April 1969 Report No. 176

UNIVERSITY OF EXETER
Department of Agricultural Economics

SUPPLY RESPONSE IN MILK PRODUCTION

BY

R. G. Cason, B.Ag.Econ. (New England)
Dip.Agric.

"Lafrowda"
St. German's Road
Exeter
Devon

Price Ten Shillings

SUPPLY RESPONSE IN MILK PRODUCTION

A STUDY IN METHODOLOGY FOR THE PREDICTION OF MILK SUPPLY BASED ON A SURVEY OF MILK PRODUCTION IN AN AREA OF GRASSLAND DAIRY FARMS IN SOUTH WEST ENGLAND, 1967

BY

R. G. CASON, B.Ag.Econ. (New England)
Dip.Agric.

FOREWORD

This publication is a report on the dairy research project for the 1966–68 period carried out under the National Investigation into the Economics of Milk Production by the University of Exeter in co-operation with the University of Bristol. The study was designed by the late J. A. Langley in consultation with colleagues in this Department and with Mr. S. R. Wragg and Mr. Vernon Baker of the University of Bristol. The field work in the South East Somerset part of the survey area was undertaken by members of the Bristol University Department of Agricultural Economics and in Devon and Dorset by Miss B. J. Roscoe and Mr. K. G. Tyers of this University. John Langley died before he had an opportunity to begin the analysis of the data. Following a joint discussion with the University of Bristol it was decided to continue the project with Mr. Baker and Mr. H. W. B. Luxton taking responsibility for the completion of the analysis and production of a publication. It was fortunate that at this stage Mr. R. Cason was appointed to the staff of Exeter University, his knowledge and experience in linear programming proving a valuable asset in the completion of the study and in the event he carried out the analysis and completed a draft report before taking up an appointment at the North of Scotland College of Agriculture. The final editing and preparation for publication have been undertaken jointly by Vernon Baker and H. W. B. Luxton.

The Author wishes to record his appreciation of assistance received from members of staff of the University of Exeter Agricultural Economics Department including Mr. V. H. Beynon, Mr. B. Nixon and Mr. W. J. K. Thomas in addition to all those mentioned above. The help received from the staff of the Exeter University Computor Laboratory is also gratefully acknowledged.

It is hoped, that after such a turbulent history, the final outcome of this study will be in some measure a fitting memorial to its originator who contributed so much to our knowledge of dairy farming in the South West.

S. T. MORRIS
Provincial Agricultural Economist,
University of Exeter.

Cover Photograph:

Bulk Milk Collection

By Courtesy of the Milk Marketing Board

CONTENTS

Cover Photograph:

Bulk Milk Collection

By Courtesy of the Milk Marketing Board

SUMMARY

A recent development to aid the prediction of agricultural supply response has been to analyse supply response at the farm firm level. Linear programming is used to derive the optimum quantity of production at varying prices for the product under investigation. The result is a normative projection of supply response. As a trial of the methodology involved, the total supply response for milk from a lowland area of South West England has been derived by aggregating supply response from typical farm types within the region.

The normative solution gave a level of supply below that currently being achieved at the present price for milk with assumed improvements in technology. Restrictions were placed on the use of resources by non milk producing activities forcing the expansion of these activities to be limited to the current levels of housing. The results, which are subject to the assumptions made in this study, suggest that there is little scope for increased production in response to an increase in the price of milk, in predominantly milk producing grassland areas. Typical farm types, derived by grouping farms according to the resources estimated to ultimately restrict milk output or according to resource ratios gave very similar results.

INTRODUCTION

Agricultural supply response has generally been analysed at the market level using regression analysis or at the production unit level using production function techniques. However, these methods, based on historical data, have been able to make little allowance for the factors affecting supply at the point of production. They have been used because data have been more readily available on an aggregate basis at the market level.

The increasing study of farm management, the improvement in farm accounting and recording, and the concentration of research effort on improving management techniques has resulted in the availability of considerable quantities of individual farm data. The result has been an improvement in the techniques for optimising factor adjustments to changing production conditions and an increased understanding of producer behaviour. It appears that this information could be used to give a more accurate prediction of supply response through aggregating predicted changes in production at the point of production.[1]

This study is a trial of a method of projecting the supply response for milk from a given area by aggregating the estimated supply response from the individual farm units.

First it is necessary to make the distinction of supply response from the general concept of a supply function, as identified by Cochrane (1,pp. 1162–1163).

1. This principle was first recorded by Ronald L. Mighell and John D. Black (Cambridge, Harvard University Press 1951) *Inter-regional Competition in Agriculture* using budgeted changes in farm plans to estimate supply response.

GENERAL THEORY OF SUPPLY

Supply Function

The general concept of a supply function is a line sloping upwards from left to right showing the amount of a commodity which producers will supply at various prices. It indicates the willingness of producers to supply more of the commodity as the price rises, and less as the price falls. This interpretation implies that all other factors affecting supply, other than inputs, are held constant. A supply function, defined in this way implies a rigorous definition of the prevailing conditions; a given time period, given technology, constant prices for substitute and competing commodities and the availability of inputs which can be varied in the amount used. The supply function is reversible; quantity supplied is a function of the price offered. Price is determined by the level of demand.[2]

Supply Response

Supply response, on the other hand, is the change in quantity offered for sale as price varies, when the conditions of constancy surrounding a supply function are removed. It depicts the response in output of the commodity when other factors affecting supply, such as technology and size of farm, are allowed to vary. A supply response curve is therefore not reversible, being a series of points of intersection of the supply and demand functions over time. It adheres more to the real world situation and can therefore be used for prediction purposes.

Since this study allows for the effect of changes in certain other factors besides price, such as an improvement in technology and capital investment in buildings, it can be said to aim to give a supply response for milk. At this point it will be useful to note the elements affecting the shape and shift in the supply curve, before outlining the general features of supply of agricultural products.

Theory of Supply

The slope of the supply curve is related to the production function for the commodity (2,pp. 677–681). When the production function has high elasticity, a small increase in inputs producing a relatively large increase in output, the supply curve will have relatively high elasticity. When the production function has low elasticity, a large increase in inputs producing a relatively small increase in output, the supply curve will have relatively low elasticity.

An increase in supply of a commodity normally requires an increase in the quantity of factors of production used and hence a marginal increase in the cost of production. If firms produce at the point where marginal cost equals marginal revenue, the sum of the marginal cost curves becomes the industry supply curve. (3,Chapter 27). Therefore, the slope of the supply curve is the slope of the marginal cost curve which is determined by the cost of the factors of production and the shape of the production function.

This theory explains the elements underlying agricultural supply in aggregate and by commodities.

---

2. For this interpretation of a supply function, demand would have to be considered as independent of the quantity supplied.

Features of Agricultural Supply

Three general categories of factors affecting agricultural supply are prices, technology and nature. In general the supply of agricultural products is characterised by low elasticity, irreversibility and steadily increasing output. These features have been explained by the improvement in technology (1,pp. 1168–1176); the stable supply of factors of production (4), demand for factors of production (5) and asset fixity (6). The demand for the factors of production outside agriculture determines their opportunity cost. There is little alternative use for the factors of production of agriculture outside the industry. The supply of some is fairly static and some once committed to agriculture, become fixed assets', e.g. land, buildings and specialised equipment. In addition, farmers reaction to risk and uncertainty causes a shift in their effective cost curve to the left of the marginal cost curve causing a less elastic supply.

The result, with a gradual improvement in technology, is a general rise in output in conditions of stable or rising prices and little or no contraction of output with a fall in price. A major portion of the increase in agricultural production has been due to the increase in technology. These are the features of agricultural production in aggregate. The response of individual commodities would be more elastic and show greater contraction and expansion of output, through the transfer of resources within the farm unit.

A most comprehensive report on supply elasticities in the United Kingdom was published by Jones (7,pp. 548). He found a long run price elasticity for milk of about 0.5. The short run elasticity was considerably less, about 0.05.[3]

METHODS OF SUPPLY RESPONSE ANALYSIS

Cowling and Gardner (8) have given a comprehensive review of alternative methods of estimating supply relations.

The two methods which have received most attention are those directed at the market level and at the technical unit level of supply.

Market Level

Most work has concentrated on the estimate of supply response at the market level. This method uses a model developed by Nerlove (9) relating total supply in one period to price, usually lagged and fitting a regression equation to identify and measure the effect of economic or other parameters on supply change. Various refinements have been made to the model incorporating coefficients for other suggested factors affecting supply such as an allowance for uncertainty and changes in technological efficiency.

This is basically an historical approach and any predictions from the analysis must be based on the assumption that farmers will react to the same stimuli in the same proportions in the future as in the past. The result is not strictly a supply curve but a hybrid function, as over a period

3. This was using cow numbers as the dependent variable, as an indication of milk production.

of time structural changes will have occurred, e.g. shifts in demand. Using aggregate data gives no measure of inter-regional aspects of supply, nor can any direct account of the effect of production on resources be derived from the results. For example fixed resources are not accounted for explicitly and these can affect supply response by imposing an upper limit on the potential level of supply for a given state of technology.

Technical Unit Level

Methods of analysing supply response at the technical unit level derive a supply curve from a production function for the commodity. This is a short run supply curve, fitting various prices and behavioural assumptions to the production function. Cross sectional data from surveys can be used to which a regression can be fitted to establish the production function. Alternatively, or in addition, data from experimental research can be used. This gives a flexible estimate of supply response in the short term, but is of little use in making long term predictions when relatively fixed factors can change. In addition, the result does not allow for the demand for resources from other production activities within the farm firm.

Farm-Firm Level

The analysis of supply at the farm-firm level using linear programming, which allows for competition among production activities for the available resources, is a more flexible model than that using the production function method. But although this model has this extra flexibility in allowing for competition for resources, the built-in linearity assumption reduces its realism in the estimation of output response at varying levels of production. This remains true despite the possibility of varying the constraints and prices. In addition this model has the same defect as production functions; that the normal behavioural assumption of profit maximization may not be valid. Besides, farmers vary in the time period over which they expect to optimise profits; this increases the range of the time period over which the estimated supply response may apply.

While stochastic models can be applied to farm-firm level data (8 pp. 441) the linear programme model is non-stochastic, implying normative conditions to the farm organization.[4] Therefore it will not be possible to make any statement of the confidence limits or range within which the true level of supply may fall. It can merely be stated that the results are estimates of what would or could be achieved.

This study takes the form of a linear programme model to estimate total supply response from a given population. It is a trial of a method, described below, the aim of which is to reduce bias which arises in the course of the aggregation of individual representative farm supply schedules. In addition to the straightforward application of the method, variations were made to the constraints in the linear programme to show the effect on the estimate of the level of supply.

4. Stochastic models provide an error statement with an estimated parameter. This statement gives the range about an estimated parameter, in which the true parameter has a given probability of occurring, e.g. an arithmetic mean is a parameter.

INDIVIDUAL FARM UNIT METHOD

Principle

In theory and in practice the industry or total supply response is the aggregation of supply response curves for the individual production units or firms. Ideally then, in order to estimate or project aggregate supply response, it would be desirable to project the supply response for each firm and aggregate the individual firm's supply to obtain the total supply response curve. Such a method is not practical in agriculture due to the large number and dispersed nature of the production units.

Using the concept of the representative firm devised by Marshall (10)[5] aggregation of supply reactions of individual production units becomes practicable. The concept of a representative firm has been applied in agriculture on numerous occasions for advisory purposes, although in this context the exact meaning has never been clearly defined. For the purposes of projecting supply response from a representative firm a more exact definition of the resource base, input output relations and behavioural characteristics of management, is necessary. Applying normative assumptions and using farm planning techniques the supply responses from the typical firms can be plotted and aggregated to a total supply response.

Method

The principle of the method was initially developed in the Mighell-Black study (11) of inter-regional competition in deriving supply response for several commodities. The main steps are:-

1. Select an area or areas homogeneous for factors affecting the supply of the commodity, such as price, climate, soil type, competing products and resource supply.

2. Take a sample of farms from each area.

3. Group the sample farms according to chosen criteria into representative farm types.

4. Define a hypothetical farm for each group by averaging the data for each group, using data from secondary sources where necessary.

5. Assume increases in technology over a given planning period.

6. Derive farm plans at various estimated levels of demand, using linear programming.

7. The supply, in order to obtain a measure of the response for the representative farms, can then be raised and aggregated so as to give the total supply response for the area.

Sources of Error

Possible sources of error inherent in this method have been classified as aggregation error, specification error and sampling error. (12)

(*a*) *Aggregation Error*

If supply response for each farm in the universe could be estimated by linear programming and aggregated this would give an unbiased esti-

---

5. Marshall used the principle of the representative firm in explaining the cost of production.

mate of total supply response. The difference between this estimate and that obtained by raising and aggregating the average production from a set of representative farms is termed aggregation bias. It is affected by the criteria on which the sample farms are classified into representative farm types and the averaging process in estimating resource levels and production from a representative farm.

If farms are grouped by the conventional method of resource magnitude as used in normal descriptive analysis, and then programmed as a benchmark farm with resources equal to the average of the group, an upward bias will result. Basically this error arises in the following way. In programming the benchmark farm, one resource will ultimately restrict output of the commodity. But under this method of grouping, the resource restricting output on the benchmark farm, may not be the same resource as that restricting output on some of the individual farms in the group. Take a situation in which labour is restricting output on farm A with AL output from labour but is in surplus on farm B which could have produced BL output from labour but where capital restricts output at BC. In this case the average level of output based on labour is $\frac{AL + BL}{2}$.

If labour ultimately restricts output on the benchmark farm then estimated aggregated output is $\frac{2(AL + BL)}{2} = AL + BL$.

However, output BC on farm B is limited by capital and so is less than output BL; hence output from the benchmark farm is biased upwards by the amount which output BL is greater than output BC. Sheehy and McAlexander give a more rigorous exposition of the cause of this bias. (13)[6]. Barker and Stanton (14) explain it in numerical terms.

If farms are grouped by absolute restricting resources then this source of aggregation error can be avoided. An absolute restricting resource is the first resource to restrict the output of a commodity when the entire supply of the resource is devoted to production of that commodity, in this case milk. If the groups of sample farms, which are averaged or otherwise condensed to produce representative or benchmark farms, are selected

---

6. Output of a commodity on farm A and farm B is dependent on Labour and Capital.
On farm A Labour ultimately restricts output.
Let LA = Max. output from Labour, CA = Max. output from Capital, therefore LA < CA.
On farm B Capital ultimately restricts output.
Let LB = Max. output from Labour, CB = Max. output from Capital, therefore CB < LB.
(If both resources are simultaneously restricting then LA = CA, LB = CB and no bias would result).

Total output possible from both farms is = LA + CB
Using the averaging process total output = ½ (LA + LB) if Labour is ultimately restricting on the average farm.
or ½ (CA + CB) if Capital is ultimately restricting on average farm.
raising these averages total output = LA + LB or CA + CB
but maximum total output = LA + CB
and LA + CB < LA + LB
LA + CB < CA + CB

Hence if an average of farms with different restricting resources is used, this gives an upward bias in the raised results.

on this basis, then these will be groups in which differences in output between farms is proportional to differences in the level of restricting resources between farms. Therefore the raised output of the representative farm will be an unbiased estimate of the aggregate output of the farms within the group.

To get a completely unbiased estimate of the raised results by this method of classification also requires the following assumptions to be fulfilled.

1. The resource restriction is operative over the entire price range being investigated.

2. Price expectations are the same for all farms.

3. The resource commodity coefficients are not distorted by the averaging process.

4. The commodity is produced on each farm by linear processes equally efficient in the transformation of the restricting resource.

Specification Error

If the linear programme does not define exactly the constraints, as quantified by farmers in implementing management decisions over a given planning period, this leads to a divergence between programmed and actual results. This is specification error. It can also be caused through errors in defining the production coefficients for activities included in the programme. Possible sources of specification error could arise from using yield data other than that obtained on the sample farms, or making incorrect estimates of the increase in technical efficiency over the period.

In addition farmers may not respond to economic stimuli as implied in the normative assumptions of linear programming.

The difference between a normative and an actual solution can be viewed as a question of specification error. The input-output data used and the definition of the linear programme restraints should be governed by the aims of the study. If it is intended to show potential supply response then the normative data should be used; but if the aim is to estimate actual future levels of supply then it is necessary to take account of farmers' allowances for risk and uncertainty and to use input-output coefficients estimated to be operating over the planning period.

Sampling Error

Sampling error occurs when the distribution of the parameters of all firms in the population is estimated by sampling techniques.

To reduce the effect of such error in estimation of supply response, more farms should be selected from areas, or farm types, where output response is more flexible due to the presence of competing commodities. Specialised farms, farms in specialised producing areas, or farms already producing at near maximum output would have little potential for supply response and should not be sampled so heavily.

In this study however, which is aimed at testing the methodology, a specialised area with simple farming systems was used.

EXPLANATION OF PROCEDURE FOLLOWED

Selection of Region

The Blackmoor Vale area of North Dorset, a contiguous area in South East Somerset and a part of East Devon were chosen as the area for study. This is a predominantly grassland area with some corn growing. In the selection of the sample parishes within the area, parishes with a high proportion of cropping enterprises were excluded as far as possible, thus concentrating on the supply response among grazing enterprises. It was thought that this would simplify the problem from the field survey and linear programming points of view.

Sampling

Parishes from the region, with over 84 per cent of their crops and grass acreage currently under grass at 4th June 1965, were selected at random from each county area to provide a population of about 350 holdings in each county. Farms of 20 acres and over from the randomly selected parishes were then stratified by farm size. A 10 per cent sample was then taken from this stratified population. A variable sampling fraction from each stratum was used, based on the proportion of the total farm area in the randomly selected parishes covered by the farms in each size group.

The sample is weighted by area, therefore, to the extent that the total supply response is related to the land area of a farm, this procedure should reduce the error in the estimate. On the other hand, if there were greater potential for supply response on farms with small areas of land, this procedure may be giving them insufficient weight. Tables 1 and 2 show the sampling details.

TABLE 1

POPULATION DETAILS

District	*Parishes with over 84 per cent of Crops and Grass area under Grass June 1965*		*Parishes and Holdings Selected at Random June, 1966 Data*		
	Number of Parishes	*No. Holdings over 20 acres*	*Number of Parishes*	*No. Holdings in Parishes*	*No. Holdings in Selected Sample*
East Devon	20	643	10	347	27
North Dorset	29	522	18	357	37
South East Somerset	16	359	16	340	40
Total .	65	1,524	44	1,044	104

TABLE 2

SAMPLE DETAILS

Size Distribution (Acres)	*Holdings in Selected Parishes*			*Sample Holdings*				*Raising Factor*
	Number	*Crops and Grass*		10 *per cent Sample Stratified*	*Reserve Sample* $\frac{1}{3}$ *Spare*	*Total*	*No. in final Sample*	
		Acres	*Per cent of Total*					
20— 49	271	9,424	8.9	9	3	12	8	33.90
50— 99	388	27,754	26.2	27	9	36	24	16.16
100—199	285	39,173	37.1	39	13	52	41	6.95
200 and over	100	29,344	27.8	29	10	39	30	3.33
Total	1,044	105,695	100.0	104	35	139	103	—

Data Collection

Data were collected to establish the level of available resources on each farm and to gauge the current pattern of resource use. This included information on land area and allocation, labour, capital (net worth), livestock building capacity, livestock numbers and milk sales. Most other input-output data were obtained from secondary sources. In addition, an attempt was made to obtain the farmer's estimate of his potential capital borrowing capacity, and his preference for type of dairy buildings in the event of expansion.

Some farmers had no idea, or were not prepared to commit themselves, as to their possible borrowing limit. Information on farmers' preference for type of building to expand the dairy herd, or on maximum corn acreage, could not always be obtained as some farmers did not seem to understand the principle of adjusting the farm plan to a hypothetical permanent change in milk price, in the context of planning or resource restraints. This difficulty was often encountered in trying to establish a limit on corn acreage, and suggests that in reality there may be some non-economic institutional constraints, for example, to the effect that farmers must milk cows.[7] This is a practical limit to the operation of the principle of an absolute restricting resource.

Estimation of Resource Restrictions

It was decided to group the sample farms according to absolute restricting resources to reduce aggregation bias, for the reasons already outlined. To explain the reasoning by which the resources, considered to ultimately limit the expansion of milk supply, were identified, it will be useful to outline the assumptions on which supply response has been based.

The date of the projected supply schedule was set five years ahead, from 1967, the date of the survey and the assumption was made that prices would remain stable. The uncertainty of short period variations in price, is thus eliminated. Hence the projected supply response at a given price is based on the assumption that farmers view this price as remaining unchanged for a sufficiently long period to warrant them making the adjustment to plant and enterprise combinations indicated.

On this basis it was assumed that land was fixed and therefore could ultimately limit milk supply given some estimated improvement in technology, e.g. increase in stocking rate over 5 years. Labour, family and permanent hired, was regarded as fixed at the present level. Labour is not a fixed resource in the long term, and as the trend is for a shift of labour off the land, it could be argued that over 5 years the level of labour could fall from the present level. But fairly conservative estimates of labour productivity have been used and no allowance was made for casual labour at present used, as this was difficult to quantify accurately in most cases. These factors could compensate for any decrease in the number of workers available.

Existing livestock building capacity is not a restricting factor because,

7. E.g. A farm growing corn could at some higher price for milk, increase income by substituting corn land for dairying. Therefore it is wrong to say it would not expand dairying and so avoid the question of preferred type of enlarged dairy buildings. Alternatively if the farm could grow all corn, it is wrong to state that no corn would be grown, as at a zero milk price corn growing would be economical.

over the period chosen, expansion of fixed assets is possible through capital investment; capital is also required to increase herd numbers irrespective of building capacity. Capital availability can therefore become a restriction where expansion of fixed assets is necessary to increase herd numbers, or where an increase in herd numbers only, is required to increase milk supply.

Land, labour and capital are therefore the restricting resources. Given the postulated increased levels in the technological efficiency of land and labour use and with given capital requirements for the expansion of buildings and herd numbers, then one of the three resources land, labour or capital will ultimately limit the expansion of milk production on each farm. Alternative methods of identifying restricting resources using variable resource programming have been outlined by Barker and Stanton. (14).

Estimating Technological Increases

Having decided which resources would ultimately restrict output, the next step was to decide on the estimated productivity level at the end of the period for these restricting resources. Productivity is governed by technology. The question arose of estimating the expected increase in technology over the planning period.

The levels of improved technology adopted were those estimated to prevail as average for the farms of the region at the end of the planning period.

The estimates made were, on the whole, very subjective, after making various analyses of the sample data. The average levels of technology for the use of land and labour in the dairy enterprise were calculated for the sample farms. Adjustments were made for the quantity of each resource used by other activities on each farm. An average of the farm coefficients was used, rather than an average weighted by the resources used as it was thought this would reflect the management factor on farms rather than an overall level of resource efficiency depicted in a weighted average. There was, however, little difference between the average and weighted average resource coefficients for land and labour.

It was originally intended to take the average coefficient of the top 25 per cent farms as the expected improved level of technology, but these appeared to be far above the general level that could be expected to be achieved by the generality of farmers. They were:

Land average of top 25 per cent
0.74 feed livestock units per acre or 1.351 acres per feed livestock unit.

Labour average of top 25 per cent
1,482 labour livestock units per 100 man hours or 42 labour livestock units per man.[8]

The percentage increase on the present mean was:
Land 33 per cent Labour 64 per cent

8. Feed Livestock unit conversion factor. Dairy cow = 1; Heifer = 0.8; 1–2years = 0.6; 0–1 years = 0.4; Bulls = 1.
Labour Livestock unit is based on the annual Labour requirements of the various grades of dairy cattle. Conversion factors used were Dairy cow = 1; Heifer = 0.278; 1–2 years = 0.311; 0–1 years = 0.444; Bulls = 0.422.

There is little information available on the rate of technological change at the farm level. However, these intended increases greatly exceed the trend of increases in productivity over the last 5 to 10 years. (15, Table 12.) (16, Table 16.) (17).

The study involves a normative approach, implying what farmers should do in view of their potential skills. To project a more realistic estimate of supply response, it was decided to adjust the estimated increases in levels of technology to comply with past attained rates of increase and keep them within limits thought feasible by advisory officers. Hence, a less ambitious estimate has been made rather than follow the rule originally proposed.

Briefly, the reasoning behind the chosen input-output coefficients for the restricting resources was:-

Land: The increase in carrying capacity for the South West from 1956–1961/62 was from 2 acres to 1.8 acres per cow, (15, Table 12.), i.e. 11 per cent. Figures show virtually no change from 1962–1965/66. (16, Table 16). However, informed opinion suggested that there was considerable potential for increased carrying capacity with increasing evidence of higher stocking densities and a figure of 1.5 acres per cow could be expected over the next 5 years, an increase of 18.9 per cent on the average for the sample. Interviews with progressive farmers support this view.

Labour: Some difficulty was encountered in estimating the technological efficiency level of labour. Firstly it was noted there was a wide dispersion in labour productivity levels among the sample farms. This dispersion was even greater when allowance was made at standard rates for labour required for fodder conservation. It was decided not to make this allowance, i.e. the figures used have included fodder labour requirements. The dispersion which still remained supported a previous hypothesis that there are different levels of productivity associated with various types and combinations of the milking-housing complexes, implying a substitution effect between capital and labour. Capital investment in a more labour efficient parlour-housing complex can increase productivity of present labour supply, hence it is possible to shift the restraint from labour to land or capital. Therefore it was decided to use two alternative levels of efficiency for labour, namely labour productivity with a conventional cowshed, or labour productivity with a milking parlour or bail and yard arrangement.

Time series and productivity studies suggest an increase in efficiency of labour use over a 5 year period from 1961/62 to 1966/67 of 12.5 per cent for all herds (17, Table 23). and difference between milking systems of 25 to 30 per cent (17, Table 28.) (18). In addition it must be remembered that these references are not directly comparable with the sample, for instance they exclude the additional labour required for fodder conservation.

TABLE 3

AVERAGE LABOUR PRODUCTIVITY OF SAMPLE FARMS

	Labour Livestock Units per Man Year*	
	Parlour or Bail	*Cowshed*
Average	29.69	20.04
5 per cent Increase	31.17	21.04
Average of Top 50 per cent	39.90	25.25
Chosen Productivity Level	33.00	25.00
Per cent Increase on Mean	11.30	24.75

* Including Labour for fodder conservation.
The suggested productivity level in parlour/bail is 32 per cent greater than that in cowshed.

The percentage increase for cowsheds may appear high but sample figures include a number of small family unit farms which could have some labour in excess supply, i.e. undeı-used labour, which would give a lower average productivity level. To test this the average productivity, on cowsheds with over 25 cows, was calculated at 22.6 labour livestock units per man, which requires only a 10 per cent increase in productivity to reach the chosen figure of 25 cows per man. The problem is to measure labour used rather than labour available.

Comparing Land, Labour and Capital Restraint Levels

Having allowed for the expected improvement in technology, it was next necessary to compare the maximum level of milk output from each resource. That resource with the lowest maximum output would be the restricting resource.

To identify which resource will ultimately restrict output, it must be possible to compare the maximum attainable milk supply permitted by each resource on each farm. Milk supply is measured by the unit of milk production, 1 cow. However, in estimating resource productivities for projecting future milk supply, account must be taken of the resources required by dairy replacements. The number of replacements would have to be increased with any permanent increase in cow numbers, and some of the resources made available through increased efficiency, or transferred to dairying from another activity following an increase in the price of milk, would have to be allocated to supporting the additional replacements.

It was assumed that the ratio of cows to replacements would remain the same at the end of the period as at the beginning, taking this ratio as at least adequate for herd maintenance at current herd size. This ignores the adjustments required to reach the projected herd size, which is a short term consideration not allowed for in this model. The effect on farm profits and supply response over the planning period of rearing additional replacement stock to provide for an increase in herd size can be provided for by use of a polyperiod model. (19.). This is a form of dynamic programming giving a long run plan over time with intermediate plans. It provides for the transfer of resources from one period to the next but gives an optimal solution for each period.

The model adopted does, however, allow for the possibility of herd increases with bought-in cows. Such a provision is feasible when the model is used at an intra or inter-regional level of analysis, but if applied at the national level this assumption would need to be amended.

The resource requirements have been calculated in feed livestock units for land, and labour livestock units for labour. In both cases one cow equals one unit. The maximum number of livestock units for each farm for each resource can be calculated by dividing the resource level by the resource coefficient. The maximum number of milkers is calculated by dividing the total possible livestock units by the ratio of milkers to replacements for the farm.

$$\text{e.g. Labour} \quad \frac{\text{Total Man Hours}}{\text{Man Hours per Labour LU.}} \Big/ \begin{array}{l}\text{Ratio Milkers:}\\ \text{to followers in Labour LU.}\end{array}$$

This calculation permits a comparison between the maximum number of milkers allowed by the land and labour resource levels.

To identify if a capital restraint was operative a subjective estimate was made of the capital needed to achieve the herd increase permitted by the land or labour restraint, using certain assumptions of the cost of additional milkers and buildings and farmer's choice of type of building. If insufficient capital were available capital was taken as the restricting resource. Farmers' estimates of capital available, including possible borrowings, were used. Where no estimate was given 20 per cent of net worth was taken as the borrowing capacity. This proportion was based on averages obtained from the survey farms. It is worth mentioning here the effect of this assumption on tenanted and owner operated farms. Owner occupiers with the net worth of the land and buildings as security, obviously have much greater borrowing capacity. An attempt was made to obtain details on the landlords potential investment, but few tenants had much idea of the investment intentions of their landlords.

On this basis six benchmark farms have been defined.

Definition of Farms Comprising Benchmark Farm Groups

1. Land Restraint with low labour productivity.

Farms with a cowshed and sufficient capital to increase herd numbers to the land restraint level, this being less than the increase permitted by the labour resource at low labour productivity. Therefore there is no question of investment to increase labour productivity to enable herd numbers increase.

2. Land Restraint with high labour productivity.

Farms with parlours or bail at present, or with capital to provide a parlour or bail milking system, as well as the increased herd numbers up to the land restraint level, this being less than the increase permitted by the labour resource at high labour productivity.

3. Labour Restraint with low labour productivity.

Farms with a cowshed and sufficient capital to increase herd numbers to the level permitted by the labour resource at low labour productivity, this being less than that permitted by the land resource but with insufficient capital to increase labour productivity through installation of parlour or bail milking. In addition it includes those farms where the farmers stated preference for building expansion was a cowshed. This involves adjusting the normative assumptions in the sense of allowing for farmers actual preferences, rather than what they ought to prefer.

4. Labour Restraint at high labour productivity.

Farms with parlour or bail milking at present, or with sufficient capital to provide a parlour or bail milking system, as well as the increase in herd numbers up to the level permitted by the labour resource at high labour productivity, this being less than that permitted by the land resource.

5. Capital Restraint at low labour productivity.

Farms with a cowshed that do not have sufficient capital to increase herd numbers up to the level permitted by the land resource or labour at the low productivity level.

6. Capital Restraint at high labour productivity.

Farms with a parlour or bail milking system that do not have sufficient capital to increase herd numbers to the land or labour restraint level; also farms with a cowshed that have sufficient capital and the stated desire to improve their labour productivity by investing in a parlour or bail system but still do not have enough additional capital to increase herd numbers to the level permitted by the land resource or the labour resource at the high productivity level.

Benchmark Farm Resource Levels

The weighted average level of resources of the farms within each group became the resource levels for the benchmark farms. Some adjustments were made to the resource levels of farms within the benchmark farm groups in an attempt to eliminate some sources of bias. This subjective analysis of each farm, while it may reduce error, increases the amount of computation.

With farms grouped according to absolutely restricting resources, the averaging process still implies the transfer of other resources between farms within a group which could cause an upward bias at less than maximum output. Inspection of expansion possibilities on farms revealed that some farms possessed surplus housing above that required by the maximum possible herd size permitted by the restricting resource. Taking an average of surplus housing for the benchmark farm implies that this unusable surplus is transferable to other farms, which is not possible in practice. This unusable surplus was excluded from the benchmark farm average available for dairy cows and was transferred to housing for use by the beef enterprise. This assumes that farms with excess dairy housing have resources to allocate to the extra beef permitted by this resource transfer.

It was noted that many farms outwintered some of their replacement stock, leaving a surplus of housing. It was assumed that the current ratio of replacement stock housed to milkers would be maintained with increased herd numbers. The replacement housing requirement on this basis was calculated for the maximum possible herd size, and any excess transferred to the beef housing resource.[9] This calculation was done using the bench-

9. The average number of followers requiring housing in each benchmark farm was calculated. The ratio of milkers to followers requiring housing at current levels was multiplied by the maximum herd size. The balance of total followers housing available was transferred to the beef enterprise.

mark farm averages. It is doubtful whether the increase in accuracy would have warranted the extra computations required to calculate the excess on each farm.

Bias can result from inconsistencies between estimated and observed data on individual farms within each group. On some farms it was noted that use of the standard estimated restricting resources coefficient permitted a smaller maximum herd than was currently being operated. Ignoring the observed and using the standard data in calculating the maximum herd size average for a benchmark farm can result in an under-estimate. This bias is in the opposite direction from that caused by averaging heterogeneous restrictions. It is caused through ignoring the degree of productivity of factors, e.g. land quality, on some farms. In constructing the linear programme for the respective benchmark farms, the question arose as to which level, the observed or the standard, should be regarded as the maximum in calculating the resource coefficients. The resource coefficient could be adjusted to force a limit at either level. The standard resource coefficients were used in identifying the restricting resource on each farm. The question is which of these coefficients is appropriate in the linear programme? To use the standard coefficient for this purpose fulfills the assumption that the standard will be the average of the population at the end of the planning period. Using the observed level of technology in the linear programme would cause the population resource coefficient to be above the estimated average.[10]

Results using both observed and standard estimated coefficients, were obtained and are given in Table 5. However, because of the potential elimination of error, the results using observed data have been used for discussion in the conclusion.

To obtain the observed coefficients those farms with herd numbers already above the estimated restraint limit for land and labour resources have been included at their present level in calculating the maximnm possible herd size for each benchmark farm. The restricting resource coefficient for dairying, for the respective benchmark farms, was adjusted in the linear programme to permit a maximum herd size at this increased level. The effect of this adjustment on maximum milk production can be seen in Table 4. to be a difference of 2274 thousand gallons or approximately 8 per cent of current production.

The weighted average resource levels for the benchmark farms as used in the linear programmes are shown in appendix Table 1.

Linear Programme Matrices

The resource levels were then included in a linear programme. The linear programme matrix for each benchmark farm follows the same layout as that shown for capital restraint high labour productivity in appendix Table 2. Activities other than dairying have been based on resource levels, restraints and modal information derived from the respective groups. For

10. The Linear programme solution uses all resources at the level stated for the activity coefficient. Therefore on a farm type e.g. Labour restraint where the Land resource is in excess supply, the Land coefficient for dairying is included at the standard (the Land resource is used at the standard level). By using the resource at a more intensive level (a high coefficient) on one farm type, in this case Land restraint farms, raises the population average of Land resource use above the original estimate.

example, in groups where only a few or no farms had pork or bacon activities, these activities were excluded from the respective linear programme matrix. This decision was justified by the greater profitability of rearing stores or weaners. It is likely that on some farms the operative set of resources and restraints would enable a pork rearing activity to occur, but it was not possible to identify these restraints from the survey data.

With the averaging method used to obtain benchmark farm data, the linear programme model does not reflect the real-world intention in deriving the capital coefficients. For example, in the dairy activities, on some high labour productivity farms the assumed expansion path involves conversion or renewal of buildings for the whole herd in order to increase from a low productivity to a high productivity situation. In these cases the benchmark farm capital coefficient does not reflect the true marginal cost of purchasing and housing an extra cow, because in calculating the coefficient the total cost of housing is divided only by the additional number of cows to be housed. This infers that the total cost of re-housing must be recoverable from only the additional cows above the present housing capacity.

The dairying activity has been defined in relation to the capital requirements for three steps of an expansion path for dairying and in relation to two sources of conserved fodder, hay and silage.

Two beef activities have been included one fattening surplus dairy progeny and a beef rearing activity supplying its own young stock to allow for beef production when no dairy calves are produced. This treatment of the beef enterprise, which assumes that the region must produce its own beef young stock, would need to be modified if the model were applied at the national level because of the importation of Irish store cattle. However, bearing this complication in mind, the results have important implications for beef and milk pricing policy.

The relative margins for dairying and beef can have an important effect of the supply response of milk. Some difficulty was experienced in establishing the gross margins for the beef rearing activities (see appendix) because there is a wide range of uncertainty in beef returns. Not only are there numerous alternative systems of production giving a wide range in costs but also a wide variation in market prices. Adhering to the normative approach, the activity coefficient has been set at the upper range of efficiency and higher level of gross margins. It could well be that this level of achievement is somewhat higher than that expected for the beef enterprise under the conditions prevailing in the survey area.

Most of the gross margin and resource data were obtained from the Bristol and Exeter Universities Farm Management Handbook (20), supplemented where possible with yield data from the survey farms e.g. milk yields or, in some cases e.g. corn yields, from Exeter Farm Management Survey farms relevant to the area under study.

Farm plans and milk supply were derived for milk prices at 0; 2*s.* 6*d*; 2*s.* 9*d.*; 3*s.* 0*d.*; 3*s.* 3*d.*; 3*s.* 6*d.*; 3*s.* 9*d.*; and 4*s.* 0*d.* per gallon. The procedure for setting out the programmes follows closely "Linear Programming Methods" by Heady and Candler (21, Ch. 3, 6, 8). The data were processed on the University of Exeter Elliot 803 computor using the linear programme 02. The programmed milk production for each benchmark farm was raised for each type group and then aggregated to give the total supply response for the region.

GROUPING BY RESOURCE RATIOS

An alternative method of grouping farms by resource ratios was tried. The method, mentioned by Barker and Stanton as an alternative, has been investigated by R. H. Day (22). One limitation of this method is that farms have to be regrouped when different resources are being compared.

Day suggests there can be wide variation in resource levels, providing this is proportionate within groups, without introducing bias. This assumes conditions of technological homogeneity and proportional prices. It is a sufficient condition, but may not be a necessary condition as the resources may not act as constraints at certain prices, or differences in input-output coefficients may cancel variations in resource ratios (23, p. 1441). By grouping farms on the basis of resource ratios, it seems there is greater chance of getting proportional variation within groups if the ratio ranges characterising the groups are small.

This method of grouping was tried out in order to compare results and computational time. Because of the blanket treatment of each farm, compared with the subjective and detailed treatment required for each farm using estimated restricting resources, the computational burden was greatly reduced.[11]

Procedure

In this comparison of the two methods, the ratio of land to labour was used. Output from these two resources in the previous method had been equated to allow comparison of their restriction levels; output from available capital had been estimated subjectively for each farm. Capital was ignored this time, as the resource ratio method would not permit an individual estimate for each farm. This considerably reduced the computational burden.

The ratio used was 100 hours of labour to 1 acre of land. The previous productivity levels were used as a basis of demarcation into groups.

At low labour productivity, 25 cows using 2,850 man hours per year require an area of 37.5 acres at 1.5 acres per cow. i.e. the ratio is 28.50 100-hour labour units to 37.5 acres = 1:1.32.

At high labour productivity 33 cows per man per year require 49.5 acres. i.e. the ratio is 28.50 100-hour labour units to 49.5 acres = 1:1.735.

Comparing these ratios with the previous resource restriction levels, any ratio less than 1:1.32 would have a land restriction irrespective of high or low labour productivity level.

Farms with ratios of 1:1.736 or above would have a labour restriction. Ratios between 1:1.321 and 1:1.735 would be land or labour restricting depending on whether they had a high or low labour productive system.

To reduce the number of farms per benchmark group, further divisions were made in the ratios. The ratio ranges used were 1: less than 1.0; 1:1.1–1:1.32; 1:1.321–1:1.735; 1:1.736–1:2.0; 1:2.0–1:3.0 and 1: more than 3.0.

---

11. Approximately one week's work by a clerical officer under supervision was required, compared with 2½ months of research officer labour using the restricting resources method.

The linear programme resource restraints and coefficients were calculated in the same manner as previously, using the same assumed improved levels of technology. However, in this case no analysis was made of the estimated maximum output from each farm. Hence no adjustment has been made for those farms already producing above the level of technological efficiency assumed for the benchmark farm. The estimated supply response should be compared with that obtained using the more individual method of classification to compare the aggregation bias.

RESULTS

The results can be interpreted in three stages. The first stage is the preliminary result when sample farms have been grouped into farm types. This provides a maximum output estimate, and is achieved without the use of a computer. The second is the step supply response curves derived from linear programming farm types at variable prices for milk. The supply response curve can be analysed in two stages; at the aggregate for the population, and for each individual benchmark farm.

1. *Preliminary Results. Table* 4

Even before programming the individual farm unit method can yield quite useful results. On the restricting resource principle the absolute maximum level of output can be derived. Resource restrictions do operate, especially where profit maximisation is the farmer's aim. Therefore it is possible to determine the absolute limits of supply response on the assumptions used.

A total increase of 7.04 million gallons is possible, which is an increase of 24.9 per cent on current level of total production. Within this total it is interesting to note the potential increase in output within the various farm types; 63.4 per cent of the potential increase in milk production is on high labour productivity farm types. Of the three restraints the land restraint farm types contain the greatest potential increase in output, amounting to 42.7 per cent of the total.

Table 4 shows also the results derived from applying a blanket level of technology rather than the observed level of technology for farms already operating above the estimated level of technology, namely a possible increase of 4.77 million gallons, compared with 7.04 million gallons. This is a difference of 2.27 million gallons at the maximum level of output, which is a difference of eight per cent in the potential increase in output on current production. Note that there is no difference for the capital restraint farms, where a subjective estimate has been applied to each farm, rather than a fixed resource coefficient as in the case of a land or labour restraint.

The result is a shift of emphasis to the capital restraint farms for potential increase in output. On this basis of calculation, their contribution is 37.5 per cent of the total, compared with 34.5 per cent from land and 27.9 per cent from labour restricting farm types.

Finally these preliminary results show the increase in supply from the increase in yield only.

TABLE 4 **PRELIMINARY RESULTS BENCHMARK FARM GROUPS**

Resource Restraint Farm Type Group	*Land*				*Labour*				*Capital*				*Milk Production Whole Population*	
	Low Labour Productivity		*High Labour Productivity*		*Low Labour Productivity*		*High Labour Productivity*		*Low Labour Productivity*		*High Labour Productivity*			
	Herd Size	*Total Production*	*Herd Size*	*Total Production*	*Herd Size*	*Total Production*	*Herd Size*	*Total Production*	*Herd Size*	*Total Production*	*Herd Size*	*Total Production*	*Total Production*	*Per cent Increase*
	No.	*Gal. '000*	*No.*	*Gal. '000*	*No.*	*Gal. '000*	*No.*	*Gal. '000*	*No.*	*Gal. '000*	*No.*	*Gal. '000*	*Gal. '000*	*%*
Current Production														
Benchmark Farm Average	17.655	13.150	45.079	34.724	31.948	22.830	64.79	46.066	15.749	11.512	55.309	40.154	28,328	
Population	4,159	3,098	13,710	10,561	5,309	3,794	10,700	7,608	1,661	1,214	2,828	2,053		
5% Increase on Current Production														
Benchmark Farm Average	17.655	13.806	45.079	36.476	31.948	23.971	64.79	48.366	15.749	12.072	55.309	42.162		
Population . .	4,159	3,252	13,710	11,089	5,309	3,983	10,700	7,987	1,661	1,273	2,828	2,156	29,740	5.0
Maximum Output [1]														
Benchmark Farm Average	19.75	15.444	47.434	38.365	33.229	24.931	69.696	52.028	23.778	18.226	72.75	55.525		
Population . .	4,652	3,638	14,426	11,668	5,521	4,143	11,510	8,592	2,891	2,216	3,719	2,839	33,096	16.8
Increase on Current Production: '000 gall. .		540		1,107		349		984		1,002		786	4,768	
Per cent of Total Increase		11.3%		23.2%		7.3%		20.7%		21.0%		16.5%	100.0%	
Maximum Output [2]														
Benchmark Farm Average	22.19	17.352	51.152	41.372	35.156	26.378	75.127	56.082	23.778	18.226	72.75	55.525		
Population . .	5,227	4,088	15,556	12,582	5,842	4,383	12,406	9,262	2,891	2,216	3,719	2,839	35,370	24.9
Increase on Current Production: '000 gall. .		990		2,021		589		1,654		1,002		786	7,042	
Per cent of Total Increase		14.0%		28.7%		8.4%		23.5%		14.2%		11.2%	100.0%	
Difference (Bias from estimated standard basis) . . .	575	450	1,130	914	321	240	896	670	—	—	—	—	2,274	

1. Using estimated standard productivity.

2. Allowing for higher observed productivity.

TABLE 5

MILK SUPPLY ('000 Gal.) WITH VARIOUS RESOURCE SPECIFICATIONS

Result	*Resource Restriction*	*Milk Price—shillings per gallon*								*Maximum Production*	*Current Production*
		0	2*s.* 6*d.*	2*s.* 9*d.*	3*s.* 0*d.*	3*s.* 3*d.*	3*s.* 6*d.*	3*s.* 9*d.*	4*s.* 0*d.*		
			'000 gal.	'000 gal.	'000 gal.	'000 gal.	'000gal.	'000 gal.	'000 gal.	'000 gal.	'000 gal.
1	Nil	—	3,577	5,221	7,709	19,647	22,752	30,557	32,336	35,370	28,328
2	Labour surplus above current dairy requirements	—	6,361	15,681	21,794	27,449	31,016	32,849	34,056	35,370	28,328
3	Labour and beef housing, surplus above current dairy requirements	—	25,496	25,969	26,759	27,743	31,005	32,819	34,227	35,370	28,328
4	Labour and beef housing, surplus above maximum dairy requirements	—	29,751	32,452	33,476	33,930	33,930	34,072	34,515	35,370	28,328
5	Average coefficients Labour and beef housing, surplus above current dairy requirements	—	23,655	24,281	27,064	27,661	29,669	30,686	30,686	33,096	28,328
6	Grouped resource ratios average coefficients, labour and beef housing surplus above current dairy requirements	—	23,982	24,389	24,389	26,196	29,732	32,161	33,340	35,171	28,328

Results 1, 2, 3 and 4, have used observed co-efficients. See page 23.

Results 5 and 6 have used standard estimated co-efficients.

2. *Results of Programming*

Normative Supply Response. The benchmark farms were linear programmed at price intervals of threepence per gallon for milk between 2*s*. 6*d*. and 4*s*. 0*d*. a gallon. Raising and aggregating the results for each benchmark farm gave the population supply response figures shown in Table 5, result 1.

This is the projected optimum milk supply at the assumed enterprise production levels with the linear programme resource base defined as allowing cattle housing to be available for dairy or beef cattle, and unrestricted availability of labour to land and using factory enterprises. It will be noted that the assumption underlying this estimate of supply response gives a lower level of milk production at current prices than is currently being achieved. Current production of 28.3m. gallons obtained with an average yearly price of 3*s*. 1*d*. a gallon is far greater than the estimated production of 7.7m. gallons, at this price.

However the estimated figure is a normative supply response; it is an estimate of supply given the current prices of commodities, and production functions as used in the linear programmes, and supposing farmers allocated resources to give maximum total revenue per farm unit. The great difference from current level of production suggests that the farmers' interpretation of their resource restrictions are different from those defined in the linear programmes.

An Example of Specification Error. To give a more realistic projection of supply response an attempt was made to specify the resource restrictions facing farmers as they would interpret them.

In addition it was reasoned that any change in farm plans would in fact have to take place from the present plan and resource base. Therefore the aim should be to programme a supply response for an increase in price from the present resource allocation, and price, which is the only realistic use of linear programmes as a predictive technique. Linear programming gives the optimum farm plan using marginal rates of substitution of resources in various enterprises which can apply both in the reduction and expansion phase from the current plan. However, in practice there are problems of asset fixity in agriculture in the contraction phase, which cannot be readily handled in the linear programme model. In practice contraction of dairying would entail sale of cows which would make capital available for the expansion of other enterprises. This has not been provided for in this model. In addition. improvements in technology are not reduced during the contraction phase.

The programmes were then re-run with three alternative restrictions on resource use.

Result 2. A surplus labour resource row was added. Labour requirements for the current level of dairy production were calculated, and only the surplus labour over current dairy requirements made available to the factory enterprises.

Result 3. In addition to the above restriction, the amount of cattle housing available to the beef enterprise was limited to that surplus from the current dairying requirement.

Result 4. Only that labour and dairy housing surplus at the maximum level of dairying, was made available to the factory and beef enterprises respectively. In this final programme the beef rearing enterprise was eliminated.

Each different specification of the resource restraint gives a different level of milk supply for the same price. These problems of specification suggest some possible steps for improving this method of supply response analysis. One is to identify those restrictions which farmers in fact place on resource allocation; possibly through the establishment of producer panels, to identify and quantify those factors which influence farmers in making their planning decisions. Another alternative is the use of a modified form of linear programme, such as recursive linear programming (24), in which upper and lower limits can be placed on farmers' adjustments from a current farm plan.

In the more detailed presentation of the results which follows production obtained with result 3 has been used. It seems clear that farmers do not behave as defined by the normative projection (result 1). Some suggested reasons for this which support the resource restrictions used are:-

1. Farmers do not regard labour as their scarce resource. Owing to the incidence of family labour and the high cost of land they tend to regard labour as a cheap resource and maximise returns of land using enterprises.

2. Flexibility in the supply of labour. It is possible to increase the supply of labour during times of peak labour requirements through working overtime or engaging casual labour. To this extent the labour resource level could be higher than that calculated for the benchmark farm linear programmes.

3. If labour is in short supply, it is not being employed to the level where marginal cost equals marginal revenue, hence it is profitable to employ available extra labour at a higher cost per unit during periods of peak seasonal requirement. Activities with seasonal labour requirements can then be maintained at higher levels than that permitted by the permanent labour force.

4. Farmers would prefer to use expensive specialised dairy buildings for dairying and keep their current dairy herd even at lower milk prices. Milk price is more stable than the alternative beef prices. Placing the restraint on availability of current dairy buildings to beef may be more realistic and should force dairying into the programmes.

5. Further, with an increase in the quantity of factory enterprise products at the national or regional levels a fall in price with a reduction in gross margin could be expected. An additional restraint should perhaps be placed on these activities to reflect the point within the population at which this change in gross margin could be expected to occur. This would increase milk supply response in the lower price ranges through the diversion of resources into land using enterprises (25).

The assumptions specified in result 4, do not seem to be very realistic although giving an expected result, i.e. an increase in milk production on current price at the end of the planning period. It assumes that labour surplus to dairy is not available for use in more profitable alternatives at milk prices when the restricting resource is not entirely devoted to milk production.

If, in fact, farmers aim to maximise returns to land-using enterprises there will be some restraint on the expansion of factory enterprises; supply response may be greater than indicated in result 1. and we could expect this to follow more the features of result 3.

Acceptance of these hypotheses still leaves a result which cannot readily be explained. Assuming resource restrictions now to be correctly represented, it is not to be expected that milk production, with increase in technology and yield, at the end of the planning period and at the current yearly average price, would be less than current production. Current level of production is only achieved at a price between 3*s*. 3*d*. and 3*s*. 6*d*. a gallon.

It may possibly be significant that this is nearer the average price for winter milk. It could be that in an area where winter production is important farmers take the winter rather than the average price into account in optimising their plans. If this is so, then under the assumptions of this model only a slight supply response is projected over the planning period.

One factor restricting milk output at above current milk prices is the continued output of beef in the linear programme models. This is brought about partly by the higher marginal value product of labour for the beef rearing activity which competes for limited labour on labour restricting farms. A further factor is the higher marginal value product of capital for both the dairy beef and beef rearing activities which compete for the limited supply of capital on the capital restricting farms.

Grouping by Resource Ratios. Result 6, Table 5. shows the supply response projection when the alternative method of grouping farms was used. Current level of production is not achieved until the 3*s*. 3*d*.—3*s*. 6*d*. price range is reached.

The total supply response projection is slightly less than that obtained in result 3, which has comparable conditions for the linear programme resource restraints. However result 6. should be more closely compared with result 5, both of which were obtained using average resource coefficients and have comparable conditions applying to the linear programme resource restraints. Only at the maximum, and in the upper price range for milk, does result 6 exceed result 5 to any appreciable extent. In grouping by ratios no provision was made for the effect of capital restraint which could be the cause of this difference at maximum and near maximum production.

It may be true that the estimated resource restrictions method, with the detailed analysis of each farm entailing subjective estimates of the capital requirements and making possible the use of observed resource coefficients, gives the least biased estimate of supply response; yet at the same time the resource ratio method may well be an acceptable alternative because of the greatly reduced computational effort involved.

Supply Response of Other Commodities with Respect to Milk Price. In addition to the supply response for milk the model also reveals important additional information. Table 6 gives the sizes of the various enterprises which govern the production of competing commodities at various milk prices. These commodity outputs follow the expected pattern, decreasing in output as the output of milk increases. The exception is barley over the price range 2*s.* 9*d.* to 3*s.* 9*d.* per gallon of milk, due to substitution between beef and barley as users of land.[12]

Although pork with its slight difference in gross margin and resource requirement was not offered as an enterprise, it can be supposed that some pork would be produced. There is considerable scope because of unused housing and labour and capital availability for increased output of pigs and poultry above the current levels even at the highest milk price.

The size of the factory enterprises is in particular due to the capital which has been assumed to be available. These enterprises arise almost exclusively on the land and labour restricted benchmark farms, and at all milk prices over 70 per cent of them are activities requiring extra housing (see Appendix Table 2.) It will be recalled that capital availability is construed in the sense of potential borrowing capacity. In the case of an owner-occupier, for example, this may be greatly in excess of what in fact he intends to borrow.

An important relationship to note is that existing between dairy and beef output, As the dairy enterprise expands with milk price increases, beef numbers fall because both enterprises compete for land, labour and housing resources. Whilst dairying does, to a large extent, supply the calves for beef, the indication is that in areas of this type and under the assumed conditions, an increase in milk price will not result in an increase in beef production, unless associated with a corresponding increase in the return on beef. This is because milk production competes with beef production on the individual farm. Only with the possibility of inter-regional transfers can milk price subsidise an increase in beef production.

Stepped Supply Response Line

Total milk supply for each price level was obtained for each benchmark farm. From these totals, a stepped supply response for each benchmark farm, and for the population, can be drawn. Diagram 1.

Kottke (26) explains the assumptions underlying a step supply response, its economic interpretation and the implications for a farm or farm type.

The vertical segments represent the price range over which production is stable. This is due to the marginal cost of transferring the next limiting resource into milk production. Between vertical sections, horizontal sections occur which refer to the operation of the profit maximising function, in the sense that once the price increase indicated by the vertical segment makes the resource transfer profitable, marginal revenue becoming greater than marginal costs, profits would be maximised by increasing milk production up to the quantity indicated by the next vertical segment.

The supply response line has been drawn, hatched and sloping, where the exact point of change in price and level of supply is not known at prices between those at which the farms were programmed. The reason the exact level of supply is not known is that there is more than one change of optimum farm plan and level of supply between the prices at which the farms were programmed.

---

12. Because a beef rearing unit requires 2 units of housing, as dairying competes with beef rearing for housing, more land is released than is required for the dairy unit. This land is released for expansion of the corn interprises.

TABLE 6

POPULATION DETAILS

Production of Other Enterprises at Alternative Milk Prices and Current Production

Enterprise	Unit	*Milk Price—shillings per gallon*								Current Production
		0	2*s.* 6*d.*	2*s.* 9*d.*	3*s.* 0*d.*	3*s.* 3*d.*	3*s.* 6*d.*	3*s.* 9*d.*	4*s.* 0*d.*	
Sheep	ewes	110,300	603	—	—	—	—	—	—	7,958
Beef Rearing	fat beasts	6,152	6,023	6,023	5,898	4,145	2,069	1,428	1,005	*unknown*
Dairy Beef	fat beasts	—	4,754	3,831	1,400	1,400	1,400	1,585	1,224	*unknown*
Total Beef		6,152	10,777	9,854	7,298	5,545	3,469	3,013	2,229	5,182
	†surplus calves	—	17,836	19,195	22,278	23,107	26,137	27,568	29,184	*unknown*
Barley	acres	25,341	16,997	16,997	18,821	21,346	18,959	16,171	15,321	6,502
Poultry	hens	615,100	615,100	615,100	623,700	623,700	504,900	456,900	415,800	142,000
Pigs	baconers	147,030	147,030	145,210	145,210	142,396	117,018	94,760	94,760	*44,023
	Sows	2,267	5,965	5,965	5,282	5,282	4,891	4,556	1,510	3,877
Dairy Units		—	32,709	33,341	34,511	36,337	40,030	42,094	44,733	38,367
‡Milk	'000 gal.	—	25,496	25,969	26,759	27,743	31,005	32,819	34,227	28,328

* Bacon and Pork sales.

† Surplus calves from dairy enterprises not required for rearing as beef. These calves would be available for slaughter as calves or for export to other regions for beef rearing.

‡ Result 3, Table 5.

Individual Benchmark Farm Results

The next stage is to look at the supply response results on the various benchmark farms. Table 7 shows the levels of milk supply for each benchmark farm, for the population represented by each benchmark farm and for the whole population.

It is important to know not only the quantity produced at each milk price but also the stability of production, i.e. the range of price over which that farm plan is optimal and the increase in profitability over the previous price. Table 8 shows this basic financial information for each farm type at the various milk prices. The level of and change in gross margin for each benchmark farm seems an important factor to be considered when policy is being planned with a view to price increases necessary to obtain desired increases of production. The end result will be an increase in gross margin from the dairy enterprise because of the higher price for milk and the greater quantity of milk produced and a loss of income from the activities replaced by the increase in dairying.

At the upper and lower limits of the lower price range for which the farm plan or level of milk production is optimal, it becomes profitable to change the farm plan. In some instances as can be seen from Table 8, there is more than one border price (change in farm plan) in the increase in milk output between the price intervals selected. Furthermore it is important to note the number of alternative plans near the optimum, i.e. plans with a gross margin within about £100 of the optimum, as this could suggest the rationale of producing alternate commodities. Apart from some of the plans in which milk price is zero, the next best plan at the same price shows a gross margin reduction of £36 or less. This suggests that even at these prices and under the linear programme restraints the optimum milk output suggested by the model results from a plan which is not much better than some other plan and therefore need not necessarily be achieved. With current production above that projected by the model, and because there is only slight variation in gross margin between near optimum plans for the benchmark farms, it seems there is very little potential for increases in milk production from this area, as a consequence of increases in milk price.

Table 7

MILK SUPPLY RESPONSE BY FARM TYPE AT PRICES FROM 2s. 6d. to 4s. PER GALLON

Gallons Produced

Resource Restraint Farm Type Group	*Milk Price—shillings per gallon*														*Maximum Output*		*Current Output*	
	2*s*. 6*d*.		2*s*. 9*d*.		3*s*. 0*d*.		3*s*. 3*d*.		3*s*. 6*d*.		3*s*. 9*d*.		4*s*. 0*d*.					
	Farm	*Aggregate* ’000	*Farm*	*Aggregate* ’000	*Farm*	*Aggregate* ’000	*Farm*	*Aggregate* ’000	*Farm*	*Aggregate* ’000	*Farm*	*Aggregate* ’000	*Farm*	*Aggregate* ’000	*Farm*	*Aggregate* ’000	*Farm*	*Aggregate* ’000
Land Restraint																		
Low Labour Productivity	12,466	2,936	12,466	2,936	12,466	2,936	12,466	2,936	15,677	3,693	17,352	4,088	17,352	4,088	17,352	4,088	13,149	3,098
High Labour Productivity	32,304	9,825	32,304	9,825	32,304	9,825	35,543	10,809	37,577	11,428	41,367	12,581	41,367	12,581	41,366	12,581	34,788	10,560
Labour Restraint																		
Low Labour Productivity	19,214	3,192	19,214	3,192	22,761	3,782	22,761	3,782	22,761	3,782	22,761	3,782	23,971	3,983	26,378	4,383	22,853	3,791
High Labour Productivity	36,128	5,966	38,989	6,439	38,989	6,439	38,989	6,439	48,365	7,987	49,116	8,111	51,832	8,560	56,082	9,262	46,066	7,608
Capital Restraint																		
Low Labour Productivity	12,071	1,468	12,071	1,468	13,314	1,619	13,314	1,619	13,314	1,619	13,314	1,619	17,895	2,176	18,225	2,217	11,900	1,214
High Labour Productivity	41,244	2,109	41,244	2,109	42,214	2,158	42,214	2,158	48,825	2,496	51,600	2,638	55,525	2,839	55,525	2,839	40,155	2,053
Total		25,496		25,969		26,759		27,743		31,005		32,819		34,227		35,370		28,327

TABLE 8

GROSS MARGIN, CHANGES IN GROSS MARGINS AND PRICE RANGE FOR STABLE PRODUCTION

Resource Restraint Farm Type Group	*Plan Change*	*Milk Price—shillings per gallon*															
		0		2*s.* 6*d.*		2*s.* 9*d.*		3*s.* 0*d.*		3*s.* 3*d.*		3*s.* 6*d.*		3*s.* 9*d.*		4*s.* 0*d.*	
		Gross Margin	*Price Range*	*Gross Margin*	*Price Range*	*Gross Margin*	*Price Range*	*Gross Margin*	*Price Range*	*Gross Margin*	*Price Range*	*Gross Margin*	*Price Range*	*Gross Margin*	*Price Range*	*Gross Margin*	*Price Range*
Land Restraint		£		£		£		£		£		£		£		£	
Low Labour Productivity	1st sub-optimum	965	0	1,690	2*s.* 4*d.*							2,339	3*s.* 6*d.*	2,536*	3*s.* 7*d.*		
	Optimum	1,155	to	1,701	to							2,340	to	2,555	to		
	Change 1	190	11*d.*	11	3*s.* 4*d.*							1	3*s.* 7*d.*	19	—		
	2			546								539		215			
High Labour Productivity	1st-sub-optimum	2,501	0	3,934	2*s.* 5d.					5,169*	3*s.* 3*d.*	5,630	3*s.* 5*d.*	6,103*	3*s.* 8*d.*		
	Optimum	2,656	to	3,957	to					5,176	to	5,633	to	6,122	to		
	Change 1	145	1*s.* 0*d.*	23	3*s.* 2*d.*					7	3*s.* 4*d.*	3	3*s.* 8*d.*	19	—		
	2			1,301						1,219		457		489			
Labour Restraint																	
Low Labour Productivity	1st-sub-optimum	1,819	0	2,444	2*s.* 5*d.*			2,959*	2*s.*10*d.*							4,133*	4*s.*
	Optimum	1,821	to	2,478	to			2,995	to							4,134	to
	Change 1	2	1*s.* 0*d.*	34	2*s.*10*d.*			36	4*s.*							1	4*s.* 3*d.*
	2			657				517								1,139	
High Labour Productivity	1st sub-optimum	3,418	0	5,006	2*s.* 6*d.*	5,458*	2*s.* 9*d.*					6,993	3*s.* 5*d.*	7,600*	3*s.* 7*d.*	8,241	3*s.*11*d.*
	Optimum	3,454	to	5,007	to	5,462	to					6,995	to	7,607	to	8,245	to
	Change 1	36	11*d.*	1	2*s.* 9*d.*	4	3*s.* 4*d.*					2	3*s.* 7*d.*	7	3*s.*10*d.*	4	4*s.*
	2			1,533		455						1,533		612		638	
Capital Restraint																	
Low Labour Productivity	1st sub-optimum	1,031	0	1,186	1*s.*			2,392	2*s.*10*d.*							3,079	4*s.*
	Optimum	1,186	to	2,082	to			2,396	to							3,082	to
	Change 1	155	10*d.*	896	2*s.* 9*d.*			4	3*s.*10*d.*							3	—
	2			896				314								682	
High Labour Productivity	1st sub-optimum	2,880	0	5,278	2*s.* 6*d.*			6,314*	2*s.*11*d.*			7,406	3*s.* 6*d.*	8,027*	3*s.* 9*d.*	8,699	3*s.*11*d.*
	Optimum	3,165	to	5,282	to			6,317	to			7,417	to	8,031	to	8,706	to
	Change 1	285	8*d.*	4	2*s.*11*d.*			3	3*s.* 4*d.*			11	3*s.* 9*d.*	4	3*s.*10*d.*	7	—
	2			2,117				1,035				1,100		614		693	

Optimum: the gross margin for the optimum plan at the respective milk price.

1*st sub-optimum:* the next most profitable plan at the respective milk price.

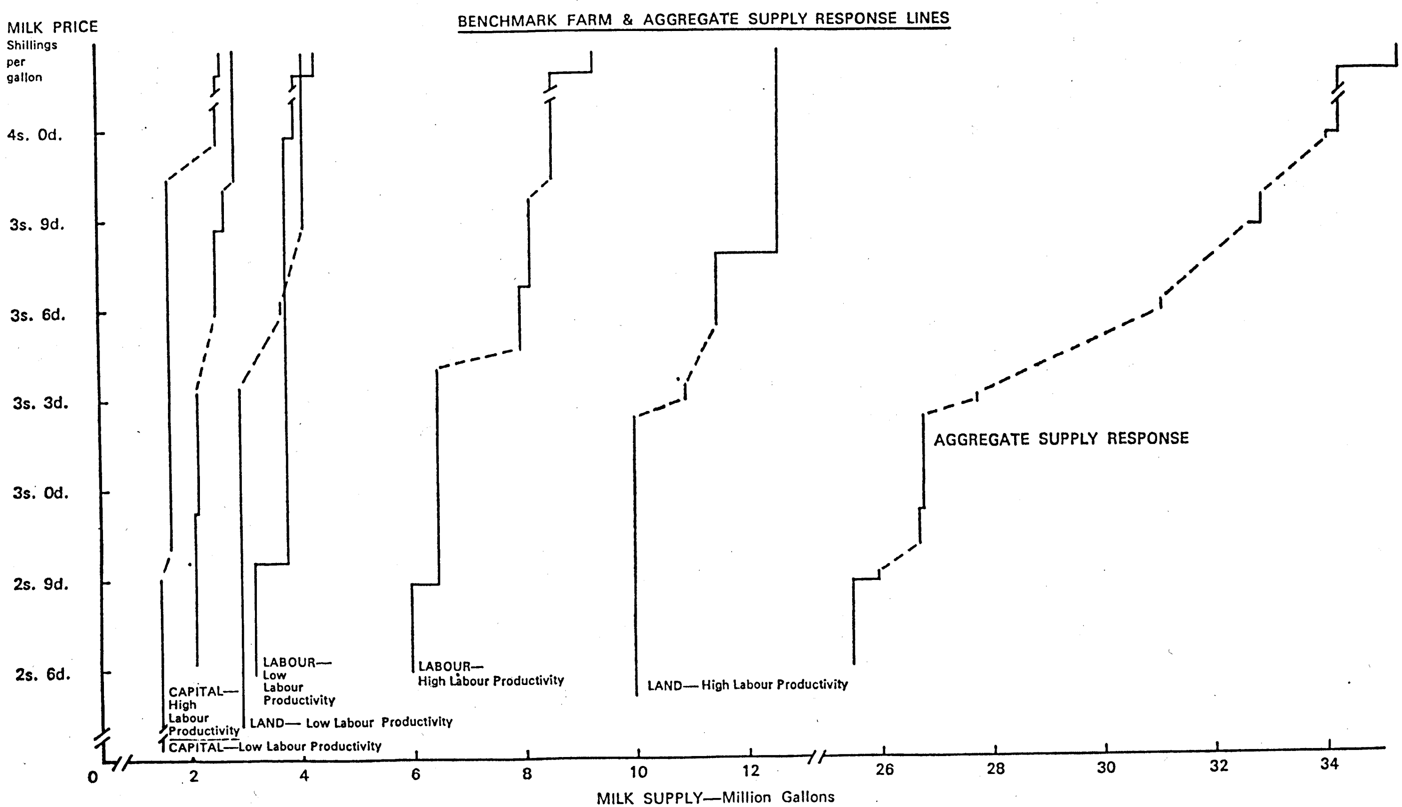
* The 1st sub-optimum is so marked when it is also the gross margin at the respective milk price, calculated for the optimum plan which was arrived at for the previous milk price. These are cases where there is only one activity alteration (change in farm plan) before the new optimum plan (and gross margin) is achieved.

Change 1*:* the difference in gross margin from the optimum plans for the previous price at which an increase in milk production took place.

Change 2*:* the difference in gross margin from the optimum plan at the next lower programmed price.
e.g. Land High Labour Productivity £3957 = gross margin at optimum plan 2*s.* 6*d.*
£5176 = gross margin at optimum plan 3*s.* 3*d.*
£1219 = change 2.

Price range: the range in price per gallon over which the plan is optimal.

DIAGRAM 1


BENCHMARK FARM & AGGREGATE SUPPLY RESPONSE LINES
MILK PRICE
Shillings per gallon
4s. 0d.
3s. 9d.
3s. 6d.
3s. 3d.
3s. 0d.
2s. 9d.
2s. 6d.
AGGREGATE SUPPLY RESPONSE
CAPITAL—High Labour Productivity
CAPITAL—Low Labour Productivity
LABOUR—Low Labour Productivity
LAND— Low Labour Productivity
LABOUR—High Labour Productivity
LAND— High Labour Productivity
0
2
4
6
8
10
12
26
28
30
32
34
MILK SUPPLY—Million Gallons

CONCLUSION

The study was primarily a trial of the methodology involved in analysing the whole farm unit to project total supply response. Basically the method conforms to the derivation of a theoretical supply function, through the summation of the supply functions of the individual farms. Previous methods of supply response analysis have concentrated on the individual production unit using production function analysis, or analysis of total supply at the market level using regression techniques. Unlike previous methods, analysing the whole farm unit, gives a non-stochastic result, based on the normative hypothesis, using linear programming to derive optimum farm plans. The flexibility of the method is limited by the linearity assumptions of the linear programme model. Concentrating on substitution relationships in the whole farm economy accounts for factors which tend to be overlooked by alternative methods in estimating total supply response of a single product. The model demonstrates that increasing milk prices will not cause beef supply from the area under study to increase unless there is a corresponding proportionate increase in beef margins. In this area, at current price ratio's, there is a surplus of calves three times greater than the requirements for beef production. The method allows for production increases due to improvements in technology, resource efficiency and price. It places an upper limit on output and identifies those resources limiting output.

To be applied at the national level, the method would need a model specified in more detail, such as to allow for inter-regional transfers, rising cost of inputs as product supply increased and hence demand for inputs increased, rearing of replacements and the possible fall in price of surplus calves as numbers of dairy cows increase. The present model implies the import of additional cows, and the export of calves surplus above replacement and beef requirements. The use of more dynamic models such as recursive programming is suggested to provide flexibility in resource constraints, or dynamic programming to account for the resource requirements and effect on farm profit in the expansion steps to the end of the planning period.

The study explains the process of aggregation to derive benchmark farms, from which milk supply was calculated and raised to give total milk supply. Grouping farms by restricting resources eliminates aggregation error in the product under study provided the other assumptions implicit in the aggregation procedure are met. However aggregation error could still occur in the output of other enterprises within a benchmark farm group.

Aggregation still implies the transfer of fixed resources among farms, for example surplus dairy housing where this is in excess of the maximum herd size for a farm within a group.

The study showed the effect of using estimated average coefficients (for dairying) for the restricting resource, rather than allowing for observed cofficients above the estimated maximum. Allowing for observed coefficients gave an increase of 8 per cent in total production at the maximum level of output.

The model allows for three steps in the expansion of dairying. The savings in cost per herd resulting from expansion may benefit all cows in the herd, however the linear programme model does not allocate the costs of expansion to all sections of the herd, but only to the extra cows added as a result of expansion.

The results of adjusting coefficients and restraint levels show the possible effects of specification error. Adjusting the availability of labour to pigs and poultry enterprises and the availability of surplus dairy housing to beef enterprises, milk output ranges from eight million gallons to 33 million at a price of three shillings per gallon. Similar difficulty was experienced in estimating potential resource coefficients (increases in technology) and applicable gross margins.

The study suggests that for the method to be a useful tool for policy makers, it requires linear programmers who are experienced with farming practices in the region under study.

A linear programme shows the gross margin of alternative farm plans, and the results for the benchmark farms show the instability of farm plans at the optimum with a difference of up to only £36 between the optimum and first sub-optimum plan for all farm plans at all prices.[13] Therefore farmers could almost equally well choose alternative near optimum plans, giving a different level of total milk supply.

The results give lower than expected levels of milk supply at most prices, although at the maximum there is potential for a 25 per cent increase in production. Results for the most likely current expansion base, give a reduction in output of 1.5 million gallons or 5.3 per cent at the current average price of three shillings a gallon.

Possible reasons for these unexpected results may be listed. Resource restraints may not be correctly specified. Gross margins or resource coefficients on individual farms may not be the weighted averages for the respective benchmark farm groups. There is likely to be aggregation error in pigs, poultry and beef with respect to housing levels causing an upward bias in their output levels. Some capital restraint on the expansion of the pig, poultry and beef enterprises could be operative; e.g. farmers may be reluctant to expand into capital intensive enterprises, where margins are being reduced through the emergence of large specialist producers. Farmers could be basing farm plans on the higher winter milk prices. Gross margins for beef are set in the upper part of a wide range of price uncertainty; beef gross margins could be varied to see their effect on milk production.

However, should the method be rejected if it gives unexpected results? If the model were set to comply exactly with current farming practices and price ratios, naturally it would give results complying with the current production, but in so doing would destroy the normative hypothesis. The results must be interpreted, understanding the limitations of the model, with consideration for the prices, coefficients and restraints used in the linear programmes. If these are considered to be feasible and rational, then current production is proved to be irrational, unless it can be justified on the grounds of hedging against risk and uncertainty.

---

13. Except for one farm, i.e. the capital restraint—low labour productivity—farm, optimum and sub-optimum plans at price 2s. 6d. per gallon for milk.

REFERENCES

(1) Cochrane, W. W. — "Conceptualising the Supply Relation in Agriculture" Journal of Farm Economics XXXVII No. 5 December 1955.

(2) Heady, E. O. — "Economics of Agricultural Production and Resource Use" Chapter 23. Prentice-Hall, Inc. N. J. 1961.

(3) Boulding, K. E. — "Economic Analysis" Third Edition. Hamish Hamilton, London.

(4) Johnson, D. Gale — "The nature of the Supply Function for Agricultural Products" American Economic Review. Vol. XL No. 4 pp. 539-564, September 1950.

(5) Gislason, Conrad — "Nature of Supply of Agricultural Products" Journal of Farm Economics. Vol. XXXIV No. 1 pp. 83-95, February 1952.

(6) Edwards, Clark — "Resource Fixity and Farm Organisation" Journal of Farm Economics. Vol. XLI No. 4 November 1959.

(7) Jones, G. T. — "The Response of the Supply of Agricultural Products in the United Kingdom to Price" The Farm Economist. Vol. IX No. 12, 1962 and Vol. X No. 1, 1962.

(8) Cowling, Keith and Gardner, T. W. — "Analytical Models for Estimating Supply Relations in the Agricultural Sector" A Survey and Critique. Journal of Agricultural Economics. Vol XV, No. 3, June 1963.

(9) Nerlove, Marc — "The Dynamics of Supply. Estimation of Farmers Response to Price". John Hopkins Press. Baltimore 1958.

(10) Marshall, Alfred — "Principles of Economics". pp. 317. MacMillan and Co. London. Eighth Edition.

(11) Mighell, Ronald L. and Black, John D. — "Inter-regional Competition in Agriculture" Harvard University Press, Cambridge, 1951.

(12) Stovall, John G. — "Sources of Error in Aggregate Supply Estimates" Journal of Farm Economics. Vol. 48. No. 2 May 1966.

(13) Sheehy, Seamus J. and McAlexander, R. H. — "Selection of Representative Benchmark Farms for Supply Estimation" Journal of Farm Economics. Vol. 47. No. 3 August 1965.

(14) Barker, Randolph and Stanton, Bernard F. — "Estimation and Aggregation of Firm Supply Functions" Journal of Farm Economics. Vol. 47. No. 3 August 1965.

(15) Roscoe, Betty J. and Langley, J. A. "Milk Production in S. W. England". University of Exeter, Dept. of Economics. (Agric.) Report No. 135. November 1962.

(16) Roscoe, Betty J. and Langley, J. A. "Some Economic Aspects of Milk Production. A Study in South West England". University of Exeter, Dept. of Economics. (Agric.) Report No. 162, March 1967.

(17) Ministry of Agriculture, Fisheries and Food "Cost and Efficiency of Milk Production 1965/66". H.M.S.O. 1967.

(18) Cowling, Keith "Labour Input in Milk Production" Farm Economist Vol. X No. 4, 1963.

(19) Cowling, Keith and Baker, C. B. "A Polyperiod Model for Estimating the Supply of Milk". Agricultural Economics Research. Vol. XV No. 1. United States Department of Agriculture, January 1963.

(20) Universities of Bristol and Exeter Farm Management Handbook 1967.

(21) Heady, E. O. and Candler, W. "Linear Programming Methods". The Iowa State University Press. Ames, Iowa, U.S.A. 1960.

(22) Day, R. H. "Linear Programming Models of Production". Journal of Farm Economics. Vol. 45. No. 4. November, 1963.

(23) Day, L. M. "Use of Representative Farms in Studies of Inter-regional Competition and Production Response". Journal of Farm Economics. Vol. 45. No. 5, pp. 1438-1445. December, 1963.

(24) Day, R. H. "Recursive Programming and Production Response". North-Holland Publishing Co. Amsterdam, 1963.

(25) Sharples, J. A., Miller, T. A. and Day, L. M. "Evaluation of a Firm Model in Estimating Aggregate Supply Response". North Central Regional Research Publication No. 179. January 1968.
Agricultural and Home Economics Experiment Station, Iowa State University of Science and Technology, Ames, Iowa. Research Bulletin 558.

(26) Kottke, M. "The Anatomy of a Step Supply Function". Journal of Farm Economics. Vol. 49. No. 1 Part 1, pp. 107-117. February 1967.

APPENDIX

The Benchmark Farm Resource Levels are set out in Table 1, a sample linear programme in Table 2, and Activity Gross Margins for land labour and capital used in the programming in Table 3.

TABLE 1

BENCHMARK FARM RESOURCE LEVELS

Resource	*Unit*	*Resource Restraint Farm Type Group*					
		Land		*Labour*		*Capital*	
		L.L.P.	*H.L.P.*	*L.L.P.*	*H.L.P.*	*L.L.P.*	*H.L.P.*
Land	Acres	37	100	102	190	68	192
Dairy Housing							
Current Herd Size .	Cow Nos.	17.655	45.079	31.948	64.79	15.749	55.309
Surplus of Current Capacity . .	,,	1.644	1.388	0.295	4.644	0.949	5.476
Followers Maximum Provision . .	Head of Stock	5.019	18.639	17.88	34.182	5.654	24.104
Housing							
Pork or Bacon . .	1 Pig	7.18	30.75	—	28.707	—	—
Sows . . .	1 Sow	0.48	0.73	2.777	1.69	7.457	0.555
Poultry . . .	100 Hens	1.16	2.97	0.22	1.143	2.06	0.135
Beef [1] . . .	Head of Stock	2.164	7.927	10.176	10.436	5.426	16.77
Capital . . .	£'s	4,042	6,729	5,323	9,886	1,536	2,678
Labour Total . . .	Man hours	3,780	7,420	5,506	7,212	5,338	8,318
Labour Excess above current dairy requirements .	,,	1,528	2,714	503	927	3,181	2,710
Milk							
Yield per Cow . .	Gallons	745	770	715	711	731	726
Including 5% Increase	,,	782	808	750	746	766	763
Beef Supply . .	1 Calf[2]	0.776	0.680	0.602	0.690	0.663	0.748
Corn Land Limit . . .	Acres	6.6	14	37.4	56.3	8.83	56.78
Maximum possible Herd Size							
Estimated Productivity	Dairy Units[3]	19.75	47.43	33.23	69.7	3 .78	72.75
Observed Productivity	,,	22.19	51.15	35.16	75.13	23.78	72.75
No. of Farms in Group		8	29	17	31	7	11
Per cent of Total		7.7	28.3	16.5	30.0	6.8	10.7

1 Beef housing includes transferred surplus housing from surplus dairy and followers requirements at maximum possible herd size.

2 Balance from calf output per dairy unit not required as replacement stock for the dairy unit. Calf output per dairy unit taken as 0.9.

3 Dairy unit includes cow plus followers.

TABLE 2

SAMPLE LINEAR PROGRAMME MATRIX. CAPITAL RESTRAINT HIGH LABOUR PRODUCTIVITY FARM

Milk Price = 0

Activity			*Dairy Hay*	*Dairy Hay and excess housing*	*Dairy Hay and extra housing*	*Dairy Silage*	*Dairy Silage and excess housing*	*Dairy Silage and extra housing*	*Hay Production*	*Silage Production*	*Wheat*	*Barley*	*Store Pigs*	*Store Pigs and extra housing*	*Poultry*	*Poultry and extra housing*	*Dairy Beef*	*Dairy Beef and extra housing*	*Sheep*	*Hay for Beef or Sheep*	*Milk Sell*	*Beef Rearing*
			P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	P.12	P.13	P.14	P.15	P.16	P.17	P.18	P.19	P.20
		Gross Margin	–43.7	–50.3	–53.8	–43.4	–50.0	–53.5	–4.2	–4.2	23.19	23.81	15.5	12.5	49.0	36.4	35.0	34.1	5.204	–4.2	0	84.1
Resource	*Resource Level*	*Unit*	1 Dairy Unit	1 Dairy Unit	1 Dairy Unit	1 Dairy Unit	1 Dairy Unit	1 Dairy Unit	1 Acre	1 Acre	1 Acre	1 Acre	1 Sow	1 Sow	100 Hens	100 Hens	1 Fat Unit	1 Fat Unit	1 Ewe	1 Acre	100 gall.	1 Fat Unit
Land . .	192	1 acre	0.96	0.96	0.96	0.83	0.83	0.83	1	1	1	1	0.05	0.05			0.8	0.8	0.42	1		1.6
Hay Supply .	0	1 ton	1.93	1.93	1.93				–2													
Silage Supply	0	1 ton				7.74	7.74	7.74		–7												
Dairy Housing																						
Current Herd	55.3	1 cow	1			1																
Surplus .	5.47	1 cow		1			1															
Followers .	24.1	Head of Stock	0.33	0.33	0.33	0.33	0.33	0.33														
Capital .	268	£10		11	17.3		11	17.3						5		21		1.5	1.1			7
Housing																						
Pigs . .	0.55	1 sow											1									
Poultry .	0.13	100 Hens													1							
Beef . .	101	Head of Stock		1.33	0.33		1.33	0.33									1					2
Beef supply .	0	1 calf	–0.7	–0.7	–0.7	–0.7	–0.7	–0.7									1	1				
Hay . .	0	1 ton															1.2	1.2	0.3	–2		2.4
Corn land .	56.7	1 acre									1	1										
Milk Production	0	100 Gallons	–7.6	–7.6	–7.6	–7.6	–7.6	–7.6													1	
Labour total .	8,318	Man hours	91.7	91.7	91.7	90.4	90.4	90.4	10	10	12	10.4	36	36	88	88	48	48	6.3	10	0	64
Labour Excess	2,710	Per year											36	36	88	88						

TABLE 3

ACTIVITY SPECIFICATIONS

Gross Margin Data used in Linear Programme Matrix, Appendix Table 2.

Per Acre of Land, Per Hour of Labour and Per £ of Capital.

	Gross Margin	*Land*	*Gross Margin per Acre*	*Labour*	*Gross Margin per Hour*	*Capital*	*Gross Margin per £ Capital*
	£	acres	£	Hours	£	£	£
P 1 Dairy .	66.70	1.92	34.7	101.3	0.66	—	—
P 2 Dairy .	60.10	1.92	31.3	101.3	0.59	110	0.55
P 3 Dairy .	56.60	1.92	29.4	101.3	0.56	173	0.33
P 4 Dairy .	66.50	1.93	34.5	101.5	0.66	—	—
P 5 Dairy .	59.90	1.93	31.0	101.5	0.59	110	0.54
P 6 Dairy .	56.40	1.93	29.2	101.5	0.56	173	0.33
P 9 Wheat .	23.19	1.00	23.2	12.0	1.93	—	—
P10 Barley .	23.81	1.00	23.8	10.4	2.29	—	—
P11 Pigs . .	15.50	—	—	36.0	0.43	—	—
P12 Pigs . .	12.50	—	—	36.0	0.35	50	0.25
P13 Poultry .	49.00	—	—	88.0	0.56	—	—
P14 Poultry .	36.40	—	—	88.0	0.41	210	0.17
P15 Dairy Beef	32.50	1.40	23.2	54.0	0.60	—	—
P16 Dairy Beef	31.60	1.40	22.6	54.0	0.59	15	2.11
P17 Sheep .	4.57	0.57	8.0	7.8	0.59	11	0.42
P20 Beef Rearing	79.10	2.80	28.3	76.0	1.04	70	1.13

Notes

Dairy gross margins are calculated at 3/- per gallon price level.

Dairy P1	£
763 gallons at 3*s*.	114.5
Negative g.m. of P1	— 43.7
Negative g.m. of $\frac{1.93}{2.0}$ acres hay at £4.2	— 4.1
Gross Margin per unit allowing for hay	66.7

(Grazing) Land per unit	0.96 acre
Hay Land $\frac{1.93 \text{ acre}}{2.0}$	+ 0.96 acre
Land per unit	1.92 acres
Labour hours per unit	91.7
Hay hours $\frac{1.93 \text{ acres}}{2}$ at 10 per acre	+ 9.6
Total labour hours per unit	101.3

Figures for dairy activities P2 to P6 are calculated in parallel fashion. A change in milk price of 3*d*. per gallon alters gross margin per acre by about £5, and gross margin per hour by about £0.1.

Dairy Beef P15	£		
Gross Margin per unit	35	(Grazing) Land per unit	0.8 acre
Negative g.m. of $\frac{1.2}{2}$ acres hay at £4.2	— 2.5	Hay Land $\frac{1.2}{2.0}$ acre	+ 0.6 acre
		Land per unit	1.4 acres
		Labour hours per unit	48
Gross Margin per unit allowing for hay	32.5	Hay hours $\frac{1.2}{2}$ acres at 10 per acre	+ 6
		Total labour hours per unit	54

Dairy beef P16 calculated similarly.

Sheep P17	£		
Gross Margin per unit	5.204	(Grazing) Land per unit	0.42 acre
Negative g.m. of $\frac{0.3}{2.0}$ acres hay at £4.2	—0.630	Hay Land $\frac{0.3}{2.0}$ acre	+ 0.15 acre
		Land per unit	0.57 acres
		Labour hours per unit	6.3
Gross Margin per unit allowing for hay	4.574	Hay hours $\frac{0.3}{2.0}$ acres at 10 per acre	+ 1.5
		Total labour hours per unit	7.8

Beef Rearing P20. This includes a beef cow.

	£		
Gross Margin per unit	84.1	(Grazing) Land per unit	1.6 acre
Negative g.m. of $\frac{2.4}{2.0}$ acres hay at £4.2	— 5.0	Hay Land $\frac{2.4}{2.0}$ acre	+ 1.2 acre
		Land per unit	2.8 acres
		Labour hours per unit	64
Gross Margin per unit allowing for hay	79.1	Hay hours $\frac{2.4}{2.0}$ acres at 10 per acre	+ 12
		Total labour hours per unit	76

The dairying activity has been defined in relation to the capital requirements for three possible steps of an expansion path for dairying. P.1 dairying can be up to the present number of dairy cows. In this activity no capital is required for cows or housing. P.2 dairying can expand to utilise surplus housing capacity. In this activity extra capital is required to purchase or rear additional dairy cows. For dairying to expand to the P.3 stage further capital is required for housing plus extra dairy cows. On some high labour productivity farms the assumed expansion path involves conversion or renewal of buildings for the whole herd in order to move from a low to a high productivity situation. In these cases the benchmark farm capital coefficient does not reflect the true marginal cost of purchasing and housing an extra cow, because, in calculating the coefficients, the total cost of housing is divided only by the additonal number of cows to be housed. This implies that the cost of rehousing must be recoverable from only the additional cows above present housing capacity. This is a result of the averaging process on benchmark farms.

Dairying has been included for two possible sources of forage; hay and silage, therefore there are six dairy activities, three which feed on hay and three on silage. This was an attempt to compare the merits of hay and silage systems. Little comparative information could be obtained on the relative resource requirements or milk yield responses of the two sources of feed. The general advisory information given to farmers is 1½ acres per cow including forage. Taking advisory figures on fodder yield as 2 tons an acre for hay or 7 tons an acre for silage and feed requirements of 1.5 tons hay or 6 tons silage per head per year gives a hay requirement of 0.75 acres and a silage requirement of 0.86 acres. The balance is the estimated grazing requirement, i.e. 0.75 acres in the case of hay and 0.64 acres in the case of silage. Taking costs of production and resource requirements per conserved fodder acre as equal, the programme shows hay to be marginally more profitable than silage because of lower conserved fodder acreage requirements per cow and hence lower costs per acre and per cow. Depending on how these coefficients and costs differ either hay or silage would become more profitable. An earlier programme, using monthly labour requirements, did not support the hypothesis that owing to differing harvesting times a combination of the two would prove optimal rather than either one or the other.

Included in the gross margin calculation is the cost of fertiliser for grazing land. An adjustment was made to the dairy gross margin for each benchmark farm for the cost of concentrates according to yield per cow above or below 800 gallons at the rate of £.06 per gallon. The dairy enterprise was programmed by using a milk selling activity, hence gross margins for the dairying activities are negative, reflecting the cost of production for dairying. As already explained, the unit of dairy activity is one cow plus replacements in the ratio of milkers to replacements on the benchmark farm.

The milk selling activity is P.19 which provides the facility through which the price of milk is varied. The milk sell unit is 100 gallons and the milk prices included in the programmes are: zero, £12.5; £13.75; £15.0; £16.25; £17.5; £18.75; and £20.0 per unit of 100 gallons. These are equivalent to: zero; 2*s*. 6*d*.; 2*s*. 9*d*.; 3*s*. 0*d*.; 3*s*. 3*d*.; 3*s*. 6*d*.; 3*s*. 9*d*. and 4*s*. 0*d*. per gallon.

The beef activities, P.15 and P.16, rearing and fattening surplus dairy calves, are dependent on the dairy activities for their supply of stock. The coefficient for beef supply is the balance of the calf supply from a dairy unit after subtracting the calf requirement for dairy replacements. In P.16 capital can be used to provide additional housing, which allows beef fattening to expand beyond present housing capacity. The gross margin for this activity was obtained from an average of farms in the Exeter Provincial Farm Management Survey sample. P.20 is an independent beef rearing activity comprising a unit of one cow and two rearing and fattening stock in the one and two-year brackets. It therefore provides its own stock.

Regarding housing for beef, all dairy housing has been made available to beef in some programme as it was considered that this could be used equally efficiently for either dairying or beef.

The hay and silage producing activities, P.7 and P.8, used on-the-farm production costs and therefore appear as negative gross margins.

The cereal production activites, P.9, wheat and P.10, barley, are based on Farm Management Survey farms production, and Farm Management Handbook costs.

Activities P.11 and P.12, store pig production are based on survey farm output and Farm Management Handbook prices. In P.12 capital can be used to provide additional housing for expansion beyond present housing capacity.

The poultry activities, P.13 and P.14, are based on Farm Management Survey farms production, and Farm Management Handbook prices. P.14 provides for use of capital to expand beyond present housing capacity.

The sheep activity, P.17, uses Farm Management Survey prices and output and Farm Management Handbook costs.

The hay activity P.18 is the same as P.7 for dairying but supplies the beef and sheep enterprises.

Labour has been included on an annual basis which implies that labour is transferable between periods. The results have had to be checked to see that nonsensical seasonal requirements have not arisen such as a requirement of 15 hours per man per day in July. In some initial trial programmes monthly labour requirements were included, but using the coefficients available February and March labour appeared as restricting. This did not seem to correspond with farmers' estimates of peak labour requirements. Hence, in the absence of more realistic information on monthly labour requirements and supply, annual labour requirements only were used. Labour resource requirements were obtained from the Farm Management Handbook for all activities except dairying. The labour excess row is a device to limit the supply of labour available to pigs and poultry to that surplus to current dairy requirements.