AN ECONOMETRIC MODEL OF THE GRAZING LIVESTOCK SECTOR OF U.K. AGRICULTURE.

by

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I confirm that this thesis was composed by myself and that the work is my own.

Signed

SUMMARY

The primary aim is to formulate, estimate and test a semi annual "Econometric Model of the Grazing Livestock Sector of U.K. Agriculture" with the ability to produce short term forecasts of the numbers of livestock and the numbers of stock slaughtered. A secondary objective is the use of the model for an examination of agricultural policy issues.

After the introduction a general description of U.K. agriculture is given. A review of relevant models and particularly the "Nerlove Model" is carried out. The latter is judged not representative of the lagged response of livestock production, and applied models are found to be underspecified in terms of revenue, cost and competitive relationships, thus making them inadequate for forecasting under the future conditions of rapidly changing agricultural policy.

Theoretical production and store livestock price models are then formulated. The basis of the former is a system of simultaneous equations to represent competition for scarce resources, incorporating a logarithmic formation of revenue relative to cost for each product to represent decreasing production response and a time trend to allow for improving efficiency with time. The store livestock price model assumes that store livestock price is based on producers expectation of future fatstock price and production cost.

A discussion on the adequacy and the use of available statistical material for the model follows. Published statistics on heifers in calf are reformulated by algebraic and statistical methods so as to give the numbers of heifers calving six monthly.

In the empirical model constructed equations are given determining the numbers of dairy cows, beef cows, ewe flock, dairy heifers calving, beef heifers calving, calves retained for breeding, calves aged up to six months, dairy calves slaughtered, fat cattle slaughtered, cows

slaughtered, lambs slaughtered, ewes slaughtered, and determining store lamb price, calf price, cow price and ewe price. Important features of the model are a production time lag in the breeding stock equations based on the time taken to rear replacement breeding stock; the competitive relationship between dairy cows, beef cows and ewes for resources (shown by simultaneous equations); the competitive relationship between breeding cows and fattening cattle (shown by a price ratio); the different influences on production of livestock prices, livestock subsidies and general grants and subsidies; the detailed specification of the breeding stock equations with regard to revenue, cost and competitive relationships; the absence of any evidence of improving economic efficiency in sheep farming; the competitive influence of dairy cows on the proportion of dairy calves retained; and the inclusion of feed price changes in the equation for fat cattle slaughtered.

The model is adapted for forecasting by ordering the estimated equations by time sequence of events and imposing constraints on the growth rate of the ewe flock and on the reduction in the proportion of dairy calves slaughtered. Six monthly "historical predictions" are made over the period June 1970 - Dec. 1972 and also a thirty month prediction. The accuracy of the forecasts is measured using appropriate tests.

A consideration of agricultural policy matters shows that the effect of a change in support for either dairy, beef or sheep cannot be considered in isolation from the remaining two, and that increases in fat cattle price can reduce the numbers of dairy calves slaughtered and so increase resource use efficiency. Explanation for the high price of beef during the end of 1972 is given and also reasons for a long term decline in the ewe flock.

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CONTENTS

CHAPTER 1

INTRODUCTION

The aim of this work has been to construct a model of the grazing livestock sector of UK agriculture. Its completion coincides with a radical alteration in the affairs of the United Kingdom. Now that we are a member of the European Economic Community (EEC), we can no longer determine our own agricultural policy. Instead agricultural policy is determined by the collective will of all EEC member countries. Because the agricultural policy of the EEC must adhere to the Treaty of Rome, and because the Treaty of Rome and existing agricultural policy in the Common Market was formulated before the membership of the UK, entry into the EEC necessitates large changes in the systems of support for UK agriculture. This has led to a minor spate of publications purporting to show the levels of output from United Kingdom agriculture under the Common Agricultural Policy (CAP). The need for such projections has been expressed by Mansholt, the Vice president of the Commission of the European Communities (McFarquhar, A.M.M., 1971 p.v.). He stated that "More than ever there is now a general recognition among those concerned with agricultural policy of a need for projections with regard to production and consumption of agricultural products, as a contribution to the solution of the problems of disequilibrium between production and consumption and of the problems of low incomes in farming". Certainly disequilibrium has occurred within the EEC, an excellent example being the famous "butter mountain". The United Kingdom does not have a faultless record either. In December and January of 1972/73 a shortage of beef supplies and soaring beef prices led to the Prime Minister appointing a committee to "report urgently on the factual situation relating to beef supplies, with particular reference to prices" (Financial Times newspaper 8th-12th January, 1973). Part of the UK problem could be attributed to the global supply and demand situation for beef. As agricultural systems differ widely from country to country, in order to obtain global projections for supply and demand separate projections have to be made for each individual country. This thesis can be regarded as a small contribution towards the total volume of work required.

The sector of study, i.e. grazing livestock, can be regarded as being largely independent of other agricultural sectors and as production cannot respond immediately to price changes, it can be analysed separately from demand. The grazing livestock sector also contains within it several competing agricultural enterprises. This sector has therefore offered plenty of scope for the development of methodology, while being independent enough to allow for a separate analysis.

The aim has been to model the grazing livestock sector in some detail by econometric methods up to the stage of eventual slaughter of livestock, particular attention being devoted to the adequate representation of the breeding stock system, because this goes a long way to ensuring reasonable forecasts of the numbers of livestock slaughtered. Because of the change in agricultural policy brought about by the adoption of CAP, it has been important to ensure that allowance is made for competitive relationships between agricultural products, and also that a detailed allowance be made for sources of revenue and costs.

The study consists of the examination of existing econometric models of the grazing livestock sector of UK agriculture, the reformulation of theoretical models where necessary, the estimation of the model (over a pre EEC entry period), the testing of the model over a historical forecast period (up to EEC entry period), a consideration of agricultural policy and the drawing of conclusions.

CHAPTER II

UNITED KINGDOM AGRICULTURE: GENERAL DESCRIPTION

Interraction of Agricultural Enterprises

The type of agriculture that has evolved in the UK consists of many interractions between agricultural enterprises.

Hill farmers tend to specialise in keeping cows and ewes for breeding purposes. The progeny, the calves and lambs, if not required for retention as future breeding stock are mostly finished as mature animals on the richer lands of the Lowland farms. Dairy farms are also a source of calves. Those calves not required as potential breeding stock are sold either for immediate slaughter, for feeding into veal calves, or for rearing and fattening for beef. Some of the food necessary for the feeding of livestock is usually purchased. This purchased food would have been grown either by arable farmers in this country or overseas.

Agricultural incomes are subject to greater fluctuations than industrial incomes, despite guaranteed prices, because of the influence of climatic variations, disease, livestock and crop cycles of productions and events occurring elsewhere in the world. Because of this farmers are likely to specialise less than they would otherwise do.

Farm enterprises can be either complementary,[1] supplementary[2] or competitive[3] in nature with other enterprises. The growing of fodder crops is complementary with the keeping of cattle, but competitive with the growing of another crop. Generally as most arable crops are grown for the purpose of providing feed for livestock, they are complementary with the keeping of livestock. Grazing livestock enterprises can be competitive or complementary with each other. Dairy cows for instance displace beef cows and sheep. The relationship

1. An increase (decrease) in the production of a product causes an increase (decrease) in the production level of other products.
2. The level of production of a product does not influence the level of production of other products.
3. An increase (decrease) in the production of a product causes a decrease (increase) in the production of other products.

between dairy cows and the fattening of beef animals is complicated. Dairy cows are competitive with fattening beef animals as there is competition for resources, but the dairy herd is also a provider of calves for rearing for beef which is a complementary relationship. An example of a supplementary relationship is that between pigs and grazing livestock as the level of production of the one can have little influence on the level of production of the other.

Table 2.1 gives a break down of the main agricultural enterprises among the main farm types in England and Wales for 1967 (Farm Classification in England and Wales, annual).

With the exception of poultry which is highly specialised most of the other farm types have all the main farm enterprises, but nearly 80% of dairy cows are kept on farms designated as "Specialised dairy" or "Mainly dairy", over half the cereal area is on farms designated as "Cropping" and about 70% of beef cows and 57% of breeding sheep are on holdings designated as Livestock rearing and fattening. Production is therefore highly specialised.

A high degree of specialisation can lead to rigidities in production because of farmers' specialised knowledge and heavy commitment of resources to one enterprise. The enterprise structure for England and Wales although showing a high degree of specialisation still has a sufficiently wide distribution of enterprises on all farm types to allow for reasonable flexibility in what is produced. The position for Scotland and Northern Ireland is similar.

Farm Size

Farm size is important in making efficient use of resources and in adopting new technology. Small farms generally do not make good use of labour as they are too small to employ profitable modern labour

TABLE 2.1

Percentage Distribution of the Main Enterprises Among Types of Holdings in England and Wales, 1967 1/

Type of Farming	Enterprises										
	Wheat Acreage	Barley & Oat Acreage	Dairy Cows	Beef Cows	Male Cattle Over 1 Year	Male Cattle Under 1 Year	Breeding Sheep	Breeding Pigs	Hens & Pullets	Broilers	Turkeys
	%	%	%	%	%	%	%	%	%	%	%
Specialist Dairy	3	5	47	1	4	7	3	6	5	-	1
Mainly Dairy	11	13	32	4	11	16	11	11	10	2	3
Livestock rearing and fattening: cattle	1	2	-	8	9	7	-	1	-	-	-
Livestock rearing and fattening: sheep	1	1	1	5	1	2	23	1	-	-	-
Livestock rearing and fattening: cattle & sheep	4	6	1	46	23	22	34	3	2	-	-
Predominantly poultry	2	1	-	-	1	1	-	1	41	76	55
Pigs and poultry	1	2	1	1	2	2	-	25	15	12	13
Cropping: mostly cereals	24	25	1	5	8	6	4	5	2	1	3
General cropping	34	24	2	7	12	11	5	13	3	1	8
Horticulture	4	2	-	1	1	1	1	4	2	2	5
Mixed	12	14	10	9	13	15	11	16	9	5	9
Total holdings 275 smds. and over	97	95	96	87	84	90	92	85	89	99	97
Holdings under 275 smds.	3	5	4	13	16	10	8	15	11	1	3
All Holdings	100	100	100	100	100	100	100	100	100	100	100

1/ M.A.F.F. Farm Classifications.

saving machinery to any great extent, and the machinery actually employed is under utilised. Often the amalgamation of two farms can lead to the amalgamated holdings being worked with the same labour and capital equipment previously used by one holding. An ability for farms to consolidate and amalgamate is therefore important for profitable expansion of agriculture.

Farm sizes in the United Kingdom are large relative to those in other European Countries. This good farm structure was largely brought about by the eighteenth century enclosers of agricultural land. A method of measiring the size of a agricultural enterprise is by "Standard Man Days" (SMD's), 275 SMD's being considered as providing full time employment for one man in England and Wales. Table 2.2 gives the size distribution of holdings in the UK by this method.

TABLE 2.2

Size Distribution of Holdings by SMD's

	Standard Man Days	1967	1972
Percent of holdings with	26-275	46.2	43.8
	275-599	27	24.6
	600-1199	17	18.8
	1200 and over	9.8	12.8
	Total	100	100

(Annual Review of Agriculture, 1973)

The average size of farms employing one full time man or over in 1967 and 1972 were 944 SMD's and 1042 SMD's respectively. For the same years, farms employing one full time man or over contributed 91.7% and 93.3% respectively of total output, although by number they are little more than half the total of farms. Such farms allow for large changes in the capital/labour mix and ensure a high degree of efficiency. The structure of the industry nevertheless would be improved by the amalgamation of the small farms into bigger units, but the rate at which farmers retire has a large influence on the speed of this movement, and because of this progress towards an improved farm structure can only proceed slowly over time.

Labour

Labour employed in agriculture has been steadily falling as is shown by Table 2.3

TABLE 2.3

Estimated Active Population in Agriculture (000)

Average 1961-63	1968	1969	1970	1971
896	724	697	670	640

(Annual Review of Agriculture, 1973)

From 1961-63 to 1971 the active population employed in agriculture has fallen by over a quarter which is not surprising considering the low level of earnings of agricultural workers as shown by Tables 2.4 and 2.5.

TABLE 2.4

Average Earnings and hours of Agricultural Workers

	1967/68	1970/71
Earnings (£ per week*)	15.54	20.23
Hours per week	48.6	47.7

* Including payment in kind and other extras.

(Annual Review of Agriculture, 1973)

TABLE 2.5

Gross Weekly Earnings of Male Manual Workers (£)

(All Industries)

	Lower decile	Lower quartile	Median	Upper quartile	Highest decile
1968	15.1	18.2	22.4	27.4	33.1
1971	19.2	23	28.1	34.3	41.2

(Annual Abstract of Statistics, 1971)

A comparison of Table 2.4 and Table 2.5 shows that farm workers are among the poorest paid men in the country. This indicates that the movement of labour out of agriculture has still not proceeded to the point where farmers are forced to pay a competitive wage to retain labour. In particular sectors of agriculture there could, however, be lack of labour as this comparison does not take account of different structures of the labour force.

Capital Requirements

TABLE 2.6

Rate of Turnover of Assets in Various Industries

		YEAR
Owner Occupied Dairy Farms (Scotland)	0.33	1970/71
Tenanted " " "	0.94	1970/71
F.M.C.	6.3	1970/71
Unigate	3.5	1971/72
Marks and Spencer	1.5	1969

Aitken, R., thesis in course of preparation on "Capital Investment in Scottish Agriculture", West of Scotland Agricultural College.

Table 2.6 shows the proportion of Assets turned over each year. Dairy farming requires more capital in relation to its turnover than the industries with which it is being compared. Capital is therefore especially important with regard to grazing livestock.

Output

For 1969/70 sales off farms were forecast as being:

Beef and Veal	15.7%
Pork and Bacon	11.3%
Mutton and Lamb	4.1%
Milk and Milk Products	21.7%
Grain	11.1%
Other Farm Crops	7.9%
Eggs	9.4%
Poultry	5.7%
Horticulture	10.7%
Other	2.4%

(Annual Review and Determination of Guarantees, 1970)

For the same year expenses were forecast as being:

Feedingstuffs	29.5%
Labour	18.8%
Machinery	16.0%
Fertilisers	8.5%
Rent and Interest	11.2%
Others	16.0%

(Annual Review and Determination of Guarantees, 1970)

In 1968/69 out of a total home production of grain of about 13 million tons about 11 million tons were used as livestock feed (Annual Review and Determination of Guarantees, 1970). Grain is therefore primarily an intermediate output in the agricultural system, livestock and livestock products being for the greater part, the final output. Of the total expense,feedingstuffs are by far the greatest cost, followed by labour and machinery which are about equal.

Agricultural Policy

UK Agricultural Policy 1947-73

The principles of the Agricultural Acts of 1947 and 1957 has provided the basis of UK Agricultural policy from their formation up to March 1973, when UK Agricultural policy started to adjust, so as to come into alignment with the Common Agricultural Policy (CAP) of the European Economic Community (EEC) in 1978.

Those principles of the 1947 and 1957 Agricultural Acts "recognise that a stable and efficient agriculture must be maintained; that such an industry should be capable of producing such part of the nations food and other agricultural produce as in the National Interest it is desirable to produce in the United Kingdom; and that such production should be at minimum prices consistent with proper remuneration and living conditions for farmers and workers in agriculture and an adequate return on capital invested in the industry." Under the 1957 Agricultural Act safeguards against drastic reduction in agricultural support were introduced. These safeguards were necessary because otherwise the principles of the 1947 and 1957 Agricultural Acts could have been interpreted in too flexible a manner thus undermining the aim of maintaining a stable and efficient industry. Since their introduction the stress laid on the various parts of the principles has indeed varied widely.

During the decade after the war the "National Interest" was seen as producing as much food as possible almost regardless of cost, because of the food shortage then prevailing. As food became more plentiful the emphasis switched to increasing farm productivity and improving farm structure and until the early 1960's many farm prices were cut by small amounts. Because of balance of payments problems, agricultural policy began officially to embrace the concept of selective expansion of domestic farm output in order to displace imports from the early 1960's. From 1964 farm prices were steadily increased.

The mainstay of UK agricultural policy has been the system of deficiency payments, whereby the shortfall between realised average, market price and the announced guaranteed price was paid directly to the farmer from exchequer funds.

In addition to the implementation of price guarantees, a system of production grants provided an extra degree of agricultural support. Those production grants have subsidised the production of various commodities either directly, calf subsidy for instance, or indirectly through subsidising the cost of general input such as fertiliser and lime. Field works such as ploughing or drainage has often been grant assisted. The cost of capital equipment such as buildings have been grant assisted for more than a decade. In addition grants have been given for keeping business records, and to small farmers as an incentive to increase their efficiency. The number and variety of all those subsidies and grants has been constantly changing.

Common Agricultural Policy (CAP)

The Treaty of Rome signed on March 25th, 1957, provided that the Common Market should also include agriculture. The aims of CAP, set out in Article 39 of the Treaty, are as follows:

a) to increase agricultural productivity by developing technical progress, by ensuring the rational development of agricultural policy especially labour;

b) to ensure thereby a fair standard of living for the agricultural populations, particularly the increasing of the individual earnings of persons engaged in agriculture;

c) to stabilize markets;

d) to guarantee regular supplies, and

e) to ensure reasonable prices to consumers.

Article 39 continues:

2. In the working out of the Common Agricultural Policy and the special methods which it may involve, due account should be taken of:

a) the exceptional characters of agricultural activity arising from the social character of agriculture, and natural disparities of the various agricultural regions;

b) the need to make the appropriate adjustments gradually, and

c) the fact that in member states. agriculture constitutes a sector which is closely linked to the economy as a whole.

(Knox, F., 1972)

The policy aims of CAP are in fact similar to those of the UK 1947 and 1957 Agricultural Acts. Both systems aim to stabilize agricultural prices and markets, support farm incomes and improve agricultural productivity. The methods adopted to achieve those aims, however, differ to some extent and under the CAP to the disadvantage of the consumer. Prices in the UK have been kept low by a system of deficiency payments financed through common taxation. In the EEC farmers receive much more of their revenue from prices and therefore directly from the consumer.

Two methods are used to control farm produce prices. The first involves official interventions in domestic markets. If prices fall a certain percentage below the "target price" then the official agency buys up stocks from the market and effectively puts a floor in the market. The second involves the imposition of variable levies on imports. On the basis of the "threshold price", the import levy is determined; it represents the difference between the lowest c.i.f.

import price at the frontier and the threshold price. These levies are designed to keep market prices as close as possible to the "target prices", which are announced each spring and cover most of the main farm products. These "target prices" are fixed on the basis of allowing farmers to cover their costs of production subject to the desire to encourage the efficient farmer rather than all farmers.

Target prices are set for durum wheat, soft wheat, barley, rye, rice, maize, sugar, olive oil, rapeseed, sunflower seed, milk, beef (called guide price). For pigmeat, apples, pears, cauliflowers and tomatoes, no target prices exist but base prices are fixed at a level depending on past market prices. For mutton and lamb there is no common organisation of the market but a degree of protection against imports from non-member countries is given by a common external percentage tariff, supplemented for the time being by quantitative restrictions operated by individual member states.

A system of subsidised credit for agriculture will come into force in June 1973 in the Six and in January 1974 in the UK. The subsidised loans will be up to £17,000 for 15 years for development plans on farms other than poultry or intensive pig farms. A "golden handshake" for farmers leaving agriculture, training schemes for agricultural workers and a scheme to inform rural people about job opportunities and retraining schemes also come into force in the Six at June 1973, and in the UK at January 1974. These schemes, however, already exist to some extent in this country.

Transition of UK Agricultural Policy to CAP

The transition of the UK agricultural policy to that of the CAP will take place between 1973 and 1978. Before the Annual Review of Agriculture in March 1973, intervention prices were already operating for wheat, barley and oilseed rape, and a guide price had been fixed for cattle, but the system of guaranteed prices was also operating for those products. After the Annual Review of Agriculture, 1973 the guaranteed price systems were abolished for cattle and rye and CAP regulations substituted. Calf subsidy was cut by about a quarter and the Farms Capital Grant scheme was cut from 30% to 20% of cost.

Changes during the transition period are unlikely to be dramatic. Capital grants can stay under CAP rules but must be limited to 30% of cost. Fertiliser subsidies will be phased out. It has been negotiated that hill subsidies may remain, and because CAP is in a constant state of transition the **eventual** outcome may be little different from the present UK system of subsidies. Even the deficiency payments system now in the process of being abolished in the UK may be revived. "In the EEC there is a growing belief that the Community must move towards the British deficiency payments system". (Peart, T.F., January 1973).

Projections made by Aberdeen University (Scottish Agriculture and the EEC, 1972) as to incomes in 1977/78 compared with incomes in 1971/72 indicate that if farmers are to have higher incomes under CAP than under the previous UK agricultural policy, then it has to come from improved standards of farming. The future picture appears fairly similar to what it has been in the past. The farmer will have to improve his efficiency in order to absorb much of the cost increases as before. It should, however, be remembered that most projections for agriculture as far into the future as this one, are proved wrong by events long before that time to which the projection reaches has been arrived at by the march of time.

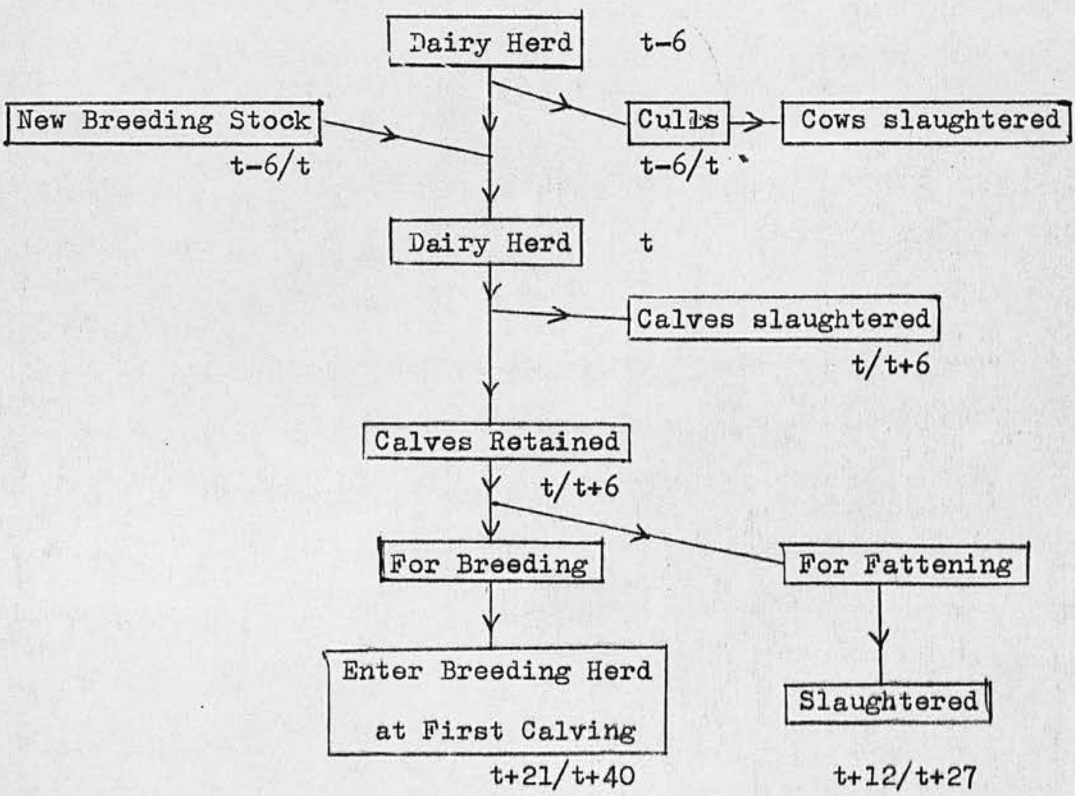
CHAPTER III

A REVIEW OF MODELS OF U.K. GRAZING LIVESTOCK

The Grazing Livestock System

A general description of agriculture in the U.K. has been given in the previous chapter. In order to fully understand what models of the grazing livestock sector seek to represent, it is necessary to describe in fuller detail what the grazing livestock sector is, and how it functions.

As described here grazing livestock in the U.K. consists of beef cattle, dairy cattle and sheep. The inventory flow that occurs for the dairy herd (excluding imports and exports) from time t in months is



In the case of the beef cow herd and the ewe flock all progeny are fattened or retained for breeding, otherwise the inventory flows are essentially the same as for the dairy herd, except that the time lags involved are of different lengths.

Some farms may specialise entirely in one type of livestock, but as shown by Table 2.1 it is usual for a farm to have more than one kind of grazing livestock. To some extent different livestock types may be complementary, for instance cattle may improve the pasture for sheep, however, beyond a limited expansion an increase in cattle numbers reduces the resources available for sheep production and thereby forces a reduction in their number. With the exception of fattening livestock being dependent upon breeding stock number, grazing livestock types are competitive for the scarce resource of grazing and fodder.

Several distinctions can be drawn between sheep farming and beef or dairy farming as regards the use of resources. While cows generally have to be housed, ewes do not. This causes a certain rigidity in the system of farming, as it is difficult to change over from keeping ewes to keeping dairy cows, or beef cows, because of the tremendous amount of capital involved, while it is relatively easy to change over from keeping cows to the keeping of ewes. The most important resource of all is the availability of new breeding stock. These have to be reared, and because of this, differences in production lags between decision making and changes in the production level exists for ewes, dairy cows and beef cows. For the ewe flock new breeding stock takes about 18 months to rear, but for the dairy herd and the beef cow herd the replacement stock on average takes about 30 and 24 months respectively to rear.

Because of the need to invest more capital in order to increase production, the level of production can be expected to be related to revenues and costs. Generally an improvement in production tends also to result with the passage of time due to improved production and managerial methods. Weather is also an influential factor because of its influence on grass growth, crop growth and mortality rates among livestock.

Because of the lags involved in production, current supply is largely predetermined, and dependent upon decisions previously made.

Different Types of Models [1]

To formulate a model of the grazing livestock sector, it is first necessary to set up a theoretical model of the system. At this stage a hypothesis is made as to the stimuli that supply will respond to. The second stage is the estimation of the supply response from empirical data by using mathematical or statistical methods, and a necessary third stage is the testing of the model to find out if it can fulfil its intended function.

A division is sometimes made with regard to economic models depending on whether they are normative, positive, stochastic or not. A positive model is descriptive in so much as the term positive describes a philosophy or model dealing only with matters of fact; while a normative model is based on the achievement of a norm or the acceptance of a particular standard, such as the maximization of profit. The difference between stochastic and non-stochastic models is that a stochastic model introduces a random variable into the model so that probability statements can be made about the parameters, while non-stochastic models do not contain a random variable and are completely deterministic. Linear programming models (see for instance Baumol, W.J., 1965) are generally taken as being non-stochastic, but are often based on production functions which are stochastic; econometric models (see for instance Johnston, J., 1960) are stochastic and generally taken to be positive, but to make use of the estimated parameters a desired objective such as profit maximization must be introduced. The general description of the types is therefore not fully correct.

There are two methods of approach that are generally used for working out supply responses. These involve cross sectional and

1. This survey draws extensively from Cowling, K. and Gardner, T.W., 1963, Journal of Agricultural Economics, Vol. 15, No.3.

time series analysis. The former method can be carried out by obtaining from a technical production function a supply function by imposing prices and costs in addition to assumptions about producers behavioural relation. These technical production functions can be obtained from experimental, or in come cases survey methods. Alternatively the parameters of technical production functions may be estimated by regression analysis using cross section data (Antill, A.G., 1955, pp.1-11), or supply relations may be estimated directly provided spatial variations in the price of the product is used in the analysis. Parry and Herr (Parry, S.P. and Herr, W.M., August, 1954, pp.519-522) used the hypothesis that within a homogeneous region around a city, concentric areas where price varied by a transport differential would provide different points on a marginal cost curve for a whole region. Hildebrand (Hildebrand, J.R., November, 1960, pp.897-905) has, however, shown that quite conflicting results may be obtained from one year to the next. This is hardly surprising, as efficiency can be expected to be constantly improving with time.

The methods of cross sectional analysis discussed have the advantage that generally many more statistical observations can be obtained than is the case for time series. The methods are, however, very much more expensive than time series analysis, as they require surveys or experiments to obtain the necessary data. Another consideration is that as the levels of many of the subsidies are the same to all farmers in a region, cross sectional analysis offers the possibility that the influence of price and cost on supply can be considered with the subsidy content of revenue being held constant. This has statistical advantages, as the influence of subsidy on supply can then be estimated from time series data with the influence of price eliminated, by restricting the value of its parameter to its cross sectional estimate. In addition to the cost element, another disadvantage is the aggregation problem. Because of the interrelation among farms, as the output of one farm may be the input of another, demand functions for output and supply functions for input have to be incorporated into the model.

An alternative cross sectional approach is that of linear programming. This method involves the maximization (or minimization) of some objective such as profits (or costs) subject to a number of limiting factors or constraints. This method has been much used in this country for farm planning purposes, as it can determine how to maximize farm gross margins subject to the resources available. If required the method can be used for planning more than one year in advance by taking into account restraints, such as certain classes of livestock generated by the model in the immediate past. The tremendous advantage is that all sources of revenue, cost and possible alternative production can be easily taken into consideration. This method suffers from problems of aggregation bias (Buckwell, A.E. and Hazell, P.B.R., 1972) as indeed do other methods of cross sectional analysis.

Most supply analysis has been based on time series models using regression techniques. The development of such analysis has been prolonged, due perhaps to the lack of computer facilities in the early years. Keith Cowling and T.W. Gardner (Cowling, K. and Gardner, T.W., 1963, pp.442-443) trace briefly the history of the development of the analysis of time series data for agricultural supply responses. As long ago as 1933 Murray (Murray, K.A.H., Sept. 1933) was using a lagged deflated price in studying pig supply, and so allowed for production time lags and the influence of cost. In 1955 Johnson (Johnson, R.W.M., May 1955) showed that part of supply was likely to be determined by external factors such as weather. He also used first differences of variables, a device which is mentioned in the next section. It can, subject to certain conditions, help to ensure that the error term in the equation is theoretically correct, i.e. independent.

Those early works were single equation models with a single time lag for price, which assumes that supply is independent of demand. Where this is not so both supply and demand are endogenous (i.e. determined within the system), therefore a two equation model is required. This system is known as a simultaneous equation system. In 1947 Girschick and Haavelmo (Girschick, M.A. and Haavelmo, T., 1953, pp.92-111) applied such a system in determining the structural parameters of a system which included a demand and supply equation for food. As agricultural supply cannot be readily adjusted in the short term, agricultural supply models are still generally of the single equation type.

An important development was the distributed lag model. This type of model assumes that because of factors such as adaptive expectations of price changes and the nature of production techniques, production adjustments are likely to take place over several periods. Nerlove's model (Nerlove, M. 1955) is the best known one in this field.

The Choice of Model

The perfect model does not exist and insufficient work has been done on model building to have proved one form of model building superior to other forms. Research should continue on all model types, both cross sectional and time series models, and also combinations of both. Here because of constraints of cost and time availability only one choice is available, that of time series. The rest of this chapter will therefore be devoted to a review of such models.

Problems in Estimating Statistical Models

Statistical or econometric models are generally linear in parameters because other forms are usually difficult to estimate. This causes some difficulties in the estimation of supply responses, as it is unlikely that supply would respond by a fixed amount for every equal increase or decrease in profitability. Indeed economic investigations have shown that eventually less and less output is produced from every extra input. One method of allowing for "diminishing returns" is to transform the variables in the model to some other form. Various LOG. and reciprocal transformations are given by Johnston (Johnston, J., 1963, pp.44-50). By using these, or a combination of these, it is possible to build the correct shape of theoretical response into the model.

A difficulty that can often occur in econometric estimation of coefficients is when an explanatory variable can be explained as a linear function of the other variables in the equation. This is known as multicollinearity. What happens is that the estimates of the coefficients often have a large degree of error. This may be shown up by the standard errors being very large, standard errors being the measure of the area around the estimated coefficients into which the true coefficient will fall with a given probability. Frisch (Frisch, R., 1933) shows that this is not always the case. A method of checking for multicollinearity is to regress each explanatory variable in turn against the other explanatory variables in the equation to see if a linear relation does exist. If established, multicollinearity can be overcome by setting restrictions on parameters, for instance setting two parameters equal, or in other cases the difficulty can be overcome by inserting cross sectional results into equations using time series variables. For instance in a demand model the income elasticity of demand may be obtained from cross sectional analysis, and by restricting the income elasticity in the time series analysis to its cross sectional analysis estimate, the price elasticity of demand may be estimated without the possibility of multicollinearity between price and income variables. In many cases the problem may not be solved but instead variables may be omitted in order to achieve statistically significant results on the remaing variables. In such cases the omissions have to be borne in mind when interpreting the results, as it cannot be said that the omitted variables had no effect.

The properties of the estimators depend on the theoretical error term in the equation being independent. If this is not so then the error term is said to be autocorrelated or serially correlated. This is likely to happen with time series data. In such a case the least squares procedure still gives unbiased estimates (unless the vector of exogenous variables contains a lagged endogenous variable, in which case it results in bias as well as inefficiency), but these estimates are not necessarily fully efficient and the standard error formulae and significant tests do not apply (Johnston, J., 1960). A test for autocorrelation is the Durbin-Watson test (Durbin, J. and Watson, G.S., 1950-51). Autocorrelated errors may indicate that the model has not been formulated correctly. This may be due to an important variable being excluded, the error specification being incorrect or the necessity of transforming data (Cochrane, D. and Orcutt, G.H., 1949, pp.749-809)(Hildreth, G. and Lee, J.Y., Nov. 1960).

A severe limitation to model building is that set by the amount and quality of the statistical date that is available. Models have to be so formulated that they can be estimated and tested from statistical data that is obtainable. For methods of estimation see for instance (Johnston, J., 1963).

Recent Models

The Theoretical Models Used

The publication of "The Dynamics of Supply" by Marc Nerlove (Nerlove, M., 1958) marks a watershed in the development of econometric models of agriculture. Although not applied to United Kingdom agriculture by Nerlove, all major works by authors that have sought to construct econometric models of the grazing livestock sector of U.K. agriculture have adopted the Nerlove Model. This is hardly surprising in view of the apparent elegance of Nerlove's model, but rather surprising in view of the number of pitfalls to the use of the model.

Like Cagan (Cagan, P., 1956), Nerlove assumed that people have adaptive expectations. Briefly Nerlove's model assumes that people would on the past movement of a variable X, form an expectation X* as to the future value of X, in accordance with the relationship

$$X_t^* - X_{t-1}^* = \beta (X_t - X_{t-1}^*) \quad : \quad 0 < \beta \leq 1 \qquad (3.12)$$

Peoples expectations are therefore assumed to adjust according to the discrepancy emerging between the current value and the previous expectation. Equation (3.12) is equivalent to

$$X_t^* = \sum_{\lambda=0}^{\infty} \beta (1-\beta)^{\lambda} X_{t-\lambda} \qquad (3.13)$$

People are expected to adjust the desired level of Y (Y^*) in accordance with the relation

$$Y_t^* = bX_t^* \qquad (3.14)$$

Some lags may also exist in the adjustment of Y to Y^*, for instance because of technical and institutional rigidities, as Nerlove suggests. This can be written

$$Y_t - Y_{t-1} = \delta (Y_t^* - Y_{t-1}) \quad : \quad 0 < \lambda \leq 1 \qquad (3.15)$$

or

$$Y_t = \sum_{\lambda=0}^{\infty} \delta (1-\delta)^{\lambda} Y_{t-\lambda}^* \qquad (3.16)$$

Equations (3.13) and (3.16) are similar. In equation (3.13) the expected value of X is an exponentially weighted average of all previous actual X values. In equation (3.16) the actual value of Y is an exponentially weighted average of all previous desired values of Y. A possible reduction of equations (3.13) and (3.16) is

$$Y_t = \delta Y_t^* + (1-\delta)Y_{t-1} \qquad \text{from (3.15)}$$

$$= b\delta X_t^* + (1-\delta)Y_{t-1} \qquad \text{substituting (3.14)}$$

$$= b\delta[\beta X_t + (1-\beta)X_{t-1}^*] + (1-\delta)Y_{t-1} \text{substituting (3.12)} \qquad (3.17)$$

Substituting for X_{t-1}^* from the second equation above gives

$$Y_t = b\beta\delta X_t + [(1-\beta) + (1-\delta)] Y_{t-1} - (1-\beta)(1-\delta)Y_{t-2} \qquad (3.18)$$

As β and δ enter equation (3.18) symmetrically, it is not possible to obtain separate estimates of their values from the regression coefficients. It is, however, possible to obtain estimates for b, $\beta\delta$, and $\beta + \delta$. If the expected value of X, X^* is equal fo X, then β equals 1 and equation (3.18) becomes

$$Y_t = b\delta X_t + (1-\delta)Y_{t-1} \qquad (3.19)$$

If there is no partial adjustment process, then δ equals 1 and equation (3.18) becomes

$$Y_t = b\beta X_t + (1-\beta)Y_{t-1} \qquad (3.20)$$

Equations (3.19) and (3.20) are of the same form and it is interesting to note that these are in turn identical to a model formulated by Koyck (Koyck, L.M., 1954), but through different reasoning.

Much has been proved about the least squares estimates of the coefficients of autoregressive systems (equations with lagged values of the dependent variable in the right hand side). If the error term is independently distributed then the least squares estimates will not be biased asymptotically (Hurwicz, L., 1950), but for small samples the least squares estimates may be seriously biased. Hurwicz has demonstrated the existence of this bias. Johnston (Johnston, J., 1960, pp.214-215) gave a proof that is mathematically simpler, but demonstrates only the sign of the bias and not its magnitude. The bias is negative for the coefficient of Y_{t-1}, for true values of the coefficient that are greater than zero. Malinvaud (Malinvaud, E., 1970, pp.551-552) examined the scheme,

$$x_t = bx_{t-1} + az_t + c + \epsilon_t \qquad (3.21)$$

using the 'Monte-Carlo Method'. This involves running experiments many times in order to find out how estimators behave. Artificial samples each of twenty observations were used. The results indicated an average bias for the estimate of b of -0.08, the actual value of b being 0.60.

If the residuals are not independent but are autocorrelated the situation is made much worse. Orcutt and Cochrane (Orcutt, G.H. and Cochrane, D., 1949, pp.356-372) examined the scheme

$$Y_t = 0.4Y_{t-1} + u_t \qquad (3.22)$$

where the u_t were positively autocorrelated. The Monte-Carlo Method was used. The mean of 20 sample determinations put the coefficient of Y_{t-1} at 0.90, a value more than twice the true value. Fortunately if an exogenous variable is present, it improves the situation (Malinvaud, E., 1970, pp.558-561). Malinvaud shows, however, that the asymptotic bias will remain significant in most cases. For positive (negative) autocorrelation of the residual, the estimates of the coefficient of the lagged dependent variable will be positively (negatively) biased, even asymptotically.

An extension of the case of autocorrelation in the residual is when the distributed lag model is the incorrect model but is applied in the presence of serial correlation in the disturbance. Griliches (Griliches, Z., 1961) found that as long as there was positive autocorrelation in the residual, and that the exogenous variable explained only a small fraction of the variation in the independent variable that positive and often statistically significant coefficients for the lagged dependent variable are likely to be estimated. The autoregressive model may therefore work but for the wrong reasons.

Mundlak (Mundlak, Y., 1966) showed that bias can also result from aggregation (e.g. quarterly to annual data). This aggregation will induce a positive dependence between the aggregated true disturbances and the lagged values of the aggregate dependent variable and cause an overestimation of the implied average lags.

It is not the case that the Durbin-Watson test (Durbin, J. and Watson, G.S., 1950-51) can be used for testing for autocorrelation of the errors of autoregressive models, because the test in such cases is biased. The source "of the upward bias in the coefficients of lagged dependent variables will lead to a downward bias in the serial correlation of the estimated residual" (Griliches, Z., 1967).

A danger in the use of the Nerlove model would appear to be over-enthusiasm in its use. It is a simple matter to obtain a significant coefficient on a lagged dependent variable. Unfortunately this can come about through misspecification. For instance the omission of an autocorrelated exogenous variable from the model would cause autocorrelation in the residual and a probably significant coefficient on the lagged dependent variable. In seeking to justify the use of this model, underspecification is a real possibility. Also the same equational form can arise from different assumptions, so that the reason for an autoregressive model working may not be because Nerlove 's model is correct, but because other assumptions which gives the same equational form is correct. In addition, different assumptions can give rise to the same model. An example of this is equation (3.19) and (3.20) which are special cases of Nerlove's model. The one is based on adaptative expectations, while the other is a partial adjustment model.

It may be added that methods exist for attempting to overcome the problems of autocorrelation in autoregressive models. A method similar to the treatment of autocorrelation in simple regressive models can be used. Considerable asymptotic bias may however remain if the nature of the errors is incorrectly specified, and the estimates of the correlation of the errors in small samples appear much less favourable than their asymptotic properties (Malinvaud, E., 1970, pp.563-566). Another method is to use certain of the lagged exogenous variables as instrumental variables. The loss of precision in this method tends to make estimation from the autoregressive form preferable for small samples (Malinvaud, E., 1970, p.568). Malinvaud states that for small samples "direct least squares fitting certainly gives the best estimates of the coefficients" (Malinvaud, E., 1970, p.569).

It is useful to look at the autoregressive form in the light of what can be deduced from statistical data on the lagged form of the farmer's response to revenue and costs. Firstly the farmer's demand for credit can be expected to be influenced by his expectations. Secondly, it is from sources such as bank loans, merchant credit, private loans and hire purchase that marginal expenditure comes. Scottish farmers' net worth for March 1972 has been estimated as being 88% of total assets (Scottish Agriculture and the E.E.C. December 1972, p.16). Excluding land and buildings, money borrowed to assets comes to 31%. As supply of credit is going to be determined by credit worthiness, it is probable that at ruling levels of interest rates demand has been higher than supply. From the above argument the hypothesis can be made that expansion is governed by present income and not on expectations.

If the factors causing lags in adjustment are considered, the most obvious is the number of replacement stock available. The dairy farmer replaces on average about 25 percent of his herd per year, and the average age at first calving is about 30 months for dairy heifers. For a stationary number of cows (period 1966-68 relatively stable) the farmer if he were to specially rear his breeding stock would therefore have replacements being reared numbering about 62.5 percent of his herd. For England and Wales for 1966/7 farmers had replacements being reared numbering 65% of herd size. (Survey of Cattle Management and Feeding Practices in England and Wales 1966-67, 1971), excluding calves under 3 months. For beef cows the figures were 46 percent and 50 percent, respectively. As most of the replacement stock is specially reared, it follows that production must lag behind the farmer's decision by an amount equal to the age of heifers at first calving. One possible form of distributed lag for cattle breeding herds is therefore based on the age distribution at which heifers first calf. Decision time could add to the mean lag of the distribution, but it would not change its shape. The necessary extensions to farm buildings and changes to the farm in general for an expansion could also be accomplished within the time limits of the lag mentioned. (The beef herd has an average age at first calving of two years and the dairy herd an average age of two and a half years). This lag is a technical lag in which it is assumed that adjustment of production is complete after a time span determined by the system of production. This is in contrast to a gradual or partial adjustment in which production incentives influence production decisions in several periods. This possibility was tested by the formulation and testing of autoregressive equations representing gradual adjustment, but no supporting statistical evidence was found.

The distribution of age at first calving for dairy heifers for England and Wales in 1966-67 is

	Percent
Less than 24 months	8
24-27 months	30
27-30	26
30-33	20
33-36	12
36+	4

(Survey of Cattle Management and Feeding Practices in England and Wales 1966-67, 1971)

This is not an autoregressive lag structure. Furthermore 88 percent of the heifer inflow takes place within a time span of 12 months, therefore if this lag structure is appropriate more frequent observation than annual is necessary in order to adequately represent the lag. Similar statements can be made for the beef herd and for the ewe flock. It should be noted, however, that unlike the cattle breeding herds, shortage of new breeding stock can act as a constraint on the level of numbers of breeding ewes. In a bad year hill farmers may be hard pressed to find enough replacements to maintain ewe numbers. For a representative model it is therefore necessary to incorporate a constraint based either on ewe lamb numbers, or the ewe flock itself suitably lagged. This is not to advocate an autoregressive system, though it is conceivable that such a system might act as a very crude constraint. Its weakness would be that its use would be assuming a constraint at all levels of expansion, which is not true.

A brief review of the factors causing lags in the farmers response indicates, therefore, that his lagged response would be a function of the age at which new breeding stock joins the existing breeding stock. This is in conflict with the use of the Nerlove Model with regard to grazing livestock.

(Jones, G.T., 1958-61)

The first major work is that carried out by Jones. Most of his work uses the simple form of Nerlove's Model, namely

$$X = d + ep_{t-1} + fX_{t-1}$$

This gives theoretically both the short run and the long run effect of response to price p. The short run response is given by e and the long run response as $e \div (1-f)$.

Jones does not systematically model the grazing livestock system through the various stages of production from numbers of breeding livestock up to numbers of livestock slaughtered. Instead he used the total number of calves reared to represent the production of beef, and the number of breeding ewes to represent the production of mutton and wool. The numbers of cows are used to represent milk production. At the time of Mr. Jones' work no division existed between the beef cow herd and the dairy cow herd in the statistic data then available, so that a number of the cows used to represent milk production did not in fact produce milk for human consumption.

Mr. Jones' main aim was to estimate the direct price elasticity of supply, but he took into consideration cross elasticities of supply when they seemed to him to be important. There were three methods by which he attempted to allow for cross elasticities:

1. Including the price of some competitive produce or the cost

of some input in his equation.

2. Deflating the price of the main product by the price of some alternative product or by the price of an important input.

3. Grouping commodities into larger and larger units. If the elasticity of supply for the larger groups was less than that of their component parts, this was taken as indicating competition within the group.

The first approach, entering feed price, was carried out with equations concerning cattle. This, while it allows for competition between livestock and arable cropping does not allow for competition between cows and sheep, and as already pointed out the two can be expected to be in competition. Including the price of some competitive products (other than an input) in the equation is not adequate as there are usually more sources of revenue than price available to the farmer. The second approach is basically the same approach as the first. It differs in that it conserves degrees of freedom. It may also be added that Mr. Jones sometimes deflated the price of a product by the price of an alternative product, or by the price of farm produce in general, which carried to its logical conclusion does not allow for a general upward expansion. Mr. Jones recognised this limitation. In other cases prices were deflated by a general index of retail prices. The relevance of the general index of retail prices to agricultural production is obscure, as economic theory connects agricultural production with revenues and costs of agricultural production and not with general price levels.[1] The third approach does not readily make sense. Mr. Jones admitted that none of the three approaches worked satisfactorily.

Most of the relationship calculated were simple linear functions of the explanatory variables, transformations of the explanatory vari-

1. This procedure yields a function homogenous of degree zero.

ables not having been made. This is not very substantial in theoretical terms as diminishing returns to inputs operate in agriculture, but the zeal with which all the variables have been deflated may have provided a substitute for such a transformation.[1]

Some attempt to allow for improvements to the farmer's return to inputs over time were included in some equations.

The rationale behind the lag structure of response is very clearly wrong. An initial lag of six months was used in the livestock models. On technical grounds this response rate is impossible. A heifer is in calf for nine months before it joins the cow herd and in addition the heifer has to be reared which adds at least another fifteen months to the lag. For a herd expansion this lag would in any case be required for erecting more buildings and making other changes. Mr. Jones discovered that the effect of milk prices on cow numbers could be made to assume a greater importance by adding in the milk price three years previously, though it did not help greatly to explain the data. With the other lags in the model wrong, this is hardly surprising.

With no R^2 coefficients having been given it is difficult to judge Mr. Jones work on statistical grounds. The coefficient signs, however, are theoretically correct for a normal response to revenues and costs, but by no means all of the coefficients are statistically significant even at the 90% level. Judging by the degree of specification of the equations in terms of revenues included they are fairly satisfactory. The omission of subsidies from the equation for cow numbers is fairly serious, however, but the other equations appear to include most of the revenue variables existing when the model was formulated. Many more sources of revenue have since entered the scene.

This work of Mr. Jones was a fairly early model in the field of supply response in agriculture. The problems in constructing it were

1. In empirical terms a linear function may yield as good a fit as a non-linear function, although it may not yield such good forecasts.

increased by the time series involved 1924-39 + 1946-58, which were periods of uneven technical progress, and the poorer quality of statistical data then available. He nevertheless laid a foundation on which many people since then have built.

(Jones, G.T., 1965)

Jones published a later model in 1965 with the equations being estimated from statistical data from the period 1955-64. This period is much more normal than the period over which his previous work was estimated, due to the country being at peace and because steady improvements in efficiency were taking place.

Again the model is not a complete model in that it does not include many of the production stages involved in producing livestock for slaughter. For cattle and sheep equations are given for the influence of price on proportions of calves reared, the inflow disappearance and slaughter of cows, the numbers of cows, the number of breeding ewes and the inflow and outflow of sheep from the breeding flock.

Nerlove's theoretical model is used both in the form containing two lagged dependent variables and in the form containing one lagged dependent variable. In this model, as semi annual data is used instead of the annual data used in the previous model, seasonal variations in production had to be represented by a seasonal dummy variable.

The general form of the variables entered in the equations are simple. For the equations explaining the influence of price on the proportions of calves reared, beef prices for both the guaranteed price level and the free market price level are used, and also milk price and feed price. An equivalent value to the calf subsidy and hill cow subsidy are also included in the guaranteed beef price.

Deflators are not used in any of the equations for any product. Out of eleven equations, that attempt to explain the proportion of calves reared by different assumptions, only one is statistically significant at the 95 percent probability level. In this equation the proportion of calves reared is taken as being the number of yearlings, and a single time lag of the dependent variable is used. All the signs on the coefficients are acceptable, positive signs appearing on revenues and negative signs on costs. No R^2 coefficients are given for any of the equations.

The inflow and disappearance and slaughter of cows has not been satisfactorily explained, because most of the standard error terms are much larger than the estimated coefficients. The explanatory variables used are those of prices of inputs and outputs, which theoretically are hardly sufficient as a large part of the influence is from factors causing disease such as old age. The total number of cows has also not been satisfactorily explained. This is possible due to the equations being under specified, no allowance having been made for competitive relationships, or indeed for general grants and subsidies as a revenue variable.

With regard to breeding ewes, Mr. Jones has one equation that is largely statistically significant. This equation explains the numbers of ewes at June in terms of a single index for lambs, hoggets, and wool, a trend term (not significant) and a lagged explanatory variable. In explaining the inflow and outflow of sheep into and out of the breeding flock Mr. Jones is perhaps more successful than with his other equations. He explains the (percentage inflow of lambs for breeding (Dec.))/(Ewes at June) in terms of the total price index for sheep, lambs, hoggets and wool; the market price index for sheep, lambs and hoggets; the ewe population (June); and the market price of hoggets. The percentage slaughter of ewes is explained in terms of the total price index and the ewe population at June. The responses estimated are normal in form as in Mr. Jones' earlier work, but he again has a tendency not to give the farmer time to respond by altering the numbers of new breeding stock. In his equations for cows the prices of the last 6 months or for the last year is entered, which is an impossible response time, as indeed are those for the inflow, disappearance and slaughter of cows and for the inflow of sheep into the breeding herd. There is also the possibility that as a trend term has been incorporated into most equations, it would have been theoretically better to have assumed diminishing returns (trend excluded) than a simple linear relationship between prices and output.

The extent of the achievement of Mr. Jones' work is that he has proved that statistical supply curves can be estimated in some cases. He has, however, given insufficient thought to the technical side of production and has not systematically dealt with the problem of allowing for competitive products. Also to some extent the question arises as to whether he has sufficiently allowed for the different sources of revenues and costs. General grants and subsidies, or fertiliser cost have not been included, for instance.

(Evans, E., 1971)

The work by Evans is based to a large extent on the work carried out by Jones (Jones, G.T., 1955-61) (Jones, G.T., 1965). There are three models. The first two models are termed the MM (mainly milk) and BOM (beef and milk) models. The third model is termed the MM/F (mainly milk depending on feed price) model.

The MM and MM/F models contain equations for the following:-

a) The numbers at December of
   - Male calves
   - Female calves
   - Heifers in first calf
   - Cows

b) The number of
   - Home fed steers and heifers
   - Cows and bulls
   - Calves

   slaughtered during the year ending in December.

c) The annual production of
   - Clean beef
   - Cow beef
   - Veal
   - Milk

d) The average level during the year of
   - Market prices for fat cattle
   - Producer returns for milk.

The BOM model differs from the other two in that it distinguishes between the numbers of home fed steers slaughtered and the numbers of home fed heifers slaughtered. A distinction is also drawn between the numbers of beef cows and the number of dairy cows.

In the MM model the number of exogenous variables has been kept to a minimum. They consist of the guaranteed prices for milk and for fat cattle, the index of gross prices received for all farm products, and a time trend factor. Although the model is a mainly milk model, the herd that it is dealing with contains beef cows as well as dairy cows, so that beef subsidies should not have been ignored. An attempt to remedy this was made in model BOM, with calf rearing subsidy, hill cow subsidy and beef cow subsidy being introduced. It would appear that the statistical difficulties of estimating the effect of subsidies on production was kept unnecessarily high by trying to estimate separate coefficients for each subsidy. Some system of constraints on the coefficients could have been adopted in several cases, and so made some of the results more plausible. For instance while calf rearing subsidy and hill cow subsidy is shown to influence cow numbers, cow subsidy is not, and that is not at all logical.

A difference between the MM/F model and the other two is that in the latter variables have been deflated by an index of gross prices received for all farm products, while in the former the price of compound cattle feed has been used. The rational behind this is not clear. While the price of an input can be related to a theoretical supply curve an agricultural all products index cannot in any logical sense. Subsidies are often deflated by an index of retail prices which again does not equate with production economies.

Many of the variables are expressed in LOG. transformation form. This gives a theoretical supply response that allows for diminishing returns occuring. Not all the coefficients are very plausible. Models MM and BOM for instance indicate that an increase in the guaranteed price of beef would lead to a reduction in the proportion of heifers put into calf, however model MM/F gives a more plausible result by showing that the proportion of heifers in calf increases as the guaranteed price of beef in the previous period increases, but decreases as the ratio of guaranteed price of beef to producer returns for milk increases. Having shown that numbers of heifers in calf are related to the guaranteed price of beef it is then shown that the net increase in cow herd size increases, not according to beef price, but according to the guaranteed price of milk, but with a few subsidies included in the case of model BOM. This makes doubtful sense as heifers in calf influence herd size.

It is to be wondered if the detailed breakdown of the aggregate producer response into sub-responses in this work, while an admirable thing to do, has not increased certain difficulties. The inflow of heifers into the cow herd is partly to replace the number of cows culled and partly to vary the herd size. This outflow will in turn depend on factors such as disease, which can be expected to be governed to a large extent by the age distribution of the cows. No allowance was in fact made for this factor of outflow either through age variation or by other means. The number of heifers in calf being merely expressed as a ratio of the number of female calves lagged one year. In a whole herd model it would be possible to assume that the farmer knew the likely numbers of cows to be culled well in advance from their age distribution, and that he varied the heifer inflow so as to maintain the desired herd size. No problem concerning the outflow of cows would therefore arise. In model MM/F an attempt was in fact made to estimate the size of breeding herd directly. The breeding herd was assumed to depend on milk price deflated by feed price. which is not convincing as there are equally relevant factors such as general grants and subsidies.

Some difficulty over suitable statistical material exists. The number of heifers in calf at December is assumed to be in constant proportion to the number of heifers that will calf during the year commencing December. This is unlikely to be strictly true (the gestation period for cattle is nine months). Outflow of cows from the herd is assumed to equal cows slaughtered, plus cows exported: there is also a fairly substantial mortality which has not been taken account of. In using statistical data on cattle numbers at December use has not been made of the best statistics on cattle numbers that are available. Statistics on cattle numbers in England and Wales at December are based on a sample enquiry from farmers and contain sampling errors, while statistics for June are based on a census. This is discussed at greater length in Chapter V.

Some equations are given for price. These are very straightforward relationships between price and quantity with national disposable income, or time, occasionally making its appearance.

While a great deal has been achieved in this work as regards the breaking down of the aggregate response into sub-responses much has still to be achieved before the model can be expected to be able to forecast under rapidly changing agricultural policy conditions. In particular competitive relationships between cattle and sheep should be included, and also a more comprehensive inclusion of revenue variables. Consider what would happen with an abolition of calf subsidy and cow subsidy, but the retention of hill cow subsidy and winter keep subsidy. Only two of these at the most have been entered into an equation, but they all can be expected to influence the breeding livestock farmer, with regard to his numbers of breeding stock, in the proportion to which he receives each. The answer is that the model would cease to forecast in any way accurately. The same applies with regard to a dramatic increase in the competitiveness of sheep production for resources.

(McFarquhar, A.M.M. and Evans, M.C., 1971)

The section on livestock models in this work is an expansion on the work just discussed (Evans, M.C., 1971) to include sheep. No interrelation between sheep production and cattle production is however assumed.

Six equations or identities are given to explain sheep production. These are for breeding flock, sheep and lamb slaughter, ewe and ram slaughter, lamb production, mutton production and total mutton and lamb production. Again a Nerlove type model is used for breeding stock. The variables are deflated by an agricultural all products index. Only the variables guaranteed price for fat sheep and guaranteed price for wool appear in the equation for breeding flock. This is most unsatisfactory, as hill sheep subsidy, winter keep sheep subsidy and general improvement grants are also important revenue variables.

Apart from under-specification (omitting important variables in the equation for the breeding flock) the sheep model seems admirable. Factors such as the guaranteed price of wool and weather influences are entered into the equation for sheep and lamb slaughter. Price as a variable is omitted but it is possible to deduce that price is a function of numbers of lambs slaughtered which in turn is a function of the size of breeding flock lagged one period, and this latter variable is in fact entered in the equation. In general a degree of under-specification at this stage is less important than for the equation for breeding flock.

(Ferris, J., 1971, pp.25-97).

This work does not model the production of livestock included in the grazing livestock sector of U.K. agriculture in any great detail. Equations are, however, given for dairy cow numbers, milk production per cow, numbers of beef cows, dairy calves reared as a percent of those surviving birth and numbers of ewes for breeding purposes. Several other equations outwith the grazing livestock sector were also estimated.

A Nerlove type model was used with one lagged dependent variable. An interesting feature of this model is that gross margin variables were used rather than individual revenue and cost variables. This was because prices had been relatively stable over the period of the time analysis concerned. The gross margin approach has the advantage of being consistent with farm planning methods, of conserving degrees of freedom in a regression analysis and of reducing the possibility of multi-collinearity.[1] Improving technology can also be incorporated into the gross margins. It has to be noted though that livestock prices have a different influence from other revenue sources. Because of this it was found necessary to enter the price of cull cows as a separate variable. No logarithmic transformed data were used.

The equation for the ewe flock has a negative coefficient on the gross margin for sheep. This is not a plausible result, but it is hardly a surprising result because beef and dairy cows have been pushing ewes off the low ground for quite some time, and the omission of such competitive relationships from the equation could possibly lead to the wrong estimates of coefficients on included variables.

Supplementary to the historical time-series analysis was a Linear Programming analysis. This was carried out because the authors did not feel that historical time series analysis was an adequate approach for predicting output of U.K. agriculture with the adoption of the

1. The Gross Margin approach imposes restrictions on parameters in that all revenues and all variable costs are assumed to have an influence on production related to their proportion of the Gross Margin.

common agricultural policy of the E.E.C. This is because entry into the E.E.C. is likely to lead to quite substantial price increases for many products and so result in farm prices well in excess of previous experience. In addition there are likely to be large changes in relative profitability both between enterprises and between alternative production systems within enterprises. The Linear Programming approach, however, on this occasion yielded results that were very poor. For instance 1712 thousand dairy cows were forecast for the year 1968, the actual number reached was 3025 thousand. Work is however still continuing on this approach.

Conclusion

Particular emphasis has been put on the need for very full specification of models (including all the influential variables on production in the models). This is because while in the past the exclusion of some variables from the model did not very much matter as long as those variables were highly correlated with variables included, this correlation is not likely to continue in the future. With the adoption of CAP "traditional" relationships between explanatory variables can expect to be discontinued. Because of the substantial changes in the relative profitability of alternative production possibilities expected under CAP an adequate representation of production possibilities is also necessary for forecasting models of livestock production. Because of the possibility of prices rising substantially above previous levels, the theoretically correct shape of supply curve and the correct lag structure of response are also important and have been examined.

With the exception of the correct theoretical shape of the supply curve it is not accepted here that the other requirements in the previous paragraph have been met by any of the econometric models reviewed. The task is therefore to construct a model that will fulfil these conditions.

CHAPTER IV

THE THEORETICAL MODEL

Introduction

This chapter sets out in theoretical terms a production model and a store livestock price model. These basic models are then adapted in CHAPTER VII to explain the different stages of production. The linkage between these two theoretical models is that store livestock price is an input into the production model.

Production Model

Production Motivation

It is rational to suppose that entrepreneurs respond to higher profits by increasing production. Indeed neo-classical economic theory assumes that the entrepreneur organises his production so that his profit is as large as possible. Since the most profitable level of production of any commodity is the level at which marginal revenue equals marginal cost (marginal cost increasing), to maximize profits entails increasing production in response to a rise in revenue or a decrease in costs.

Production is seldom so simple that only the choice of how much to produce of one product presents itself to the entrepreneur. When a choice of producing several products with his limited resources exists, the entrepreneur will maximize his profit by producing each product up to the point where marginal revenue equals marginal cost. This can be shown by mathematical techniques such as "Linear Programming", to require that an increase in profitability of one enterprise will, subject to various constraints, lead to a reduction in other enterprises if maximum profitability is going to be achieved.

It is recognised here that the term profit in reality is likely to equate with net satisfaction. The entrepreneur may include in the concept of profit more leisure time for himself and his workers. Fortunately, investment in more intensive techniques is quite compatible with both higher production and increased leisure time. Both have increased considerably with the passing of the years. Again the entrepreneur may prefer to produce one product rather than another because it gives him satisfaction rather than for wholly financial reasons. An extreme case is that of the farmer who likes to have horses on the farm, not because of any possible profitability in terms of income, but because it gives him pleasure. He is of course quite right to do so even in economic terms, because it is the equivalent of earning profits and renting grazing so as to indulge his hobby. In proper accounting techniques, revenues should be imputed to such hobbies. Fortunately a satisfactory model can be formulated on the concept of profit maximization, without the impracticality of imputing revenues to non revenue creating benefits as a fixed difference between the theoretical elasticity of supply and the estimated elasticity of supply can be hypothesised, because the resources used in such occupations are likely to be relatively small and fairly constant over time.

The Agricultural Supply Curve

Continuing the discussion in terms of the entrepreneur being a farmer, the farmer's production at any one time is related to the quantity and quality of his land and other equipment. If production is to be increased then either the quantity or the quality of his production plant has to be increased. An increase in the quantity of the production equipment could also be expected to increase the quality because of the steady improvement in technology. Indeed farmers in order to ensure their long term prosperity have to purchase advanced technology to keep their costs down. This is especially so because of the ever increasing cost of an agricultural worker's wages. In 1970/71 it was over £1,000 per man per year (Table 2.4). The reduction of the work force therefore releases a steady stream of capital that can flow into the purchase of improved technology. This can take place either by farms dismissing labour or by farms merging. Table 2.3 shows that the active population in agriculture has been declining.

In the U.K. few extra farms can come into production and farms going out of production are likely to be amalgamated with other farms because of the resulting reduction in costs. Agricultural area can therefore be taken as remaining fairly constant.

With regard to individual products, it is possible that a farmer has invested capital to produce a specific product. With a fall in price he may discover that he is not covering his average total costs. He can then continue to produce for a time as long as he is covering his average variable costs before eventually going out of business, if prices continue to be low. Because capital equipment employed in agriculture can generally be used for producing a variety of products there is the possibility, however, that he may be able to change over to producing an alternative product. For instance the buildings used for dairy cows and beef cows are often quite similar. It is therefore important to allow for the production of alternative products in any model of the system. The situation that is difficult to allow for is when a farmer makes a large investment of capital, price falls and he does not have an alternative profitable product that he can produce. The likelihood of this occurring is however very low. It has not been a feature of post war agriculture in the U.K. for grazing livestock which require a large amount of capital equipment, and in the political climate of the E.E.C. is unlikely to become so. To all intents and purposes, then, taking into account competitive products allows for irreversibility of the supply curve.

As stated earlier (p.27) farmers can be expected to formulate expectations about future revenue and costs, but a number of circumstances exist which relate production to current revenues and costs. These will be examined in more detail here. Firstly by deliberate government policy much of the uncertainty has been taken out of agricultural production by a system of stabilized prices and production grants, therefore very simple expectations hypotheses may be appropriate. It is also the case that a large part of agricultural cost is depreciation. The replacement of worn out machinery and buildings leads to an adoption of better technology which reduces costs. Therefore an improvement in agricultural efficiency results each year. The best way to avoid uncertainty is therefore to reduce costs faster than prices are likely to fall, or in other words to properly maintain the farm. With the uncertainty as to future profits much diminished the need for having adaptive expectations is reduced. Secondly a system of rewards and penalties exist such as might be expected to equate investment closely with existing profits. If a farmer hoards his profits, he is taxed (penalty). A programme of investment on the other hand results in a saving of taxation (reward). A project can be expected to save taxation at the standard rate of income tax for every pound spent, the saving being spread over a number of years. In addition capital grants are often payable (reward). These have tended to vary between 30% to 70% of cost. Thirdly, expectations are expensive if it is assumed that prices are going to rise when prices have been low, as a large part of the capital for expansion would probably have to be borrowed; so that expected profits have to be discounted to allow for an interest charge, and this has the effect of bringing the expected profit level down closer to the existing profit level. Fourthly, for the tenant farmer, his borrowing power is geared to profitability as a result of having little security against which to borrow. An agricultural charge would allow him to pledge his crops and stock, but it is unpopular among farmers and seldom used. As an agricultural charge takes precedence over other debts, other creditors on hearing that the farmer has signed one may demand payment immediately (Sturrock, F., 1967, p.52). The result may be bankruptcy rather than salvation. The owner occupier could offer the title deeds as security against a loan, however banks are unlikely to lend if the farmer does not have a good financial case, as banks are unlikely to be interested in staving off a farmer's bankruptcy for a few extra years. The strength of a farmer's case is likely to rest on current revenues and costs rather than on any expectations he might have as to future market prices. Where big savings in costs are possible through extra investment, the banks could be expected to be sympathetic, however. The dependence of farmers on borrowed capital, the importance of which has already been stressed in Chapter III, makes it unlikely that farmers can respond with adaptive expectations.

It is reasonable then to accept that production is geared to current revenue and costs. The alternative, that of adaptive expectation response need not, however, complicate matters. Briefly if the farmer with breeding livestock varies his production in response to expected revenue and costs, he will also vary the number of store livestock coming on to the market, because of the variation in the numbers of livestock retained for breeding, and so influence livestock price. This influence would be augmented by the farmer who purchases the store stock paying a price for the store livestock largely according to his expectations of what the fatstock price will be when he comes to sell the finished beast. (The store livestock market is not subject to government intervention, and the formulation of expectations is an important consideration in modelling this market). Simply entering the price of store livestock therefore effectively makes the model one with adaptive expectation as regards price.

With regard to the shape of the supply curve, it is to be expected that at the level of optimum production diminishing returns are occurring. That is for every extra unit of input a smaller increment to total output is taking place. Improving technology and better managerial techniques is going, however, to cause a downward movement of the marginal cost curve in the medium to long term. As this movement can be expected to be largely dependent upon the rate at which technology enables capital to replace labour, and at the rate at which agricultural education progresses, this increase in efficiency can be expected to proceed fairly smoothly over time.

The Framework of the Model

The aim is to model the grazing livestock sector in some detail up to the stage of eventual slaughter of livestock. Particular attention will be devoted to the adequate representation of the breeding stock system because a high degree of accuracy there goes a long way to ensuring accurate forecasting of the numbers of livestock slaughtered.

The livestock system consists of a series of inventories. The breeding stock produces progeny, part of that progeny is retained for breeding, part may be slaughtered at an early age and the rest can be expected to be fattened to maturity before being slaughtered.

Changes in the breeding stock size comes about through the inflow of new breeding stock and the culling or mortality of existing breeding stock.

It is possible theoretically to model the system using inventories alone, and from these building up the numbers of breeding stock. There are a number of objections, however, to this approach. Firstly the statistics on the inflow of new breeding stock and the culling of existing breeding stock are not very useful. A suitable breakdown of statistics of heifers inflow is presented in Chapter VI, but the available statistics on inflow of new ewe breeding stock are inadequate. While for culling, statistics on the number of animals slaughtered are available but the mortality factor is unknown. Secondly the inflow of new breeding stock is, naturally enough, largely a function of the outflow of culls. This is because a large part of the inflow is merely replacements for existing breeding stock. As outflow is largely determined by disease or old age; in order to have a satisfactory explanation for both inflow and outflow knowledge of the age distribution is required. This is not available. An alternative approach is to make use of the farmer's knowledge. The farmer by varying the inflow in response to outflow, which he is in a position to know from the age distribution of the breeding stock, will obtain his desired level of breeding stock. The problem of age distribution therefore ceases to exist when a whole breeding herd or breeding flock model is used. To obtain maximum accuracy this approach is adopted but supplemented by an inventory approach.

To some extent every stage of the livestock production process requires a different model. It is not proposed to go to such extremes here, but merely to give a theoretical model for the numbers of breeding livestock and a theoretical model for store livestock price. The principles behind those models will however be adapted for formulating the other equations necessary for modelling the grazing livestock system. A discussion of the formulation of those other equations together with the practical application of the theoretical models following is given in Chapter VII.

In order to model the system in reasonable detail equations for the following livestock inventories are proposed:-

Numbers of dairy cows, numbers of beef cows, numbers of breeding ewes, numbers of dairy heifers calving, numbers of beef heifers calving, calves retained for breeding, the numbers of beef cows calved, the numbers of calves at age six months, the numbers of dairy calves born, the number of dairy calves slaughtered, numbers of calves that will be fattened for slaughter, the number of steers and heifers slaughtered in each period, the numbers of cows slaughtered, the numbers of lambs slaughtered and the numbers of ewes slaughtered. A number of prices will also be determined within the system. The interlinkage of those equations will then enable the actual system to be simulated with reasonable completeness of detail.

<u>The Theoretical Production Model</u>

Assuming that the increase in efficiency is a simple linear function of time, and that diminishing returns apply and furthermore that there is more than one enterprise that can use the scarce resources, we can give the following model for breeding livestock.

$$Y_1 = \beta_1 X_1 - \beta_2 X_2 + \beta_5 T \qquad (4.1)$$

$$Y_2 = -\beta_3 X_1 + \beta_4 X_2 + \beta_6 T \qquad (4.2)$$

where Y_1 and Y_2 are the desired production of products 1 and 2 respectively

T = improving efficiency with time

X_1 = vector of LOG (revenue relative to costs for Y_1)

X_2 = vector of LOG (revenue relative to costs for Y_2)

The model is only given in terms of two products, but the same principles would hold for more than two products. A LOG transformation of revenue relative to costs is made as this gives the shape of supply curve for reflecting conditions of diminishing returns. Expressing revenue relative to costs effectively allows for movements in the supply curve due to changes in costs. The model gives an increase in production of a product if that product's revenue relative to cost increases and a decrease in the production of the competitive product (everything else remaining constant).

Rearranging equations (4.1) and (4.2) gives

from (4.2) $X_2 = Y_2/\beta_4 + (\beta_3/\beta_4)X_1 - (\beta_6/\beta_4)T$ (4.3)

subst. (4.3) in (4.1)

$$Y_1 = \beta_1 X_1 - \beta_2(Y_2/\beta_4 + (\beta_3/\beta_4)X_1) + (\beta_5 + \beta_2\beta_6/\beta_4)T \quad (4.4)$$

$$= (\beta_1 - \beta_2\beta_3/\beta_4)X_1 - (\beta_2/\beta_4)Y_2 + (\beta_5 + \beta_2\beta_6/\beta_4)T \quad (4.5)$$

similarly for (4.2)

$$Y_2 = (\beta_4 - \beta_3\beta_2/\beta_1)X_2 - (\beta_3/\beta_1)Y_1 + (\beta_6 + \beta_3\beta_5/\beta_2)T \quad (4.6)$$

As a product's own price elasticity of supply can be expected to be much greater than its cross elasticity of supply, the coefficients of X_1 and X_2 can be expected to be positive. As reformulated the model is a simultaneous model and has to be estimated by appropriate methods.

Equations 4.1 and 4.2 are still the assumed structural set, therefore the estimating procedure adopted is an unusual one which would not normally be appropriate, but is used for this particular model for the following reasons:

(i) because 4.1 and 4.2 may be subject to multicollinearity;

(ii) because the degrees of freedom for estimating 4.5 and 4.6 are greater than for 4.1 and 4.2.

Multicollinearity in 4.1 and 4.2 would lead to a large degree of error in the coefficients which would probably be shown up by the standard errors being very large. Estimating the structural set by the transformations 4.5 and 4.6 if multicollinearity was present in equations 4.1 and 4.2 would not entirely eliminate the difficulty. The usual method of estimating simultaneous equations is by two stage least squares in which the endogenous explanatory variables are certain linear functions of all the exogenous variables. This makes it likely that some degree of multicollinearity is present in such estimates. Where the multicollinearity is high in the first stage estimates (i.e. equations 4.1 and 4.2) the degree of multicollinearity in the second stage estimates will also tend to be high but not so high as in the first stage estimates because of the saving in degrees of freedom and because individual exogenous variables that might have been highly correlated have been in effect weighted and combined into one variable (the explanatory endogenous variable).

The procedure has the difficulty that if the first stage calculations are statistically and economically acceptable they should be used. If they are not, this may be the result of multicollinearity, in which case the procedure adopted is appropriate, but it may alternatively be the result of an incorrectly specified model. Also although the second stage results may appear satisfactory, this does not guarantee that the implied values of the structural coefficients are all satisfactory as over identified restrictions may be operating.

A difficulty arises in that the simplification of the model for estimation purposes makes the coefficients difficult to translate into elasticities of supply. For instance, the higher the negative coefficients on Y_1 and Y_2 in equations (4.6) and (4.5) respectively, when caused by the magnitude of β_3 and β_2 in the coefficients of Y_1 and Y_2 respectively, the greater will also be the coefficients on the trend term T. A simpler method of evaluating the effect of a change in revenue and costs is by simulating the system and varying the levels of revenues and costs.

In practice also as the producer response takes time to complete, X_1 and X_2 have to represent distributed lags of revenues relative to costs for a semi annual model. Because the producer is assumed to respond to actual revenue and costs these distributed lags are however easy to work out. When the production time lag for different products are not of equal length, then the production possibilities for the product with the shortest production time lag is closely controlled by the production decisions already made for the competitive enterprises. The implications of this will, however, be further examined in Chapter VII.

Store Livestock Price Model

Like most commodity markets, the store livestock market is largely a speculator's market. Store livestock may only be held for a matter of weeks before being resold for a profit. At the most store livestock can be expected to be fattened for about two years (this assumes buying a calf of only a few weeks of age). The business of fattening livestock is characterised by uncertainty. Fewer production grants are available than is the case for breeding livestock, and consequently much more of the profit has to come from the difference between the buying and the selling price of livestock. Quite often small movements in price can mean the difference between a profit and a loss for those dealers expecting a quick profit. Stabilization of fatstock price by government policy although reducing the risk to some extent does not eliminate it.

The capital required for purchasing fattening stock is essentially short term capital and consequently easier to obtain than the relatively long term capital required by breeding stock farmers.

The ability to make a profit in the business of fattening livestock comes from making a correct assessment of future market prices for livestock and by paying a realistic price for the store livestock based on the expected price of fat cattle, and expected costs of fattening.

A reasonable assumption is that the demand for store livestock is determined by

$$Q_t^d = \beta_7 X_t^* - \beta_8 P_t \qquad (4.7)$$

where Q^d = demand

X^* = relationship of expected fatstock price to fattening cost

P = current store livestock price

Supply can be expected to be largely predetermined by the numbers of breeding stock. The farmer will however require to retain some of the stock for breeding and some types of stock may be slaughtered at birth. The numbers of stock not marketed for these reasons will depend on current store stock price and other production incentives. The expected relation is therefore

$$Q_t^s = \beta_9 PP_t - \beta_{10} P_t - \beta_{11} OPI_t \qquad (4.8)$$

where Q^s = supply to market

PP = predetermined production

P = current store livestock price

OPI = other production incentives

Assuming that the market is just cleared

$$Q_t^d = Q_t^s \qquad (4.9)$$

i.e. $\beta_7 X_t^* - \beta_8 P_t = \beta_9 PP_t - \beta_{10} P_t - \beta_{11} OPI_t$ (4.10)

therefore $(\beta_8 - \beta_{10}) P_t = - \beta_9 PP_t + \beta_{11} OPI_t + \beta_7 X_t^*$ (4.11)

i.e. $P_t = - \beta_9 / (\beta_8 - \beta_{10}) PP_t + \beta_{11} / (\beta_8 - \beta_{10}) OPI_t + \beta_7 / (\beta_8 - \beta_{10}) X_t^*$

(4.12)

Assuming that the relationship of expected fatstock price to fattening cost is determined by

$$X_t^* - X_{t-1} = \beta (X_t - X_{t-1}^*) \qquad (4.13)$$

An adjustment in expectations being assumed to depend on the current value and the previous expectation. This equation is equivalent to

$$X_t^* = \sum_{\lambda=0}^{\infty} \beta (1-\beta)^{\lambda} X_{t-\lambda} \qquad (4.15)$$

If $Y_t = \beta_1 X_t^*$

$$= \beta_1 \sum_{\lambda=0}^{\infty} \beta (1-\beta)^{\lambda} X_{t-\lambda} \qquad (4.16)$$

then this equation can be reduced by lagging it once, multiplying through by $(1-\beta)$ and subtracting it from the original equation (Koyck, L.M., 1954). This yields

$$Y_t = \beta_1 (1-\gamma) X_t + \gamma Y_{t-1} \qquad (4.17)$$

The variable X_t can be expected to consist of present fatstock price, or some measure of purchasing power. In addition the supply of store stock to the market and current fattening costs will be important. Substituting for $\beta_7 / (\beta_8 - \beta_{10}) X_t^*$ in equation (4.12) gives

$$P_t = \gamma P_{t-1} - \beta_{12} / (\beta_8 - \beta_{10}) [- \beta_9 PP_t + \beta_{11} OPI_t] + \beta_{13} NDI + \beta_{14} FC$$
$$+ \beta_{15} PP_{t-1} - \beta_{16} OPI_{t-1} \qquad (4.18)$$

where NDI = national disposable income

FC = fattening costs

The terms PP_{t-1} and OPI_{t-1} can be excluded as high levels of correlation are likely between these variables and their present values. This gives an equation which is easy to estimate, but this form of the model often leads to some bias in the estimation of the coefficients as pointed out in Chapter V.

CHAPTER V

THE STATISTICAL MATERIAL USED IN THE MODEL

Introduction

An indication of the necessary statistical data for the model has been given in the previous chapter. Statistics are required on livestock inventories, on revenues and costs, and on weather influences. The availability and the quality of these statistics influence the final form of the model used and also the degree of success of the model. A considerable amount of thought has therefore to be devoted to obtaining the best statistical material possible. The actual statistical data used is contained in the STATISTICAL APPENDIX and published sources are given in the remainder of this chapter.

Livestock Population

In the United Kingdom statistical data on livestock populations is collected by means of postal enquiries. All classes of livestock are covered: dairy cattle, beef cattle, sheep, pigs and poultry. In addition there are censuses on the area under crops and grass, on the production of crops, on agricultural machinery, on agricultural workers, on agricultural holdings and on horticultural production. Altogether there is a wealth of statistical material on the agricultural industry.

For grazing livestock, namely dairy animals, beef animals and sheep, statistical information is collected in the countries comprising the U.K. at 4th June and 4th December, but in addition for England and Wales statistics are collected at 4th March and 4th September. Although the statistics on grazing livestock are collected seperately for Scotland, Nothern Ireland, and for England plus Wales, the classifications under which they are collected are similar so that aggregated results for the U.K. can be estimated. Differences in the statistical methods of obtaining the livestock populations in the different countries of the U.K. require examination however.

In England and Wales census returns are collected from holdings that are "statistically significant". The definition of what is statistically significant has changed over the years. Statistical amalgimation of holdings has also tended to lag behind the physical reality. In 1966 there were about 17,800 holdings out of a total of 312,182 deemed as being statistically insignificant because they were believed to consist of one acre or less in area. In 1967 many of those holdings were found to be no longer functioning as distinct agricultural holdings. Consequently the number of insignificant holdings was reduced to 12,900. The advent of automatic data processing led to statistically insignificant holdings being determined by "standard man days" rather than acres of crops and grass. As a result, about 47,000 holdings, including the 12,900 previously treated as insignificant, were from 1968 no longer required to make census returns because they had under 10 acres of crops and grass, no regular whole time workers and a labour requirement of less than 26 standard man days. Elimination on those grounds has continued. From June 1973 the threshold of significance is to be raised to 46 standard man days, which will eliminate another three to four thousand holdings from the census. The process has not been entirely in the direction of fewer agricultural census returns. In 1970 about 2,000 holdings of one acre or less were included in the agricultural census on the grounds that they had 26 or more standard man days. Estimates for those holdings excluded from the census returns are made, but it is now proposed that to allow for changes in the status of farms a simple enquiry form be sent to a sample of statistically insignificant holdings each June, so that eventually all such holdings would be examined. This would also allow for more accurate estimates of the production of those farms to be made.

While 4th June returns are collected from all statistically significant holdings, those returns for the 4th March, September and December are collected from a different sample of holdings on each successive census. These sample returns are then raised statistically to give the census figures. This method is subject to a degree of sampling error.

For the census material used here the sample was a third of statistically significant holdings up to but not including September, 1972. From September, 1972 a stratified sample has been taken. For December this means a sample of about 45,000 holdings as compared with 70,000-80,000 for the one third samples. For March and September small stratified samples probably of about 30,000 holdings are to be taken (Horsecroft, P.G., August, 1969).

Standard errors are not normally published for the sampling errors in the March, September and December raised sample estimates. For 1970, however, these are published in the Journal of the Royal Statistical Society, Series A, Volume 135 No.3, 1972 (Orton, C.P., 1972).

TABLE 5.1

England and Wales Raised Sample Estimates 1970: Cattle and Ewes (000)

	March		September		December	
	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
Dairy cows in milk	2,279	6.6	2,223	5.2	2,230	5.4
Dairy cows in calf but not in milk	481	3.8	546	5.5	566	4.5
Dairy Heifers in calf	550	4.4	479	3.1	374	3.5
Beef cows in milk	351	3.5	571	3.5	349	3.6
Beef cows in calf but not in milk	295	5.7	110	2.7	339	7.3
Beef Heifers in calf	108	2.1	102	1.8	110	1.9
Ewes in lamb or with lambs at foot	7,987	35.3	-	-	-	-
Breeding Ewes	-	-	6,622	21.2	6,674	27.8
Shearling Ewes	-	-	1,332	10.0	1,276	12.2

TABLE 5.1 gives the Standard Errors for the 1970 March, September and December published livestock numbers for England and Wales. The S.E. on Dairy cows in milk is small, being only about .25% of the estimate, and the S.E. on Breeding Ewes and on Ewes in lamb or with lambs at foot is only slightly larger. For the other estimates, however, the S.E. runs at about 1% of the estimate. This low standard of accuracy in the Ministry of Agriculture, Fisheries and Food agricultural statistics is to be deplored. Too large a portion of an apparent change in livestock numbers could be due to inaccurate statistics. It is to be assumed that the accuracy of the statistics from the stratified sample system now in force will not be worse than the one third samples previously used.

On the credit side greater accuracy can be assumed for the June census, as a 100% return is asked for. Not all farmers in fact respond to the census. Orton (Orton, C.P., 1972) puts the response rate at 92-93 per cent. For these non-respondents their most recent June return is "imputed" into the current June results, and for the sample returns they are omitted from the sample altogether. For the sample returns the non-response rate is similar to that of the June census. The imputing of the most recent June returns into the current June return will cause the census to underestimate when livestock numbers are increasing and vice versa. Where farmers have not made a return for a number of years, the error could be serious. A degree of error can also be expected from such sources as errors made by farmers that are not detected by credibility tests, data preparation errors and computational errors.

For Scotland returns were collected from all holdings in June and December up to 1970. In 1970 about 16,000 holdings, generally with a labour requirement of less than 26 standard man days per annum, were omitted from the main censuses. Altogether these holdings account for one-half per cent of Scottish Agricultural activity. Limited information is now collected from these statistically insignificant holdings every three years, so that the composition of these holdings can be reviewed. A number of intensive units previously omitted have been added to the census cover from 1970.

Returns are collected in June and December for grazing livestock in Northern Ireland. For livestock the census figures are collected from all owners, irrespective of the size of the holding and also from landless stock-holders.

Livestock statistics to be useful have to be compiled according to type of animal, and purpose for which the animal is used. A division should be made, for instance, between cows used for beef purposes and cows used for dairy purposes. Curiously enough this was not generally done until 1959. The division in the census returns is whether a cow is mainly used for dairy purposes or mainly used for beef purposes. This division is as clear cut a division as it is possible to obtain between the beef herd and the dairy herd. Unfortunately the division is going to depend to a large extent on the farmer's opinion of what the cow is mainly used for. Conceivably a number of cows are dual purpose, and could therefore be classified as being either beef or dairy cows without any dishonesty taking place. A subsidy that could include an element of incentive to enter such cows as being mainly used for beef, has been introduced with the payment of beef cow subsidy from 1967 on lowland cows "primarily for breeding calves for beef". Cows whose milk is mainly used for sale or domestic consumption do not qualify. Despite possible variations in classification, the division for cows is undoubtedly the best possible.

Separate enumeration is given for cows and heifers in milk, cows in calf but not in milk, and heifers in calf with first calf. For purposes of analysis, heifers in calf with first calf is not a very suitable statistic. A cow or heifer has a gestation period of nine months. Consequently this statistic does not impart information on the numbers of heifers calving semi-annually, which would be the ideal return to ask for in the semi-annual livestock censuses for the United Kingdom.

Calves have been returned as being under 6 months old, and from 6 months but under one year old, from June 1965 for Great Britain. Previously they were returned as being under 1 year old only, and this form of return is still used for Northern Ireland. Returns for male and female calves are listed separately.

Some discrepancy exists between those calves returned as being under 6 months old and those calves returned as being from 6 months old, but under one year old. For instance at June 1965 there were 759 thousand male calves, but at December 1965 there were 858 thousand calves aged from 6 months up to one year old in Great Britain, according to the agricultural census statistics. This increase is surprising as imports of calves has not been a feature of this country's trade, and exports of calves from Northern Ireland to Great Britain has also not been a feature. The conclusion would appear to be that farmers are uncertain about the age distribution of their calves, and do not classify them properly. This view would tend to be further supported by the fact that some of the calves aged under 6 months old would be slaughtered before reaching the age of 6 months. Fortunately farmers are likely to have a better idea of the ages of recently born calves than of older age groups, so that calves aged under 6 months are likely to be returned fairly accurately, so that the bias is likely to be in the other age groups.

For the United Kingdom the census results for ewes are published as "Ewes for breeding" and "Shearlings put to the ram", the two headings being given as one total for December.

The census statistics for the United Kingdom are published by the Ministry of Agriculture, Fisheries and Food, the Department of Agriculture and Fisheries for Scotland and the Ministry of Agriculture, Northern Ireland in "Agricultural Statistics, United Kingdom", annual.

Prices

Fat Cattle Price

Fat cattle prices are obtained from weekly average market prices for fatstock eligible for certification under the Fatstock Guaranteed Scheme. From these weekly series, monthly series are calculated. These are published in an index form. As used here the index base is 1954/55-1956/57 = 100. Grades of quality are distinguished in the composition of the index, and the prices for steers and heifers are combined in a fixed ratio of 64:36 respectively.

During some periods a considerable proportion of animals marketed are not entered under the Fatstock Guarantee Scheme (Economic Trends, No. 11 February 1962 p.Vl). This may cause the index to be less reliable as at such times it is based on a smaller sample of fatstock, and possibly not a completely representative sample, as animals likely to exceed the guaranteed price are unlikely to be certified. This would mean a downward bias and a larger standard error for the index if one was calculated.

To obtain an average index of fat cattle price for the periods 1st December-31st May and 1st June-30th November, these periods being in agreement with the semi-annual agricultural censuses, a simple 6 monthly average of the monthly indices was used, as this seemed adequate for a 6 monthly period. A weighted average would give a better indication of the average price received by farmers, but not necessarily of the potential of the market, namely the price that farmers assume to have been available if their marketing had been better.

Monthly fat cattle price index statistics are given in "Monthly Digest of Statistics", and "Agricultural Statistics, United Kingdom", annual.

Fat Cow Price

Fat Cow Price is based on England and Wales alone, there being no comparable statistics for the rest of the country. As transport and communications are of a high standard in the United Kingdom, the market in fat cows can be assumed to be reasonably perfect, so that the omission of Scotland and Northern Ireland should not be of much consequence. Prices are expressed as £s per cwt. Weekly prices are based on an average of prices at about sixty auction markets in England and Wales. With such a large sample of auction marts the average price should be representative. As before, average prices for six monthly periods are calculated by means of a simple average. The monthly statistics are to be found in "Agricultural Statistics, England and Wales", annual.

Calf Price

For calf price the market prices are also confined to England and Wales. The average auction market price is again based on about sixty auction markets. Prices are for calves of not more than 3 weeks old. The type of calf on which prices are based is first quality beef and beef dairy crosses. Prices for bull and heifer calves are combined in the ratio 50:50 respectively. A simple average is used to obtain the average price over a six monthly period. The monthly calf statistics are given in "Agricultural Statistics, England and Wales", annual.

Store Lamb Price

Like cow price and calf price, store lamb price is for England and Wales only, and for the same reason, namely incomparable statistics for the countries which make up the U.K. Second quality "Store sheep other than hill sheep breeds" was taken as being fairly close to the average of store lamb prices. For those years for which prices for this class of store sheep was not published, the most comparable published class to it was used. These store sheep prices are based on the average market price at about sixty auction markets in England and Wales. A simple average was used for obtaining average prices over six monthly periods. The monthly store sheep price statistics are given in "Agricultural Statistics - England and Wales", annual.

Ewe Price

Ewe price is the price of "Light" ewes in England and Wales. Prices are given in pence per pound estimated dressed carcase weight. Light ewe price was used because many of the ewes in this country are hill ewes and these tend to be lighter than lowground sheep. This price should therefore be closer to the true average price than the price for "Heavy" ewes. Ewe prices are based on the average price at about sixty auction markets in England and Wales. Simple averages are used to obtain the six monthly average prices. The monthly ewe price statistics are given in "Agricultural Statistics - England and Wales", annual.

Milk Price

Milk price is the weighted average wholesale producer pool price paid by each of five milk marketing boards:

England and Wales M.M.B.
Scottish M.M.B.
Aberdeen and District M.M.B.
North of Scotland M.M.B.
Northern Ireland M.M.B.

Milk price is expressed as an index, and in the form used here the base is 1936-38 = 100. These milk price indices are given in "Agricultural Statistics, United Kingdom", annual and "Monthly Digest of Statistics". To obtain a six monthly average price a simple average of the published monthly indices was used.

Concentrate Feed Price

The average of all types of concentrate feed price is used, For the U.K. the monthly average prices for cattle, calf, pig and poultry compound feed prices are combined in the following ratio:

Cattle	32.0
Calf	4.2
Pig	28.0
Poultry	35.8

The average monthly prices are obtained from manufacturers price lists. The prices are expressed in index form and as used here with the average of 1954/55-1956/57 (July-June Years) = 100. The monthly indices of concentrate feed prices are contained in "Agricultural Statistics", annual and "Monthly Digest of Statistics". A simple average of the monthly indices was used to obtain the average indices for six monthly periods.

Fertiliser Price

The price of fertilisers is obtained by combining the prices of four types of straight fertiliser and two types of compounds using a system of fixed weights. As used here price is expressed as an index with base 1954/55-1956/57 = 100. A simple average of monthly price indices is used to obtain the average price for a six month period. These monthly indices are published in "Agricultural Statistics" - United Kingdom, annual and "Monthly Digest of Statistics". The indices used here are net of subsidy.

Wool Price

Wool price is the average producer price paid by the British Wool Marketing Board. It includes any subsidy on wool. Recent prices are published in the "Annual Review of Agriculture", 1973, and previous prices can be found in the "Annual Abstract of Statistics".

Building Material Costs

Building material costs are expressed in index forms with the average of 1954 equalling 100. The cost is taken at wholesale level. These indices are published in "Monthly Digest of Statistics", and are of general building costs.

Livestock Subsidies

Livestock subsidies used are hill cow subsidy, cow subsidy, calf subsidy, winter keep cattle subsidy, hill sheep subsidy (proper), upland hill sheep subsidy, and winter keep sheep subsidy. The average known value of the subsidy is taken as the average amount of subsidy over each six monthly period. Details of changes in subsidy levels are announced by the government every March. These are contained in the "Annual Review and Determination of Guarantees".

General Grants and Subsidies

General grants and subsidies includes ploughing subsidy, field drainage grants, small farmers scheme, farm business records, crofting grants, water supply grants, livestock rearing grants, hill land grants, farm capital grants, farm improvement grants and crofting improvement grants. Almost everything in fact that cannot be tied to a specific commodity. The number of these general grants and subsidies have been constantly changing over time. The total amount paid by the government each half year is used as the variable. These general grants and subsidies are published in the "Annual Review and Determination of Guarantees", up to 1972 and the "Annual Review of Agriculture", from 1973.

National Disposable Income

National disposable income as used in the model is the total personal income before tax (£ million) less payment of income, national insurance and contributions and net transfer abroad. It is before providing for depreciation, stock appreciation and addition to tax reserves. The source of publication of these statistics is the "Monthly Digest of Statistics". Semi annual totals Jan.-June, July-Dec. are used.

Bank Rate

The Bank of England bank rate is published in the "Monthly Digest of Statistics".

Slaughter Statistics

The statistics for livestock slaughtered are for steers and heifers, cows and bulls, calves, ewes and rams and finally other sheep and lambs. These figures are for animals slaughtered in the United Kingdom, including imported fat animals. These slaughter statistics are derived from returns recording slaughterings in public and licensed slaughterhouses. A source of publication of these statistics is " Monthly Digest of Statistics".

Temperature Statistics

Temperature statistics are given in degrees fahrenheit and are a weighted average of the temperatures in Scotland, Northern Ireland and England and Wales for the months of January, February and March. The weighting factors are 0.284 for Scotland, 0.678 for England and Wales and 0.0379 for Northern Ireland. These weighting factors correspond approximately to the proportion of the total breeding ewes in each country. Originally intended for use in the sheep equations, this variable ended up in the dairy herd equation as it was here that it was found to have most influence. A source of publication for these temperature statistics is "Monthly Digest of Statistics".

Import-Export Statistics

Calves

Until August 1967 export of calves from the U.K. were severely restricted by the regulations covering the type of animal for which export licences could be granted, and the numbers involved, though not known with precision, were negligible in comparison with the numbers of calves retained or slaughtered in the U.K. In August, 1967, it was decided to allow the export, on a trial basis and under certain conditions, ofyoung calves with a minimum weight of 100lb. The trade was halted in November because of an outbreak of foot and mouth disease in this country. Exports were resumed in August 1968 but from that date calves had to be a minimum weight of 110lbs. before they could be exported.

Statistics on calves exported are from 1969 onwards the numbers that have been recorded as having been exported by the Department of Trade and Industry in the "Overseas Trade Statistics of the United Kingdom". Prior to 1969 the estimates of calves exported were provided by the Ministry of Agriculture, Fisheries and Food in a communication. Their estimates were based on information provided by their Animal Health Division and the accuracy is not guaranteed.

Export of Cows, Bulls and Heifers

Statistics on cows, bulls and heifers are obtained from the "Overseas Trade Statistics of the United Kingdom". The total is taken of cows, bulls and heifers exported for all purposes.

Trade in Cattle (calves excluded)

Cattle slaughter statistics for the U.K. include imported fat stock. To allow fully for the extra cattle made available for export in the U.K., account has also to be taken of net imports of heifers and cows as importation of these allows a larger proportion of the cattle in the U.K. to be slaughtered, because fewer have to be retained as replacements for the breeding herd. Accordingly the number of cattle slaughtered was assumed to increase by the net figure for import of all cattle except calves. These statistics were obtained from the "Overseas Trade Statistics of the United Kingdom".

The Statistical Tables

Tables of the statistical material used are contained in the STATISTICAL APPENDIX.

CHAPTER VI

A REFORMULATION OF THE HEIFER STATISTICS

Available statistical material is not always suitable for the purpose required. This is the case for census statistics on the numbers of heifers joining the beef and dairy herds respectively (Agricultural Statistics, United Kingdom, annual). These statistics give the number of heifers in calf for the first time, which because heifers have a gestation period of nine months is the equivalent of stating that these heifers will join the beef and dairy herds during the next nine months. What is required is the numbers of heifers to join the beef and dairy herd during the next six months (calving during the next six months). The problem is how to obtain a suitable reformulation of the existing statistics.

The statistics available are from the semi-annual census of livestock for the whole U.K. and from the quarterly livestock censuses for England and Wales. If the number of heifers returned as being in calf at each quarterly census in England and Wales is represented by

Q_i where i = time periods 1,2, ... , n and the number of heifers to calf in each quarterly period is represented by

q_i where i = time periods 1,2, ... , n+2 because heifers have a gestation period of nine months (278-283 days)(Moore, I, 1968, p.283)

$$Q_i = q_i + q_{i+1} + q_{i+2} \qquad (6.1)$$

Rearranging identity (6.1) can give

$$q_i = Q_{i+2} - (q_{i-1} + q_{i-2}) \qquad (6.2)$$

and also

$$(q_{i-1} + q_{i-2}) = Q_{i-3} - q_{i-3} \qquad (6.3)$$

Combining identities (6.2) and (6.3) gives

$$q_i = Q_{i-2} - Q_{i-3} + q_{i-3} \tag{6.4}$$

In identity (6.4) Q_{i-2} and Q_{i-3} are known being census statistics, but q_{i-3} is unknown. It is apparent that if a value is assigned to q_{i-3} in identity (6.4) and it is higher (lower) than the true value by an amount α, then the estimated value of q_i will also be higher (lower) than its true value by an amount α. Indeed the values in the series

$$q_{i-3}, q_i, q_{i+3} \ldots\ldots \tag{6.5}$$

will all be in error by an amount α.

If in identity (6.1), values are assigned to q_1, q_2, q_3 such that identity (6.1) is true, then all q_i where $i > 3$ can be estimated. This series can be represented as three series such as in (6.5), series 1 containing q_1, q_4; q_7 ......, series 2 containing q_2, q_5, q_8..... and series 3 containing q_3, q_6, q_9 ...... Each series will have a constant error $\alpha 1$, $\alpha 2$, and $\alpha 3$ respectively. We can therefore say that

$$\hat{q}_i = q_i + \alpha 1 + \alpha 2 + \alpha 3 \tag{6.6}$$

where $\hat{q}_i$ is the estimate of q_i

$\alpha 1$ = error in series 1 when $\hat{q}_i$ is contained in series 1, otherwise $\alpha 1 = 0$.

$\alpha 2$ = error in series 2 when $\hat{q}_i$ is contained in series 2, otherwise $\alpha 2 = 0$.

$\alpha 3$ = error in series 3 when $\hat{q}_i$ is contained in series 3, otherwise $\alpha 3 = 0$.

Unfortunately all terms to the right of identity (6.6) are unknown, however by substituting instrumental variables for q_i the size of the error in each of the series 1, 2 and 3 can be estimated by least squares, i.e.,

$$\hat{q}_i = f(D1, D2, S1, S2, S3, T, C) \tag{6.7}$$

where D1 = 1 if $\alpha 1$ does not equal zero, otherwise D1 = 0

D2 = 1 if $\alpha 2$ does not equal zero, otherwise D2 = 0

S1 = 1 if $\hat{q}_i$ is an estimate of heifers calving 4th June-3rd Sept., otherwise S1 = 0

S2 = 1 if $\hat{q}_i$ is an estimate of heifers calving 4th Sept.-3rd Dec., otherwise S2 = 0

S3 = 1 if $\hat{q}_i$ is an estimate of heifers calving 4th Dec.-3rd March, otherwise S3 = 0

T = trend = $\hat{q}_{i-1} + \hat{q}_i + \hat{q}_{i+1} = Q_{i-1}$

C = constant term.

If β_1 and β_2 are the coefficients of D1 and D2 respectively, the relationship between these coefficients and $\alpha 1$, $\alpha 2$ and $\alpha 3$ are

$$\beta_1 = \alpha 1 - \alpha 3 \tag{6.8}$$

$$\beta_2 = \alpha 2 - \alpha 3 \tag{6.9}$$

i.e. β_1 and β_2 are measured from origin zero minus $\alpha 3$.

It also follows from the definition of $\alpha 1$, $\alpha 2$ and $\alpha 3$ and equation (6.1) that

$$\alpha 1 + \alpha 2 + \alpha 3 = 0 \tag{6.10}$$

i.e. an overestimate (underestimate) in any $\hat{q}_i$ leads to the same degree of underestimate (overestimate) in $(q_{i+1} + q_{i+2})$

from (6.8) and (6.9) $\quad \beta_1 + \beta_2 = \alpha 1 + \alpha 2 - 2\alpha 3 \quad$ (6.11)

from (6.10) $\quad \alpha 1 + \alpha 2 = -\alpha 3 \quad$ (6.12)

substituting (6.12) into (6.11) $\quad \beta_1 + \beta_2 = -3\alpha 3 \quad$ (6.13)

therefore $\quad \alpha 3 = -(\beta_1 + \beta_2)/3 \quad$ (6.14)

from (6.8) $\quad \alpha 1 = \beta_1 + \alpha 3 \quad$ (6.15)

from (6.9) $\quad \alpha 2 = \beta_2 + \alpha 3 \quad$ (6.16)

$\alpha 1$, $\alpha 2$ and $\alpha 3$ can then be used to correct the series 1,2 an 3 containing q_i, q_{i+1} and q_{i+2} respectively.

In practice imperfections in the theory that heifers in calf are the number that will calf in the next nine months occur. For instance the outbreak of foot and mouth disease in the winter of 1967/68 led to the slaughtering of heifers, so that not all heifers returned as being in calf in the agricultural census just before the outbreak did in fact calf. Large variations in exports or imports of heifers in calf can also lead to inaccuracies between the numbers of heifers in calf and the number that do in fact calf. It is also true that a farmer cannot know until 20-21 days (the average interval between oestrus (bulling or heat) whether or not a heifer is in calf. Depending on whether farmers return heifers as in calf after the heifer has been first mated or whether the farmer waits until he is certain that the heifer is in calf before entering it as so in the census return, can mean either that the numbers of heifers returned as being in calf are an over-statement or an under-statement. A sampling error also exists for the September, December and March agricultural censuses for England and Wales.

Because of imperfections in identity (6.1), the series of estimates of heifers calving each quarter occasionally had to be broken off and restarted. This occurred if every fourth residual to (6.7) had the same sign. This in fact only occurred once for dairy heifers and once for beef heifers, which shows that despite the many reasons for a breakdown in identity (6.1), the theory worked well.

Having obtained statistics for heifers calving quarterly for England and Wales, the problem remains of obtaining similar statistics for the rest of the United Kingdom. If the heifer calving distribution were the same for the rest of the U.K. as for England and Wales, then it would be possible to raise statistically the numbers calving in

England and Wales so as to account for all the heifers calving in the U.K. A method of raising the results for England and Wales is

$$(q_i + q_{i+1} + q_{i+2})(Q_i UK/Q_i EW)$$

where $Q_i UK$ is the half yearly census statistics for heifers in calf for the U.K., and $Q_i EW$ is the equivalent statistic for England and Wales. For the same percent increase (decrease) of heifers in the U.K. as in England and Wales $Q_i UK/Q_i EW$ should be a constant if the calving distribution is the same for the U.K. as it is for England and Wales, therefore as two seperate raised estimates are obtained for the heifers calving in the quarter year starting 4th June, these should be equal. The same applies for the two estimates for the quarter starting 4th Dec.

TABLE 6.1

U.K. Raised Values of Beef Heifers Calving Quarterly

Census	Total (000)	Breakdown (000)		
J.66	143	58.5	30.9	53.6
D.66	178	55.9	76.3	45.8
J.67	131	45.3	48.7	36.9
D.67	154	38.1	69.2	46.7
J.68	133	47.9	39.0	46.1
D.68	177	47.0	70.4	59.6
J.69	156	61.3	48.3	46.4
D.69	196	46.7	84.0	65.3
J.70	167	65.7	52.5	48.8
D.70	206	48.7	89.9	67.4
J.71	169	66.9	48.3	53.9
D.71	231	54.9	106	70.1

TABLE 6.2

U.K. Raised Values of Dairy Heifers Calving Quarterly

Census	Total (000)	Breakdown (000)		
J.66	607	186.4	301.7	118.9
D.66	477	119.2	130.3	227.4
J.67	686	225	304.1	156.9
D.67	488	159.8	138.7	189.5
J.68	693	190.4	333.4	169.2
D.68	495	163	123.5	208.5
J.69	666	217	316.8	132.2
D.69	480	132.8	125.3	221.8
J.70	696	218.8	337.5	139.7
D.70	469	141.7	116.6	210.7
J.71	662	206.7	310.1	145.2
D.71	475	148.3	123.1	203.6

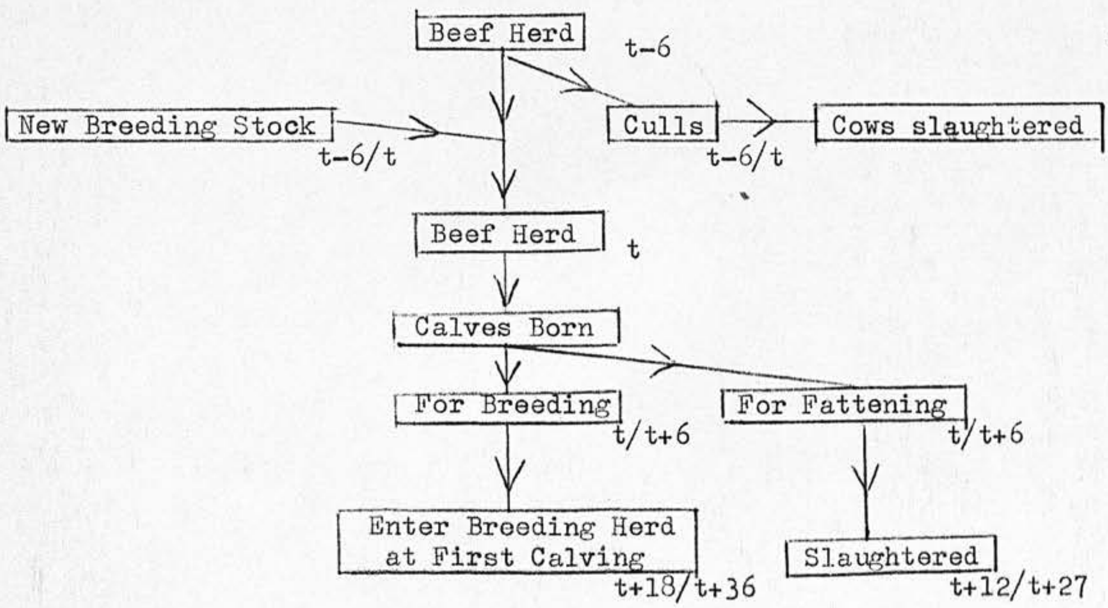
In TABLE 6.1 and TABLE 6.2 the result of raising the numbers of heifers calving quarterly in England and Wales to give U.K. estimates of beef and dairy heifers calving quarterly are given. The number of heifers at the end of each line of the "Breakdown" should be close to the number of heifers at the beginning of the next line of the Breakdown, if the raising method is satisfactory, as these are both estimates of heifers calving in the same time period. In most cases these are extremely close, which makes it reasonable to accept the raising method. For the final estimate an average value was taken where the results gave two alternative estimates, and an adjustment made to that quarter for which only one estimate was made (the second column in the Breakdown), so as to bring the total calving in a nine month period as given by the Breakdown the same as returned in the agricultural census.

CHAPTER VII

APPLICATION OF THE THEORETICAL MODEL

Introduction

Chapter IV described the theoretical model, and Chapters V and VI discussed the statistical material necessary for the model. In this chapter the practical problems in applying the models are considered, and the empirical equations are estimated and discussed. The methods of estimating the equations are by two stage least squares for simultaneous systems and by ordinary least squares regression elsewhere. The system to be estimated for dairy, beef and sheep are similar with regard to inventory flow. For the beef herd the directional flow is



(In subscripts, / denotes time interval and t+i months from time t)

A flow diagram for the dairy herd has already been given in the "Introduction" to Chapter III. Essentially the difference between dairy, beef and sheep inventory flows is the age of new breeding stock and the age at slaughter.

Formulation of the Empirical Model (Method)

The transition from the theoretical to the empirical model is normally one of reducing the complexity of reality into managable form for the estimation of parameters. This is no easy task as a count of the various sources of revenue and cost which can be expected to influence the numbers of breeding stock reach over thirty. Some system of aggregating these variables without eliminating distinctly seperate variable influences and the logical incorporation of distributed lags is necessary. In developing the empirical model variables were not accepted into or rejected from the breeding stock model simply on statistical grounds. The procedure followed was that if the author was satisfied that a variable should be included on logical grounds, if it was not statistically significant then reasons for the lack of statistical proof were looked for. This resulted in the grouping of variables to reduce the degree of multicollinearity and a very full specification of the model in terms of variables included. The first part to be developed was the breeding stock model and once this was known the majority of variables influencing the grazing livestock system was known and these same variables (with in some cases the distributed lags adjusted) together with some extra variables could be used to explain the other stages of livestock production.

With regard to the store livestock price model the criterion used was that of reasonable statistical results, as full specification was impossible because some of the influences on price stem from global rather than national events.

General Features of the Production Equations

Time Lag in Response

Factors determining the time lag of response were discussed to some extent in Chapter III. The time taken to rear replacement stock being advanced as the main cause. In the case of dairy heifers their age at first calving is:-

Age in Months	Percent
< 24	6.93
24-30	55.44
30-36	32.83
>36	4.8

This calving distribution is based on the percentage distribution of age at first calving for Ayrshire cows and Friesian cows in England and Wales in 1966-67 (Survey of Cattle Management and Feeding Practices in England and Wales 1966-67, 1971). The percentage distribution for Ayrshire and Friesian cows respectively, were weighted according to the importance of each breed in the national dairy herd, combined and raised to 100% in order to compensate for the omission of less important breeds.

If the only technical factors causing a lag in the adjustment of the breeding herd through an inflow of heifers were the time taken to rear the replacements, the change in production level would be brought about by a weighted average of the numbers of heifer calves retained for breeding at different points in time, i.e.

$$H_t = \sigma_1 R_{t-21} + \sigma_2 R_{t-27} + \sigma_3 R_{t-33} + \sigma_4 R_{t-39}$$

where H_t is the number of heifers entering the breeding herd in time period t, and R_{t-i} is the number of heifer calves retained for breeding in time period t-i and entering the herd in time period t.

But

$$DH_t = DH_{t-1} + H_t - C_t$$

where C_t is the number of culls.

The number of culls from the dairy or the beef breeding herd are not seperately recorded in available statistics, however as the farmer can be expected to know in advance the cows he is going to cull from the age distribution and general performance of his cows, he will vary the inflow of heifers in order to replace the percentage of culls necessary in order to obtain his desired herd size. One may then postulate that

$$R_{t-i} = f\,(\text{revenue/cost})_{t-i} \qquad (7.1)$$

if there are no economic lags involved. Replacing R by P to represent profit, i.e. the relationship between revenue and costs, gives

$$DH^* = f(.0693P_{-21} + .5544P_{-27} + .3283P_{-33} + .048P_{-39}) \qquad (7.2)$$

where DH^* = desired level of the dairy herd

and the weighting factors are as detailed on the previous page.

The average lag for the initial desired level for the dairy herd is about 29 months. This gives time to extend buildings, improve drainage, or pastures through reseeding, or any other alterations that have to be made to the farm. The average of the lag for the desired level for the beef herd is about 24 months, which again gives enough time for farm improvements. The majority of ewe lambs enter the ewe flock at 18 months, but as few buildings are needed for sheep production, this also allows enough time for farm improvements if an increase in production is planned. Decision time could possibly add to the production lag but it is not going to change its basic shape. The lag distribution of the initial desired level of production is therefore equal to the age distribution when new breeding stock enters into the numbers of total breeding stock.

Numbers of breeding stock can not only be changed by altering the rate of inflow of new breeding stock, but also by altering the culling rate. Variations in the dairy herd size could be brought about in from 7 to 19 months by varying the rate of culling (assuming the cow being in milk for 10 months and that there is a 3 month period between calving and being mated again). Similar impressive reductions in the time lag needed to vary production exist for the beef cow herd and the ewe flock by assuming that production levels can be varied by altering the rates of culling. This lag is much too short to allow for much alteration in the stock carrying capacity of the farm. A switch from dairy production to beef production would be possible as the housing requirements are largely compatible; a switch from beef cows to dairy cows is less easy as specialised dairy equipment is needed; a switch from breeding ewes to breeding cows is virtually impossible, but a switch from breeding cows to breeding ewes very possible. There is in fact no economic justification for culling before age or disease has made the return from an animal uneconomical, unless the animal can be replaced by a more profitable alternative. When the alternative is replacement by another class of livestock production, the technical lag would be the production lag of the other class of livestock production. This possibility can be dealt with by a simultaneous system of equations for beef cows, dairy cows and breeding ewes as in the theoretical model, by assuming that the initial desired levels of production interract on each other so as to produce the final level of production.

These time lags in response apply to the time taken to change the numbers of breeding stock, the time taken to rear replacements, and through definition of the lag structure an equation for replacements reared can be translated into breeding stock retained at birth, simply by substituting unlagged variables for the lagged distribution of variables.

The Simultaneous System

In the empirical version of the transformation of equations 4.1 and 4.2 the actual numbers of beef cows, dairy cows and breeding ewes can be taken as the respective desired level of production for each breeding stock enterprise. Taking the theoretical model to its conclusion, cattle and sheep being fattened, being competitive with breeding livestock, ought also to be included. Stock being fattened are likely to bear a close approximation to numbers of breeding stock, so the simultaneous model can be reduced to the numbers of breeding stock.

Because of different time lags involved in the rearing of replacement stock for the beef breeding herd, the dairy breeding herd and the ewe flock, producer decision on changing the numbers of breeding stock not having the longest time lag has to be dependent on the numbers of breeding stock being reared having longer time lags. The dairy herd has the longest production period, therefore the producer can be expected to formulate an initial desired level of production for the dairy herd and later modify it in response to incentives to change the numbers of beef breeding cows and breeding ewes. The producer's initial desired level of production can be expected to impose a fairly rigid constraint on the upward limit to the size of the dairy herd, because it is then that he has to decide how many heifers to rear and also to set in progress plans for accommodating the extra breeding stock if an increase is planned. Some flexibility still remains. He can alter his rate of culling to some extent, or fatten up some of his intended additional breeding stock for slaughter. For ewes, as they have the shortest production period, their numbers have to be decided in the light of production targets already largely determined for dairy breeding cows and beef breeding cows.

Despite different lengths of production period, the end result is a competitive relationship between current numbers of beef cattle, dairy cattle and sheep. This can indeed be said to be self evident as the pasture can only support so many livestock units at any one time.

Revenue and Costs

In the theoretical model it was stated that the X_1 and X_2 variables used to represent revenue relative to cost would in reality represent vectors of revenues and costs. This is because there are many different sources of revenue and costs in agriculture in the United Kingdom, and it is usually impossible to express the revenue and costs for a product as one variable.

For the dairy herd total revenue consists of income from milk, income from calves and income from culled cows. There are many breeds of calves and cows and therefore many prices but these are highly correlated, therefore one common calf price and one common culled cow price can be used if adjusted by a fixed factor for each enterprise so as to represent more closely the income from livestock. For the dairy herd income from cows and calves can be further adjusted so as to give income from these sources expressed as income per gallon of milk. As milk yield per cow rises steadily over time, a further adjustment can be made to express income from cows and calves as the income per gallon of milk that can be expected to exist when the farmer's response to revenue and costs has worked its way through to herd size. This allows for improvements in technology which the farmer can be expected to be aware of. A method of making this adjustment is to divide cow and calf prices by MPR, where MPR is the fitted values of the equation

$$AMY = \underset{(14.7)}{535} + \underset{(3.8)}{47.2MPDL} + \underset{(9.3)}{4.95T} \qquad (7.3)$$

MPDL = lagged distribution of revenue/cost per gallon of milk (see variables p.92)

AMY = Average Milk Yield;

T = Time Trend

Numbers in brackets are student t statistics

$\bar{R}^2$ = .85

F statistic (2,20) = 65.19

Durbin-Watson statistic = 2.5

Number of Observations = 23 (June 1958 - June 1969)

The equation assumes merely that milk yield will improve with time, and with genetical improvements in cows due to the inflow of better quality heifers. The inflow of heifers is expected to vary according to the price of milk and variable cost.

In economic theory the marginal cost (MC) curve above the average variable cost (AVC) curve is the supply curve. The interaction of revenue (R) on MC gives the quantity Q. The marginal cost curve cannot be regarded as constant as it will move with any change in the cost of inputs. An increase in cost would move the MC curve to the left so that the optimum level of production would be reduced. As this is similar to a fall in R, R can be adjusted according to the position of the MC curve by deflating by variable costs. Variable costs are taken as being feed and fertiliser cost in the empirical model and are combined together in a fixed ratio. Because of the large amount of capital that farmers have borrowed (see theoretical model) and also to allow to some extent for the possibility of more attractive investment opportunities elsewhere, an interest charge equal to bank rate was added to variable costs. For U.K. agriculture as a whole feeding stuffs and fertiliser amounts to about 38% of total costs, (Chapter II section output) and consist of nearly all the variable costs in livestock production. For theoretical reasons outlined in the theoretical model a LOG transformation of the ratio revenue/variable costs was used.

In the beef herd model and the ewe flock model livestock prices and livestock subsidies can not be combined into one revenue variable. This is because there is a technical difference between them. The opportunity cost of increasing livestock production is to some extent the income that would be received for the potential breeding stock if they were marketed immediately, while subsidies are simply revenue. Breeding cattle subsidy consists of Hill Cow Subsidy, Cow subsidy, Calf Subsidy and Winter Keep Subsidy. As there are no essential differences between these, they were weighted in approximate accordance with average numbers of cattle receiving each and combined. The resultant variable was then deflated by variable costs. The theory behind this deflater is that the supply curve moves in response to subsidy as well as to costs. The position of the curve is therefore related to the ratio, subsidy/variable costs.

Breeding ewe subsidies consist of Hill Sheep Subsidy (proper), Upland Sheep Subsidy and Winter Keep Subsidy. These were combined on the same principle as the cattle subsidies, but wool price was also included as no essential difference between producers' response to wool price and ewe subsidies is likely to exist. The combined revenues were then deflated by a LOG transformation of variable costs, because it was felt that variable costs would have diminishing influence with rising cost, as ewe numbers can easily be adjusted to the number that the land can support without the aid of variable costs.

For the cow herd cow price and calf price were suitable weighted and combined into one variable. In addition as calf price represents the expectation of levels of future fat cattle price, and store lamb price the expectation of future levels of fat sheep price, these were expressed as a ratio, the lagged distribution being marginally shorter than that used for cattle prices alone. This equated with the time of decision on whether to rear replacements or to fatten livestock. The ratio expresses the desirability of fattening beef in terms of the opportunity cost of fattening sheep.

For the ewe flock store lamb price and ewe price were weighted and combined.

A large part of farmers' expenditure on expansion comes not from profits that can be tied to a particular commodity but from general grants and subsidies. These grants and subsidies are many and varied. Several of them aid farmers with their capital expenditure by paying a percentage of the cost; another give assistance for ploughing up old pasture; and another scheme enables payments to be made to small farmers for improving their business methods. Although these grants and subsidies should relate to the livestock sector, this data was not available, therefore data on the industry as a whole was used instead.

The number and changing nature of these grants and subsidies makes a drastic simplification necessary before they are entered into the model. If improvement grants alone were considered, it might seem possible to incorporate them into the model by using the percentage grant offered as a measure of the incentive to expand production. This is not however the case because the value of these grants are going to be much higher initially to the farmer when the farm's fixed equipment is likely to be in relatively poor condition. The approach used here was to enter into the model the benefit of these general grants and subsidies to the complete agricultural industry. The total benefit is of course the amount paid out by the government. No ideal lag exists for these grants and subsidies. The average lag used was nine months, which as improvements are made before the receipt of government grants, is reasonable. Those payments were deflated by an index of wholesale building material costs so as to keep the value of the grants in perspective. The average lag on the costs was 12 months, as costs are incurred before the improvements are finished.

Efficiency

A downward movement of the supply curve is allowed for in the theoretical model. Here the reasons for it are considered in more detail.

Economies of scale can be expected to exist in agriculture. The amalgamation of two farms for instance can reduce costs as explained in Chapter IV. Economies of scale are reflected in the financial data relating to Scottish farms (Scottish Agricultural Economics, 1968) for the year 1966/67. The results of several farming systems were as follows:-

TABLE 7.1

Gross Output per £100 Input

Standard Man Days	Dairy Farms	Rearing with Intensive Livestock	Hill Sheep
275-599	£94	£102	£115
600-1999	£104	£113	£116
> 2000	£113		£105

For each size group and type of farm TABLE 7.1 gives gross output for every £100 input, which includes farmer and wife labour. The table gives a fairly typical order of profitability of farms over the years. If "Rearing with Intensive Livestock" is taken as representing beef rearing farms, economies of scale are indicated for dairy farms and beef rearing farms but not for hill sheep farms.

These economies of scale can be interpreted in two different ways. It may be possible that some farmers are not reaching their desired level of production for instance because of difficulties of borrowing capital. This could mean unnecessarily high average total costs. Actual acreage (quality adjusted) seems a more likely reason for economies of scale. Increases in farm size can, however, only proceed gradually. This is because the development of larger farms depends on the amalgamation of holdings. Amalgamations can only proceed at the pace at which farmers retire, which is largely determined by age. This movement towards larger farms can therefore be taken as a gradual process over time.

There are other reasons for expecting the agricultural industry not to be in long term equilibrium. More efficient machines may be relatively cheaper than employed labour, and so reduce costs. The adoption of new technology by purchasing capital equipment is however a gradual process. If a farmer already has a machine which can perform a function adequately he has to balance the worth of the improvement in efficiency in a new machine as compared with his existing machine, against the additional capital needed. As most increases in efficiency in farm machinery are small and perhaps not fully appreciated at first, the replacement of old machinery by new more efficient machinery is likely to proceed at the pace at which existing machinery wears out. Totally new technology can also occur. Historical examples are the replacement of milking by hand by milking by machine. Such events do not occur overnight, however. The dissemmation of new practices is likely to spread from the farmers who are the leaders in adopting new methods, through to the least adventurous farmers. This takes time to say nothing about the problem of finding the capital. Similar considerations apply to farm buildings.

Often the farmer may not know the optimum level of production. The adoption of optimum use of fertilisers was for instance very slow. This can be expected as the farmer often has to experiment himself before he is satisfied as to the correct application. Fertiliser subsidies were introduced by the government in an attempt to speed up the process, but even today many farmers are using little or no fertiliser. Many farmers also do not make much use of the agricultural advisory service, but prefer their own methods, which are often rule of thumb, for finding the optimum level of production.

The breeding of improved livestock is also a process which takes time. About a quarter of a cow herd can be expected to be replaced each year. This continual replacement can be expected to result in a constant improvement in the quality of livestock.

Reasons for expecting a constant improvement over time in agricultural efficiency have been given. The list is not exhaustive but it gives good reasons for expecting a good correlation between improved efficiency with time. It may be mentioned that no less an authority than Her Majesty's government also takes the improvement in annual efficiency as a constant (Annual Review and Determination of Guarantees, Annual).

Weather

Weather is rather difficult to allow for in an econometric model, but it is important both in regard to crop growth and the level of incidence of some diseases. The main food for grazing livestock is grass, and its growth is highly dependent on temperature and moisture. Grass will not grow at a temperature much below 42°F and grows best when the level of moisture in the soil is near, or at, field capacity. No success was obtained by using measures of irrigation requirements during the growing season in equations. Using temperature proved more successful. The average temperatures for the months of January, February and March were used. The average of these temperatures for each country of the U.K. was then weighted by the average proportion of breeding ewes in each country and combined as weather was thought to influence sheep farming more than other grazing livestock. The basic theory behind this variable is that high temperatures indicate an early start to the growing season and a low likelihood of such diseases as "staggers" occuring.

It is perhaps hardly surprising that a measure of moisture deficiency proved of no practical use. This is because during the growing season the soil may suffer from drought one month and poaching of the soil by livestock due to the moisture of the soil being above field capacity the following month. Any average of moisture deficiency is therefore likely to be a very crude instrument indeed to represent weather. The average yield of hay as a measure of the weather is unsuitable as yield has changed unduly due to changes in technology.

The Empirical Model

Variable Symbols

Variables are stated as actual numbers at 4th June and 4th December where agricultural census material is used, for instance for cow and ewe numbers. Where animals are slaughtered or heifers are calving, these are given as a total for the six months up to but not including 1st June or 1st December. For prices the average of the six months up to 1st June or 1st December, is given. Subsidies are stated as the average known level of subsidy in each 6 month period with the exception of general grants and subsidies which are given as a total amount paid out by the government. Where variables are stated with a lag these will be denoted by subscripts. More information on the variables is contained in Chapter V and VI and the actual variables can be found in the statistical appendix.

Endogenous Variables

BCOWCAV	=	Estimated Beef Cows Calved (000)
BH	=	Beef Cow Herd (000)
BHEF	=	Estimated Beef Heifers Calved (000)
CALP	=	Average Calf Price (£ per head)
CALVES	=	Estimated Calves Born (000)
CAS	=	Estimated Calves that will eventually come forward to slaughter (000)
CASL	=	Calves Slaughtered(000)
COSL	=	Cows Slaughtered (000)
COWP	=	Average Fat Cow Price (£ per live cwt)
DCB	=	Estimated Dairy Calves Born
DH	=	Dairy Herd (000)
DHEF	=	Estimated Dairy Heifers Calving (000)
ECRB	=	Estimated Calves Retained for Breeding (000)
EF	=	Ewe Flock (000)
EFCSL	=	Average Number Of Steers and Heifers Available for Slaughter (000)
EFSL	=	Ewes Slaughtered (000)
EP	=	Average Fat Ewe Price (p per lb. est. dressed carcase weight)
FCSL	=	Fat Cattle Slaughtered (000)
LAMSL	=	Lambs Slaughtered (000)
MPR	=	Estimated Average Milk, Produced per Cow, for Sale (gallons)
OUTF	=	Outflow of Cows from Breeding Herds (000)
SSP	=	Store Lamb Price (£ per head)

Exogenous Variables

BC	=	Average Building Cost Index (1954 = 100)
CAEX	=	Calves Exported (000)
CEP	=	Cows Exported (000)
CFPI	=	Average Concentrate Feed Price Index (1954/55 - 1956/7 = 100)
CSUB	=	Average Cattle Subsidies (£ per cow)
D	=	Seasonal Dummy Variable (0 for June, 1 for December)
DI	=	National Disposable Income (£000)
FCAP	=	Average Fat Cattle Auction Price (1954/55 - 1956/57 = 100)
FERPI	=	Average Fertiliser Price Index (1954/55 - 1956/57 = 100)
G	=	General Grants and Subsidies (£ millions)
IE	=	Net Imports of Cattle (000)
INT	=	Bank Rate (percent)
PMP	=	Average Pool Milk Price Index (1936-1938 = 100)
SSUB	=	Average Sheep Subsidies (£ per ewe)
T	=	Time Trend (1959 = 1)
TEMP	=	Average Temperature, Jan-March ($^{\circ}$F)
WP	=	Average Wool Price (£ per ewe)

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PULL OUT

Construction of Variables

Revenues are combined according to their importance where similar influences by revenues are hypothesised. Costs are similarly combined. To allow for changes in cost certain revenue variables have been expressed as a ratio of cost. The revenue and cost variables are

$CATP = 2COWP + .7CALP$

$COWSUB = CSUB/((.8CFPI + .2FERPI)(1 + INT/100))$

$ES = (TEMP - 42^{o}F)$ at June $(42^{o}F - TEMP)$ for Dec. if $TEMP > 42^{o}F$, otherwise equals 0

$MPD = PMP/((.75CFPI + .25FERPI)(1 + INT/100))$

$SD = (LOG\ (SHSUB))D$

$SHSUB = (80SSUB + 5.8WP)/(LOG((.8CFPI + .2FERPI) \times (1 + INT/100)$

$SP = 4.44EP + 200SSP$

Construction of Distributed Lags

The coefficients on the revenue and cost variables represent the rate of adjustment in each period, the sum of the adjustments being equal to one. Logarithmic (LOG) transformations are made so as to represent the hypothesised correct shape of supply curve. More detailed explanations are given later in the chapter. The distributed lag variables are

$BSUBDL = LOG(.355COWSUB_{-3} + .476COWSUB_{-4} + .168COWSUB_{-5})$

$CATPDL = LOG(.355CATP_{-3} + .476CATP_{-4} + .168CATP_{-5})$

$CPSP = (.5CALP_{-3} + .5CALP_{-4})/(.5SSP_{-3} + .5SSP_{-4})$

$GDL = LOG(G_{-1}/(.5BC_{-1} + .5BC_{-2})$

$MPDL = .0693MPD_{-3} + .5544MPD_{-4} + .3283MPD_{-5} + .049MPD_{-6}$

$MPG_{-3} = ((14.9PMP_{-3}/300) + (45.1CALP_{-2} + 200COWP_{-3})/MPR^{*}/((.75CFPI + .25FERPI)(1 + INT/100)$

$IPGDL = LOG(.0693MPG_{-3} + .5544MPG_{-4} + .328MPG_{-5} + .049MPG_{-6})$

$SLAG = CFPI_{-1} - .5CFPI_{-3} - .5CFPI_{-4}$

$SPDL = LOG(.25SP_{-1} + .25SP_{-2} + .5SP_{-3})$

$SSUBDL = LOG(.25SHSUB_{-1} + .25SHSUB_{-2} + .5SHSUB_{-3})$

$WDL = .33TEMP + .33TEMP_{-1} + .34TEMP_{-2}$

* Fitted Values

Notes on Construction of Variables

1) CATP – assumes that for every 100 cows, 17 10cwt cows will be sold as culls. This gives a weighting factor of (17/100) x 10 = 1.7. For every 100 cows, 60 calves are assumed sold. This gives a weighting factor of (60/100) = .6. The weights are therefore in the ratio 2/.7.

2) COWSUB – CFPI and FERPI combined in ratio determined by average expenditure 1969/70 – 1971/72 in England and Wales for beef cattle (Agricultural Incomes in England and Wales, annual)

3) ES – see page 105

4) MPD – CFPI and FERPI weights determined as in COWSUB

5) SHSUB – assumes wool clip of 5.8lbs per ewe and that 80% of hill sheep producing wool will receive sheep subsidy. CFPI and FERPI weights determined as in COWSUB.

6) SP – assumes 44.4lbs is dressed carcase weight of ewes and that 10% of ewes are sold each year. This gives a weighting factor of 44.4/10 = 4.44 for EP. Lamb numbers sold were taken as being equal to ewe numbers in flock. This gives a weighting factor of 1 (multiplied by 100 in order to convert SSP to pence as in EP). In addition the weighting factor on SSP was doubled to allow for the greater influence this variable is likely to have on the farmers replacement policy. This gives a final weighting factor of 200.

Notes on Construction of Distributed Lags

1) Technical lag on beef cow breeding herd adjustment assumes that the average age of replacements is 24 months, and that all replacements take place between 21 and 33 months of age.

2) Technical lag on dairy cow breeding herd adjustment is as described on page 29.

3) Technical lag on ewe flock adjustment assumes that .25 of replacements are ewe lambs, and .75 are about 18 months old.

4) Technical lag on general grants and subsidies and building grants are as described on page 86.

5) Ratio of calf price to store sheep price lag is as described on page 85.

6) Weights used in SLAG are as described on page 105.

General Comments

In reality these weights will fluctuate from year to year and permanent changes may occur over time. Occasionally therefore these weights may have to be altered. It is difficult to give specific references as to the source of all weights used as they were often based on the weighting of evidence from a variety of sources together with years of practical farm experience.

The Breeding Stock Equations

The theoretical model transforms most easily into equations for breeding stock and the discussion of the empirical model relates also most closely to the breeding stock equations. The equations to be expected are:-

Beef Herd = f'(Dairy Herd, Ewe Flock, Beef Livestock Price*†, Beef Livestock Subsidy/Beef Variable Costs*†, General Grants and Subsidy/Building Cost*†, Weather*, Time Trend)

Dairy Herd = f''(Beef Herd, Ewe Flock, Revenue per gallon milk/variable cost per gallon of milk*†, General Grants and Subsidy/Building Cost*†, Weather, Time Trend)

Ewe Flock = f'''(Beef Herd, Dairy Herd, Sheep Livestock Subsidy/Sheep Variable Cost*†, General Grants and Subsidy/Building Cost*†, Weather, Time Trend)

* denotes a distributed lag and † a log transformation of data. All variables except the endogenous variables can be expected to have positive signs. In addition variables to represent season, or variables to represent competition between fattening and breeding stock may be necessary.

The estimated breeding stock equations are:-

$$\underset{(11.25)}{DH = 5451.46} + \underset{(6.73)}{314.781GDL} + \underset{(2.4)}{512.921IPGDL} + \underset{(7.09)}{26.4965WDL} \qquad (7.4)$$

$$- \underset{(3.12)}{69.9249CPSP} + \underset{(5.3)}{20.0203T} - \underset{(3.1)}{.560293BH} - \underset{(13.7)}{.0681009EF}$$

$\bar{R}^2 = .95$

Numbers in brackets are Student T Statistics

F-Statistic (7,15) = 65.89

Durbin-Watson Statistic = 2.48

Number of Observations = 23 **(June 1959 - June 1970)**

Sum of Squared Residuals = 3929.5

Standard Error of the Regression = 16.185

$$BH = 990.876 + 307.681BSUBDL - 191.101CPSP + 98.5517GDL \qquad (7.5)$$
$$(2.17) \quad (4.2) \quad (4.3) \quad (2.7)$$
$$+ 740.362CATPDL + 11.9686T - .249229DH - .0183481EF$$
$$(5.0) \quad (6.47) \quad (2.83) \quad (2.3)$$

$\bar{R}^2 = .99$

F-Statistic (7,15) = 297.109

Durbin-Watson Statistic = 1.74

Number of Observations = 23 (June 1959 - June 1970)

Sum of Squared Residuals = 2972.21

Standard Error of the Regression = 14.08

$$EF = -805.127D + 9883.34SSUBDL + 828.235SPDL \qquad (7.6)$$
$$(8.7) \quad (9.9) \quad (2.1)$$
$$+ 4522.81GDL - 4.97443BH - 3.31872DH$$
$$(11) \quad (9.1) \quad (4.2)$$

$\bar{R}^2 = .93$

F-Statistic (5,17) = 62.74

Durbin-Watson Statistic = 1.7

Number of Observations = 23 (June 1959 - June 1970)

Sum of Squared Residuals = 5420.46

Standard Error of the Regression = 178.564

The first stage calculations for equations 7.4 - 7.6 are

$$BH = -2945.72 - 29.0945D - 58.3039GDL + 140.844IPGDL$$
$$(1.97) \quad (2.32) \quad (0.789) \quad (0.643)$$
$$+ 332.179BSUBDL - 173.317CPSP + 486.717SPDL$$
$$(3.7) \quad (2.8) \quad (2.3)$$
$$- 158.443SSUBDL + 2.35761WDL + 675.934CATPDL$$
$$(0.74) \quad (0.56) \quad (3.5)$$
$$+ 10.01T$$
$$(2.27)$$

$\bar{R}^2$ = 0.99

F-Statistic (10,12) = 240.134

Durbin-Watson Statistic = 1.5

Number of Observations = 23 (June 1959 - June 1970)

Sum of Squared Residuals = 2064

Standard Error of the Regression = 13.1

$$DH = \underset{(2.3)}{4397.36} + \underset{(5.2)}{83.5242D} + \underset{(2.6)}{248.79GDL} - \underset{(0.14)}{39.677IPGDL}$$

$$+ \underset{(3.86)}{439.57BSUBDL} + \underset{(1.32)}{104.99CPSP} - \underset{(0.05)}{12.756SPDL} + \underset{(0.38)}{103.36SSUBDL}$$

$$+ \underset{(3.89)}{20.99WDL} - \underset{(1.75)}{428.52CATPDL} - \underset{(0.13)}{0.7695T}$$

$\bar{R}^2$ = 0.95

F-Statistic (10,12) = 43

Durbin-Watson Statistic = 2.62

Number of Observations = 23 (June 1959 - June 1970)

Sum of Squared Residuals = 3340

Standard Error of the Regression = 16.7

$$EF = \underset{(2.67)}{41230.1} - \underset{(5.23)}{674.18D} + \underset{(2.64)}{2008GDL} + \underset{(1.23)}{2771.61IPGDL}$$

$$- \underset{(7.02)}{6471.91BSUBDL} - \underset{(1.54)}{990.037CPSP} - \underset{(2.62)}{5609.37SPDL} + \underset{(0.88)}{1948.8SSUBDL}$$

$$- \underset{(0.074)}{3.2743WDL} + \underset{(0.74)}{1459.4CATPDL} + \underset{(3.03)}{137.7T}$$

$\bar{R}^2$ = 0.96

F-Statistic (10,12) = 56

Durbin-Watson Statistic = 2.7

Number of Observations = 23 (June 1959 - June 1970)

Sum of Squared Residuals = 219570

Standard Error of the Regression = 135.27

The first stage results are characterised by statistically insignificant values for Student T Statistics on many of the variables and also by many of the coefficients having wrong signs. By contrast the second stage least squares have variables that are statistically significant and with coefficients having the correct sign. There is little to choose between the levels of $\bar{R}^2$ achieved by first and second stage least squares. The results confirm the view that estimation by two stage least squares is preferable and these results are used in the model.

A feature is the omission of the T (improving efficiency) variable from the EF equation, because its inclusion could not be statistically substantiated. This can be expected in some cases where improving efficiency is occurring at a very slow rate. A sign that the system could have been extended to include further equations is the inclusion of the variable CPSP (calf price/store lamb price) in equations 7.4 and 7.5 to represent competition for resources from fattening cattle. Seasonal variation in the livestock numbers has also had to be allowed for in the case of EF in the form of the variable D, but a variable to represent weather (WDL) was only significant in equation 7.4. Apart from these differences the empirical estimated equations are similar to what can be expected.

The estimated coefficients are all of the correct sign. Although the composition of the coefficients are extremely complex as shown by equations 4.4 and 4.5, the difference in magnitude of the coefficients on DH and BH in the EF equation compared with the coefficients on EF in the DH and BH equations indicates that the influence of breeding ewe numbers on the numbers of beef and dairy cows is much smaller than vice versa. This is to be expected from the difference in production lags (Chapter VII p. 81). The influence of BH on DH appears also to be greater than vice versa. This is the opposite of what could be expected if production lags alone were considered but not surprising because of the greater ease of changing from dairy to beef farming than from beef to dairy because of the more elaborate equipment necessary for dairying.

The proportion of the total variance explained is high in all three equations, the lowest being 93%. This is important because these equations are the "key stones" of the production system. The estimated coefficients are all significant at the 95% probability level and statistical significance of the equations as tested by the F-Statistic are above the 99.9% probability level.

Heifers Calving

It is necessary to forecast the number of heifers calving for the first time, both to allow for retentions when calculating the numbers of steers and heifers that can come forward to slaughter, and for forecasting the number of cull cows that will come forward to slaughter.

It is extraordinarily difficult to represent the production stages taken by the farmer in deciding on the number of heifers he wants calving for the first time. Basically speaking the decisions made by the farmer are exactly the same as represented in the beef and dairy herd models, but with the essential difference that the farmer has to decide how many cows to cull and replace by heifer inflow.

Many reasons exist for cows being culled. The farmer may selectively cull dairy cows in the first or second lactation because of low milk yield or low milk quality. He may have slipped from being a winter milk producer to being a summer milk producer through having a longer than a twelve monthly calving interval. In such a case he may cull selectively on the basis of calving dates, so as to regain his position as a winter producer. Dairy cows increase their milk yield up to about their 6th lactation (Unpublished Ph.D thesis, P. Street, p.127) but the average herd life varies from about 2.5 lactations for Poll Fresians to 4.9 lactations for Shorthorns (P. Street, p.164). If sufficiently detailed slaughter statistics were available and statistics on the age distribution of cows in the dairy herd at the national level, then it would be possible to estimate probabilities of a cow being slaughtered for different rates of change in herd size. Similarly this could be done for beef cows.

Variations in heifer numbers in order to change herd size will depend on the farmer's initial desired level of production as in the beef herd and dairy herd models. The equation to explain heifer inflow would therefore take the form

Beef heifers = f (BR/C$^{*}_{t}$, probability of culling at specific ages)

Dairy heifers = f (DR/C$^{*}_{t}$, probability of culling at specific ages)

where BR/C and DR/C are the respective revenue/cost variables included in the equations for the beef and dairy cow equations. A competitive relationship between beef and dairy heifers can also be expected to exist, though this relationship is likely to be largely accounted for by the variable, probability of culling at specific ages, as the probability has to be weighted by herd size. In practise this variable cannot be estimated and has to be represented by heifers entering the herd in a previous period.

The estimated equations are:-

$$DHEF = \underset{(39)}{84.9232MPDL} + \underset{(27.6)}{263.24D} \qquad (7.7)$$

$\bar{R}^2$ = .98

F-Statistic (1,18) = 743.082

Durbin-Watson Statistic = 1.41

Number of Observations = 20 **(Dec., 1960 - June 1970)**

Sum of Squared Residuals = 8239.73

Standard Error of the Regression = 21.39

$$BHEF = - \underset{(7.48)}{25.44D} + \underset{(5.8)}{98.658CATPDL} - \underset{(2.8)}{45.5976CATPDL_{-2}} + \underset{(3.08)}{31.3BSUBDL} \qquad (7.8)$$

$\bar{R}^2$ = .84

F-Statistic (3,16) = 34.45

Durbin-Watson Statistic = 1.9

Number of Observations = 20 **(Dec., 1960 - June 1970)**

Sum of Squared Residuals = 917

Standard Error of the Regression = 7.57

Very few of the variables included in the Beef Cow Herd and the Dairy Cow Herd proved statistically significant in the heifer equations. This is not surprising because culling policies could not be properly incorporated in the equations. To some extent the age distribution of the beef herd is allowed for in the beef heifer model by entering the lagged livestock price distribution twice, one of which is the normal lag. This shows to some extent if the age distribution is biased towards young cows or old cows. In the dairy heifer model because of a singular lack of variation in the numbers of dairy heifers entering the dairy herd, it was not possible to allow for the age distribution as a factor in determining the number of dairy cow replacements.

No success was had with trying to prove competitive relationships, however this is not an inconsistency. In all probability the competitive relationship comes about by variations in herd size caused by variations in culling. This is because heifers are in an advanced state of being reared before the farmer has to make the final decision on whether to allocate his grazing to breeding ewes or breeding cows. His decisions already made only allow for limited flexibility. As heifer replacements should have better breeding than his existing breeding herd it is probable that he will increase culling if a decrease in herd size is required. If an increase in herd size is required then the only possible method is to reduce culling. Any variations on heifer inflow due to competitive relationships can therefore only be very small.

Statistically the coefficients are satisfactory, all being highly statistically significant. With regard to yielding a satisfactory explanation of heifers calving, equation 7.7 is superior to equation 7.8 in terms of variables included but lower in terms of $\bar{R}^2$. This is probably, however, due to the lack of movement in the numbers of heifers calving over the sample period.

Estimates of Calves Retained for Breeding

In equation (7.1) it is postulated that

$$R_{t-i} = f(\text{revenue/cost})_{t-i}$$

where R is the number of calves retained for breeding. This is the equational relationship required to explain the number of heifer calves retained for breeding. Unfortunately, however, the actual number of calves retained for **breeding** is unknown. There is a way around this difficulty, because the coefficients of this equation have already been estimated (equations 7.7 and 7.8). These equations differ only in that a technical time lag has been incorporated in order to allow for the time required to rear the heifers retained for breeding. If this technical lag is removed the sum of the right hand sides of equations 7.7 and 7.8 is then an estimate of heifer calves retained for breeding, i.e. BSUBDL is COWSUB entered with a technical lag. In order to remove the technical lag COWSUB is substituted for BSUBDL. Carrying out this procedure on all variables in equations 7.7 and 7.8 and retaining the estimated coefficients gives the equation

$$\text{ECRB} = 119 + 84.9\text{MPD} + 98.658\text{LOG(CATP)} - 45.5970\ \text{LOG}(\text{CATP}_{-2}) + 31.3\ \text{LOG(COWSUB)} \qquad (7.9)$$

An average value of the dummy variable D in equation 7.7 and 7.8 was taken.

Estimate of Calves Born

Calves born form the first part of the production chain after the numbers of breeding cows, i.e.

$$\text{calves born}_t = f(\text{Beef cows}_{t-1}, \text{Dairy cows}_{t-1})$$

The numbers born were estimated by summing the numbers of calves under 6 months, the number of calves exported during the last 6 months and the number of calves slaughtered during the last 6 months. As some of these calves slaughtered would have died in any case a degree of error exists in this estimate. The above explanatory relationship can be estimated with seperate coefficients for each half year by entering the beef and dairy cows twice, one of which is multiplied by a half yearly dummy variable, and the other by a half yearly dummy variable lagged one period.

This gives

$$CALVES = f((BH_{-1} \times D) + (BH_{-1} \times D_{-1}) + (DH_{-1} \times D) + (DH_{-1} \times D_{-1}) + CASL)$$

CASL is entered to allow for the degree of error that exists in the estimate of calves born, i.e. some of the calves slaughtered would have died.

This equation proved not statistically significant in some of the variables probably due to multicollinearity. One approach to this problem is to constrain some of the coefficients. In order to do this advantage was taken of the fact that those beef cows due to calf in the period 4th December - 4th June can be taken as those cows in calf but not in milk at 4th December, together with those beef heifers entering the beef cow herd in the period 4th December - 4th June. Those cows that have calved in the period 4th June - 4th December can be taken as being those cows in milk at 4th December. The equation

$$BCOWCAV = f(BH_{-1} \times D) + (BH_{-1} \times D_{-1})$$

was then estimated. The estimated equation is

$$BCOWCAV = \underset{(78.7)}{.409246}(BH_{-1} \times D) + \underset{(137.5)}{.683072}(BH_{-1} \times D_{-1}) \qquad (7.10)$$

$\bar{R}^2 = .99$

F-Statistic (1,21) = 1867

Durbin-Watson Statistic = 2.3

Number of Observations = 23 (Dec., 1959 - Dec., 1970)

Sum of Squared Residuals = 7112

Standard Error of the Regression = 18.4

The coefficients show that most of the cows have calved in the period

4th December - 4th June.

Constraining the seasonal pattern of beef cow calvings to the ratio estimated above, the following equation was estimated:

$$CALVES = \int((.409246(BH_{-1} \times D) + .683072(BH_{-1} \times D_{-1}) + (DH_{-1} \times D) + (DH_{-1} \times D_{-1}) + CASL))$$

This equation was successfully estimated, the result being

$$CALVES = \underset{(2.75)}{.558228}(.409246(BH_{-1} \times D) + .683072(BH_{-1} \times D_{-1})) + \underset{(11.3)}{.449220}(DH_{-1} \times D) + \underset{(7.72)}{.449932}(DH_{-1} \times D_{-1}) + \underset{(1.85)}{.352564}CASL \qquad (7.11)$$

$\bar{R}^2 = .89$

F-Statistic (3,11) = 41.65

Durbin-Watson Statistic = 2.3

Number of Observations = 15 (June 1965 - June 1972)

Sum of Squared Residuals = 18315

Standard Error of the Regression = 40.80

Both equations give good results statistically except for CASL being only significant at the 90% probability level. Attempts to bring heifers calving for the first time more into equation 7.11 were not successful due probably to interrelations between heifers calving and herd size. This omission of heifers calving from equation 7.11, together with some inevitable degree of double counting of cows when estimating BCOWCAV from beef cows dry and in milk is one reason for the erroneous impression that a higher proportion of dairy cows calf each year than is the case with beef cows. The rest of the explanation is probably due to the increasing calf price (equation 7.13) as this decreases the estimate of calves born because the national mortality rate will be higher (i.e. if a calf is slaughtered it is included in the variable CALVES, but if it is retained but dies it is not) and the increase in the size of the variable BH due also partly to an increase in calf price (equation 7.5), i.e. mortality rates and BH are correlated.

Calves Slaughtered

It has long been the case that only dairy calves are likely to be slaughtered and not reared because only they are of dubious quality for beef production. This view has, however, been rapidly changing. Now some dairy breeds are considered as dual purpose. As calves from the dairy herd are not seperately distinguished from calves from the beef herd in available statistics, an estimate of the number of dairy calves born (DCB) was obtained from equation 7.11 i.e.

$$DCB = .44922(DH_{-1} \times D) + .449932(DH_{-1} \times D_{-1}) \qquad (7.12)$$

Calves retained either have to be reared for breeding or fattened for beef production. If the farmer has decided that he wishes to increase his dairy herd, more dairy type bulls will be used, which means that calves will be less suitable for fattening than otherwise. This makes the effect of retaining more calves for breeding uncertain with regard to total calves retained as the negative effect on calves retained for fattening could outweigh the positive effect of extra calves retained for breeding. Numbers of calves retained for fattening are likely to be largely influenced by demand as measured by the price of rearing calves, but prices for veal calves could have an opposing effect. Competition for resources on the dairy farm as measured by the size of the dairy herd may also influence the number of calves slaughtered.

The expected equation is

Proportion of Dairy Calves Slaughtered = f (rearing calf price, veal calf price, dairy herd, dairy production incentives f)

The estimated equation is

$$\underset{}{CASL/DCB} = \underset{(4.82)}{-1.24088} + \underset{(3.44)}{.033171D} + \underset{(4.063)}{.000330281DH} + \underset{(14.5)}{7.25502(1/CALP)} \qquad (7.13)$$

$\bar{R}^2$ = .94

F-Statistic (3,14) = 89.4

Durbin-Watson Statistic = 2.21

Number of Observations = 18 **(Dec., 1961 - June 1970)**

Sum of Squared Residuals = .0032

Standard Error of the Regression = .015

The proportion of dairy calves (numbers of dairy calves obtained from the equation explaining the numbers of calves born) slaughtered are explained in terms of numbers of dairy cows and the reciprocal of rearing calf price. The reciprocal is used because there is an asymptotic limit to the number of calves that can be retained. No statistical evidence of incentives to retain calves for breeding, or the price of veal calves influencing slaughter rates was found.

A high proportion of the total variance is explained by the equation, and with the exception of the variable D which allows for seasonal changes in slaughter rates, the coefficients are significant at the 99% probability level.

Export of Calves

No attempt has been made to explain the numbers of calves exported, because the determining factor in the past has been political considerations.

Steers and Heifers Slaughtered

Steers and heifers slaughtered form the end of the production line for calves fattened for slaughter. These calves are taken as being the estimated calves born minus calves retained for breeding.

Calves fattened for slaughter have to come forward to slaughter eventually, the question requiring answering is in regard to the time lag between a calf's birth and when it is slaughtered as fatstock. Cattle returned in the agricultural censuses are recorded in the following age groups:- 0 - 6 months

6 - 12 months

12 - 24 months

$>$ 24 months

Using these statistics forecasting of the numbers of livestock slaughtered at different age groups could be attempted, but econometrics applied to this approach is impossible at present because of a shortage of degrees of freedom. Instead it is proposed to explain variations in the proportion of the average number of animals available for slaughter that are in fact slaughtered. i.e.

$$EFCSL = .25CAS_{-2} + .5CAS_{-3} + .25CAS_{-4} + IE \quad \text{where} \qquad (7.14)$$

$$CAS = CALVES - ECRB - CASL - CAEX \qquad (7.15)$$

This assumes half the cattle are slaughtered aged 18-24 months old, a quarter are slaughtered at ages 12 to 18 months old and 24-30 months old, respectively. Figures for Scotland for 1964/65 to 1968/69 (Scottish Agricultural Economics, 1970) put the weights at .1, .5 and .4 for increasing age of slaughter. These have been adjusted here so as to allow for the earlier slaughtering of cattle in England and Wales, as a higher percentage of these are animals from the dairy herd.

Variations in the relative price of calves and the expected price of fat cattle could influence feeding methods and therefore slaughter age. As the theoretical model for store stock price presupposes that store stock price is a function of expected fat stock price, the relationship between calf price and expected fatstock price is therefore theoretically a constant, (see equation 7.21), so that variation in slaughter rates from this influence can be disregarded. (Entry into the E.E.C represents a special but not recurring case). Feeding methods are, however, likely to change in response to changes in the price of concentrate feed. An increase in the price of concentrate feed cost can be expected to result in a longer fattening period so that beef that would otherwise have come forward in the present period for slaughter comes forward instead in a future period. Variations in slaughter rates will therefore depend on the difference between present and past concentrate feed costs. If it is assumed that no concentrate feed is fed to those cattle slaughtered at over two years of age and the amounts of concentrate feed fed to those cattle slaughtered at 12-18 months and 18-24 months are in the ratio 2:1, assuming that the farmer keeps six months feed in store, we have, using the weights in (7.14) and the ratio of importance of concentrate feed in the diet,

$$\text{Cost of Conc. up to slaughter} = .5(.33(FP_{-9} + FP_{-15} + FP_{-21}) + .25(.66(FP_{-9} + FP_{-15})$$

where FP represents feed price and the subscripts represented average time in months. This assumes that the same amount of concentrate is fed over the life of the animal. The difference between (Cost of Concentrate up to slaughter) and (Cost of Concentrate up to slaughter)$_{-6}$ was then used as a variable in the model. This gives 0.33(FP_{-9} minus $.5FP_{-21}$ minus $.5FP_{-27}$). In fact while reality is somewhat more complicated, attempts to allow for it made no significant difference in the form of the variable obtained, and simplicity has decided merits.

An earlier than normal growing season can be expected to increase the numbers of fat cattle coming forward to slaughter during the period 1st December-1st June, and consequently decrease the number coming forward in the period 1st June-1st December. As grass growth commences at approximately 42°F, an earlier growing season can be taken as being conditional upon the average temperature in the period 1st January to 1st April being above 42°F. In such cases the difference from 42°F was entered into the equation positively for those cattle coming forward to slaughter in the period 1st December-1st June and negatively for those cattle coming forward to slaughter in the following period 1st June-1st December.

The expected equation is therefore

Fat Cattle Slaughtered/Average cattle number available for slaughter = f (feed price, weather)

with the possibility of a seasonal dummy variable also being necessary.

The estimated equation is

$$FCSL/EFCSL = \underset{(113)}{1.03331} + \underset{(6.05)}{.0774589D} - \underset{(7.9)}{.00691927SLAG} + \underset{(5.93)}{.109609ES} \qquad (7.16)$$

$\bar{R}^2 = .95$

F-Statistic (3,7) = 60.98

Durbin-Watson Statistic = 1.8

Number of Observations = 11 (June 1967 - June 1972)

Sum of Squared Residuals = .0024

Standard Error of the Regression = .0187

The number of observations are rather few in this equation because of the comparitively short time period over which statistics have been available on steers and heifers slaughtered. Nevertheless the equation is well established statistically, the coefficients being extremely significant (>99.9% probability level) and the level of $\bar{R}^2$ being .95.

Cows Slaughtered

Various reasons for culling cows were given in relation to the equations on numbers of heifers calving. Because of too many unknown values it was found not possible to give a very full econometric explanation for numbers of cows culled. As, however, the outflow of cows from the breeding herds is equal to inflow of heifers minus net increase in breeding herd size i.e.

$$OUTF = (BHEF + DHEF) - (\Delta DH + \Delta BH)$$

This identity can be used to explain the numbers of cows coming forward to slaughter, but as part of the outflow can be attributed to mortality and as not all cows will be slaughtered in the period in which they are culled, outflow adjusted for exports will not be equal to, but will be a function of the outflow of cows from the herd. To allow for seasonality of slaughtering a seasonal dummy variable can be entered into the equation.

The expected equation is

Cows slaughtered = f (outflow of cows from herd minus exports)

and the estimated equation is

$$COSL = \underset{(7.37)}{94.4961D_{-1}} + \underset{(44.3)}{.7360540UTF} \qquad (7.17)$$

To correct for autocorrelation the variables in this equation were transformed by RHO = -0.40774 (i.e. each variable has had 0.40774 times its value in the previous period added to its present value). RHO was estimated from one iteration of the Cochrane-Orcutt Iterative Technique (Cochrane, D., and Orcutt, G.H., 1949).

$\bar{R}^2$ = .82

F-Statistic (1,16) = 78.4

Durbin-Watson Statistic = 2.1

Number of Observations = 18 **(Dec., 1961 - June 1970)**

Sum of Squared Residuals = 5121

Standard Error of the Regression = 17.89

Equation 7.17 is not very successful in terms of $\bar{R}^2$ due probably to the time between culling and slaughter being largely random. The coefficients, however, are highly statistically significant.

Lambs Slaughtered

For both lambs and ewes slaughtered, a less comprehensive inventory approach has to be adopted than was the case for cattle slaughtered. This is because of insufficiently detailed statistical data being available. Instead of the number of lambs retained for breeding being subtracted from the total number of lambs so as to give the potential number for slaughter, which is the equivalent of the method used for cattle slaughtered, an equation containing both variables responsible for numbers of lambs born and ewe lambs retained for breeding has to be established to explain the number of lambs coming forward to slaughter.

The largest influence on the number of lambs born is naturally the number of breeding ewes. Those lambs of suitable age for slaughter in the 6 monthly period 1st June to 30th November can with high probability be expected to have been born from ewes contained in the breeding flock at 4th June, and those lambs of suitable age for slaughter in the 6 monthly period 1st December to 31st May can be expected to have been born from ewes contained in the breeding flock at 4th December. A number of the ewes in the breeding flock at these periods can be expected to have produced lambs for slaughter in the previous period, but assuming reasonable constancy of the proportion of ewes in the breeding flock that produce lambs that came forward to slaughter in the succeeding period, the above relationships can be used to largely explain the number of lambs of suitable age for slaughter occurring in each 6 monthly period.

Another factor involved in determining the number of lambs of suitable age for slaughter is variations in weather. In a bad year a hill farmer because of high mortality among both ewes and lambs alike may be hard pressed to even find enough replacements to maintain his ewe flock. The temperature over the period January-March is the important factor here, though weather combinations may interact to make more or less serious extremely low temperatures.

The equation can be expected to take the form

$$\text{Labs Slaughtered} = f\,(\text{Ewe Flock}_{-1},\ \text{temp Jan-March}^{*},\ \text{revenue/cost}^{*})$$

where revenue/cost represents those variables included in the Ewe Flock equation, but adjusted appropriately for time lag. A seasonal dummy variable could also be necessary. The estimated equation is

$$\text{LAMSL} = \underset{(4.8)}{-10910.5}D_{-1} + \underset{(4.4)}{.685558}EF_{-1} - \underset{(3.87)}{2712.13}SD + \underset{(4.66)}{158.757}TEMP \qquad (7.18)$$

$\bar{R}^2 = .94$

F-Statistic (3,15) = 91.99

Durbin-Watson Statistic = 2.4

Number of Observations = 19 **(June 1961 - June 1970)**

Sum of Squared Residuals = 1619530

Standard Error of the Regression = 328.5

Because of difficulties in allowing for the age distribution of ewes, interdependence between variables responsible for the number of lambs of a suitable age for slaughter and those variables responsible for the number of lambs retained for breeding and also to some extent the lesser importance of the numbers of lambs retained for breeding, a less complete description of the factors involved in determining the numbers of lambs retained for breeding is given in this equation than was given in the equation explaining the size of ewe flock.

Ewe Flock can be taken as giving a simple approximation to the number of replacement breeding stock needed to maintain the size of the ewe flock. The accuracy of this approximation depends on the constancy of the age distribution.

The importance of sheep subsidies was established. As selection of ewe lambs for breeding generally takes place in June and affects only the number of lambs coming forward to slaughter in the period June-December this variable was set to zero for the period December-June.

Other variables shown to be important in determining the size of the ewe flock in equation 7.6 and therefore of importance in determining variabion in retention of new breeding stock for other than replacement of stock reasons were not significant. The reason for the non statistical significance of lamb price can be due to price not being wholly independent of lamb supply which is in fact largely dependent on a variable already included in the equation, that of ewe flock size. Attempts to include other variables determining lamb price such as national disposable income met with no success. This could be due to these factors influencing livestock prices in general so that the competitive position of sheep is not in fact influenced.

As mentioned there are other influences on the numbers of ewe lambs retained for breeding, but because of statistical difficulties already outlined they have not proved statistically significant in this equation. The estimated equation is, however, highly successful with regard to the statistical tests.

Ewes Slaughtered

The greater importance of the age distribution of the ewe flock in explaining the numbers of ewes slaughtered than in explaining the numbers of lambs slaughtered enables a more complete specification of this aspect of culling. As the single greatest influence on changes in ewe flock size can be expected to be the increasing competitiveness of beef cows, the size of the beef cow herd together with the size of ewe flock gives a good indication of the age distribution of the ewe flock. The size of the dairy herd ought also to impart a similar influence.

If ewes are not showing a profit, then they should be culled. Profit can be expected to vary in response to sheep price, sheep subsidies, variable costs and general grants and subsidies. Because of considerations outlined in the previous equation lamb and ewe prices were again omitted. Sheep subsidies, variable costs and general grants and subsidies have however been included.

The expected equation takes the form

$$\text{Ewes Slaughtered} = f\left(\text{Ewe Flock}_{-1},\ \text{Beef Herd}_{-1},\ \text{Dairy Herd}_{-1},\ \text{Revenue/Cost}^{\dagger}\right)$$

where Revenue/Cost are those revenues and costs contained in equation 7.6 but without the lag distribution.

The estimated equation is

$$EFSL = \underset{(7.27)}{-2482.76} + \underset{(7.70)}{.150695}EF_{-1} + \underset{(1.98)}{.454383}BH_{-1} \qquad (7.19)$$
$$\underset{(2.9)}{-615.211}GDL_{-1} - \underset{(2.18)}{22.48}SHSUB_{-2}$$

$\bar{R}^2 = .82$

F-Statistic (4.14) = 22

Durbin-Watson Statistic = 1.72

Number of Observations = 19 **(June 1961 - June 1970)**

Sum of Squared Residuals = 40851

Standard Error of the Regression = 54.01

The influence of the dairy herd was not statistically proved but the influence can be expected to exist as the dairy herd can be expected to have a similar influence to that of the beef herd. Revenue and cost is well represented in this equation as sheep prices can be expected to be largely a function of EF_{-1}.

Statistically the coefficients are of the correct sign and are all significant at the 95% probability level except for the coefficient on BH_{-1} which falls just outside this level. The level of $\bar{R}^2$ is comparatively low as was also the case for the equation explaining cows slaughtered. This indicates that slaughtering is difficult to explain with the available statistics.

Lamb Price

In order to estimate an equation for lamb price the theoretical store livestock price model has to be expressed in such terms that the model can be empirically estimated.

In the translation of the theoretical model into empirical terms, the lamb fatteners expectation of the price that he will receive for fat lambs can be expected to partly depend on the present and past levels of national disposable income. (This is likely to be observed in reality through general price levels). Possibly to some extent the price he expects fat cattle to be fetching could also influence his expectations. Fattening costs is likely to be of little importance as purchased feed is not important as an input. Supply of store lambs to the market will be an important element in the fatteners expectations. Predetermined production can be represented by the size of ewe flock lagged one period. The breeding farmers demand for lambs to retain as breeding stock can be expected to be influenced by sheep subsidies and general grants and subsidies.

The empirical translation of equation 4.18 can therefore be expected to be

$$\text{Store Lamb Price} = f(\text{National Disposable Income}_{-1}, \text{Ewe Flock}_{-1}, \text{General Grants and Subsidies}^{*\dagger}, \text{Store Lamb Price}_{-1}, \text{Fat Cattle Price}, \text{Sheep Subsidies})$$

with a dummy variable for seasonality probable being necessary. The estimated equation is

$$\begin{aligned} SSB = {} & 5.91062 + .0001237DI_{-1} - .0001936EF_{-1} \\ & (3.2) \qquad (3) \qquad\qquad (2.36) \\ & + 1.07527GDL + .857358D_{-1} + .533648SSP_{-1} \\ & \quad (2.63) \qquad\quad (5.15) \qquad\quad (3.1) \end{aligned} \qquad (7.20)$$

$\bar{R}^2 = .92$

F-Statistic $(5,16) = 50.33$

The Durbin-Watson Statistic has not been given, for as detailed in page 26 this test is unsuitable for auto regressive equations.

Number of Observations = 22 (Dec., 1959 - June 1970)

Sum of Squared Residuals = 0.37

Standard Error of the Regression = .156

Although it was supposed that competition from other grazing livestock need not be taken account of due to the inclusion of ewe flock in the equation, attempts were made to include this factor further in the equation, but no statistical proof of its applicability could be found, nor that of fat cattle price or sheep subsidies.

With regard to the statistical estimates the coefficients are of the correct sign, the coefficients are significant at levels greater than the 95% probability level and the level of $\bar{R}^2$ is .92. Statistically then the equation is satisfactory. About half of the producers expectations come from current influences on price and the remainder comes from historical influences on price.

Calf Price

The model for calf price is also based on the theoretical store livestock price model. It is hypothesised that the farmer who fattens store cattle bases his expectation of fat cattle price partly on present and past levels of fat cattle price (fat cattle price in the E.E.C. can be accepted as given as it is controlled by various measures).

The farmer can be expected to allow for changes in feed price in arriving at the price which he is prepared to pay for a calf. Supply has not traditionally been an important factor as the supply of calves have exceeded the number required for fattening but price of veal (many calves have been slaughtered for veal) could be a factor.

The expected equation is

Calf Price = (Fat Cattle Price, Feed Price, Price of Veal)

and the estimated equation (insignificant variables excluded) is

$$CALP = .091196FCAP + .4258CALP_{-1} \qquad (7.21)$$
$$\qquad\quad (4.9) \qquad\qquad (3.5)$$

$\bar{R}^2 = .91$

F-Statistic (1,20) = 214

Number of Observations = 22 (Dec., 1959 - June 1970)

Sum of Squared Residuals = 14.8

Standard Error of the Regression = .86

The Durbin-Watson Statistic has not been given, for as detailed in page 26 this test is unsuitable for auto regressive equations.

Feed price proved not statistically significant as did veal price though in practice these can be expected to have some influence. The estimated equation gives a good statistical result.

Fat Cow Price

The price of fat cows is expected to be closely related to the price of fat steers and heifers. The estimated equation is

$$COWP = .0457417FCAP \qquad (7.22)$$
$$\qquad (62.6)$$

$\bar{R}^2 = .92$

Durbin-Watson Statistic = 1.9

Number of Observations = 21 (June 1960 - June 1970)

Sum of Squared Residuals = 1.27

Standard Error of the Regression = .253

This equation was autocorrelated i.e. the residuals were not independent. To correct for this the variables in the equation have been transformed by RHO = 0.39589 (i.e. each variable has had deducted its value in the previous period times 0.39589) where RHO was estimated from one iteration of the Cochrane-Orcutt Iterative Technique (Cochrane, D., and Orcutt, G.H., 1949).

Although extremely simple, equation 7.22 gives a very good statistical result.

Fat Ewe Price

Fat Ewe price can be expected to be related to its own supply, national disposable income and sheep subsidies as they give an indication of the farmers own demand for ewes for breeding stock, and probably other livestock prices.

The expected equation is

$$\text{Ewe Price} = f\,(\text{ewes slaughtered, National Disposable Income}_{-1}, \text{Sheep Subsidies, Other Livestock Prices})$$

The estimated equation is

$$\underset{(6.1)}{EP = -00922EFSL} + \underset{(4.8)}{.000515DI_{-1}} + \underset{(4.45)}{.24206SHSUB} \qquad (7.23)$$

$\bar{R}^2 = .83$

F-Statistic (2,16) = 44.58

Number of Observations = 19 **(June 1961 - June 1970)**

Durbin-Watson Statistic = 1.7

Sum of Squared Residuals = 6.65

Standard Error of the Regression = .644

Other livestock prices (Fat Cattle and store lamb prices) were included but proved not statistically significant.

The level of $\bar{R}^2$ is fairly low in this equation but the estimated coefficients are all very highly significant. Meat prices can be expected to be determined partly by world influences so the result obtained by "national" variables only are very good.

Conclusion

Within the limits of the research field chosen the estimated equations are satisfactory. Some of the prices, however, could probably be better explained at the world level while culling rates could probably be better explained at the micro level because of the possibility of obtaining information from the farmer on the age distribution of the breeding stock. Longer time series should have been preferred for dairy heifers calving because of the lack of variation in the numbers. With increasing observations and better statistical data becoming available more detailed equations should be possible in some instances, but not in the "key stone" equations, the equations for dairy herd, beef breeding herd and ewe flock as these are fully developed in terms of variables and are statistically satisfactory.

CHAPTER VIII

THE USE OF THE MODEL FOR FORECASTING

Introduction

The model was used for forecasting over a historical period immediately following the sample period in order to test its performance. The forecasting consisted in generating values for the endogenous variables from the equations, the equations being arranged in such an order as to reflect the order of events in reality, and the generated values being fed back recursively into the other equations of the system. Actual values of exogenous variables were used.

Two different forecasting exercises were carried out. In the one approach the time period from which the predictions were made was moved forward so as to be constantly six months behind the forecast. In this way a series of semi annual forecasts were made from the 'present time'. In the other approach the base period for the predictions was held constant so as to give consecutive predictions of 6, 12, 18, 24 and 30 months ahead. The difference is that more variables are endogenous in the latter approach, due to the length of the production lags incorporated into the equations, because when the forecast length becomes longer than the production lag, variables fed back recursively into the other equations influence the forecasts.

Because the estimated rates of producer response contained in the equations can only be regarded as being valid within the physical constraints on the system, such as the maximum possible number of new breeding stock, to avoid making forecasts which are physically impossible account has been taken of these limits to producer response.

Constraints

Although diminishing returns to inputs has been hypothesised in the equations, and the influence of competitive enterprises taken into consideration, a number of more definite constraints exist which have not been taken into account at the equation formulation stage. This was because it was not necessary to deal with them as these constraints were not encountered in the historical analysis of time series. They have, however, been incorporated at the forecasting stage.

Perhaps the most obvious constraint is the number of potential replacement breeding stock. For cattle this constraint is of little importance because cull rates and potential breeding stock can be expected to allow an expansion of about 20 percent per annum, a rate which is unlikely to be called for by the level of production incentives. The equivalent constraint on the ewe flock is quite a different matter. In a bad year the hill sheep farmer may not have enough new breeding stock to increase his flock at all. Because lambing percentages are higher in the lowland farms this constraint is not going to apply at the same level for lowland and hill farms. To overcome this problem historical rates of increase of the ewe flock were examined, an average being taken of two year periods so as to smooth out fluctuations in weather patterns to some extent. This examination of historical data suggested a maximum rate of growth for the ewe flock of 3.5 percent per annum for 4th June Census Return years. The equivalent increase for December is that the ewe numbers fall only be 5 percent from the level at June (a seasonal decline in ewe numbers occurs at December). Accordingly this constraint has been imposed on the rate of increase of the ewe flock.

A decline has been occurring in the number of dairy calves slaughtered in recent years. The most extreme constraint on the number of calves slaughtered would be the limit zero, as for clear reasons less calves than this cannot be slaughtered. Because some calves are not of good enough quality for breeding or fattening the constraint has however been fixed at a five percent slaughter rate.

Entry into the E.E.C.

Entry into the E.E.C. has changed the composition of some of the variables in the model. Calf price is explained in terms of expected fat cattle price. Previous to entry into the E.E.C. expected fat cattle price was formulated from present and past fat cattle price in the U.K. Now that fat cattle price in the U.K. is scheduled to increase to the level in the original E.E.C. countries by not later than 1978, the expected fat cattle price is largely based on the adjustment of U.K. fat cattle price to the fat cattle price in the rest of the community. To allow for this situation the present fat cattle price in the calf price equation has from December 1971 (by December 1971 it could reasonably have been expected that we would enter the E.E.C.) been taken as the average of U.K. fat cattle price and the fat cattle price in a full member country of the E.E.C., Belgium. This is also a necessary adjustment for the eventual free trade situation between all the countries of the E.E.C.

No further changes were made to variables on account of the E.E.C., but it can be envisaged that the content of National Disposable Income will eventually have to be modified so as to take account of the wealth of other member countries.

Brucellosis

In the forecasting it was necessary to allow for variations in cattle breeding stock numbers due to the brucellosis erradication schemes. The influence of slaughtering of cattle on account of brucellosis can be expected to be an initial reduction in cow numbers because of breeding heifer numbers not having been geared to compensate for cows slaughtered for such a reason. It is also the case that replacements have to be stock that has been tested for brucellosis to avoid risk of reinfecting the herd. At the early stages the shortages of such heifers is likely to have an influence greater than the number of cows slaughtered on account of brucellosis. After the initial stage of a reduction in cow numbers, the inflow of heifers into the breeding herd can be expected to increase so as to compensate for the previous shortfall in heifer numbers and also by this time, as the farmers can be expected to know the percentage rate of slaughtering on account of brucellosis, to maintain the herd at its desired level. The long term prospect would be for an increase in cow numbers due to profitability being enhanced due to the erradication of the disease.

TABLE 8.1

Cattle Slaughtered on Account of Brucellosis

Year	Number Slaughtered
1968	1,079
1969	2,458
1970	7,404
1971	23,365
1972	38,200

(Animal Health, 1971)

TABLE 8.1 above gives the numbers of cattle slaughtered on account of brucellosis. The initial stage, that of a reduction in cow numbers, was taken as being 1970. This is fairly clearly indicated by TABLE 8.1. as it is in this year that the brucellosis erradication schemes really got underway. For June and December, 1970 the forecast number of dairy cows was reduced by 9(000) and the beef cow herd by 4.5(000). This gives a similar percentage decrease for both, and is consistent with TABLE 8.1 and the assumptions made in the previous paragraph. The second stage, that of an increase in heifer numbers is assumed to occur from June 1971. This is consistent with the lagged response assumed in the heifer models and with the start of the brucellosis erradication schemes. From this date the heifer inflow has been increased by .5 percent of the number of breeding cows lagged three periods. This assumes that the farmers anticipate in 1971 the slaughter rate of cows in 1972, and also in 1971 make good the previous slaughtering of cows. It further assumes that the farmers will allow for a similar percentage increase in replacements over the remainder of the forecast period. Based also on the lag of heifer response the number of dairy heifers forecast for Dec., 1970 were increased by 40(000) to allow for extra replacements to replace dairy cows slaughtered in the winter of 1967/68 due to an outbreak of foot and mouth disease.

A gradual underestimation of breeding cow numbers by the model can now be expected to occur as it does not allow for the profitability of cows being enhanced due to the less prevalence of brucellosis disease.

The Results of Forecasting

The results of forecasting are given in TABLES 8.2-8.15. These are given for Semi Annual Predictions and for consecutive forecasts of 6, 12, 18,24 and 30 months (predictions from June, 1970). The two forecasting exercises differ in that the latter approach contains more endogenous variables because when the forecasts exceed the production lags in the model, generated values replace known values of variables in the right hand side of equations.

TABLE 8.2

Beef Herd Numbers (000)			
Time	Actual Number	Semi Annual Predictions	Predictions from June, 1970
Dec., 1970	1330	1356.9	1356.9
June, 1971	1378	1393.3	1394.5
Dec., 1971	1405	1438	1439.2
June, 1972	1476	1479.2	1499.1
Dec., 1972	1547	1534.1	1544.5

TABLE 8.3

Dairy Herd Numbers (000)			
Time	Actual Number	Semi Annual Predictions	Predictions from June, 1970
Dec., 1970	3337	3327.2	3327.2
June, 1971	3234	3256.6	3258.8
Dec., 1971	3347	3364.7	3367.0
June, 1972	3325	3338.5	3332.3
Dec., 1972	3482	3440.8	3431.0

TABLE 8.4

Ewe Flock Numbers (000)			
Time	Actual Number	Semi Annual Predictions	Predictions From June, 1970
Dec., 1970	11681	11845.4	11845.4
June, 1971	12685	12801.4	12784.9
Dec., 1971	11952	11977.4	11960.5
June, 1972	13106	13129.0	13232.4
Dec., 1972	12438	12450.7	12570.8

TABLE8.5

	Beef Heifers (000)		
Time	Actual Number	Semi Annual Predictions	Predictions from June, 1970
Dec., 1970	118	107.9	107.9
June, 1971	140	133.6	133.6
Dec., 1971	111	111	111
June, 1972	162	144.9	144.7
Dec., 1972	147	123.4	122.5

TABLE 8.6

Dairy Heifers (000)		
Time	Actual Number	Semi Annual Predictions
Dec., 1970	555	543.1
June, 1971	260	241.6
Dec., 1971	518	498.9
June, 1972	273	255.7
Dec., 1972	533	517

TABLE 8.7

Calves Born (000)			
Time	Actual Number	Semi Annual Predictions	Predictions from June, 1970
Dec., 1970	1842	1814.7	1814.7
June, 1971	2002	2062.7	2063.2
Dec., 1971	1864	1812.7	1817.5
June, 1972	2100	2088.6	2093.8
Dec., 1972	2001	1864.1	1865.77

TABLE 8.8

Calves Slaughtered (000)			
Time	Actual Number	Semi Annual Predictions	Predictions from June, 1970
Dec., 1970	155	172.8	172.8
June, 1971	161	166.3	167.5
Dec., 1971	108	90.5	92.8
June, 1972	88	88.4	85.3
Dec., 1972	73	75	74.8

TABLE 8.9

Cows Slaughtered (000)			
Time	Actual Number	Semi Annual Predictions	Predictions from June, 1970
Dec., 1970	401	298.2	298.2
June, 1971	432	322	342.6
Dec., 1971	379	243.6	292.8
June, 1972	352	268.6	313.8
Dec., 1972	369	234	295.2

TABLE 8.10

Lambs Slaughtered (000)			
Time	Actual Number	Semi Annual Predictions	Predictions from June, 1970
Dec., 1970	5796	5891.2	5891.2
June, 1971	4250	3971.5	4027.4
Dec., 1971	5859	5835.1	5881.1
June, 1972	4113	4063.7	4066.6
Dec., 1972	6179	6028.8	6086.9

TABLE 8.11

Ewes Slaughtered (000)			
Time	Actual Number	Semi Annual Predictions	Predictions from June, 1970
Dec., 1970	701	657.1	657.1
June, 1971	623	477.9	514.9
Dec., 1971	597	598.6	621.1
June, 1972	479	411.1	428
Dec., 1972	598	471.6	501.1

TABLE 8.12

Store Lamb Price (£ per lamb)			
Time	Actual Price	Semi Annual Predictions	Predictions from June, 1970
Dec., 1970	6.7	7.1	7.1
June, 1971	8.0	8.0	8.1
Dec., 1971	7.8	7.8	7.8
June, 1972	9.4	9.0	8.9
Dec., 1972	9.4	9.0	8.7

TABLE 8.13

Ewe Price (p per lb e.d.c. wt)			
Time	Actual Price	Semi Annual Predictions	Predictions from June, 1970
Dec., 1970	10.4	10.3	10.3
June 1971	12.2	12.7	12.4
Dec., 1971	11.7	12.4	12.2
June 1972	15.2	15.0	14.8
Dec., 1972	14.7	14.7	14.6

TABLE 8.14

Cow Price (£ per cwt)		
Time	Actual Price	Semi Annual Predictions
Dec., 1970	7.0	7.1
June, 1971	8.3	8.1
Dec., 1971	8.3	8.3
June, 1972	10.1	9.1
Dec., 1972	11.0	10.6

TABLE 8.15

Calf Price (£ per Calf)		
Time	Actual Price	Semi Annual Predictions
Dec., 1970	24.7	24.2
June, 1971	26.2	26.6
Dec., 1971	32.3	30.6
June, 1972	36.9	36,1
Dec., 1972	42.8	40.5

The Prediction Performance of the Model

Theil's Inequality Coefficients

Point predictions are seldom perfect, therefore a method of measuring the degree of imperfection against certain standards is useful. One method of measuring the imperfection of a forecast is by means of a correlation coefficient. The grave disadvantage of this method is that a perfect positive correlation does not necessarily imply perfect forecasting, but only the existence of an exact linear relationship with positive slope between individual predictions and the actual value. In the equation

$$P_i = a + \beta A_i$$

where P_i = predicted change

and A_i = actual change

for a perfect prediction a = 0 and β = 1. This is not always the case for a perfect positive correlation.

An alternative coefficient to the correlation coefficient is

$$U^1 = \frac{\sqrt{\frac{1}{n}\sum(P_i - A_i)^2}}{\sqrt{\frac{1}{n}\sum P_i^2} + \sqrt{\frac{1}{n}\sum A_i^2}}$$

where P_i---P_n are the predicted changes and A_i---A_n are the corresponding actual changes. This coefficient has been extensively used by Theil (Theil, H., 1970). He termed it the "inequality coefficient". Values that U^1 can take are confined to the interval 0-1, unless all A_i and P_i take the value zero, in which case U^1 is indeterminate. For perfect forecasts U^1 takes the value zero. The value unity is taken if zero predicted changes of non-zero actual changes are always made, or if non-zero predicted changes are made of actual changes which are always zero, or if predicted changes are positive (negative) when actual changes are negative (positive).

Unlike the correlation coefficient the inequality is not invariant with respect to a shift of the origin. For instance for the two series

-3	5	10	-4
-1	7	7	-1

and the pair of series

97	105	110	96
99	107	107	99

where the second two series are equal to the first pair of series increased by 100, the correlation coefficient is equal to 0.95 in both cases, but the value of U^1 takes the value of 0.23 for the first pair of series and 0.01 for the second set. This intuitively makes sense.

Another inequality test derived by Theil (Theil, H., 1966) is

$$U^{11} = \sqrt{\frac{\sum (P_i - A_i)^2}{\sum A_i^2}}$$

Again U^{11} takes the value zero for perfect prediction, but in this inequality coefficient, the value one is reached if the forecasts are no better than naive no-change extrapolation. Considerably higher values than one can be reached for U^{11}, indicating that it is possible to do considerably worse than a no-change extrapolation. In conditions of no-change a simple no-change extrapolation will of course give an unbeatable prediction. This test, therefore, depends largely on the extent of change that has occurred for its value of U^{11}, and because of this doubt has to be thrown on its usefulness. If for instance the Beef Herd predictions were being tested over a period of little change, the values of U^{11} would be much higher than for a period of rapid changes, assuming an equal degree of absolute error in the predictions of both periods.

Table 8.16 below gives both the values of U^{1} and U^{11} for the predictions tested by these methods. The forecast period is from December, 1970 up to December, 1972.

TABLE 8.16

Values of U^1 and U^{11} for Semi Annual Predicted Percentage Changes

	U^1	U^{11}
Beef Herd	.19.	.41
Dairy Herd	.11	.2
Ewe Stock	.05	.09
Calf Price	.17	.3
Cow Price	.28	.45
Store Lamb Price	.14	.29
Ewe Price	.11	.22
Dairy Heifers	.03	.06
Beef Heifers	.22	.41
Calves Slaughtered	.28	.51
Cows Slaughtered	.76	3.7
Lambs Slaughtered	.04	.07
Ewes Slaughtered	.43	.94

(Not all parts of the model have been tested by prediction because in some cases all available observations had to be used to estimate the equation).

TABLE 8.17 below gives frequency distributions for the values of U^1 and U^{11} in TABLE 8.16.

TABLE 8.17

Frequency Distributions of U^1 and U^{11} Values in TABLE 8.16

Intervals	Frequency U^1	Frequency U^{11}
0 - .2	8	4
.2 - .4	3	3
.4 - .6	1	4
.6 - .8	1	0
.8 - 1	0	1
1 +	-	1

In TABLE 8.17 the frequency distribution for the inequality coefficient U^1 has a very strong bias towards the perfection end of the scale 0 - 1. Indeed eight out of the thirteen predictions fall into the interval 0 - .2. The frequency distribution for the inequality coefficient U^{11} given in the same table have a rather wider distribution. Only one of the values of U^{11}, however, exceeds one, so that in only one of the cases is the forecast worse than a no-change extrapolation. This prediction is for cows slaughtered, and depends on the predictions for heifer inflow into the cow herd and net increase in herd size, and is therefore influenced by the error in these.

A comparison of the values for U^1 and the values for U^{11} in TABLE 8.16 shows that in all cases the values of U^{11} are higher than for U^1 indicating that as in both cases the value zero is taken for perfect predictions, U^{11} is a tougher test of prediction ability. However the equation $U^1 = 0.108 + 0.196U^{11}$ has a correlation r of 0.93 and is very highly statistically significant, therefore the measures of predictive ability are closely related.

If a model were fully specified, the coefficients accurately estimated and no unexpected circumstances occurred to upset supply, then a supply model should predict accurately except for a random residual. As probably none of these conditions can be met fully it is useful, indeed essential to have a method of measuring the nature of the inequalities if improvements to the forecasts are to be made. One method of achieving this is by the following decomposition of the numerator of U^1.

$$\frac{1}{n}\sum(P_i - A_i)^2 = (\bar{P} - \bar{A})^2 + (Sp - Sa)^2 + 2(1 - r)\ SpSa$$

where $\bar{P}$, $\bar{A}$, Sp, Sa are the means and standard deviations of the series P_i and A_i respectively, and r is their correlation coefficient. Dividing each term on the right by the left hand term $\frac{1}{n}\sum(P_i - A_i)^2$, gives

$$U^m = \frac{(\bar{P} - \bar{A})^2}{\frac{1}{n}\sum(P_i - A_i)^2}\ ; \qquad U^s = \frac{(Sp - Sa)^2}{\frac{1}{n}\sum(P_i - A_i)^2}\ ; \qquad U^c = \frac{2(1 - r)SpSa}{\frac{1}{n}\sum(P_i - A_i)^2}$$

U^m = proportion of inequality to bias.
U^s = " " " " unequal variation.
U^c = " " " " imperfect covariation.

THEIL (THEIL, H., 1966)(THEIL, H., 1970) develops the theory of these proportions to quite a detailed extent. Briefly the bias proportion if it is large means that the average predicted change deviates substantially from the average realised change. This is serious but the forecaster can be expected to be able to correct for it. The proportion due to unequal variation would probably be caused by the omission of an important variable out of the model. In the course of time the forecaster may be able to correct to some extent for unequal variation, but never completely. The covariation proportion is zero if the correlation coefficient is equal to one or if the covariance of predicted and realised changes takes its maximum value, namely the product of the two standard deviations SpSa. The error proportion due to imperfect covariation may be said to be the random component, as little can be done to correct for it.

TABLE 8.18

Proportions U^m, U^s and U^c of the Inequality Coefficient

	U^m	U^s	U^c
Beef Herd	.4	.25	.34
Dairy Herd	.0008	.43	.56
Ewe Flock	.53	.0055	.46
Calf Price	.55	.21	.24
Cow Price	.45	.30	.25
Store Lamb Price	.21	.24	.55
Ewe Price	.17	.01	.82
Dairy Heifers	.91	.056	.033
Beef Heifers	.69	.064	.24
Calves Slaughtered	.1	.0014	.89
Cows Slaughtered	.97	.00056	.031
Lambs Slaughtered	.27	.1	.63
Ewes Slaughtered	.66	0	.34

TABLE 8.18 gives the proportion of the error due to bias, unequal variation and imperfect covariation. These proportions are based on rather scanty evidence as the number of predictions are only five in number. An example of possibly misleading evidence is the estimated bias for the Beef Herd, as the bias is unlikely to continue.

TABLE 8.19

Percentage Change in Beef Herd

	Actual	Predicted	(Actual-Predicted)
December 1970	2.3	4.4	-2.1
June 1971	3.6	4.8	-1.2
December 1971	2.0	4.4	-2.4
June 1972	5.1	5.3	-0.2
December 1972	4.8	3.9	+0.9

TABLE 8.18 shows that 40 percent of the error is due to bias. An examination of TABLE 8.19 above, however, shows that there is no

evidence to support the supposition that this bias will continue, because the last prediction unlike the first four underestimates the percentage change. In fact only for heifers and for cows slaughtered has there been a consistent one-directional bias.

If future predictions were to be modified in the light of the values of the unequality proportions, a simple fixed value adjustment could be expected to eliminate the bias proportion. For dairy heifers and cows slaughtered this would reduce the error by over 90 percent, and for four of the remainder by over 50 percent. Error due to unequal variation can possibly be corrected for. It has been already pointed out that error due to this cause could be due to the omission of an important variable from the model. The same result could also be caused by the elasticity of response being different from what it is specified in the model either due to error of estimation or because the shape of the supply curve is different from that postulated in the model. To re-estimate the coefficients over more observations could probably benefit the predictions if the shape of the supply curve has been incorrectly specified. Also as more observations become available it might be possible to formulate the model in greater detail due to increased variation in the variables and also due to increased degrees of freedom. The values for U^S in TABLE 8.18, however, are all under 45 percent which indicates that the degree of error from this source is not serious.

An alternative method of dealing with the bias proportion and the unequal variance proportion of the inequality coefficient can be obtained from an alternative decomposition of the numerator of the inequality coefficient. The alternative decomposition is

$$\frac{1}{n}\sum(P_i - A_i)^2 + (S_p - rS_a)^2 + (1-r^2)S_a^2$$

(THEIL, H., 1970) (THEIL, H., 1966)

Dividing the right hand terms through by the left hand term gives

$$U^m = \frac{(\bar{P} - \bar{A})^2}{\frac{1}{n}\sum(P_i - A_i)^2} \quad ; \quad U^r = \frac{(S_p - rS_a)^2}{\frac{1}{n}\sum(P_i - A_i)^2} \quad ; \quad U^d = \frac{(1 - r^2)S_a^2}{\frac{1}{n}\sum(P_i - A_i)^2}$$

where U^m is as before, U^r is the regression proportion because it deals with the deviation of the regression slope β in the regression $P_i = a + \beta A$ from unity, and U^d is the disturbance proportion because it deals with the variance of the regression disturbances. As before the three unequality proportions add up to unity.

THEIL (THEIL, H., 1970) shows that if an optimum linear transformation of the data of the form $a + \beta P_i$ were used, the bias proportions vanishes, as does also the regression proportions. The disturbance term, therefore, only is left.

TABLE 8.20

Proportions U^m, U^r and U^d of Inequality Coefficient

	U^m	U^r	U^d	$U^m + U^r$
Beef Herd	.4	.007	.59	.407
Dairy Herd	.0008	.33	.67	.3308
Ewe Flock	.53	.0027	.47	.5327
Calf Price	.55	.13	.32	.68
Cow Price	.45	.17	.37	.62
Store Lamb Price	.21	.15	.64	.36
Ewe Price	.17	0	.83	.17
Dairy Heifers	.91	.054	.03	.966
Beef Heifers	.69	.037	.27	.727
Calves Slaughtered	.1	.39	.51	.49
Cows Slaughtered	.97	.006	.026	.974
Lambs Slaughtered	.27	.12	.61	.39
Ewes Slaughtered	.66	.024	.32	.684

TABLE 8.20 gives the values for U^m, U^r, U^d and also the value for $U^m + U^r$, the amount of the error that would disappear if a linear transformation of the predictions were to be carried out. In most cases the improvement to the predictions would be of substantial mag-

nitude. Good reasons would have to exist, however, for believing that the linear transformation would continue to improve the accuracy of the predictions before there would be grounds for its use.

In summary tested by Theil's Inequality Coefficients, the forecasts are adequate as they have a strong bias towards the perfection end of the 0 - 1 scale (TABLE 8.17), and with experience of the nature of the forecasting errors, they could be reduced still further (TABLES 8.18 and 8.20)

Long Term Predictive Ability

The nature of the errors for semi annual predictions has been examined. It is also important to know whether the model retains its accuracy over longer periods, or whether a rapid loss of accuracy results.

Long term predictions may be defined as the forecasting of the results of present agricultural policy. To attempt to predict further ahead than the influences of known agricultural policy is merely to speculate rather than to predict. The influence of present milk price has repercussions on the size of dairy herd for up to three years, but the main part of the influence is accounted for in the time span of two and a half years. This then is the period over which predictions can usefully be made. Even for this period assumptions have to be made about the size of some variables.

To test its long term predictive ability the model was made to forecast in 6 month consecutive steps from June 1970 up to 30 months ahead.[1] The Root-Mean-Squared-Error for the long term predictions (RMS") that were functions of variables fed back recursively into the system was then expressed as a ratio of the Root-Mean-Squared-Error of the semi annual predictions (RMS'). This shows if the degree of error increases for long term prediction.

1. The correct values of exogenous variables were used.

TABLE 8.21 gives the ratio RMS"/RMS' which takes values greater than unity if there is a loss in accuracy for long term predictions. In fact out of the ten comparisons the ratio RMS"/RMS' exceeded unity seven times and was less than unity three times. Only slight evidence exists, therefore, for there being a loss in accuracy for long term predictions.

TABLE 8.21

Comparison of Long Term and Semi Annual Predictions

	RMS"/RMS'
Beef Herd	0.99
Dairy Herd	1.16
Ewe Flock	0.84
Store Lamb Price	1.18
Ewe Price	1.19
Beef Heifers	1.1
Calves Slaughtered	1.2
Cows Slaughtered	1.15
Lambs Slaughtered	0.64
Ewes Slaughtered	1.03

A Comparison With Census Accuracy Requirements

Policy makers by no means require, or expect, absolute accuracy in census results. Grazing livestock censuses for March, September and December for England and Wales are subject to sampling error. A 100% census return is made annually at June but the fact that a degree of sample error is normally acceptable shows that even in census results complete accuracy is not looked for. An example of the degree of sampling error in census results is shown in TABLE 8.22. The table gives a one third sample estimate made in June for comparison purposes against the 100% June census. The actual error tends to be rather larger than the calculated Standard Error of the Estimate. In five of the eight cases given the actual error exceeds one percent for the one third census result.

TABLE 8.22

June 1970 Census, England and Wales (all Figures in '000)

	One Third Sample Estimate	S.E.	100% Result	Actual Error
Cattle				
Dairy cows in milk	2402	6.8	2378	24
Dairy cows in calf but not in milk	343	2.8	336	7
Dairy heifers in calf	570	4.3	563	7
Beef Cows in milk	560	4.2	552	8
Beef cows in calf but not in milk	117	212	114	3
Beef heifers in calf	90	2.4	89	1
Sheep				
Breeding ewes	6972	32.2	6927	45
Two-tooth ewes	1468	14.9	1467	1

(Orton, C.R., 1972)

To compare the predictions with census accuracy requirements gives an indication of the success of the predictions. Unfortunately as prediction accuracy requirements, because of the uncertainty involved, are less than the requirements for accuracy for census data it is difficult to decide where the pass mark should be for this kind of comparison. Certainly a degree of error in the predictions equal to that contained in the census statistics can be taken as very much exceeding requirements.

TABLE 8.23 expresses the prediction error in term of the census error. MAEP is the mean absolute percentage error of the predictions from the realised number, APES is the actual error of the one third census in June 1970 (TABLE 8.22) while SES is the estimated Standard Error of the June 1970 one third census (TABLE 8.22).

TABLE 8.23

Comparison of Errors of Prediction with the Errors of the One Third Sample Census of England and Wales June 1970

	MAEP/APES	MAEP/SES
Beef Herd	.4	.51
Dairy Herd	.48	1.56
Ewe Flock	1.0	.98

TABLE 8.23 shows that the predictions for Beef Herd, Dairy Herd and Ewe Flock are of as high a standard as the one third sample censuses used in England and Wales, and therefore they can be considered as sufficiently accurate by this test.

A Comparison with Other Forecasts

The final and ultimate test for a forecasting model is whether it can predict as well as existing methods of forecasting. Even though a model may be judged as adequate by any other measure, it is this test which decides whether a model should be adopted. Unfortunately existing published methods of forecasting grazing livestock numbers have not been tested in a manner which makes comparisons possible. A comparison can, however, be made against the Ministry of Agriculture and Fisheries forecasts (unpublished). This has been carried out for the most important part of the model, namely the Beef Herd, Dairy Herd and Ewe Flock.

A suitable measure of comparison is

$$CM = \sum (Ex/A) / \sum (Ee/A)$$

where CM = comparison measure

Ex = error of forecasts being tested from actual values

Ee = error of established method of forecasting from actual values

A = actual value

(all values expressed in absolute terms)

A comparison between the forecasts of the model being tested here and the Ministry forecasts for periods of 6 months, 12 months and 24 months are made in TABLE 8.24. In the case of Ewe Flock the Ministry forecasts were only made up to 15 months.

TABLE 8.24

Comparison With Ministry Forecasts

Period from June 1970	Dairy Herd CM	Beef Herd CM	Ewe Flock CM
6 months	.51(2)	.82(2)	.54(5)
12 months	.23(2)	.35(2)	.23(2)
24 months	.39(1)	.34(1)	-

(numbers in brackets give the number of comparisons)

Where the CM values in TABLE 8.24 are less than unity, the forecasts being tested are better than the Ministry forecasts. All CM values are in fact less than unity, indicating that the model being tested has reached a higher standard of forecasting. The improvement over the Ministry forecasts is markedly greater for longer terms forecasting, being in fact 39 percent or less of the errors of the Ministry forecasts. Useful improvements have also, however, been achieved in the semi annual forecasts. This improvement is smaller for the Beef Herd (cows in milk or in calf), the CM value being .82, but improvements of the order of 50 percent have been achieved for the Dairy Herd (cows in milk or in calf) and for the Ewe Flock (ewes for breeding and shearlings put to the ram). The comparison is, however, limited in number (number of comparisons given in TABLE 8.24). This is because the Ministry forecasts for breeding cows were only made for numbers in June.

In the model being tested actual values of exogenous variables were used. Actual values used here which could not have been used in the Ministry forecasts assuming these forecasts to be made at March/ April are:-

price of fat cattle one year ahead
general grants and subsidies 2 years ahead
temperature 30 months ahead
fertilisers and feed prices 2 years ahead
national disposable income 2 years ahead
interest rates 2 years ahead
Average Building Cost Index 2 years ahead
Average Sheep subsidies 2 years ahead.

Because of the structure of the lags incorporated into the model, lack of knowledge of these variables have a progressive effect governed by the weights used in 'Construction of Distributed Lags'.

Conclusions

In conclusion the forecasts have been given a variety of tests. Some tests shed light on the nature of the errors rather than compared them against certain standards. These tests served a useful purpose in highlighting possible improvements that could be made to the forecasts. When compared against certain standards the forecasts can be said to have performed adequately. The predictive performance of the model using the first stage estimates of equations 7.4 - 7.6 was not investigated due to the unsatisfactory estimates of those equations.

CHAPTER IX

AGRICULTURAL POLICY CONSIDERATIONS

Introduction

The model was primarily constructed for short term forecasting with regard to the numbers of grazing livestock and the numbers of these slaughtered, but the formulation of the model also allows an insight into how agriculture can be directed if direction is necessary.

Analysis

The theoretical supply model shows that the simultaneous part of the model is extremely complex and has to be interpreted with caution. The method of evaluating a policy change would be to simulate the system, but several facts can, however, be obtained directly from the equations.

The agricultural policy maker has to bear in mind that to influence the size of the dairy herd, beef cow herd,or ewe flock, the size of one cannot be influenced in isolation, from the other two. In order to expand one and retain the others at their previous size he has in fact got to increase the level of agricultural support to all three. Also in increasing agricultural output the question arises of what commodities should have their output increased. With regard to the present world meat shortage an important consideration could be to maximize home production of meat for a given support level. The model could be used to evaluate by a trial and error approach the contribution of different distributions of support among beef, dairy and sheep so that an estimate of the least cost method of meat production could be made.

Of importance is the time lag between producers decision and actual change in production. This is shortest for the ewe flock followed by the beef cow herd, therefore by increasing the level of support to sheep the quickest change in output would result. The production time lag needs to be taken into account in the formulation of agricultural policy as present policy will influence production not in the present but in 18 to 36 months time. An idea of demand in that time period and the required degree of agricultural support necessary to obtain the desirable proportion of total production to meet "home" demand is necessary if effective control is to be exercised over agriculture. The model can be used for finding this degree of agricultural support.

A very important element of the model as regards expansion of output is the unequal effects between an increase in calf price and an increase in subsidy as regards output. In fact price fulfils several different roles in the system. Calf price is not only a source of revenue to the farmer who keeps cows but also represents the expectation of the level of future fat cattle price. A high calf price therefore means to some extent a switch from keeping breeding cows to fattening cattle. This is implied by the coefficients of the variable CPSP in the equations 7.4 and 7.5. Equation 7.13 also shows that fewer calves are slaughtered when calf price is high, so that more cattle are therefore available for fattening. In order to make efficient use of agricultural resources it is important to minimize the slaughter of dairy calves because the fewer the number of calves slaughtered the fewer are the number of cows that are necessary for producing calves for fattening. The model suggests that the manipulation of price if correctly directed could lead to increases in efficiency.

Some interesting reflections on the consequences of the adoption of the Common Agricultural Policy (C.A.P.) are possible with the use of the model. The adoption of C.A.P. could be expected to have the following results:-

(1) The certainty of price rises for fat cattle up to 1978 when U.K. price will equate with the E.E.C. price. As a result the farmers who fatten their beef animals for the longest period can expect a relatively higher price for their fatstock and can therefore outbid the intensive beef farmer for calves.

(2) Following from (1) a swing to less intensive beef systems can be expected with calf price becoming geared to E.E.C. fat cattle price rather than to U.K. cattle price.

(3) The higher calf price means fewer dairy calves slaughtered and an eventual interval during which fewer cattle come forward to slaughter as the fattening period is lengthened.

Events in reality have followed closely the above pattern. From the six months up to June, 1972 calf price no longer followed U.K. fat cattle prices but instead E.E.C. fat cattle prices had to be taken into consideration in using the model for forecasting. Also during the six months up to June 1972 the slaughtering of dairy calves fell to what is possibly its lowest possible level. By the end of 1972 panic reigned over the shortfall in beef supplies. Increased retention of heifers for breeding contributed to the reductions in home produced supplies, but part of the decrease can only be attributed to a lengthening in the fattening period. It therefore follows that the housewives who blamed entry into the Common Market for the rise in beef prices had a valid argument, although the world demand and supply situation was another contributing factor.

On the completion of the entry period into the E.E.C. it is unlikely that fattening patterns will return to their former state because of high feed prices.

Indications of the long term pattern of the grazing livestock sector are given by the coefficients on the trend term T in equations 7.4, 7.5, and 7.6. As is shown by the theoretical model these coefficients are a composite of the gain in efficiency in the grazing livestock enterprise being explained with part of the gain in efficiency in the other two grazing livestock enterprises. It is therefore of importance that this term was found to be not significant in the ewe flock equations (equation 7.6). Because of the compound nature of the coefficient for this variable an actual decline in efficiency is indicated for the ewe flock. This can be expected to be caused by the reduction in lowland flocks, the encroachment into the better hill land of beef systems of productions and the lack of technical progress in systems of managing sheep. A long term decline is therefore indicated for the ewe flock.

With regard to prices, fat cattle price has been taken as exogenous (i.e. not determined within the model) as under the rules of C.A.P. the market price for fat cattle is controlled. Lamb and ewe prices, however, are endogenous (i.e. determined within the model) so therefore the effect of a change in production from the sheep flock can be evaluated in terms of price changes for sheep which ultimately affects the price of mutton and lamb.

Conclusion

The interraction of beef, dairy and sheep production is extremely complex. In order to formulate agricultural policy a model spelling out the interraction is highly desirable if the policy maker is to have adequate knowledge of the result of any action he might take. This model though primarily intended for forecasting rather than evaluation of policies can be used for the latter purpose as well.

CHAPTER X

CONCLUSIONS

An econometric model of the grazing livestock sector of U.K. agriculture has been formulated, estimated and tested. The most important part of the model is equations 7.4, 7.5, and 7.6 which deal with the number of breeding stock. Indeed many models take the numbers of breeding stocks as representing the final supply of slaughtered animals. These equations support the theoretical Production Model. Competitive relationships do exist between the beef herd, the dairy herd and the ewe flock. The influence of the size of the ewe flock on the size of the dairy herd and the beef cow herd is small as was to be expected from the different production time lags involved, whilst the influence of the dairy herd and the beef cow herd on the size of the ewe flock is large, which is also to be expected.

Some of the less important parts of the model suffer from the inadequacy of the statistical material. This is the case for culling and also for the inflow of new breeding stock, as these can be expected to depend to a large extent on the age distribution of the breeding stock, which is unknown. A significant improvement in the statistical material was achieved in the case of the statistics on the numbers of heifers calving. A shortage of the statistical series on calves aged under six months led to a shortage of degrees of freedom in equation 7.16, which explains numbers of steers and heifers slaughtered, and so limited the number of variables that could be contained in this equation. Nevertheless as changes in the fattening period was allowed for to some extent the result is an improvement on previous econometric models. With better statistical material a fuller specification of these parts of the model mentioned should be possible, however with the possible exception of cows slaughtered, these parts of the model were satisfactory as regards statistical tests.

The theoretical model for Store Livestock Prices has also been statistically supported. Store livestock price is found to be a function of expected fatstock price.

The model passed the tests to which it was subjected. With regard to the most important part, the numbers of breeding stock, it is an improvement on anything previously achieved in this field. This is so as regards the correct economic relationships between the classes of breeding livestock, and as regards the completeness of the specifications of the revenues and costs involved in production. For instance the importance of general grants and subsidies have not been hitherto shown by econometric models. While a statistical model such as that developed cannot definitely validate the theoretical structure assumed, it does show that reasonable forecasts can be produced.

To finally conclude, a tool has been produced which can give advance warning of patterns of production in the grazing livestock sector of U.K. agriculture. This is essential if periodical shortages of meat supplies are to be avoided. Important indications of how to direct production can also be derived from the model, and this can be regarded as an important supplement to the model's forecasting ability.

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STATISTICAL APPENDIX

Endogenous variables for the forecast period Dec. 1970 - Dec. 1972 given in CHAPTER VIII are not repeated here.

TABLE A1

Breeding Stock Numbers (000)			
Time	BH	DH	EF
June, 1959	810	3040	13450
Dec., 1959	814	3198	12634
June, 1960	848	3163	13792
Dec., 1960	869	3294	12739
June, 1961	908	3246	13977
Dec., 1961	947	3363	13252
June, 1962	978	3291	14363
Dec., 1962	1002	3354	13447
June, 1963	1013	3247	14322
Dec., 1963	1005	3257	13350
June, 1964	981	3144	14379
Dec., 1964	998	3260	13310
June, 1965	1018	3187	14542
Dec., 1965	1053	3270	13494
June, 1966	1106	3162	14585
Dec., 1966	1124	3251	13198
June, 1967	1142	3215	14223
Dec., 1967	1143	3300	12981
June, 1968	1152	3226	13873
Dec., 1968	1174	3358	12680
June, 1969	1211	3275	13311
Dec., 1969	1255	3309	12046
June, 1970	1300	3243	12807

TABLE A2

Heifers Calving (000)		
Time	BHEF	DHEF
Dec., 1960	90	545
June, 1961	115	268
Dec., 1961	83	558
June, 1962	111	276
Dec., 1962	77	551
June, 1963	92	257
Dec., 1963	66	497
June, 1964	96	260
Dec., 1964	67	542
June, 1965	101	253
Dec., 1965	99	489
June, 1966	122	246
Dec., 1966	88	488
June, 1967	132	251
Dec., 1967	94	528
June, 1968	107	298
Dec., 1968	86	527
June, 1969	117	282
Dec., 1969	109	534
June, 1970	131	260

TABLE A3

Estimated Calves Born (000) and Steers plus Heifers Slaughtered (000)		
Time	CALVES	FCSL
June, 1965	1942	-
Dec., 1965	1708	-
June, 1966	1947	-
Dec., 1966	1731	-
June, 1967	2024	1407
Dec., 1967	1852	1541
June, 1968	2044	1397
Dec., 1968	1787	1401
June, 1969	2056	1317
Dec., 1969	1760	1308
June, 1970	1991	1429
Dec., 1970	-	1456
June, 1971	-	1432
Dec., 1971	-	1408
June, 1972	-	1459

TABLE A4

Calves Slaughtered (000) and Cows Slaughtered (000)		
Time	CASL	COSL
June, 1959	314	-
Dec., 1959	312	-
June, 1960	486	-
Dec., 1960	445	-
June, 1961	484	350
Dec., 1961	465	347
June, 1962	440	384
Dec., 1962	430	376
June, 1963	391	377
Dec., 1963	313	399
June, 1964	301	400
Dec., 1964	208	300
June, 1965	197	305
Dec., 1965	184	276
June, 1966	236	344
Dec., 1966	272	323
June, 1967	302	383
Dec., 1967	349	306
June, 1968	271	430
Dec., 1968	228	318
June, 1969	255	375
Dec., 1969	180	371
June, 1970	183	381

TABLE A5

Lambs Slaughtered (000) and Ewes Slaughtered (000)		
Time	LAMSL	EFSL
June, 1961	4571	492
Dec., 1961	7793	570
June, 1962	3933	438
Dec., 1962	7389	676
June, 1963	4128	505
Dec., 1963	6668	719
June, 1964	4666	597
Dec., 1964	6703	731
June, 1965	4534	530
Dec., 1965	6243	655
June, 1966	5043	719
Dec., 1966	7012	928
June, 1967	4877	684
Dec., 1967	7106	870
June, 1968	4304	642
Dec., 1968	6552	774
June, 1969	3901	537
Dec., 1969	5307	749
June, 1970	4123	597

TABLE A6

Store Lamb Price (£ per lamb) and Fat Ewe Price (p. per e.d.c.wt.)		
Time	SSP	EP
June, 1957	6.15	8.21
Dec., 1957	5.7	7.04
June, 1958	6.1	7.62
Dec., 1958	5.4	6.75
June, 1959	5.9	7.04
Dec., 1959	5.3	5.29
June, 1960	6.0	7.5
Dec., 1960	5.25	6.33
June, 1961	6.2	7.71
Dec., 1961	5.6	5.62
June, 1962	6.7	7.33
Dec., 1962	5.75	5.83
June, 1963	6.5	7.29
Dec., 1963	5.8	5.87
June, 1964	6.6	8.37
Dec., 1964	5.95	7.5
June, 1965	6.35	9.25
Dec., 1965	5.75	7.42
June, 1966	6.2	8.75
Dec., 1966	5.35	6.87
June, 1967	6.1	9.29
Dec., 1967	5.6	6.71
June, 1968	6.3	7.62
Dec., 1968	5.95	7.92
June, 1969	7.0	10.75
Dec., 1969	6.55	9.46
June, 1970	7.45	11.25

TABLE A7

Cow Price (£ per cwt.) and Calf Price (£ per calf)		
Time	COWP	CALP
Dec., 1955	5.05	15.7
June, 1956	4.6	13.85
Dec., 1956	3.9	12.6
June, 1957	4.55	13.7
Dec., 1957	4.0	15.3
June, 1958	4.6	16.95
Dec., 1958	5.15	18.25
June, 1959	5.75	19.15
Dec., 1959	5.25	18.65
June, 1960	5.5	17.45
Dec., 1960	5.05	15.5
June, 1961	4.85	15
Dec., 1961	3.95	15
June, 1962	4.45	16.1
Dec., 1962	4.5	16.3
June, 1963	4.3	16.6
Dec., 1963	4.6	17
June, 1964	5.8	18.25
Dec., 1964	6.05	19.75
June, 1965	6.5	21.8
Dec., 1965	6.2	22.4
June, 1966	6.25	20.65
Dec., 1966	5.4	18.95
June, 1967	5.6	18.25
Dec., 1967	5.15	18.45
June, 1968	6.95	21.45
Dec., 1968	5.95	21.65
June, 1969	6.45	22.8
Dec., 1969	6.55	23.8
June, 1970	6.9	24.15

TABLE A8

Cows Exported (000) and Calves Exported (000)		
Time	CEP	CAEX
June, 1961	29	0
Dec,, 1961	37	0
June, 1962	36	0
Dec., 1962	42	0
June, 1963	36	0
Dec., 1963	36	0
June, 1964	82	0
Dec., 1964	75	0
June, 1965	74	X
Dec., 1965	100	X
June, 1966	88	X
Dec., 1966	27	X
June, 1967	70	X
Dec., 1967	78	X
June, 1968	24	X
Dec., 1968	50	X
June, 1969	36	X
Dec., 1969	40	38.1
June, 1970	32	9.4
Dec., 1970	38	18.6
June, 1971	21	9.2
Dec., 1971	18	10.5
June, 1972	34	6.2
Dec., 1972	69	10

X Estimates obtained by private communication from the Ministry of Agriculture, Fisheries and Food.

TABLE A9

Concentrate Feed Price (1954/55 - 1956/57 = 100), Fertiliser Price (1954/55 - 1956/57 = 100) and Building Cost (1954 = 100)			
Time	CFPI	FERPI	BC
June, 1956	99.6	99.6	-
Dec., 1956	100.8	96	-
June, 1957	102	102	-
Dec., 1957	96.1	91.5	114
June, 1958	90.2	90.2	115
Dec., 1958	90	85.7	114
June, 1959	89.8	89.8	113
Dec., 1959	90.5	86.15	114
June, 1960	91.1	91.1	114
Dec., 1960	90.5	85.4	113
June, 1961	87.1	87.65	113
Dec., 1961	86.85	84.43	113.5
June, 1962	91.17	88.4	114
Dec., 1962	92.3	81.58	118
June, 1963	92.2	86.71	125.6
Dec., 1963	94.1	83.47	126
June, 1964	96.6	87.67	127.5
Dec., 1964	95.4	86.67	130
June, 1965	98.75	89.65	132.5
Dec., 1965	99.58	89.17	135.5
June, 1966	99.27	92.38	139.5
Dec., 1966	98.83	91.76	140
June, 1967	98.98	95.57	141.5
Dec., 1967	100.23	101.12	143
June, 1968	103.38	109.68	146
Dec., 1968	104.6	110.67	148
June, 1969	105.38	110.5	150.1
Dec., 1969	107.05	106.47	154.2
June, 1970	111.63	111.0	160.7
Dec., 1970	118.79	108.2	167.9
June, 1971	132.35	124.2	175.5
Dec., 1971	126	140.86	183.6
June, 1972	122.3	145.36	187.5
Dec., 1972	126.9	163	197.2

TABLE A10

Pool Milk Price (1936 - 1938 = 100), Fat Cattle Auction Price (1954/55 - 1956/57 = 100) and Wool Price (p. per lb.)

Time	PMP	FCAP	WP
June, 1956	338	-	-
Dec., 1956	312	-	-
June, 1957	303	-	-
Dec., 1957	293	86.2	21.675
June, 1958	308	104.2	21.675
Dec., 1958	296	110.3	20.675
June, 1959	328	118,6	20.675
Dec,, 1959	303	112.9	20.708
June, 1960	311	115.2	20.708
Dec., 1960	283	107.3	20.367
June, 1961	300	105	20.367
Dec., 1961	279	85.5	20.2
June, 1962	288	110.5	20.2
Dec., 1962	267	106.7	19.937
June, 1963	310	98.3	19.937
Dec., 1963	276	106.4	19.85
June, 1964	314	116.1	19.85
Dec., 1964	298	128.3	20.59
June, 1965	321	132.7	20.59
Dec., 1965	301	132.7	20.1
June, 1966	324	136.9	20.1
Dec., 1966	307	121.7	19.62
June, 1967	332	119.9	19.62
Dec., 1967	314	107.8	19.19
June, 1968	329	149.6	19.19
Dec., 1968	313	137.3	18.958
June, 1969	334	147.2	18.958
Dec., 1969	309	146	19.583
June, 1970	347	146.9	19.583
Dec., 1970	342	152.7	18.782
June, 1971	386	176	18.782
Dec., 1971	384	179.9 (221.9)*	19.4

TABLE A10 continued

Time	PMP	FCAP	WP
June, 1972	418	198.8 (245)*	19.4
Dec., 1972	396	221.7 (272.3)*	-

* Fat cattle price in Belgium expressed in the same price index as U.K. fat cattle auction price. The fat cattle prices were obtained from International Market Survey - Cattle - Sheep - Pigs, quarterly, Meat and Livestock Commission, Milton Keynes.

TABLE A11

Cattle Subsidy[+] (£ per cow), Sheep Subsidy [‡] (£ per ewe) and General Grants and Subsidies (£ millions)			
Time	CSUB	SSUB	G
Dec., 1956	12.62	–	–
June, 1957	12.83	–	–
Dec., 1957	13.1	0	–
June, 1958	13.1	0	9.8
Dec., 1958	13.1	0	10.4
June, 1959	13.68	0	11.58
Dec., 1959	14.46	0	13.15
June, 1960	14.46	.023	14.54
Dec., 1960	14.46	.054	16.4
June, 1961	14.41	.058	17.04
Dec., 1961	14.36	.063	17.9
June, 1962	14.36	.082	18.14
Dec., 1962	14.36	.108	18.45
June, 1963	14.3	.139	17.7
Dec., 1963	14.25	.18	16.7
June, 1964	15.27	.32	16.22
Dec., 1964	16.63	.506	15.6
June, 1965	16.92	.455	15.26
Dec., 1965	17.29	.387	14.8
June, 1966	18.85	.51	14.29
Dec., 1966	20.92	.675	13.6
June, 1967	21.4	.658	13.56
Dec., 1967	22.0	.636	13.5
June, 1968	23.2	.597	13.82
Dec., 1968	24.74	.546	14.25
June, 1969	25.17	.546	15.06
Dec., 1969	25.74	.546	16.15
June, 1970	27.08	.57	17.16
Dec., 1970	28.87	.60	18.5
June, 1971	30.21	.673	21.59

TABLE A11 continued

Time	CSUB	SSUB	G
Dec., 1971	32	.768	25.7
June, 1972	32.15	.786	30.8
Dec., 1972	32.37	.81	37.6

+ Cattle Subsidy consists of (Hill Cow Subsidy)/2 + (Winter Keep Cattle Subsidy)/2 + (Calf Subsidy) x .95 + (Cow Subsidy)/2.

‡ Sheep Subsidy consists of (Hill Sheep Subsidy + Winter Keep Sheep Subsidy) x .36 + (Upland Sheep Subsidy + Winter Keep Subsidy) x .15

TABLE A12

Average Temperature (January-March, °F.), Milk Sold per dairy cow + (gallons)		
Time	TEMP	AMY
Dec., 1957	43.99	-
June, 1958	38.98	630
Dec., 1958	38.98	630
June, 1959	40.78	657
Dec., 1959	40.78	656
June, 1960	40.94	719
Dec., 1960	40.94	700
June, 1961	43.75	730
Dec., 1961	43.75	715
June, 1962	39.71	740
Dec., 1962	39.71	737
June, 1963	35.65	728
Dec., 1963	35.65	741
June, 1964	40.47	721
Dec., 1964	40.47	735
June, 1965	39.88	748
Dec., 1965	39.88	745
June, 1966	41.5	744
Dec., 1966	41.5	746
June, 1967	42.8	746
Dec., 1967	42.8	786
June, 1968	40.32	744
Dec., 1968	40.32	791
June, 1969	38.6	754
Dec., 1969	38.6	813
June, 1970	38.93	786
Dec., 1970	38.93	822
June, 1971	40.47	817
Dec., 1971	40.47	833
June, 1972	41.96	849
Dec., 1972	41.96	-

+ Milk Sold per Dairy Cow = (Milk marketed 6 months up to period t)/((Dairy Cows at period t + Dairy Cows at period t-1) X .25)

TABLE A13

National Disposable Income (£ millions) and Bank Rate (percent)		
Time	DI	INT
June, 1956	-	5.0
Dec., 1956	-	5.5
June, 1957	-	5.2
Dec., 1957	-	5.5
June, 1958	-	6.5
Dec., 1958	-	5.0
June, 1959	8295	4.0
Dec., 1959	8694	4.0
June, 1960	8895	4.5
Dec., 1960	9335	5.5
June, 1961	9589	5.0
Dec., 1961	9894	6.5
June, 1962	9904	5.5
Dec., 1962	10308	4.5
June, 1963	10544	4.4
Dec., 1963	11174	4.0
June, 1964	11423	4.6
Dec., 1964	11827	5.0
June, 1965	12092	7.0
Dec., 1965	12448	6.0
June, 1966	13043	6.0
Dec., 1966	13147	6.8
June, 1967	13233	6.4
Dec., 1967	13925	6.0
June, 1968	14297	7.7
Dec., 1968	14968	7.4
June, 1969	15252	7.5
Dec., 1969	15965	8.0
June, 1970	16410	7.7
Dec., 1970	17723	7.0
June, 1971	18108	6.7
Dec., 1971	19605	5.5
June, 1972	20299	6.0
Dec., 1972	-	-