firm-specific' effects are mostly associated with the generally constant components of the natural environment such as topography, soil and vegetation types. Since these components of the natural environment show less variability across districts within one agro-ecological region. their aggregation at the regional level is assumed to be an acceptable simplification.

The model (4.7) was estimated by OLS. As Dielman (1989) noted, when using panel data, the problems of serial correlation and heteroskedasticity may occur simultaneously. Two consequences of heteroskedasticity and autocorrelation are:

1. The least square estimator is still a linear and unbiased estimator, but it is no longer efficient.

2. The standard errors are usually no longer appropriate, and hence confidence intervals and hypothesis tests that use these standard errors may be misleading.

In the present study the second consequence is a major concern, since, the use of 'proper' standard errors is crucial to testing the hypotheses formulated. One simple solution to this kind of problem, which is employed in the present study, is the use of heteroskedastic and autocorrelation consistent covariance matrices (Griffiths, 1996).[1]

4.4 The Production function

4.4.1 Model and estimation

The production function, in general form, is specified as:

$$G=f(C, L, F, V, W, H, A, P, T) \qquad (4.8)$$

where

G - natural growth rate of animals

C - capital

L - labour

F- supplementary fodder

V - veterinary services

W- weather index

H- stocking rate

A- age of herder (proxy for skills)

P- weight of private livestock in total number of herd (proxy for a private incentive)

T - time trend (proxy for technical change)

It is hypothesised that the translog functional form is the best representation of the real production function in the extensive livestock industry in Mongolia. This function allows arbitrary and variable elasticities of substitution among input categories. It provides a second order approximation to an arbitrary production function at any given point (Christensen, Jorgenson and Lau, 1973).

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[1] Heteroskedastic and autocorrelation consistent covariance matrices were obtained using SHAZAM (Griffiths, 1996). With heteroskedasticity, the HETCOV option is used with an OLS command. With, autocorrelation, the AUTCOV=n option is used with an OLS command where n is lag length of the autocorrelation.

Before specifying the statistical production function it seems adequate to clarify two things- possible specification errors and the question of how to incorporate the weather index in the production function.

From the explanatory variables in the general model (4.7), the only variable for which data were not obtained was the age of herders as a proxy for skills. Accordingly, the statistical model is specified with six economic inputs excluding the average age of herders. To support this specification, it has been assumed that the average age of herders is generally constant over time so that its omission does not influence the estimated coefficients of the variables included in the production function. With respect to the skills of herders, the question of the possible differences in the educational levels of herders needs to be clarified. There is enough evidence to suggest that the herding skills are usually developed informally within families. Consequently, it can be safely assumed that the differences in the formal educational levels of herders do not much influence the skills of herders.

To avoid a possible multicollinearity between the weather index and the other explanatory variables and to save the degrees of freedom the production function was estimated using the independent variable adjusted for the weather index.

The translog function with Hicks' neutral technical change was written as follows :

$$\ln G_{nt}^{a} = \sum_{k=1}^{5} C_k D_{knt} + \sum_{i=1}^{6} \beta_i \ln x_{\text{int}} + \frac{1}{2} \sum_{i=1}^{6} \sum_{j=1}^{6} \beta_{ij} \ln x_{\text{int}} \ln x_{jnt} + \alpha_1 T + \frac{1}{2} \alpha_2 T^2 + u_{nt} \tag{4.9}$$

where G^a = weather-adjusted natural growth rate of animals

n = districts (n=1,2,..., 36)

t = an individual year (t=1,2, ..., 20)

k= agro-ecological regions (k=1,2,...5)

x_i= economic variables (i=1,2,...,6)

D = dummies for agro-ecological regions

T = time trend as a proxy for technical change

C , β, α= the coefficients to be estimated

u = the disturbance term

The assumptions about model (4.9) are much the same as those for model (4.5).

The validity of the translog specification was tested against the Cobb-Douglas and the CES form. If

$\beta_{ij}=0$ (i=1,2,..,6 and j=1,2, ..,6) (4.10)

then (4.8) reduces to the Cobb-Douglas function, since $\beta_{ij}=\beta_{ji}$ for all i, j

If on the other hand

$\beta_{11}=\beta_{22}=\beta_{33}=\beta_{44}=\beta_{55}=\beta_{66}=-0.5(\beta_{12}=\beta_{13}=\beta_{14}=\beta_{15}=\beta_{16}=\beta_{23}=\beta_{24}=\beta_{25}=$

$=\beta_{26}=\beta_{34}=\beta_{35}=\beta_{36}=\beta_{45}=\beta_{46}=\beta_{56})$ (4.11)

then (4.9) reduces to the Kmenta's Taylor approximation to the CES function (Kmenta, 1967).

The F test was used for the restrictions (4.10) and (4.11).

The test statistic is:

$$F=\frac{(RSS_r-RSS_u)/(N-1)}{RSS_u/(NT-N-K')} \qquad (4.12)$$

where *RSSr* and *RSSu* denote restricted and unrestricted sums of squares respectively, *(N-1)* is the number of restrictions, and *(NT-N-K')* is the number of degrees of freedom in the unrestricted model.

The test statistic (4.12) was also used for testing whether the intercepts in the models (4.7) and (4.9) differed between the districts. The null and alternative hypothesis are given by:

Ho: $C_1= C_2=...= C_{36}$

H1: the C_n's are not all equa

A test of this hypothesis is of interest, because if the intercepts do not vary across districts, and other assumptions of the models (4.7) and (4.9) hold, then there is no basis for differentiating between the time-series and cross-section observations, and for estimation purposes the data can be treated as an ordinary sample of NT observations.

Another problem to consider is the possibility of contemporaneous correlation in the analysis of panel data (Dielman, 1989). Contemporaneous correlation is often a reasonable assumption when we are faced with the estimation of more than one regression equation. Often such equations appear unrelated in the sense that they include different variables, they have different coefficient vectors, and they can each be estimated separately using OLS. However, it is possible to improve on separate OLS estimation if the disturbances in each equation are correlated across equations at the same point in time. If contemporaneous correlation does not exist, OLS applied to each equation is fully efficient and there is no need to employ the seemingly unrelated regression (SUR) estimator (Doran, 1995). For example, in the analysis of agricultural supply response the effect of weather in a given year is likely to have related effects on the disturbances for different crops or animals. With respect to our model, contemporaneous correlation may exist across the equations of cattle and small stock. This may happen, for example, if the weather index fails to capture some facets of weather that have a common effect on cattle and small stock. If contemporaneous correlation exists then we can improve the estimates of both equations using SUR. Moreover, testing for contemporaneous correlation appears to be important in the sense that it shows indirectly how well the effect of weather is accounted for. If the influence of weather on animals is more or less fully captured by the weather index, then contemporaneous correlation is unlikely to exist. An appropriate test statistic for contemporaneous correlation is a Lagrange multiplier statistic, suggested by Breusch and Pagan (1980). This statistic, automatically produced by SHAZAM, has a χ^2 distribution with M(M-1)/2 degrees of freedom under the null hypothesis of no contemporaneous correlation, where M is number of equations.

It is well known that an application of OLS to models such as (4.9) can result in biased coefficient estimates since, some of the input variables may be jointly determined with output and hence not independent of the error term. However, in agriculture, where the error term is largely dependent on weather, and production takes a substantial amount of time, it is often assumed that the correlation between the largely weather-affected error variable and the largely predetermined input variables is zero or very small. Furthermore, if the production function is well specified (has a small residual error) then the simultaneous equation bias will be small. This seems to be the case in our model.

4.4.2. Definition of variables and data

All the economic data were collected from the accounting report that was prepared and presented to the Ministry of Agriculture and the Central Statistics Board every year by each district separately. The economic data cover the period from 1969 to 1986.

Natural Growth Rate (NGR) of animals. The data required for deriving the NGR include the birth rate and the mortality rate. The birth rate was calculated as a ratio of total losses to the total number of animals at the beginning of year. The birth rate was calculated as a ratio of total births to the total number of animals at the beginning of year. The calculation of the birth rate in this way was demanded by two factors. First, it takes account of the share of breeding females. The more the share of breeding females, the more the birth rate and *vice versa*. The birth rate, often calculated as a ratio of births to the number of females, does not consider this important indicator of reproductive capacity of animals. The basic assumption in the present study is that the share of breeding females is a function of the explanatory variables in the corresponding models. Put in other way, the influence of factors out of the model such as administrative decisions of higher authorities that may affect the share of the breeding females has been assumed to be not significant. Second, it can be directly combined to the mortality rate to come to a final indicator of animal production - the natural growth rate.

Labour. Data on labour were collected as man-days per a sheep-unit. A sheep-unit, originally designed for the calculation of feed requirements for animals, is equal to 5.7 for camel, 6.6 for horse, 6 for cattle and 0.9 for goat. Man-days per a sheep-unit was calculated using the formula:

$$M=H*280/SU$$

where: M=man-days per sheep-unit (SU)
H=the number of herders
280=the average number of working days per year

The employees of agricultural cooperatives other than herders are not included in the total number of man-days because: (i) services of some important personnel such as a veterinarians were included in the model as veterinary services (ii) if the proportion of employees not engaged in animal production varies either over time or across cross-sectional units, then their inclusion would cause more harm than good.

Capital. The main capital assets for livestock in Mongolia are shelters and wells. Ideally, the number of shelters and wells are the simplest but reasonable indicators of shelter and water supply. However, since, data on the number of shelters and wells were not available, the stock value of the total capital assets excluding the asset value of animals were collected. In addition to the value of shelters and wells the value of other assets such as buildings, tractors, trucks and equipment was also included. So, capital in the present study can be regarded as a proxy for all the services that capital assets can provide to animals. The asset value was preferred to depreciation charges mostly because the recording system of the former was less associated with accounting errors, hence, more reliable than the latter. Finally, the capital per sheep-unit was calculated as a ratio of the total asset value to the number of sheep-units at the beginning of the year. The unit of measurement is tugrug/sheep-unit. Tugrug is the basic monetary unit in Mongolia, currently 800 tugrug are equal to $US 1.

Supplementary fodder. Data on supplementary fodder were collected as kg of feed-units per physical animal (not sheep-unit) at the beginning of year. A feed unit is equal to one kg of oats.

Veterinary service. It is the total expenditure on veterinary services per one physical animal at the beginning of the year. The unit of measurement is mungu/animal. Mungu is a lower monetary unit in Mongolia (1 tugrug=100 mungu).

Stocking Rate. Stocking rate is calculated as a ratio of the total number of sheep-units at the beginning of year to the hectares of pasture. Since the size of pasture does not vary much over time, a change in the stocking rate reflects basically a change in animal numbers. The unit of measurement is sheep-units/ha.

Private incentive. As mentioned in chapter 1, in addition to *negdel*-owned animals, each household was allowed to have a small number of private animals - a maximum of up to 75 in desert and semi-desert regions and 50 in other regions. Accordingly, there was some, though unstable, evidence to suggest that herders pay more attention to their private animals. Therefore, it seems reasonable to test whether this evidence is statistically significant. The percentage share of privately owned animals in the total number of district animals is included mostly to test this hypothesis. The assumption here is that if herders indeed pay more attention to their private animals, then this would have an impact on the average NGR of districts.

4.4.3 Accounting for growth

Using a traditional accounting approach initiated by Solow (1957), accounting for total growth in the NGR of animals was carried out as follows:

1. Taking the first derivative of (4.9) with respect to time, technical change was accounted for as:

   $\partial \ln G^a/\partial T=\alpha_1+\alpha_2 T$ or

   $\partial G^a/\partial T=(\alpha_1+\alpha_2 T)\,G^a$ since (4.13)

   $\partial \ln G^a/\partial T=(\partial \ln G^a/\partial G^a)(\partial G^a/\partial T)$ and

   $\partial \ln G^a/\partial T=(1/G^a)(\partial G^a/\partial T)$

2. Total growth in the NGR in year t was calculated as:

   $TGt=G_t^a - G_{t-1}^a$ (4.14)

   where TGt= Total Growth in the NGR in year t

   G_t^a and G_{t-1}^a = NGR in year t and t-1, respectively

3. Growth in the NGR which resulted from the intensification of production or growth in inputs per animal, was calculated as the difference between total growth (4.14) and technical change (4.13)

   $It=TGt - (\alpha_1+\alpha_2 T)\,G^a$

   where It= Growth in the NGR which resulted from the intensification of production

5. RESULTS AND DISCUSSION

5.1 Introduction

The production function analysis of the extensive livestock industry in Mongolia was carried out in two stages. In the first stage, weather-yield models were estimated and used for testing hypothesis 1 and deriving a weather-adjusted production measure for cattle and the small stock in Mongolia. In the second stage, the aggregate production function was estimated using weather-adjusted dependent variable derived in stage one. The production function was used to analyse production structure and output growth in the industry. An attempt was made to separate the total growth of output into two sources - technical change and intensification. Regional patterns of output growth were analysed using the averages of data in each agro-ecological region. Hypotheses 2, 3, 4, and 5 were tested.

5.2 Weather-Yield Model

5.2.1 Selection of the weather regressors

Selection of the weather regressors has been carried out at three levels of aggregation; (i) district or meteorological station, (ii) agro-ecological sub-region, (iii) agro-ecological region. The statistical package SAS (1995) was used for running the stepwise selection technique. The stepwise method resulted in generally low values of adjusted R-squared at both regional and sub-regional levels when the number of weather regressors was 11. For example, in cattle models, the value of adjusted R-squared, the main criterion for model selection, was 0.23 (Hangai-Huvsgul Region), 0.43 (Orhon-Selenge Region), 0.78 (Altai Region), 0.27 (Steppe Region) and 0.38 (the Gobi Desert Region). For agro-ecological sub-regions which were represented by more than one district, it ranged between 0.26 and 0.87. These relatively low values of adjusted R-squared at higher levels of aggregation is attributable to non-homogeneity of weather within agro-ecological regions and subregions. Accordingly, to best capture weather-animal relationships, the model (4.2) was estimated by using district data (Appendix 2). As an alternative to adjusted R-squared, the Akaike's information criterion was used to validate the model selection procedure. Thus, the stepwise technique selects the model which maximises the adjusted R-squared and minimises the Akaike's information criterion. All weather regressors included in district weather-yield models were significant at 1.5% to 3.5% level. As shown in Appendix 2, in cattle equations, the value of adjusted R-squared was greater than 0.90 for all 36 districts except Tudevtei (0.88). Similarly, the adjusted R-squared for equations for the small stock were greater than 0.90 for all districts except for Erdenemandal (0.876). The signs of the coefficients in weather-yield models were generally in accordance with our expectations as discussed below.

Cattle

Temperature in cold months tended to have positive coefficients indicating the negative impact of cold temperature on animals. In a few cases it had negative coefficients, which could be caused by the fact that relatively warm temperatures cause the upper covering of snow to melt and eventually become an icy cover leading to serious difficulties to animal grazing. Temperature in warm seasons tended to have negative coefficients for districts in more hot steppe and desert regions indicating the negative effect of high temperatures on animals. In contrast, it was mostly positive for districts in cooler mountainous areas.

Most of the coefficients for the severity index were negative, as expected for obvious reasons.

Precipitation had mostly positive coefficients in the spring-summer period indicating the positive impact of rainfall on pastures. For cold months, it had mostly negative coefficients pointing out to the difficulties for grazing created by snow falls.

The coefficients of wind in cold seasons were generally negative especially for districts in mountainous regions. In contrast, for districts in forest-steppe areas such as Orhon, Teshig, Bayan, Undurshireet and Hujirt, these coefficients were positive indicating to the positive effect of wind as it blows heavy snow falls and thus frees pastures for animals. In warm months the coefficients of wind were positive for most districts except for a few in high-mountainous and desert areas.

Snow depth and snow cover had mostly negative coefficients pointing to the negative impact of these variables, which create difficulties to animal grazing. Similarly, the number of days with electric storms had also negative signs for most districts. Variables such as the number of days with continuos slight rain, blowing snow storms, ordinary snow storms and storm wind were selected only in a few cases. This is likely to indicate that their influence on cattle is generally insignificant.

Small stock

As expected, temperature had mostly positive coefficients in cold months. Because of both negative and positive impacts on animals, temperature in warm months was not inclined to a particular sign. When positive, it indicates to the positive impact of a warm temperature on pastures. When negative, it points out to the negative impact of high temperatures on the animal's performance and pasture yield.

Precipitation in October and November strongly tended to have negative coefficients. This is because snow falls in these months are unlikely to have any positive impact on animals. Starting from December, the precipitation coefficients became both positive and negative. The negative coefficients indicate to heavy snow which prevents animals from normal grazing. In contrast, the positive coefficients indicate that the positive impact of snow as a drink for animals outweighs its negative impact. Precipitation in warm months had both negative and positive coefficients. Its negative impact is mostly due to cold rains which are known as one of the main causes of animal deaths in this season. In contrast, rainfalls in spring and early summer have a critical positive impact on pastures.

The sign of the wind coefficients in cold months varied across districts depending basically on the topography in each area. In non-mountainous areas such as the Orhon-Selenge and the Steppe Regions, wind tended to have a positive effect because it blows heavy snow, thus frees pastures for animals. In contrast, in mountainous areas (the Hangai-Huvsgul and the Altai Regions) the negative impact of wind as a chilling factor outweighs its positive impact. Wind in warm months tends to have positive coefficients in most districts except for a few in cooler high-mountainous areas.

As a result of the interaction of positive and negative impacts of wind and temperature, the severity index has both positive and negative coefficients. For example, the positive sign indicates that wind does more good than harm to animals by blowing snow.

The signs of the coefficients of number of days with ordinary snow storms, blowing snow storms and storm wind has a similar pattern as those of wind and the severity index in cold months.

The number of days with a continuos slight rain has positive coefficients for all districts indicating that the positive impact of these rains on pastures is dominant over their negative impact.

Coefficients for number of days with electric storms had both positive and negative signs. The positive impact of the electric storms on animals is probably associated with its influence on pastures. Their negative impact, as they directly kill animals, is found to be significant in districts Zuunhangai, Hujirt, Altai and Hanhongor.

The number of hot days was selected in a few districts and has both positive and negative coefficients. Our expectation with respect to this variable is that its impact should be negative in hot areas and insignificant or positive in moderate to cool areas. The results generally justify this expectation.

As expected, the coefficients of the duration of snow cover and snow depth show both positive and negative impacts on animals. They are negative in mountainous areas and positive in steppe and desert areas.

5.2.2 Weather Variability

As explained in section 4.3.4, weather variability was estimated as the deviation of NGR associated with observed weather from that associated with mean weather and can be positive and negative. For example, an estimated weather variability of 5 percent in a given year suggests that the NGR would have been lower by 5 percent in that year if the weather had been average. By contrast, a weather variability of -5 percent implies that the NGR would have been higher by 5 percent if the weather had been average. The estimates of weather variability from 1969 to 1990 by agro-ecological sub-regions and regions are shown in Appendix 3 and Table 5.1, respectively. These estimates were calculated as averages of the district estimates.

These estimates are very important in that they provide a basis for drawing a general picture of weather pattern in Mongolia. As mentioned in section 4.2.2, it is believed that agricultural development efforts can be improved if the weather restraints are properly identified and development programs are focused on "removing" some of their effects.

Table 5.1: Weather Variability of the Natural Growth Rate by Agro-Ecological Regions

Year	Hangai-Huvsgul		Orhon-Selenge		Altai		Steppe		The Gobi Desert	
	cattle	small stock	cattle	small stock	cattle	small stock	cattle	small stock	cattle	small stock
1969	-5.188	-0.050	-12.164	0.363	-16.690	-6.178	-2.300	3.828	-4.173	-2.970
1970	0.775	2.125	-1.043	-0.917	4.524	-0.600	-5.165	-4.415	-0.814	-1.640
1971	-1.038	-4.253	-3.309	-3.400	1.156	-6.658	-10.838	-7.288	-7.551	-2.746
1972	4.812	-0.101	6.984	-3.009	4.104	-3.130	12.530	6.955	1.980	-0.996
1973	4.195	3.668	2.336	0.063	1.748	2.400	9.828	7.158	-13.644	-6.953
1974	4.670	6.239	8.413	6.617	3.516	4.340	17.623	4.218	17.801	10.745
1976	1.348	-5.193	4.971	-8.303	-7.290	-4.402	5.717	1.072	3.805	-1.860
1977	-1.344	-8.697	-6.457	-10.216	-6.374	-4.840	0.783	-1.390	8.375	-2.065
1978	0.727	8.021	2.303	6.490	-5.884	3.796	2.788	9.908	7.790	8.823
1980	1.123	-1.543	-4.607	-2.514	5.364	7.000	-13.177	-19.407	-5.509	-8.421
1981	-3.903	1.723	2.064	6.640	5.098	7.164	-4.573	3.897	6.075	2.830
1982	-4.154	0.647	-0.156	3.794	1.298	10.174	-0.252	2.587	2.656	0.495
1983	-4.748	-11.466	-2.826	-6.524	-2.910	-6.052	-8.342	-12.420	-11.676	-15.494
1984	-1.084	-6.269	-1.960	-2.254	1.474	7.672	-0.113	-4.315	4.816	0.413
1985	-2.255	-7.867	-2.224	-5.091	8.436	8.902	-1.657	2.808	3.561	-4.209
1986	2.845	5.185	3.711	6.617	4.724	11.328	2.462	7.533	1.463	4.518
1987	3.374	5.229	0.316	2.993	4.572	8.952	-2.992	0.428	5.674	2.648
1988	-4.917	-2.082	-1.909	0.650	2.058	0.938	-1.037	-4.338	4.059	-1.011
1989	2.611	9.080	3.011	5.623	1.008	7.912	1.312	4.948	4.193	4.211
1990	2.143	5.609	2.540	2.981	-9.926	-8.680	-2.605	-1.763	-5.663	-1.860
st. dev.	3.348	5.862	4.769	5.238	6.267	6.570	7.421	7.213	7.425	5.822
min	-5.188	-11.466	-12.164	-10.216	-16.690	-8.680	-13.177	-19.407	-13.644	-15.494
max	4.812	9.080	8.413	6.640	8.436	11.328	17.623	9.908	17.801	10.745

The average volatility of weather in each region was assessed by the standard deviation of the weather variability. As shown in Table 5.1, regions with most volatile weather for cattle and small stock are the Gobi Desert (7.43) and the Steppe (7.42), respectively. In contrast, regions with the least volatile weather are the Hangai-Huvsgul (3.35) and the Orhon-Selenge (4.77), respectively. Compared with cattle, the estimated standard deviations for small stock varied less across agro-ecological regions. In general, the effect of weather was less variable in the regions to which animals were better suited.

Another question related to the weather patterns is an association of weather between regions and sub-regions. This question is important because if good weather in one region/sub-region is offset by bad weather in another, then the variability of the NGR attributable to weather will be dampened at the national scale. On the other hand, if weather effects in regions/sub-regions are positively correlated, then the variability in their combined NGR attributable to weather would be large. A positive or negative association of weather variability between two regions can be measured by the correlation matrix of the estimated variabilities. These estimates are shown in Table 5.2 by agro-ecological regions and in Appendix 4 by agro-ecological sub-regions. Appendix 4 shows that (i) weather tends to be positively correlated among the sub-regions within the same region indicating to a similarity of weather within one region, (ii) positive weather association is dominant in terms of both the frequency and the value of correlation coefficients indicating the general similarity of weather effects across the country.

Table 5.2a: Correlation Matrix of the Weather Variabilities between Agro-Ecological Regions (Cattle)

1. Hangai-Huvsgul	1.000				
2. Orhon-Selenge	0.685	1.000			
3. Altai	0.253	0.376	1.000		
4. Steppe	0.549	0.660	0.010	1.000	
5. The Gobi Desert	0.142	0.360	0.175	0.466	1.000
	1	2	3	4	5

Table 5.2b: Correlation Matrix of the Weather Variabilities between Agro-Ecological Regions (Small stock)

1. Hangai-Huvsgul	1.000				
2. Orhon-Selenge	0.864	1.000			
3. Altai	0.335	0.518	1.000		
4. Steppe	0.536	0.472	0.229	1.000	
5. The Gobi Desert	0.682	0.685	0.416	0.640	1.000
	1	2	3	4	5

The weather association at the regional level shows that (i) the positive weather association is more prominent indicating that the weather pattern in Mongolia is generally similar across the agro-ecological regions, (ii) weather is more similar between the pairs: Hangai-Huvsgul and Orhon-Selenge; Orhon-Selenge and Steppe for cattle and Hangai-Huvsgul and Orhon-Selenge; Hangai-Huvsgul and the Gobi-Desert; Orhon-Selenge and the Gobi-Desert; and Steppe and the Gobi-Desert for the small stock (Table 5.2).

5.2.3 Aggregate Weather-Yield Model

As discussed in section 4.3.4, the aggregate weather yield model (4.7) was defined for testing hypothesis 1. The estimated model (4.7) is shown in Table 5.3. The weather index was highly significant[1] for both species of animals and its variability explains the significant proportion of the output variability. This is in agreement with hypothesis 2 which says that livestock production was primarily dependent on weather variables.

Table 5.3: The Aggregate Weather-Yield Model

Coefficients	Cattle		Small stock	
	Parameter Estimate	T-ratio	Parameter Estimate	T-ratio
C_1	2.456	15.223	3.235	37.507
C_2	2.387	14.243	3.289	48.017
C_3	2.317	9.991	3.105	18.831
C_4	2.337	10.167	3.245	42.881
C_5	2.430	13.731	3.342	45.931
ω	1.116	11.351	1.354	30.918
α_1	0.114	3.100	0.062	2.856
α_2	-0.004	-2.590	-0.003	-2.235
R-squared	0.700		0.815	

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[1] significant at 1% level

The null hypothesis that all the regional dummy variables are equal to each other was rejected at 1% level for cattle and at 5% level for the small stock. This suggests that the agro-ecological regions lie on different levels of efficiency. As noted earlier, since weather was explicitly taken into account, these differences are largely dependent on factors such as topography, vegetation and soil type.

The coefficients of the trend term (α_1 and α_2) were highly significant for both species of animals implying that the NGR was increasing at a decreasing rate. These results suggest that development initiatives in the form of intensification of production and technical change had a positive impact on the NGR of animals. This issue is discussed in the following sections

5.3 Production function

As indicated in section 4.4.1, the production function with Hicks-neutral technical change was defined as:

$$\ln G_{nt}^{a} = \sum_{k=1}^{5} C_n D_{knt} + \sum_{i=1}^{6} \beta_i \ln x_{\text{int}} + \frac{1}{2} \sum_{i=1}^{6} \sum_{j=1}^{6} \beta_{ij} \ln x_{\text{nt}} \ln x_{jnt} + \alpha_1 T + \frac{1}{2} \alpha_2 T^2 + u_{nt} \qquad (4.9)$$

The null hypothesis of no contemporaneous correlation across the equations for cattle and small stock was not rejected at 1% level (critical χ^2=6.64; computed χ^2=0.099 with 1 degrees of freedom). Accordingly, there was no need to use the seemingly unrelated regression (SUR) technique across the equations for cattle and small stock. In addition, as noted in section 4.4.1, contemporaneous correlation would exist if the estimated weather index fails to capture some facets of weather that have a common effect on cattle and small stock. Accordingly, the test for contemporaneous correlation shows indirectly that the method of accounting for weather effects performs quite well.

The model (4.9) was explicitly tested against the Cobb-Douglas and CES forms as alternatives to the translog form. In equation for small stock both alternatives were rejected at the 1% level of significance (critical F value was 1.57; computed F value was 3.11 for the Cobb-Douglas restriction and 3.26 for the CES restriction). In the cattle model both alternatives were not rejected at the 5% level (critical F value was 1.57; computed F value was 1.51 for the Cobb-Douglas restriction and 1.49 for the CES restriction). However, the signs of the main input coefficients in the translog form were better than the other alternatives.

The model (4.9) was tested for structural change. The period under investigation was divided into three periods: 1969-1975, 1976-1980 and 1981-1985.[2] These periods basically coincide with 5-year plans which were the basic means for the socialist government to fulfil its economic program, including the investment projects. The Chow test did not reject the null hypothesis of no structural change between the last two periods for both cattle and the small stock (critical F =1 at both 1% and 5% level of significance, computed $F_{324,152}=0.915$ for cattle and $F_{324,149}= 0.988$ for the small stock). The null hypothesis was rejected at 1% for the small stock (critical F=1.70, computed $F_{30,307}=3.94$) and at 5% level for cattle (critical F=1.46, computed $F_{30,316}=1.51$) between the first two periods. Accordingly, the model (4.9) was estimated separately for two periods: 1969-1975 and 1976-1985. Because of the limited relevance of production technology in 1969-1975, only the model for 1976-1985 data is reported below.

The estimated production function is shown in Table 5.4 and production elasticities are shown in Table 5.5.

Comparing the estimated production elasticities from the two models one could make the following conclusions.

1. The all-coefficients model is in better agreement with economic theory. The insignificance of many coefficients in this model can be explained by the existing low level of use of economic inputs and multicollinearity which is characteristic of any model of this type;
2. The significant-coefficients model is in less agreement with economic theory. The coefficients of capital and supplementary fodder in the cattle equation and supplementary fodder and stocking rate in the small stock equation had the wrong signs and the labour coefficient in the small stock equation became insignificant. The only improvement was veterinary services in the small stock equation the coefficient of which changed from negative to positive.

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[2] most of economic data are missing after 1986
Data for 1979 are also missing

Table 5.4: The estimated aggregate production function (1976-1985)

Coefficients	Cattle				Small stock			
	All Coefficients		Significant * Coefficients		All Coefficients		Significant Coefficients	
	Estimates	T-ratios	Estimates	T-ratios	Estimates	T-ratios	Estimates	T-ratios
C_1	-0.022	-1.270	-0.023	-1.373	0.039	3.128	0.051	1.646
C_2	-0.042	-1.782	-0.027	-1.158	0.008	0.693	0.022	0.635
C_3	0.032	1.789	0.035	2.007	-0.008	-0.557	0.016	0.497
C_4	-0.010	-0.492	-0.020	-0.902	0.009	0.826	0.039	1.247
C_5	-0.095	-3.973	-0.085	-3.389	0.025	1.681	0.031	0.973
β_1	-0.731	-1.773	-1.042	-2.413	-0.199	-0.654	xxx	xxx
β_2	-0.315	-1.096	-0.174	-2.335	1.150	8.743	24.264	24.264
β_3	0.320	2.260	0.353	3.878	0.096	1.094	-5.571	-5.571
β_4	0.328	1.319	xxx	xxx	-0.287	-2.072	-2.284	-2.284
β_5	-0.703	-1.751	xxx	xxx	0.045	0.214	3.921	3.921
β_6	1.781	6.718	1.872	8.477	1.001	7.185	17.186	17.186
β_{11}	0.012	0.860	xxx	xxx	0.002	0.045	xxx	xxx
β_{22}	0.040	1.318	xxx	xxx	-0.045	-1.441	xxx	xxx
β_{33}	0.001	0.246	xxx	xxx	0.006	1.185	xxx	xxx
β_{44}	0.004	0.400	xxx	xxx	0.002	0.161	xxx	xxx
β_{55}	0.098	3.252	0.018	1.703	0.013	0.774	xxx	xxx
β_{66}	-0.226	-4.707	-0.242	-5.683	-0.036	-2.063	-0.054	-3.215
β_{12}	0.086	2.024	0.095	2.371	0.086	1.269	xxx	xxx
β_{13}	-0.031	-1.895	xxx	xxx	-0.022	-1.280	xxx	xxx
β_{14}	-0.007	-0.333	xxx	xxx	-0.014	-0.304	xxx	xxx
β_{15}	0.056	1.336	xxx	xxx	-0.050	-1.283	xxx	xxx
β_{16}	0.153	1.870	0.190	2.228	-0.034	-0.659	xxx	xxx
β_{23}	0.165	2.980	xxx	xxx	0.073	1.470	xxx	xxx
β_{24}	0.009	0.460	xxx	xxx	-0.039	-2.090	0.085	2.652
β_{25}	-0.030	-0.950	xxx	xxx	0.057	1.481	xxx	xxx
β_{26}	-0.008	-0.164	xxx	xxx	-0.220	-6.002	-0.306	-16.186
β_{34}	-0.005	-0.490	xxx	xxx	-0.011	-0.781	xxx	xxx
β_{35}	0.032	1.550	xxx	xxx	0.014	0.688	xxx	xxx
β_{36}	-0.082	-2.784	-0.097	-3.837	-0.012	-0.647	xxx	xxx
β_{45}	-0.001	-0.024	xxx	xxx	0.059	1.858	0.054	1.743
β_{46}	-0.054	-1.191	xxx	xxx	0.071	1.991	xxx	xxx
β_{56}	0.020	0.288	xxx	xxx	-0.078	-1.988	-0.127	-3.124
α_1	0.002	1.974	0.002	1.788	-0.001	-1.876	-0.002	-1.080
α_2	0.001	2.465	0.001	2.860	0.000	0.403	xxx	xxx
R-squared	0.994		0.994		0.997		0.996	

X_1=labour; X_2=capital; X_3=supplementary fodder; X_4=veterinary services; X_5=stocking rate; X_6=share of private animals

*The significant-coefficients model was estimated using only the variables which were significant at least at the 10% level in the all-coefficients model.

Table 5.5: Production Elasticities

Variables	Cattle		Small stock	
	All Coefficients	Significant Coefficients	All Coefficients	Significant Coefficients
Labour	0.019	0.037	-0.015	0.000
Capital	0.633	-0.044	0.591	0.101
Supplementary fodder	0.543	-0.023	0.335	-0.052
Veterinary services	0.121	0.000	-0.292	0.059
Stocking rate	-0 580	-0.010	-0.007	0.053
Share of private animals	0.726	0.784	0.044	0.076

However, the significant-coefficients model provides some important information.

1. Comparing the two models it can be observed which variables have a more steady impact on the NGR of animals. These variables, which kept their signs in both models, were labour, stocking rate and the share of private animals in the cattle equation and capital and the share of private animals in the small stock equation.
2. More importantly, this model resulted in the insignificant trend term for the small stock. Considering only a 10% significance level of the trend term in the all-coefficients model, this result suggests that overall, there was no technical change in the small stock industry. This is easier to explain than the negative technical change obtained in the all-coefficients model.
3. With this model one would feel more confident in supporting hypothesis 2. Although the all-coefficients model resulted in highly significant linear terms of the share of private animals for both equations (β_6), the statistical significance of the estimated production elasticities was questionable as they were calculated using some insignificant terms.

5.4 Production elasticities

Production elasticities are discussed in terms of the all-coefficients model.

5.4.1 Cattle

As shown in Table 5.5, the elasticities for cattle are in agreement with our expectations. A one percent increase in labour, capital, supplementary fodder, veterinary services and the share of private animals leads to an increase in the NGR of cattle by 0.019, 0.633, 0.543, 0.121 and 0.726 percent, respectively. Among these, capital, supplementary fodder and the share of private livestock have the largest responses suggesting that these were the most limiting factors. Compared to small stock, the effect of stocking rate is much higher, suggesting that a shortage of pasture is more serious in the cattle industry. This is likely, because compared with other animals a larger proportion of cattle is located near urban areas, where pasture is most degraded.

5.4.2 Small stock

The elasticities of capital, supplementary fodder, stocking rate and the share of private animals have the correct signs. Among these, capital and supplementary fodder have the largest effect, leading to an increase in the NGR by 0.591 and 0.335 percent respectively. Compared with cattle, the contribution of stocking rate and the share of private livestock are considerably low. A negative but relatively low response to stocking rate can be explained by the fact that these animals are more evenly located throughout the country hence, use less degraded pasture.

In contrast to our expectations, labour and veterinary services have negative elasticities. As mentioned in section 3.2, the negative sign for labour is likely due to reporting and measuring biases. The only available data on labour were the number of herders. These data represent the labour available for use rather than the labour actually used (service flows), hence, they are not free from the measurement biases. As concerns veterinary services, the negative sign may indicate that the total expenditure on the services is not a good variable to relate to the NGR of animals. The negative relationship may dominate if (i) a significant portion of these expenditures are related to services such as drenching and jetting which do not much affect the NGR, (ii) the volume of these works are correlated with some weather factors which are not captured by the weather-yield model, but have a negative impact on the NGR.

5.5 Economic implication of the dummy variable coefficients

As with the aggregate weather-yield model, the dummy variables are included to capture the differences in omitted factors such as topography, vegetation and soil type and management.

The null hypothesis that all the regional dummy variables are equal to each other was rejected at the 1% level for cattle and at the 5% level for the small stock indicating that the agro-ecological regions lie on different levels of efficiency. The ranking of the agro-ecological regions by the value of regional effects as indicated by the dummy variable coefficients is shown in Table 5.6.

As Table 5.6 shows, conditional on the omitted variables, the most efficient regions for cattle and small stock are Altai and Hangai-Huvsgul, respectively, and the least efficient are the Gobi Desert and Altai, respectively.

Table 5.6: Ranking of the agro-ecological regions by the value of the regional effects*

Agro-Ecological Regions	Cattle	Small stock
Hangai-Huvsgul	3	1
Orhon-Selenge	4	4
Altai	1	5
Steppe	2	3
the Gobi Desert	5	2

*Based on the results of the all-coefficients model

5.6 Technical Change and Accounting for Growth

As discussed in section 5.3, the small stock industry did not seem to have experienced technical change. While, the coefficients of the trend terms in the cattle model indicated that significant technical change, at an increasing rate, occurred in this industry. Thus, hypothesis 4 was accepted in the case of the cattle industry, but it was rejected in the case of the small stock industry.

The contribution of technical change and the intensification of production to the total growth in the NGR of animals is shown in Appendix 5. The NGR of cattle increased from 19.69% in 1976 to 22.17% in 1985. The contributions of technical change and the intensification of production (input growth per an animal) to this growth in the NGR were 52.8% and 47.2%, respectively. The NGR of small stock increased from 33.40% in 1976 to 35.71% in 1985. This growth was entirely due to intensification. Thus, hypothesis 4 was supported for both industries.

The pattern of growth in the NGR over time is shown in Figure 5.1. The NGR

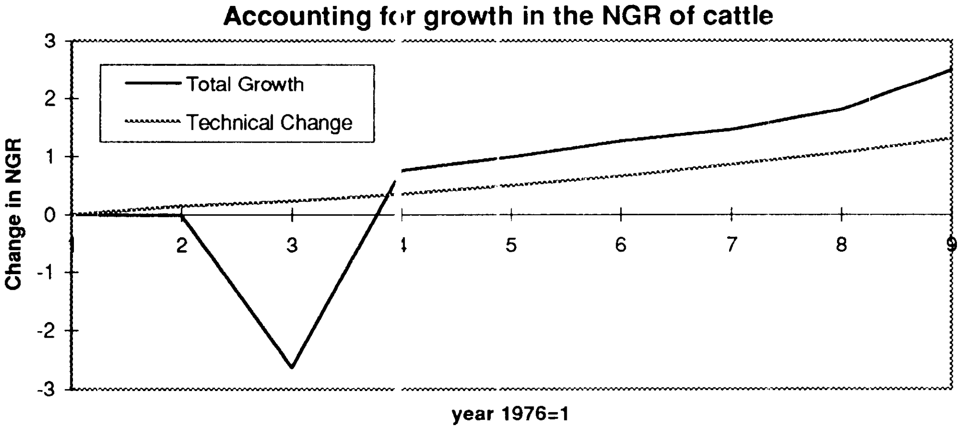

Figure 5.1a Source: Appendix 5

of cattle increased at increasing rate over the whole period. Overall, technical change and intensification of production equally contributed to this growth, however, towards the end of the period, the contribution of the latter dominated that of the former. In contrast to cattle, the NGR of the small stock increased at a generally constant rate in the first seven years and declined in the last two years. This decline was caused by a slow-down in the supply of pasture, capital and supplementary fodder towards the end of the period.

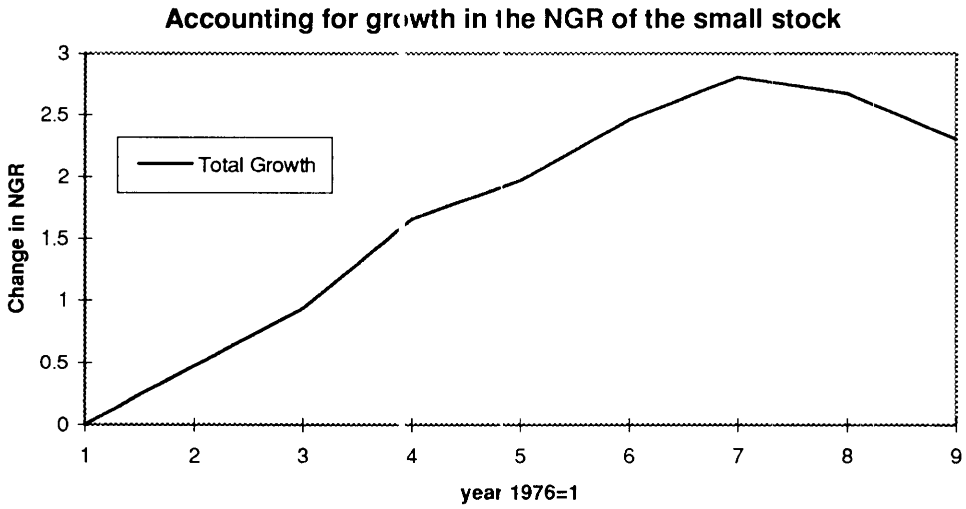

Figure 5.1b Source: Appendix 5

5.7 Regional Patterns of growth in NGR

The regional patterns of growth in the NGR of animals and the contribution of technical change and input supply to these growth patterns are shown in Appendix 5.

In the cattle industry, total growth in the NGR for the whole period was 2.93 points in the Hangai-Huvsgul region, 4.42 points in the Orhon-Selenge region, 3.30 points in the Altai Region, 0.78 points in the Steppe region and 1.19 points in the Gobi Desert region. Year to year variability in the NGR was highest in the Altai and Steppe regions and low to moderate in other regions. In the small stock industry, total growth in the NGR was 3.21 points in the Hangai-Huvsgul region, 2.94 points in the Orhon-Selenge region, 0.16 points in the Altai region, 7.9 points in the Steppe region and decreased by 1.25 points in the Gobi Desert region. Year to year variability in the NGR was low in all regions. As technical change was constant for all regions in the cattle industry and insignificant in the small stock industry, year to year variabilities in the NGR can be attributed to the differences in the input supply between agro-ecological regions.

The contribution of technical change and input growth to the total growth in the NGR of cattle is shown in Table 5 7.

The growth in the NGR of cattle was mostly driven by input growth in the first three regions. In contrast, in dry regions such as the Steppe and the Gobi Desert, which are less suitable for cattle, the NGR increase was entirely due to technical change and its effect outweighed the negative impact of declined input supply.

Table 5.7: Accounting for growth in the NGR of cattle*

Agro-ecological regions	Total growth in the NGR	Technical Change	Input growth
Hangai-Huvsgul	100	45	55
Orhon-Selenge	100	30	70
Altai	100	40	60
Steppe	100	164	-64
the Gobi Desert	100	107	-7

*Based on Appendix 5.

The differences in the pattern of the growth in the NGR across agro-ecological regions support hypothesis 5. These differences reflect the different resource endowments among agro-ecological regions which dictate different types of technological development, as well as different development strategies.