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AGRICULTURAL STUDIES

Relationship between milk production and price variations in the EC

STUDY P. 214

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FOREWORD

The study on the relationship between milk production and price variations has been undertaken in the framework of the study programme of the Directorate-General for Agriculture of the Commission of the European Communities.

This volume contains five reports: four Member State reports - each of them covering two different Member States - and one summary report for the Community.

The Member State reports have been prepared by the following authors:

The report for Germany and Denmark (abbreviation: D/DK) by Professor C.H. HANF, University of Kiel.

The report for France and Italy (abbreviation: F/IT) by J.M. BOUSSARD, Maître de Recherche, with the assistance of I. FOULHOUZE, Ingénieur de Recherche, Institut National de la Recherche Agronomique (INRA), Laboratoire d'Economie et de Sociologie Rurales, Paris.

The report for the United Kingdom and Ireland (abbreviation UK/IRL) by Professor G. JONES, Oxford University.

The report for Belgium and the Netherlands (abbreviation: B/NL) by Professor P.C. VAN DEN NOORT, Agricultural University, Wageningen.

The summary report for the Community has been prepared on the basis of a comparative analysis made by Professor P.C. VAN DEN NOORT.

The Division "Reports, studies, statistical information, documentation" and the Division "Milk products" of the Directorate-General for Agriculture participated in the work.

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Summary Report

Farmers the world over, in dealing with costs, returns and risks, are calculating economic agents. Within their small individual, allocative domain they are fine-tuning entrepreneurs, tuning so subtly that many experts fail to see how efficient they are.

T.W. Schultz
Distortions of
Agricultural
Incentives (1978) p. 4

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I. Introduction

Within the Community support system, the price of milk paid to producers is based on the target price for milk delivered to dairies which is fixed on an annual basis by the Council of Ministers. In fixing this price, the objectives of the Common Agricultural Policy have to be taken into account. Over the last few years, two objectives have been important in fixing the price level

- to ensure a fair standard of living for the agricultural community
- the need to stabilise markets.

While a great deal of information is available on the effect of producer price levels on producers' incomes, the same cannot be said on the role of the target price and, therefore, producer prices on stabilising markets, especially on the supply side of the stabilisation process. This study has as its aim to review progress which has been made in individual Member States on the response of milk supply to changes in producer price levels and to develop economic models which can explain the relationship between these two variables within a practical range. The relevance of such a study needs hardly to be emphasized at a time when control of agricultural surpluses has become of major concern throughout the Community.

Main features of milk production in the EEC

Milk production plays a dominant role in European agricultural production. Accounting for some 20 % of the total agricultural output, milk is produced in nearly all regions of the Community. According to a study carried out recently for the Commission of the EC[1] milk production represented more than 15 % of the total agricultural output in more than half of the (80) European regions; in 17 regions this figure was more than 30 % and in 5 (Basse Normandie, Franche-Comté, South West England, South of Ireland and Central-West of Ireland) even about 40 to 50 % of total regional production in agriculture. Figure 1 (density of dairy cows in the different regions) and figure 2 (milk collections by regions) give an idea of the specialization for and concentration of milk production at a regional level in the Community.

(1) Study on the regional impact of the common agricultural policy, study carried out by a working group of experts from 7 Member States. Synthesis report by P. Henry, S.E.D.E.S., Paris, December 1980

Figure 1

Dairy cows per 100 ha Agricultural land

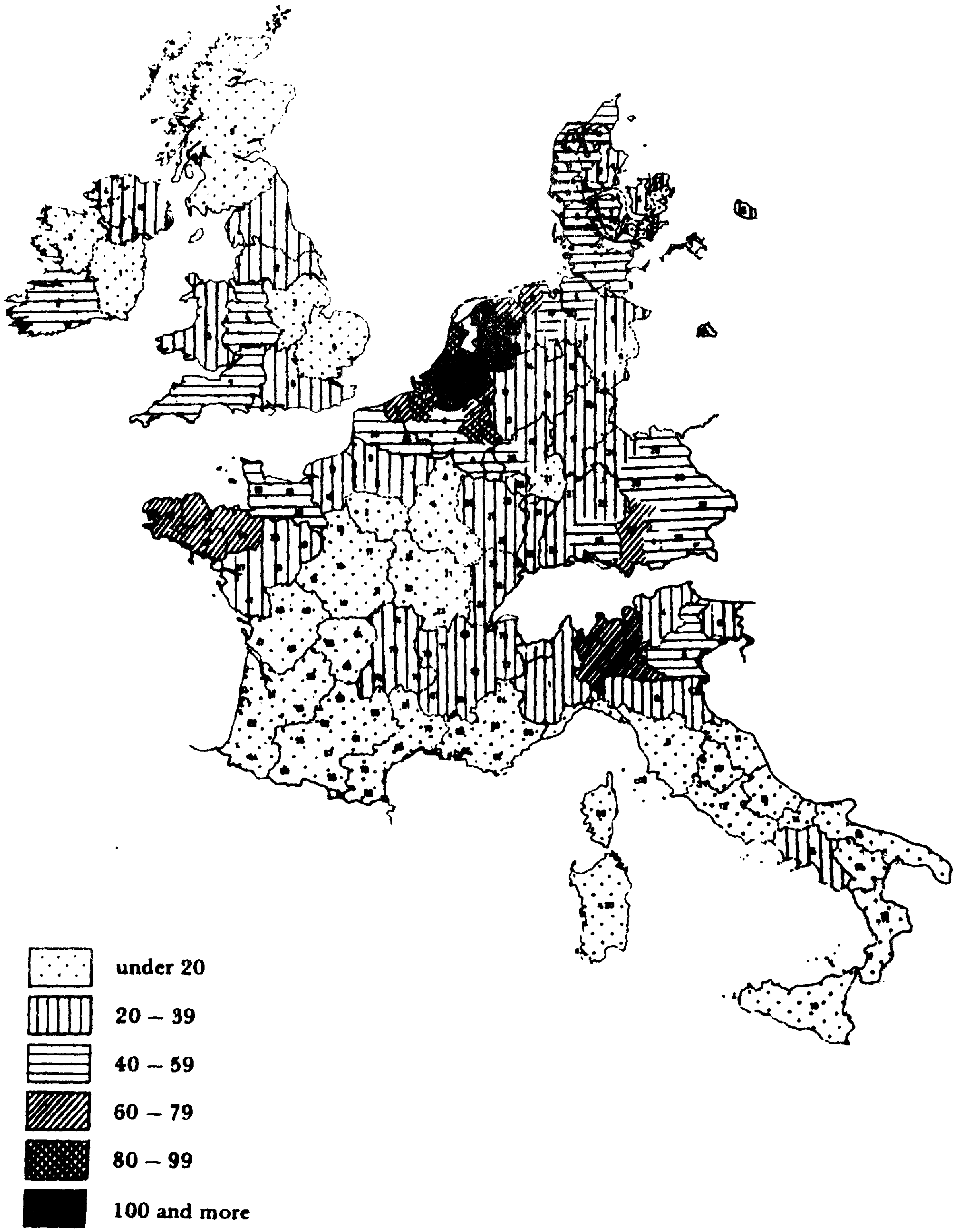
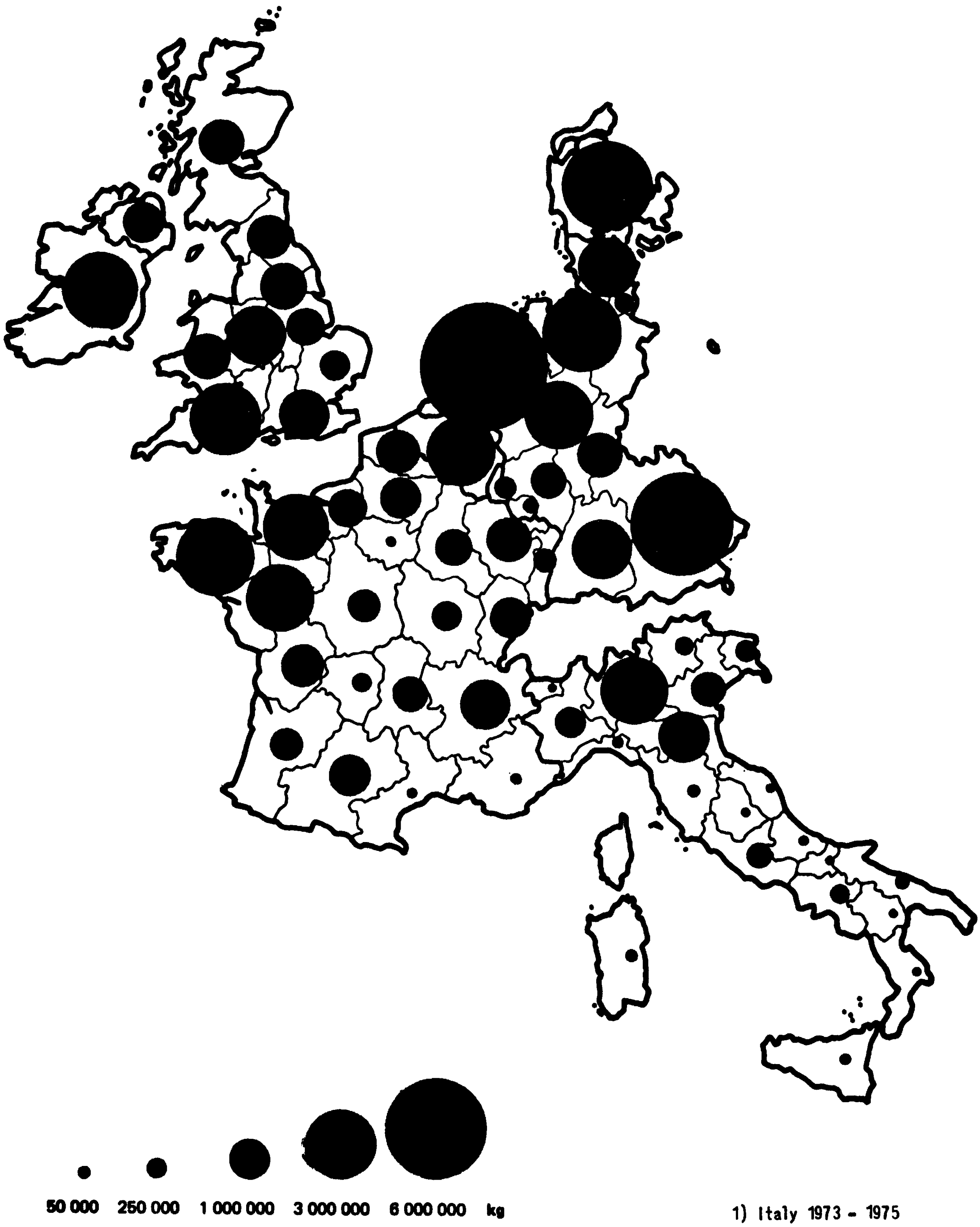


Figure 2

Milk collections by regions of the EEC, average 1974 - 1976 1)



1) Italy 1973 - 1975

Looking at the evolution during the "Community period" (1964/65-1976/77) the following five important regional trends are noted in the study :

- a relative decline in milk production in the large scale capital intensive crop production regions (Paris region, East Anglia);
- concentration in milk producing areas; for example the West of France (Brittany, Pays de la Loire), the Netherlands, the Rhine-Rhône corridor, Southern Germany;
- increased share of milk output in agricultural incomes in the three new Community Members (Denmark, Ireland, United Kingdom) after 1973;
- a relative distribution of milk output in several Italian regions with little previous experience in this field (Lazio, Molise, Apulia);
- an increase in milk production in the French mountain areas (Auvergne, Limousin, Midi-Pyrénées).

In 1977 nearly 2 million farms of the Community were involved in milk production. The average number of cows per farm was around 13. But the structure of dairy farming in the EC is extremely varied : alongside very large holdings there is a big majority of small farms operating near the subsistence level. A breakdown of the number of farmers according to the size of their dairy herd is given in table 1. It shows that, in 1977, 57 % of the farms kept less than 10 cows while, on the other hand, only 3 % of the dairy farmers owned more than 50 cows. There are, however, important differences between the Member States : 33 % of the dairy farmers in the UK had more than 50 cows, but only 0,6 % in Germany.

If one were to regard 30 dairy cows as the minimum standard for a profit-making dairy holding, only 10 % of the holdings would have met this requirement in 1977, but they produced 40 % of the total quantity of milk in the Community.

This situation explains to a large extent that one and a half million farmers stopped producing milk in the last decade. Between 1973 and 1977 alone, the number of dairy farmers fell by 20 % or roughly half a million holdings. This happened despite the unfavourable general economic climate in which high rates of unemployment made it difficult for farmers to move to other sectors of the economy. It thus appears that this structural trend will continue, albeit at a slower pace. Most of the milk producing farms that stopped production were too small to ensure reasonable profit and income levels to their holders. Indeed, the number of farms with less than 20 cows was reduced by almost 25 % between 1973 and 1977, and the number of cows in this size

Table 1 : Breakdown of dairy holdings in the EC by dairy herd size (December 1977)

1000 units

Number of dairy cows	Fewer than 10 cows		Fewer than 20 cows		Fewer than 30 cows		Fewer than 50 cows		More than 50 cows		Total	
Member State	No of holdings	%	No of holdings	%	No of holdings	%	No of holdings	%	No of holdings	%	No of holdings	%
Germany	302	58.2	448	86.3	496	95.6	516	99.4	61	0.6	577	100
France	273	47.4	459	79.5	534	92.7	569	98.8	7	1.2	576	100
Italy	390	86.1	426	94	439	96.9	447	98.7	6	1.3	453	100
Netherlands	18	21.7	36	43.4	52	62.7	71	85.5	12	14.5	83	100
Belgium	26	39.4	48	72.7	58	87.9	65	98.5	1	1.5	66	100
Luxembourg	1	25	2	50	3	75	3	75	1	25	4	100
United Kingdom	12	16.7	22	30.1	32	44.4	48	66.7	24	33.3	72	100
Ireland	70	58.3	94	78.4	106	88.3	115	95.8	5	4.2	120	100
Denmark	16	28.6	34	60.7	44	78.6	54	94.6	3	5.4	57	100
Community	1 108	56.9	1 569	80.5	1 764	90.6	1 888	96.9	120	3.1	2 008	100

Source : EUROSTAT

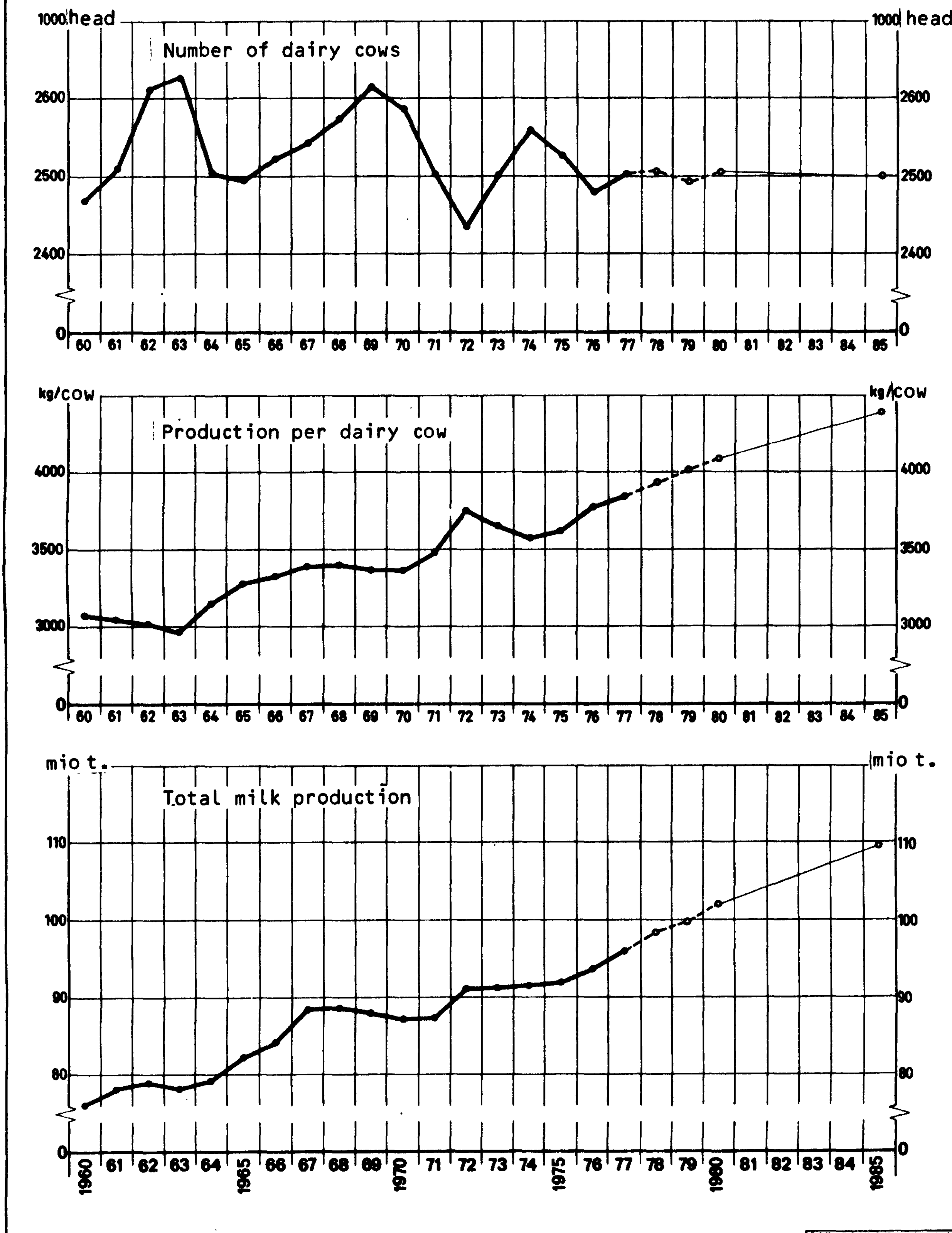
class diminished by some 20 %. In contrast, the number of dairy farms with more than 60 cows increased during the same period by nearly 25 %, and the number of cows in this class almost doubled (see tables 2 and 3 in the statistical annex at the end of this synthesis report).
In spite of these important structural changes the total dairy herd in the Community has stabilized at around 25 million heads over the last ten years (see figure 3, first graph). At the same time total milk production in the EC has clearly increased (figure 3, graph 3 and table 1a in the statistical annex). Production in 1979 was about 35 % above the level of 1960 and 17 % above the level of 1970. This increase in aggregate milk production is due to a continuing increase in milk yields per cow. Since 1960 the average annual increase in yields has been 1,5 %. Over the last few years however, the increase has actually gathered momentum and since 1975 has been almost 3 %. Today the average European cow produces annually about 4000 kg of milk as against an average of 2400 kg in 1950, 3000 kg in 1960 and 3400 kg in 1970 (figure 3, second graph). The factors making for this a considerable increase in milk yield per cow may be mainly described as follows :

- better stock selection : including the use of artificial insemination, which now accounts for more than half the pregnancies and whose object is to develop milk production qualities in the animals bred;
- efficient disease control measures : tuberculosis and brucellosis, two diseases which have for a long time been the scourge of dairy cattle, have been successfully eradicated;
- modern accomodation and equipment : the advent of a new type of cubicle - usually equipped with manure removel scrapers and the use of herring-bone parlours, may roughly be compared with the advent of the combine harvester and the tractor, which also ushered in a minor revolution. Mechanical milking has almost completely replaced milking by hand. Thus there is a greater number of cows per labour unit;
- improved care of the cattle and better feed increase production per cow;
- more rational production and use of green fodder, new production techniques and types of rough fodder and better storage in silos. The increased use of fertilizers is also boosting grass production;

Figure 3

MILK PRODUCTION IN THE COMMUNITY

(1960-1985)



- lastly, the extensive use of fodder concentrate. The milk producer has in fact at his disposal unlimited quantities of fodder from outside the farm. It is estimated that a good 20 % of milk production originates from imported fodders which are processed into fodder concentrates; the milk fodder concentrate price relationship has indeed been very favourable in the past and has thus inevitably led to steadily increasing consumption of this fodder.

The growing importance of these factors for milk production are, to a large extent at least, linked to the structural changes we mentioned above, i.e. the tendency towards concentration of milk production in relatively big units with intensive production methods.

It should, however, not be forgotten that considerable differences still exist between the Member States and between the regions within individual countries. The Netherlands, for example, would appear to be in the forefront of the new trend : almost half of the cow herd is said to be already housed in cubicles and almost 40 % of the milk yield is said to come from fodder concentrate. In this country, where the grass and grazing area constitutes barely 2,5% of the corresponding Community area, about 11 % of the Community's milk is produced. The average milk yields per cow are with more than 6000 kg per year the highest in the Community (see table 4 in the statistical annex). In constrast, milk production is much more extensive in Ireland. The traditional farm holding as an independent and self-reliant unit with its own grazing areas is typical for this country whereas the utilization of fodder concentrates is of low importance until today.

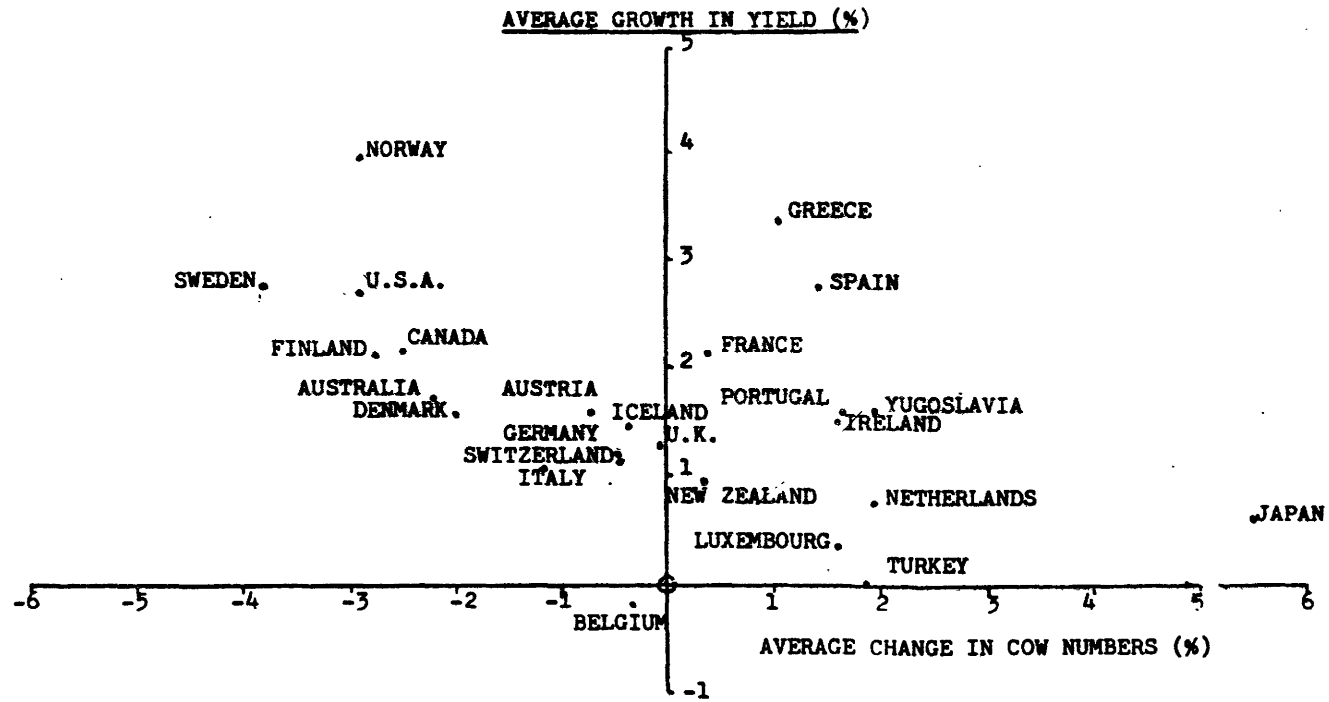
A more detailed analysis of national (and sometimes regional) pecularities of milk production will be found in the different country reports. Table 2 and figure 4 place the Member States of the Community in the wider context of the O.E.C.D. countries and thus allow us some more general comparisons of trends in milk production in the Western world. Apart from a few exceptions all O.E.C.D. countries had (sometimes quite considerable) increases in total milk production and average yields per cow between 1960/62 and 1975/77. Cow numbers decreased in more than half of the countries, but in most of the cases these decreases have clearly been overcompensated by increases in the average yield per cow.

Table 2 : Trends in Milkproduction in the Western World 1960-1977

Country	% change for the period 1960/62 - 1975/77 (rounded figures)			
	Milk production	Cow numbers	Yield per cow	Real milk price
Belgium	- 8	- 5	- 3	- 12
Denmark	- 7	- 26	+ 26	+ 14
France	+ 37	+ 6	+ 37	- 8
German	+ 12	- 7	+ 20	- 10
Ireland	+ 64	+ 27	+ 25	+ 51
Italy	- 2	- 16	+ 17	+ 53
Luxemburg	+ 32	+ 27	+ 5	n.a.
Netherlands	+ 49	+ 33	+ 11	- 18
United Kingdom	+ 22	- 13	+ 21	- 19
Total EEC	+ 21	- 0.3	+ 22	n.a.
Austria	+ 13	- 10	+ 26	- 26
Finland	- 10	- 34	+ 37	+ 17
Iceland	+ 19	- 5	+ 24	n.a.
Norway	+ 15	- 36	+ 78	- 2
Sweden	- 17	- 44	+ 50	+ 27
Switserland	+ 11	- 7	+ 19	- 17
Greece	+ 98	+ 17	+ 64	n.a.
Portugal	+ 59	n.a.	n.a.	n.a.
Spain	+ 86	+ 24	+ 50	- 25
Turkey	+ 33	+ 33	0	n.a.
Yougoslavia	+ 70	+ 34	+ 27	n.a.
Canada	- 6	- 32	+ 38	+ 64
U.S.A.	- 5	- 36	+ 41	+ 15
Japan	+149	+ 123	+ 9	- 31
Australia	- 11	- 28	+ 2	- 28
New Zealand	+ 20	+ 5	+ 15	- 6
Total O.E.C.D.	+ 13	- 9	+ 24	n.a.

Source adapted from OECD, Milk production and producer prices, Paris 1980

Figure 4: Comparison of annual % changes in yields and cow numbers for the OECD Countries 1960 - 1977
(compound rate of growth calculated using average yield and cow numbers in each country for the two periods 1960/62 and 1975/77)



Source: OECD, Paris.

There seems to be a relationship between the changes in cow numbers and the changes in milk yields as indicated in figure 4: The larger the decrease in cow number the higher the increase in yield. The reason for this could be that with decreasing herds (e.g. as a consequence of quota systems)[1)]

- the less productive animals are slaughtered first and
- marginal farmers who work under poor conditions leave their business.

Both, the microeconomic effect of cow selection and the macroeconomic effect of structural change would appear to lead to increases in the average yield.

The same type of reasonning could also be valid for the reverse case of increasing cow numbers, but **figure 4 is less clear** for this case.

Recent trends confirm clearly the picture of the past : Milk production continues to increase even in countries where producer prices for milk have been reduced considerably in real terms.

There are various reasons for the overall expansion of milk production. One may think of changes in prices for inputs and outputs (for milk and alternative productions), of technical progress and structural development as well as of governmental policies and actions. Changes in milk prices are therefore only one variable in a whole bundle of factors which influence - sometimes in quite contradictory ways - total milk production. It would appear that during the last ten years technical progress and structural development together played a predominant role in this context in Europe. They maintained the profitability of milk production for those who were able and willing to follow the new trends, even with continiously decreasing real prices. To a certain extent one may interpret the reduction of prices in real terms as the way in which consumers benefit from technical progress.

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1) Williams, R.E. 'Milk production and producer prices, OECD, Paris 1980 (Agr. IWP 3 (80)4)

II - Relationship between milk production and price variations

1. The notion of the price elasticity of supply

According to the observations made in part I one of the main difficulties to quantify precisely the relationship between milk production and price variations for milk is established by the fact that these price changes are only one factor among others influencing the behaviour of producers. This problem will be examined in more depth in the following paragraphs.

In a first step one may think of expressing the relationship between milk production and producer price variations for milk in form of a supply function where the milk production (the supply) is regarded as a dependent variable changes of which are caused by changes of an independent variable, the milk price. In other words : Milk production would be expressed as a (mathematical) function of milk prices. To illustrate the point such a function is represented by the supply curve in the following diagramme (Figure 5).

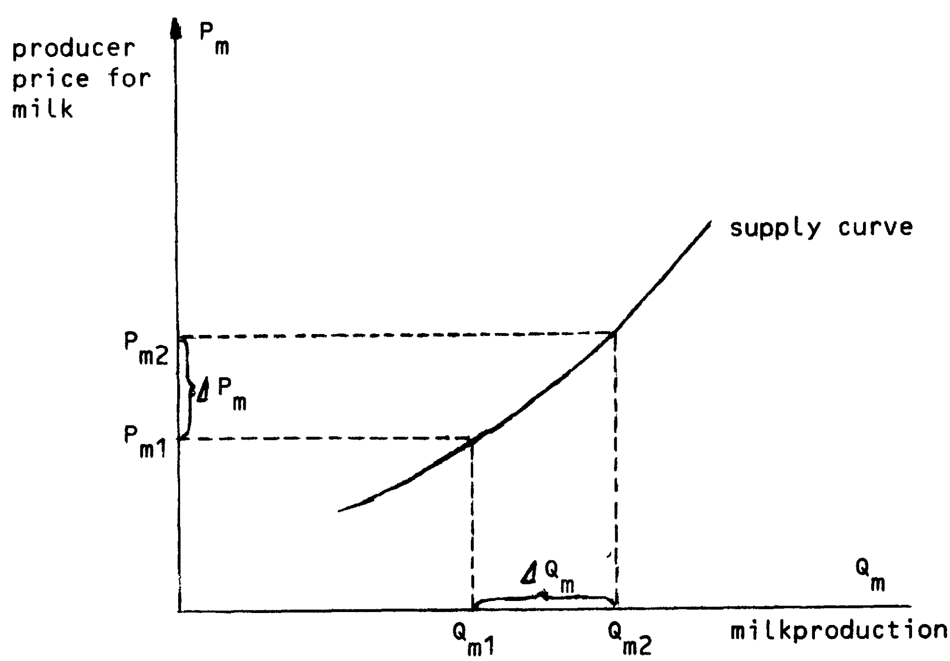

Figure 5: example of a supply curve

This is, of course, a very theoretical and static approach. It indicates for a given situation how much production will increase with increasing and decrease with falling prices and is based on the assumption that all the other influencing factors will remain constant ("ceteris paribus clause").
The price elasticity of supply is derived from the supply function and can be used to characterize this function at a given point of the supply curve (i.e. at a given price-output combination). It can (roughly) be defined as the percentage change of production that would result from a 1 % change of the milk price under given (static) conditions.

If Pm is a given price for milk and Qm the corresponding quantity of milk produced, and if we call Δ Qm the change of this quantity caused by a small (1 %) change Δ Pm of the milk price, we may write the elasticity of supply e_{sm} as follows

$$e_{sm} = \frac{\Delta\ Qm/Qm}{\Delta\ Pm/P} = \frac{\Delta\ Qm}{\Delta\ Pm} \cdot \frac{Pm}{Qm}$$

If the elasticity is negativ ($e_{sm} < 0$), production would decrease with increasing prices. If it is positive but smaller than one ($0 < e_{sm} < 1$), production would increase with increasing prices, but the increase would be less than proportional as compared to the price increase. In this case, one would expect income to be increased more than production. Finally, if the elasticity is positive and bigger than one ($e_{sm} > 1$), production increases would be more than proportional in comparison to price increases and one would expect income to be increased less than production.

In general the price elasticity of supply varies with price and output levels and has different values at different points of the supply curve. In practice one therefore normally works with average values in the relevant part of the curve.

The concrete form of the supply function (i.e. the shape of the supply curve) depends to a large extent on what the economists call the marginal cost function (marginal cost curve). Under the conditions of "perfect competition" with a profit maximizing behaviour of the producers both curves are even identical. The marginal costs of milk production are the supplementary costs that would be caused by the production of one more output unit of milk. They are determined by a number of factors, in particular by the production function (i.e. the technical relationship between inputs and outputs of milk production), by the degree of utilization of the existing production capacity, by the prices of inputs and by the availability of attractiv alternatives to milk production.

These more theoretical considerations lead us, together with the analysis of part I, to a certain number of general comments concerning the relationship between milk production and price variations :

1. Since the concrete conditions of production (and therefore marginal costs) differ from farm to farm and, at a more aggregate level, from region to region or from country to country, we may expect to find different price elasticities in the different regions and countries of the Community.

2. Any adjustment of production to price changes needs time. We may distinguish three levels at each of which the adjustment process takes place with a different speed :

   - adjustment of the output per cow (e.g. by changes in feed);
   - adjustment of the number of cows per farm (e.g. intensification of production)
   - adjustment of the number of farms per region or per country (structural change, e.g. : concentration of production).

   It is clear that these three levels of adjustment are interlinked and that again differences in the way and the speed of adjustments will be found between regions or countries. In any case, however, this indicates that we may expect the price elasticity of supply in the long run to be different from that in the short run.

3. The concept of the price elasticity of supply as it has been presented is based on the assumption that other independent factors influencing milk production would remain unchanged. This means for instance that no technical progress would occur. At least over a longer observation period, however, such an assumption cannot be maintained. As it has been shown in part I, there is in reality no possibility to observe a historical situation or evolution in which all other factors than milk prices remained unchanged. This is indeed the major difficulty to measure the price elasticity of supply.

4. Whenever a farmer plans his future production he does not really know what future prices will be. He can base his decisions only on price expectations. These expectations are often influenced by experienced price evolutions in the past but may prove wrong for future developments. For example, the expectation of rising prices may lead a farmer to enlarge his cow herd and to invest in stables or specialized machinery. If in this situation prices fall contrary to his expectations, he will not be able to react in the same way as he would have reacted on the bases of an expectation of falling prices. This explains to a certain extent that, at least in the short run, price elasticity of supply may differ between price increases and price decreases. A more realistic approach of the price elasticity of supply would therefore have to analyse price expectations and to include some assumptions about their formation.

5. Supply curves as they are normally presented imply a positive price elasticity; this means that production increases with rising prices and decreases with falling prices. The underlying assumption is very often that producers try to make as high profits as possible and behave in a rational way. But other objectives than profit maximization are certainly possible. For instance dairy farmers could be satisfied if they maintained a certain income level and would not increase production and profits, even if they had the possibilities to do so. If prices would fall in such a situation, farmers would increase production in order to maintain their income. It is clear that such a reaction would only be possible as long as prices are still high enough to allow the farmer to make a profit. This idea of an inverse supply reaction is sometimes used as an argument against the suggestion to reduce milk production by price

cuts. If such a behaviour would be widespread it would in fact lead to negativ price elasticities. We shall therefore have to examine this question again at the end of this study.

The use of models to measure price elasticities of supply

The price elasticity of supply as it has been presented is above all a theoretical tool which has been developed to describe the impact of price changes on production in isolation from the effects of other factors. It is derived from the supply function which may be regarded as an economic model. Generally speaking, economic models can be characterized as the expression of economic theories in a mathematical form. They are based on a certain number of assumptions about reality and can be more or less complicated according to the number of aspects of reality one wants to include explicitly into the model. A quite simple example for such a model would be the following function.

$$Qm = f\ (P_m,\ Pf,\ S)$$

in which Qm means the quantity of milk produced, Pm the price of milk, Pf the prices for inputs into milk production and S the state of arts in the dairy sector. It expresses the very general economic idea that milk production as a dependent variable is at the same time a function of the prices for milk, the prices for milk production inputs and the state of arts (e.g. the technical progress realized) in the dairy sector as independent variables.

In order to apply such a general model to the economic reality and to calculate, for example, price elasticities of supply at a regional or national level, some complementary steps are necessary. Thus, the concrete type of the function has to be specified and the weight the different variables have within the function to be quantified. The results of these specifications and quantifications then have to be tested on the basis of observations available for the past on the different variables in order to arrive finally at what one would call the "best possible estimate". A considerable number of estimation techniques and testing procedures have been developed for this purpose. They all imply assumptions about the characteristics of the different variables and their interrelations. Since their common purpose is to "measure" economic phenomena in reality and to verify thereby (theoretical) economic ideas and hypotheses, we speak in this context of econometric methods and econometric models.

Difficulties arise of course when basic assumptions of an econometric model concerning the characteristics of variables and their interrelations do not correspond to reality. One speaks in this case of "violations" of assumptions. For some of the difficulties created by violations cures are available, but not for all. The problem is particularly arduous if different assumptions are violated at the same time. An illustration of such assumptions and the violations that may occur is given in table 3 for the multivariate equation $Qm = X_i \beta_i + \varepsilon$, with $i = 1, 2, 3, \dots, n$ which means that milk production as the dependent variable (Qm) is explained by (is a function of) n explanatory or independent variables $X_1, X_2, \dots X_i, \dots X_n$ (each of which has a particular explanatory weight expressed by the parameter β) and a stochastic disturbance ε.

Table 3 : Possibilities and pitfalls of the use of linear models in econometrics

Assumption	Violation
1) Dependent variable is a linear function of a specific set of independent variables plus a disturbance	Wrong regressors Non-linearity Non-constant parameters Too many regressors
2) Disturbance is normally distributed and the expected value of disturbance term is zero	Biased intercept Non normal distribution
3) Disturbances have uniform variance and are uncorrelated	Heteroskedasticity Autocorrelated errors
4) Observations on ndependent variables can be considered fixed in repeated samples	Errors in variables Autoregression
5) No linear relationships between independent variables	Multicollinearity
6) Adequate statistical data available	Errors in variables Specification errors Too few regressors Wrong regressors

Table 3 indicates that even simple linear models can be extremely difficult to handle even if enough reliable statistical data are available [1]. In practice, however, statistical data are not always plentyful and reliable or comparable, giving way to additional sources of problems for estimating elasticities or for testing hypotheses. This table is a very technical, short hand summary and it should only be seen as an indication of the problems and their names in the econometric publications but not as a starting point for a complete exposé about the econometric problems, associated with the use of models.

These considerations may be regarded as a "problem background" which is more or less common to most model approaches for estimating price elasticities of supply. Several different approaches have been tried and compared in the framework of this study. They will be discussed very briefly in the following paragraphs.

In simplifying a little bit we may distinguish four main groups of approaches for the purpose of this study :

1. Approaches that estimate production and marginal cost curves on the bases of micro-economic data. Two different ways of dealing with these data may again be distinguished :

   a. Marginal cost curves and supply elasticities are directly computed from accounting data (2)

   b. The micro-economic data are used for linear programming studies from which supply curves and marginal cost curves are derived and elasticities calculated (3)

2. Approaches that estimate aggregate production and (marginal) cost functions on the basis of macro-economic data at a regional or a national level. Price elasticities of supply are then derived from these functions (4)

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(1) P. Kennedy: A Guide to Econometrics, Martin Robertson, 1979

(2) An approach of this type has been suggested by Prof. P. van den Noort for the Netherlands

(3) This type of model has mainly been used by Prof. C.H. Hanf for Germany

(4) Model approach suggested by Prof. J.M. Boussard (France) and G. Jones (United Kingdom)

3. Approaches that analyse and project past trends of producers' behaviour with econometric methods on the basis of certain (in general widely accepted) economic hypotheses. Price elasticities of supply are then estimated on the basis of the projections of past behaviour (1)

4. Opinion polls which constitute a method apart. In the simplest case dairy farmers would be asked how they would react to price changes (2).

If one has in mind the basic definitions and notions of the price elasticity of supply, it seems quite logical to think about the marginal cost curve as a basis for estimating the elasticity of supply. One can try to formulate such a marginal cost curve as a function of milk output on the basis of accounting data material. Once the econometric difficulties are overcome the price elasticities of supply are easily derived.

Using an exponential function for the Dutch dairy sector as an example we found $Q = 0.627 * 10^6 * p^{0.45}$ and with basic mathematical tools we can conclude that the supply-elasticity is 0.45. This means that 1% change in milk price will be followed by 0.45% change in volume of milk production, provided the other factors remain constant.

Another possibility is to use linear programming as a tool to estimate the price elasticity of supply. It is based on an analysis of technically feasible combinations of production factors for milk and alternative productions. The so-called production - possibility - curve, as it is presented in figure 6, illustrates this type of analysis. It shows which combinations of milk and cereal production can be realized **under given technical conditions.**

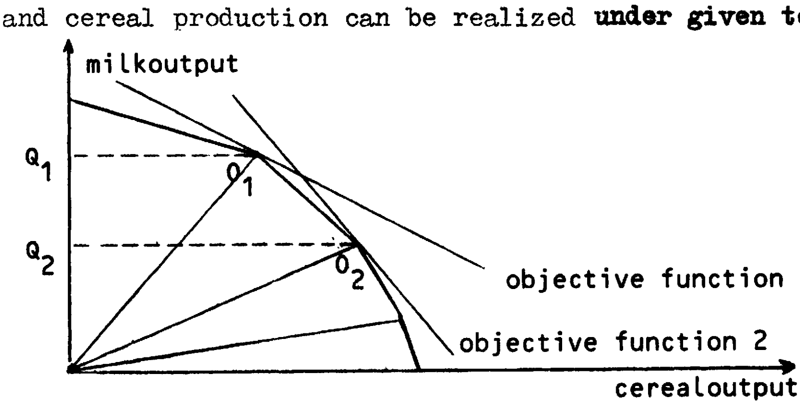

Figure 6: Example of a production possibility curve

(1) Econometric models of this type are discussed in several country studies

(2) Experience mentioned by Prof. P. van den Noort for the Netherlands

After having determined the main economic objectives of the farmers (by assumption or by observation) it is possible to define optimal production combinations to reach these objectives.
For milk price level P_1 we have objective function 1 leading to optimum O_1 which gives Q_1 as output for milk. As only the price of milk changes to P_2, we get objective function 2, leading to optimum O_2 and Q_2 as milk output. The supply elasticity of milk can be found by putting $P_1 - P_2 = \Delta P$ and $Q_1 - Q_2 = \Delta Q$ and applying the definitions. The more reliable this estimate has to be the more complete the LP-model must be. If we want to apply it to the whole dairy sector we have to include a whole series of types of farms on which milk production is or might be feasible. This originally simple idea leads then to rather complicated models.

A third possibility to describe the milk production of a country or a region is to estimate on the basis of macro-economic data national or regional production and cost functions and to derive the elasticities of supply from these functions. The so-called CES production function may be considered as one of the most modern concepts in this field. It is defined as

$$Q^{-\rho} = \sum_{i=1}^{n} \delta_i X_i^{-\rho}$$

in which Q = Milk production, X_i = factors of production, δ and ρ are coefficients or exponents typical for the dairy production function.
If the necessary statistical data are available such an aggregate production function (and the corresponding cost function) can be specified for any milk producing region or country. Once they are established it is easy to derive the corresponding price elasticities of supply.
Now it can be shown that in the case of perfect competition with profit maximizing behaviour of the producers, this elasticity can be calculated (from the CES function) according to the formul

$$e_{s_m} = \frac{\text{variable costs}}{\text{fixed costs}} \sigma$$

where σ is an elasticity of substitution. If the assumption that is equal to one can be reasonably justified, in some cases at least, the price elasticity of supply can be calculated simply by dividing the variable costs of milk production by the fixed costs in the dairy sector of a region or a country. This illustrates well the point that sometimes, even when starting with e relatively complicated theoretical tool (in our case the CES production function) one may end up with rather simple estimating procedures. The problem with this approach, however, is that in practice it is sometimes quite difficult to define precisely variable and fixed costs. These definitions would indeed have to be different for short and long term considerations. If the connected problems cannot be solved more complicated versions of the model will have to be applied.

Still another approach would be to develop relatively simple supply function (linear or not) and to specify them with econometric methods on the basis of historical data. One example for this approach is the following function developed by M. Nerlove (1) :

$$\log Q_{mt} = \beta_0 + \beta_1 \cdot \log P_t + \beta_2 \cdot \log Q_{mt-1}$$

in which Q_{mt} is the milk production in a period t, P_t the milk price of the same period and Q_{mt-1} the milk production of the period before. β_0, β_1 and β_2 are parameters that have to be estimated. This is a famous formulation leading to short-run elasticity of β_1 and long run elasticity of $\beta_1 / (1- {}_2)$.

In this econometric field there are numerous other possibilities e.g. X_1 = milk price, X_2 = feed price and X_3 = productivity. This is a simple and straightforward one, altough perhaps not an adequate model, but there are so many other formulations possible. The problem being that there is no economic, statistical or econometric criterion to rule out one or more of these possibilities. So we have to be very careful in applying such "models" because they will not always lead us to reliable estimates of the supply-elasticity, but also to "mongrels" and nonsens correlations. This problem is the so-called specification problem : which variable should be included and in what way ?

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(1) Nerlove, M. : The dynamics of supply, Baltimore 1958

Quite a different starting point for analysing producers' reactions to price changes is to be found in the field of public opinion polls. One could in fact try to question farmers about their intended reactions to price changes using the available psychological techniques in the field of questionnaires and interviewes.

These five examples indicate that the economist has several possibilities to find the supply-reaction of dairy farmers. Each "method" has it pros and cons, depending on the relevancy of the theory, assumptions applied and the data available. It cannot be ruled out beforehand that the various "methods" lead to somewhat different estimates and also that by applying the same method we can arrive at different values for the supply elasticity because of variations in assumptions, data and period under investigation.

The results : Price elasticities of milk supply in the EC

It has not been possible in the framework of this study to develop one common model for all countries of the Community. Several different models were available for each country. Some of them were as well applicable to other countries, but no one was applicable to all of them, mainly for reasons of lacks in the statistical data base. A complete summary of the results of different methods in each of the countries where they were applied is presented in table 7 in the statistical annex.

The use of different models may lead to problems of interpretation of results at the Community level, principally because differences in the results may be due to country peculiarities as well as model characteristics. A very pragmatic approach had to be chosen to solve these problems. After an in-depth-examination of the different models for each of the countries he was in charge of, each expert developed in his final conclusions, based on his particular knowledge and experience, on overall judgement on the situation in "his" countries indicating a most probable value around which the elasticities probably lie. These final judgements are summarized in table 4. They make a distinction between short and long term elasticities considering a period of 2 years as short and over 5 years as long term.

As we have seen there are in fact good reasons to believe that the reaction of milk producers to price changes will depend on the time horizon. Let us take the example of a price fall in the present situation. Within the very short term (e.g. 1 year) there will not be probably any clear result. Some farmers will perhaps try to increase their production as some public opinion polls indicate, whereas others will try in the opposite direction and not few will not change their production plans at all. The overall reaction will, of course, depend very much on the general expectations. If farmers generally believe that the price fall is an unique event which will soon be corrected again, they certainly will react in a different way as if they believed in a more fundamental change in price policy. But even in the latter case clear results could probably not be expected in the very short term.

Table 4 : Export judgements on price elasticities of milk supply

Country	estimated price elasticity of milk supply	
	short term (x 2 years)	long term (y 5 years)
Belgium	0,4 (± 0,1)	0,5
Denmark	0,4 (± 0,1)	0,4
France	0,5 (± 0,1)	1,8
Germany	0,45 (± 0,2)	0,9
Ireland	0,4 (± 0,1)	0,7
Italy	1,0 (± 0,5)	2,5
Netherlands	0,4 (± 0,1)	1,1
United Kingdom	0,5 (± 0,1)	1,0
EEC (EUR 9)	0,55 (± 0,1)	1,3

Source : Member States reports

The price elasticity of milk supply for the Community as a whole has been calculated in table 4 as the weighted average of the national elasticities. The short run elasticity for the EC would be around + 0,55 according to this procedure. This leads to the conclusion that on the average farmers will increase their production if prices are expected to rise and decrease their production in the opposite case. For technical and psychological reasons, it may be, however, that their reactions are not exactly the same in a situation of falling prices as in a situation of rising prices, in particular as far as short term reactions are concerned. On the other hand, our results clearly do not support the hypothesis that production will increase as milk prices are expected to fall (sometimes indicated as "backward sloping supply curve" or "perverse supply reaction"). This does of course not exclude that certain types of farmers can and will react otherwise, but there is no evidence that their behaviour will dominate.

Furthermore, the results summarized in table 4 confirm that the longer the period in consideration the more substantial the influences of price changes become, and it would appear that in the long run there is still less evidence of perverse supply reactions. Our results clearly support the opposite hypothesis of a positiv price elasticity of supply.
The direct influence of milk prices on milk production in the long run is considerable. But we must be aware of the fact that on long run milk-prices - levels as well as trends - have influence on the rate of technological and structural change in that industry, so that these changes cannot anymore be considered as completely exogenous factors. They will obscure the estimates of the price-elasticities of supply. We arrived at simple handy reckoners for our supply elasticities of milk in the EEC. They were based on passed experience. In applying them for the future one has to keep in mind that farmers, their behaviour, production techniques and alternatives have changed and will continue to change. The employment situation now is quite different from the one in the period 1960-1970. The labour mobility has been affected and this has a diminishing effect on the supply elasticities of products like milk. The structure of the dairy industry is different from the one in 1960. We have more big and specialized farmers and we may expect these farmers to have different supply elasticities.

So we have to be careful when applying the complicated estimates as handy reckoners. Given all these considerations we can conclude that the net effect of 1% change in milk price on milk production in the EC will be in the present situation around 0,5 to 0,6 % in the short term and 1,3 % in the long term.

Statistical Appendix

Table 1a: Milk production in the EEC, 1960 - 1980 ('000 tons)

YEAR	B	DK	D	F	IRL	IT	LX	NL	U.K.	EUR 9
1960	3 914	5 399	19 264	16 982	2 746	9 153	200	6 838	11 454	75 950
1961	3 918	5 524	19 885	17 594	2 862	9 264	207	6 953	11 966	78 173
1962	3 972	5 355	20 307	17 952	2 963	8 790	195	7 269	12 266	79 069
1963	3 837	5 086	20 714	18 753	2 979	7 822	195	7 011	11 904	78 301
1964	3 692	5 233	20 840	19 135	3 091	8 283	182	6 956	11 647	79 059
1965	3 772	5 367	21 183	20 532	3 236	8 889	188	7 143	12 019	82 329
1966	3 767	5 306	21 357	21 693	3 329	9 462	196	7 236	11 868	84 214
1967	3 872	5 193	21 717	23 016	3 565	9 120	208	7 535	12 236	86 462
1968	3 913	5 122	22 121	23 845	3 781	9 455	215	7 710	12 532	88 694
1969	3 920	4 872	22 216	23 307	3 975	9 060	211	7 075	12 650	88 006
1970	3 745	4 637	21 856	22 963	3 742	8 884	217	8 239	12 870	87 153
1971	3 601	4 556	21 165	23 275	3 853	8 903	218	8 392	13 204	87 167
1972	3 647	4 786	21 490	24 474	4 054	9 484	232	8 951	14 067	91 185
1973	3 611	4 729	21 266	24 850	3 566	9 350	239	9 354	14 316	91 281
1974	3 708	4 818	21 508	24 900	3 436	8 987	251	9 915	13 913	91 436
1975	3 621	4 918	21 604	24 855	3 699	8 960	248	10 221	13 856	91 982
1976	3 592	5 045	22 165	24 613	3 974	9 131	250	10 490	14 384	93 144
1977	3 623	5 138	22 523	25 142	4 275	9 456	249	10 612	15 168	96 187
1978	3 766	5 325	23 296	25 850	4 691	9 727	256	11 363	15 971	100 245
1979	3 771	5 225	23 907	26 450	4 770	10 156	263	11 592	16 000	102 134

Source: EUROSTAT

Statistical Appendix

Table 1b: Dairy cow numbers at the beginning of the year

'000

year	B	DK	D	F	IRL	IT	LX	NL	UK	EUR 9
1960	1 003	1 459	5 670	7 848	757	3 190	54	1 548	3 175	24 704
1961	1 015	1 440	5 800	8 116	774	3 414	54	1 592	3 283	25 488
1962	1 054	1 472	5 897	8 344	791	3 496	55	1 652	3 364	26 125
1963	1 066	1 429	5 922	8 453	833	3 378	55	1 726	3 410	26 272
1964	1 009	1 354	5 835	7 607	861	3 306	55	1 642	3 368	25 037
1965	1 007	1 336	5 816	7 558	916	3 387	57	1 650	3 260	24 987
1966	1 025	1 334	5 854	7 595	995	3 432	58	1 695	3 271	25 259
1967	1 029	1 318	5 858	7 639	1 029	3 485	59	1 767	3 251	25 435
1968	1 040	1 305	5 866	7 784	1 085	3 479	60	1 816	3 301	25 736
1969	1 067	1 262	5 878	7 830	1 164	3 679	61	1 865	3 358	25 164
1970	1 066	1 194	5 848	7 773	1 152	3 555	62	1 916	3 309	25 875
1971	1 000	1 127	5 561	7 688	1 124	3 214	62	1 899	3 337	25 012
1972	973	1 092	5 414	7 227	1 180	3 165	63	1 895	3 347	24 356
1973	1 000	1 130	5 466	7 402	1 182	3 256	68	2 023	3 482	25 009
1974	1 018	1 154	5 486	7 683	1 431	3 051	72	2 171	3 545	25 611
1975	997	1 130	5 393	7 751	1 406	2 927	73	2 215	3 387	25 279
1976	980	1 106	5 395	7 549	1 380	2 883	70	2 196	3 249	24 808
1977	986	1 102	5 388	7 627	1 436	2 897	66	2 197	3 318	25 017
1978	974	1 087	5 417	7 512	1 484	2 945	68	2 212	3 327	25 027
1979	981	1 100	5 443	7 491	1 510	3 010	68	2 308	3 384	25 199
1980	978	1 056	5 443	7 441	1 503	3 074	67	2 343	3 343	25 258

Source: EUROSTAT

Statistical Appendix

Table 2: Changes in cow numbers in the EEC herd by herd size, 1973/1977

	E U R - 9	DEUTSCHLAND	FRANCE	ITALIA	NEDERLAND	BELGIQUE	LUXEMBOURG	UN. KINGDOM	IRELAND	DANMARK
NUMBER OF ANIMALS / NOMBRE D'ANIMAUX - 1000										
TOTAL HOLDERS										ENSEMBLE DES DETENTEURS
1973	25604	5486	7683	3051	2255	1000	68	3544	1431	1086
1975	24875	5395	7549	2883	2259	994	71	3250	1380	1094
1977	25078	5417	7510	2945	2245	983	68	3327	1484	1099
% 77/75	0.8	0.4	-0.5	2.2	-0.6	-1.1	-4.4	2.4	7.5	0.4
HOLDERS WITH 1-2 ANIMALS										DETENTEURS AVEC 1-2 ANIMAUX
1973	840	171	161	392	9	17	1	11	69	9
1975	735	143	138	344	9	14	1	10	68	8
1977	619	115	119	301	9	12	0	6	50	6
% 77/75	-15.8	-19.6	-13.7	-12.6	2.2	-18.4	-19.5	-39.2	-26.0	-20.5
HOLDERS WITH 3-4 ANIMALS										DETENTEURS AVEC 3-4 ANIMAUX
1973	1338	393	320	468	21	33	2	12	74	15
1975	1116	335	254	399	18	26	1	10	62	11
1977	955	280	232	343	15	19	1	8	48	9
% 77/75	-14.4	-16.6	-8.9	-14.0	-15.4	-26.1	-21.6	-16.5	-22.3	-18.1
HOLDERS WITH 5-9 ANIMALS										DETENTEURS AVEC 5-9 ANIMAUX
1973	3668	1310	1207	571	87	148	6	56	176	107
1975	3206	1150	985	593	76	117	5	46	150	83
1977	2814	1007	866	546	59	91	4	33	144	63
% 77/75	-12.2	-12.4	-12.1	-8.0	-22.6	-22.5	-22.9	-27.2	-3.8	-23.5
HOLDERS WITH 10-14 ANIMALS										DETENTEURS AVEC 10-14 ANIMAUX
1973	4086	1277	1611	315	160	204	11	107	201	200
1975	3607	1176	1414	278	141	176	8	78	176	159
1977	3262	1092	1267	270	108	151	7	64	178	124
% 77/75	-9.6	-7.1	-10.4	-2.8	-23.6	-14.1	-20.6	-18.5	0.9	-21.7
HOLDERS WITH 15-19 ANIMALS										DETENTEURS AVEX 15-19 ANIMAUX
1973	3369	869	1434	191	218	168	12	124	164	189
1975	3248	880	1416	184	197	156	9	103	148	157
1977	3054	886	1302	202	151	144	8	82	151	129
% 77/75	-6.0	0.7	-8.0	9.6	-23.2	-7.5	-17.5	-20.3	2.1	-17.6
HOLDERS WITH 20-29 ANIMALS										DETENTEURS AVEC 20-29 ANIMAUX
1973	4462	914	1653	284	507	229	19	320	277	259
1975	4517	1018	1773	210	469	244	21	261	259	262
1977	4657	1120	1830	305	382	241	20	234	277	248
% 77/75	3.1	10.0	3.2	45.1	-18.5	-1.5	-2.8	-10.1	6.7	-5.2
HOLDERS WITH 30-39 ANIMALS										DETENTEURS AVEC 30-39 ANIMAUX
1973	2369	328	658	153	435	111	10	362	168	144
1975	2614	403	843	161	411	132	13	305	165	179
1977	2843	502	932	182	382	153	15	287	194	197
% 77/75	8.8	24.4	10.5	12.8	-7.1	16.0	13.5	-6.1	17.6	9.8
HOLDERS WITH 40-49 ANIMALS										DETENTEURS AVEC 40-49 ANIMAUX
1973	1471	117	334	100	313	49	4	370	108	76
1975	1560	152	346	112	328	67	7	328	116	105
1977	1859	214	480	129	334	83	7	332	146	133
% 77/75	19.1	41.3	38.8	15.5	1.8	25.1	-4.0	1.2	25.7	26.6
HOLDERS WITH 50-59 ANIMALS										DETENTEURS AVEC 50-59 ANIMAUX
1973	921	44	118	101	201	20	3	336	63	35
1975	1061	63	222	78	223	28	6	312	77	53
1977	1063	92	103	91	257	40	6	311	89	74
% 77/75	0.2	47.0	-53.5	15.9	15.4	45.4	16.2	-0.3	14.9	39.5
HOLDERS WITH 60-99 ANIMALS										DETENTEURS AVEC 60-99 ANIMAUX
1973	1882	45	164	257	243	18	-	984	133	38
1975	1911	57	129	275	304	29	-	900	158	58
1977	2368	87	349	289	419	41	S	950	147	88
% 77/75	23.9	51.3	171.2	4.8	37.7	38.3	S	5.6	-7.5	52.1
HOLDERS WITH 100 ANIMALS AND MORE										DETENTEURS AVEC 100 ANIMAUX ET PLUS
1973	1200	18	23	219	61	3	-	862	S	14
1975	1299	17	30	247	83	5	-	896	S	20
1977	1585	22	31	289	129	8	S	1019	61	27
% 77/75	22.0	29.2	2.6	16.7	55.7	60.2	S	13.7	S	31.5

Source: EUROSTAT

Statistical Appendix

Table 3: Changes in numbers of cow holders by herd size in the EEC, 1973/1977

	E U R - 9	DEUTSCHLAND	FRANCE	ITALIA	NEDERLAND	BELGIQUE	LUXEMBOURG	UN. KINGDOM	IRELAND	DANMARK
NUMBER OF HOLDERS / NOMBRE DE DETENTEURS - 1000										
TOTAL HOLDERS										ENSEMBLE DES DETENTEURS
1973	2432	630	697	607	99	85	5	93	144	72
1975	2187	572	628	536	94	75	4	80	133	63
1977	1950	519	576	453	83	66	4	72	120	56
% 77/75	-10.8	-9.2	-8.4	-15.5	-11.1	-12.0	-12.6	-9.9	-10.0	-11.8
HOLDERS WITH 1-2 ANIMALS										DETENTEURS AVEC 1-2 ANIMAUX
1973	578	108	105	286	6	11	0	8	47	6
1975	510	92	90	253	6	10	0	8	47	5
1977	417	74	79	206	6	8	0	5	35	4
% 77/75	-18.3	-19.4	-12.5	-18.5	4.9	-16.6	-16.8	-39.9	-25.5	-19.4
HOLDERS WITH 3-4 ANIMALS										DETENTEURS AVEC 3-4 ANIMAUX
1973	400	113	92	150	6	10	1	3	22	4
1975	332	96	73	126	5	7	0	3	18	3
1977	275	80	67	99	4	5	0	2	14	3
% 77/75	-17.1	-16.8	-8.3	-21.1	-15.3	-26.0	-23.2	-16.3	-24.2	-18.3
HOLDERS WITH 5-9 ANIMALS										DETENTEURS AVEC 5-9 ANIMAUX
1973	553	194	175	100	12	22	1	8	26	15
1975	480	170	144	97	11	17	1	6	22	12
1977	417	148	127	85	8	13	1	5	21	9
% 77/75	-13.1	-12.6	-11.8	-12.7	-22.7	-23.2	-23.2	-28.4	-3.6	-23.5
HOLDERS WITH 10-14 ANIMALS										DETENTEURS AVEC 10-14 ANIMAUX
1973	351	110	136	31	13	18	1	9	17	17
1975	308	101	120	26	12	15	1	6	15	13
1977	278	93	107	24	9	13	1	5	15	10
% 77/75	-9.9	-7.4	-10.4	-7.5	-23.6	-14.3	-20.7	-18.7	2.7	-21.7
HOLDERS WITH 15-19 ANIMALS										DETENTEURS AVEX 15-19 ANIMAUX
1973	202	52	86	12	13	10	1	7	10	11
1975	196	53	85	12	12	9	1	6	9	9
1977	183	53	78	12	9	9	0	5	9	8
% 77/75	-6.7	0.5	-8.6	0.9	-23.3	-7.6	-17.3	-20.1	2.2	-17.7
HOLDERS WITH 20-29 ANIMALS										DETENTEURS AVEC 20-29 ANIMAUX
1973	192	40	71	14	21	10	1	13	12	11
1975	194	44	77	10	20	10	1	11	11	11
1977	196	48	76	13	16	10	1	10	12	10
% 77/75	1.2	9.7	-0.3	30.8	-18.9	-1.8	-3.2	-10.6	8.2	-5.6
HOLDERS WITH 30-39 ANIMALS										DETENTEURS AVEC 30-39 ANIMAUX
1973	71	10	20	5	13	3	0	11	5	4
1975	78	12	25	5	12	4	0	9	5	5
1977	83	15	26	5	11	5	0	8	6	6
% 77/75	6.1	24.2	3.1	8.7	-7.5	15.7	12.1	-6.0	18.0	9.4
HOLDERS WITH 40-49 ANIMALS										DETENTEURS AVEC 40-49 ANIMAUX
1973	34	3	8	2	7	1	-	9	3	2
1975	36	4	8	2	7	2	0	7	3	2
1977	41	5	9	3	8	2	0	8	3	3
% 77/75	14.2	40.8	13.7	22.6	1.5	24.8	-5.0	1.8	25.9	26.5
HOLDERS WITH 50-59 ANIMALS										DETENTEURS AVEC 50-59 ANIMAUX
1973	17	1	2	2	4	-	-	6	1	1
1975	20	1	4	2	4	1	0	6	2	1
1977	20	2	2	2	5	1	0	6	2	1
% 77/75	-2.8	47.1	-57.1	-10.4	15.4	45.5	16.7	-0.1	13.3	39.4
HOLDERS WITH 60-99 ANIMALS										DETENTEURS AVEC 60-99 ANIMAUX
1973	25	1	2	4	3	-	-	13	2	1
1975	25	1	2	3	4	0	-	12	2	1
1977	31	1	4	4	6	1	S	12	2	1
% 77/75	24.0	51.6	133.3	8.4	37.0	38.4	S	5.0	10.5	51.3
HOLDERS WITH 100 ANIMALS AND MORE										DETENTEURS AVEC 100 ANIMAUX ET PLUS
1973	8	0	-	1	1	-	-	6	S	0
1975	8	0	0	1	1	0	-	6	S	0
1977	10	0	0	1	1	0	S	7	0	0
% 77/75	17.9	35.2	-86.7	8.1	55.2	62.5	S	13.4	S	31.0

Statistical Appendix

Table 4: Development of average milk yield per cow in the Community since 1974

Kg.

	1974	1975	1976	1977	1978 (1)
Belgium	3 643	3 632	3 610	3 690	3 860
Denmark	4 175	4 352	4 561	4 662	4 900
Germany	3 921	4 006	4 108	4 180	4 320
France	3 241	3 207	3 260	3 296	3 340
Ireland	2 373	2 752	2 796	2 891	3 170
Italy	2 946	3 061	3 167	3 264	3 330
Luxembourg	3 468	3 397	3 751	3 658	3 860
Netherlands	4 567	4 614	4 777	4 830	5 130
United Kingdom	3 925	4 091	4 427	4 571	4 770
Community	3 576	3 648	3 770	3 840	4 000

(1) Provisional

Source : EUROSTAT

Statistical Appendix

Table 5: Basic data of cow numbers and yields for OECD countries, 1960 - 1977

Country	Cow Numbers ('000)			Average Yield per Cow (kg)			Annual % Change 1960/62-1975/77	
	1960/62	1970/72	1975/77	1960/62	1970/72	1975/77	Cows	Yield
EEC								
Belgium	1,036	1,013	986	3,787	3,620	3,662	-0.3	-0.2
Denmark	1,465	1,060	1,083	3,687	4,247	4,652	-2.0	+1.6
France	7,196	7,431	7,615	2,374	3,195	3,255	+0.4	+2.1
Germany	5,787	5,561	5,397	3,422	3,868	4,094	-0.5	+1.2
Ireland	1,206	1,495	1,533	2,299	2,520	2,869	+1.6	+1.5
Italy	3,455	3,311	2,902	2,699	2,755	3,158	-1.2	+1.1
Luxembourg	55	62	70	3,390	3,551	3,563	+1.6	+0.3
Netherlands	1,656	1,920	2,210	4,239	4,440	4,720	+1.9	+0.7
UK	3,305	3,315	3,281	3,647	4,014	4,401	-0.1	+1.3
Total EEC	25,161	25,168	25,077	3,083	3,511	3,757	-	+1.3
Other W. Europe								
Austria	1,132	1,061	1,016	2,576	3,111	3,247	-0.7	+1.6
Finland	1,159	858	761	3,091	3,843	4,231	-2.8	+2.1
Iceland	39	36	37	2,818	3,370	3,490	-0.4	+1.4
Norway	600	417	385	2,700	4,197	4,813	-2.9	+3.9
Sweden	1,187	698	664	3,213	4,198	4,836	-3.8	+2.8
Switzerland	944	883	885	3,270	3,603	3,887	-0.4	+1.2
Total W. Europe	5,061	3,953	3,748	2,989	3,689	4,043	-2.0	+2.0
S. Europe								
Greece	416	433	488	893	1,290	1,465	+1.1	+3.4
Portugal	n.a.	193	212	n.a.	2,379	2,533	+1.7	+1.6
Spain	1,470	1,876	1,821	1,953	2,397	2,934	+1.4	+2.8
Turkey	4,148	4,772	5,498	600	597	603	+1.9	-
Yugoslavia	2,016	2,200	2,699	1,115	1,206	1,413	+2.0	+1.6
Total S. Europe	8,050*	9,474	10,718	991*	1,163	1,280	+1.9	+1.7
Total OECD Europe	38,272*	38,595	39,543	2,631*	2,952	3,113	+0.2	+1.1
Canada	2,969	2,271	2,028	2,773	3,544	3,813	-2.5	+2.2
USA	17,200	11,847	11,058	3,298	4,537	4,905	-2.9	+2.7
Japan	574	1,226	1,279	3,734	3,949	4,072	+5.5	+0.6
Australia	3,218	2,695	2,301	2,063	2,681	2,651	-2.2	+1.7
New Zealand	1,965	2,210	2,073	2,697	2,735	3,097	+0.4	+0.9
Total OECD	64,198*	58,844	58,282	2,799*	3,295	3,479	-0.6	+1.5

* Figures for 1960/62 exclude Portugal.

Source: OECD, Paris

Table 6: Summary of milk production and prices in OECD countries 1960 - 1977

Country	Annual Milk Production ('000 tonnes)			Milk Production Annual % Change		Index of Real Price of Milk (1960/62 = 100)	
	1960/62	1970/72	1975/77	1960/62-1970/72	1970/72-1975/77	1970	1977
EEC							
Belgium	3,924	3,664	3,612	-0.7	-0.3	96.6	88.2
Denmark	5,426	4,508	5,034	-1.8	+2.2	92.2	114.2
France	21,713	27,920	29,813	+2.5	+1.3	93.1	92.0
Germany	19,806	21,504	22,097	+0.8	+0.5	85.8	90.2
Ireland	2,774	3,769	4,541	+3.1	+3.8	87.2	151.1
Italy	9,842	9,556	9,628	-0.3	+0.2	124.1	152.6
Luxembourg	188	223	249	+1.7	+2.2	n.a.	n.a.
Netherlands	7,020	8,527	10,441	+2.0	+4.1	92.7	81.7
UK	11,916	13,444	14,524	+1.2	+1.6	77.0	81.1
Total EEC	82,609	93,115	99,939	+1.2	+1.4		
Other W. Europe							
Austria	2,916	3,299	3,301	+1.2	-	87.4	73.8
Finland	3,585	3,296	3,218	-0.8	-0.5	103.3	116.6
Iceland	108	122	128	+1.2	+1.0	n.a.	n.a.
Norway	1,619	1,751	1,854	+0.8	+1.1	97.1	98.2
Sweden	3,862	2,932	3,221	-2.7	+1.9	100.3	126.8
Switzerland	3,087	3,179	3,439	+0.3	+1.6	95.9	83.9
Total W. Europe	15,177	14,579	15,161	-0.4	+0.8		
S. Europe							
Greece	366	559	724	+4.3	+5.3	n.a.	n.a.
Portugal	347	459	550	+2.8	+3.7	n.a.	n.a.
Spain	2,870	4,501	5,344	+4.6	+3.5	86.8	74.9
Turkey	2,492	2,849	3,317	+1.3	+3.1	n.a.	n.a.
Yugoslavia	2,248	2,651	3,815	+1.7	+7.6	n.a.	n.a.
Total S. Europe	8,323	11,019	13,750	+2.8	+4.5		
Total OECD Europe	106,109	118,713	128,850	+1.1	+1.7		
Canada	8,235	8,039	7,724	-0.2	-0.8	112.4	163.6
USA	56,709	53,765	54,213	-0.5	+0.2	105.4	115.0
Japan	2,146	4,708	5,356	+8.2	+2.6	n.a.	n.a.
Australia	6,634	7,306	5,902	+1.0	-4.2	95.5	69.0
New Zealand	5,338	6,079	6,418	+1.3	+1.1	72.4	67.7
Total OECD	185,171	198,610	208,463	+0.7	+1.0		

Notes: 1 The "real price of milk" is the result of the producer prices divided by the consumer price index (CPI).

2 Production figures are average of three years' figures in OECD tables. They are used for the purpose of illustrating trends and calculating the compound annual percentage change.

Source: OECD, Paris

Statistical Appendix

Table 7: Price elasticities of milk supply in the EEC: Model results

Table 7a: Short run price elasticity of milk supply in the EEC

Model type	B	DK	D	F	IRL	IT	NL	UK	EUR 9
cost function	-	-	-	-	-	-	0.45	-	-
production function									
- JONES (1)	0.42	-	-	-	0.35	-	0.41	0.7	-
- BOUSSARD (1)	-	-	0.55	0.52	-	0.71	0.38	0.45	-
- others	-	-	0.2	-	-	-	-	-	-
linear programming (2)	-	-	0.01-0.28	-	-	-	0	1.3	-
econometric models (2)	0.25-0.33	0.3 - 0.5	0.06-0.8	0.11-0.27	0.5	0.59	0.3 - 0.9	0.75	-
public opinion poll	-	-	-	-	-	-	0	-	-
final judgement of the expert	0.4 (±0.1)	0.4 (±0.1)	0.45 (±0.2)	0.5 (±0.1)	0.4 (±0.1)	1.0 (±0.5)	0.4 (±0.1)	0.5 (±0.1)	0.55 (±0.1)

Table 7b: Long run price elasticity of milk supply in the EEC

Model type	B	DK	D	F	IRL	IT	NL	UK	EUR 9
cost function	-	-	-	-	-	-	-	-	-
production function									
- BOUSSARD (1)	-	-	1.94	1.87	-	2.54	1.22	1.72	-
- others	-	-	0.74	-	-	-	-	-	-
linear progr.	-	-	0.4 - 1.2	-	-	-	-	-	-
econometric models (2)	0.45	0.4	0.14-1.8	0.13-1.87	0.7	0.77	0.4 - 1.22	1.0	-
final judgement of the expert	0.5	0.4	0.9	1.8	0.7	2.5	1.1	1.0	1.3

(1) results comparable between countries
(2) results not fully comparable between countries

Source: Member States reports

Relationship between milk production and price variations in Germany and Denmark

by

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University of Kiel

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PART ONE : G E R M A N Y

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CONTENTS

1 Structure and development of the milk production in Germany (F.R.)

1.1 The German dairy sector in comparison with other EC countries

Production, consumption, surplus

The German agricultural sector produces about 22 mill. t of milk a year (22.5 mill. t in 1977). By this figure Germany is the second largest milk producer of the EC with a portion of almost one quarter (23.4 p.c. in 1977). Only France is producing more milk, whereas the UK and the Netherland do not reach much more than 50 p.c. of this production quota.

On the other hand West Germany is also to be regarded as one of the most important consumer of milkproducts within the EC; after the UK and France Germany held the third place. This third rang is caused by the relative small per head consumption of milk products in Germany, whereas Germany dispose over the largest consumer potential with a population of 61 Mill. people compared with 53 Mill. in France and 56 Mill. in the UK.

The low level of per head consumption causes a level of selfsufficiency in Germany which is somewhat higher than the EC average although the production quota is proportional to the quota of citizens. The degree of self-sufficiency - given in table 1 - indicates that the German milk producing sector do not belong to the most excessive "surplus producer", at least in relative terms.

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Table 1: Production and consumption of milk in the EC countries in 1977

	EC	D	F	I	NL	B/L	GB	IR	DK
Milk production in mill t	96.1	22.5	25.1	9.5	10.6	3.9	15.2	4.2	5.1
Milk prod. in % of EC	100	23.4	26.1	9.9	11.0	4.1	15.8	4.4	5.3
Degree of selfsufficiency		(s.14) 117	117	67	179	103	76	165	207
Milk consumtion in mill t	89.6	19.2	21.5	14.2	5.9	3.8	20.0	2.5	2.5
Milk cons. in % of EC	100	21.4	24.0	15.8	6.6	4.2	22.3	2.8	2.8
Milk surplus in mill t	6.5	3.3	3.6	-4.7	4.7	0.1	-4.8	1.7	2.6
per head consumption									
- freshmilk kg	101	81	87	78	136	83	142	211	152
- cheese kg	12	13	17	13	12	11	6	3	10
- butter kg	7	7	10	2	4	10	8	12	8
milk sales in % of total sales	19.5	22.5	16.5	12.7	26.6	16.4	22.1	30.4	25.7
milk/cow in kg	3.840	4.181	3.296	3.264	4.820	3.690	3.658	2891	4662
cows/holder	12.9	10.4	13.0	6.5	27.0	15.0	45.6	12.5	20.0
cows/100 ha farm-/grassland	2.7	4.1	2.3	1.7	10.9	6.6	1.8	2.6	3.8
cows/ha permanent	6.0	10.4	5.7	5.7	18.8	13.8	2.9	3.1	39.4
Relation: milk prod./beef prod.	15.2	16.3	14.3	11.1	23.7	14.3	15.6	9.0	20.9

Sources: Statistisches Jahrbuch über Ernährung, Landwirtschaft und Forsten 1978, Hamburg und Berlin 1979.
ZMP BILANZ 78 Milch, Bonn-Bad Godesberg 1979.

In absolute figures the picture changes. Beside France and Netherlands, Germany belongs to the countries with the largest positive difference between production and consumption. For 1977, the German surplus is guessed to be 3.3 mill. t, which is almost as much as the French surplus. However, it should be emphasized that the degree of selfsufficiency is not a suitable measure to justify any national quota of production within an economical and political community. On the other hand, the absolute and the relative degree of selfsufficiency give a first indication, wether the production and the production development of a country have a significant impact on the general situation of the community. From these figures it can be concluded that already a relativ small change of the German milk production will influence the community's situation strongly.

The dairy sector within the agricultural sector

The most meaningful indicator of the importance of a subsector for the situation of the whole sector is doubtless the subsector's contribution to value added. As the national statistics do not differenciate the factor input by corresponding products a direct measurement of the contribution is not possible. Hence, the portion of the gross value of production may be used as an indirect measurement. The corresponding figures are given in table 1. Obviously it is able to distinguish by this indicator three groups of countries within the EC. In Italian plays the milk production a relative unimportant role with a portion of only 12.7 p.c., whereas in Belgium/ Luxemburg and in France about one sixth of total production comes from dairying. All other countries are marked by quotas around a quarter. However, in intertemporal and international comparison it should be considered that the percentage of the value of production is only an indirect hint on the importance of this special product for the income formation as there may exist considerable differences with respect to the input structure. Taking into account the considerable differences with respect to the application of concentrates it might be argued that the situation of Ireland is significantly distinct from the other countries mentioned, whereas the difference with respect to the income formation between Germany and the Netherlands and Denmark are to be regarded less significant as the gross value of product indicates.

Input and production structure

As mentioned above there is no direct statistical information available about the inputs of the milk producing sector. Hence, it is tried to give a crude outline and comparison by using indirect information. It can be argued that within the EC the technical progress, the technical potential, the breeding potential with respect to milk production a.s.o. are relatively similar. Furthermore there do not exist extreme differences with respect to the natural conditions for milk production, perhaps except Italy and Ireland. Hence, the milk yield may be regarded as an indirect measure of the intensity of concentrate feeding. By this indirect measure considerable differences of concentrate feeding are to identify. Germany and UK realize obviously a middle intensive production whereas Denmark and especially the Netherlands are marked by a high level of concentrate feeding (see table 1).

A reciprocal indirect measure of the feeding intensity is the land input per cow. However, it is less stringent because there exist considerable differences in the fertilizing intensity and because of differences in the natural production conditions which are in this context more important. Unfortunately there do not exist statistical information about the special land input for the dairy industry. Hence, the relation of cows per 100 ha must be used as an indirect figure which can only be used to compare the countries which have a comparable relation between milk and other agricultural products. This indirect measure indicates that the concentrate use in Netherlands is to be suspected to be significantly differing from all other countries. The smaller numbers of cows per ha in Denmark is partly due to the higher proportion of milk production compared to Germany. However, it is to be interpreted also as a sign of a higher intensity in roughage production (compare cows per ha permanent grassland in table 1).

Considerable differences between the countries exist with respect to the input of labor and capital. The number of cows per farm and per cow holder resp. may be used as an indirect measure of the labor/capital input ratio. Thereby it is to take into account that the capital input per cow increases with the herd size as well as the labor productivity. With 9 cows per holder Germany reports a relatively small herd size, which is about 25 % smaller than the EC average and only Italy show a smaller herd size. All other countries have significantly larger herd sizes, the Netherlands reach a figure which is almost three times as large (24 cows/holder) and UK even an average size which is 4 or 5 times larger than the German.

This is partly depending on the small average farm size in Germany, however partly it is also due to the relative modest specialisation of the German farms. This modest specialisation of the German farms is also expressed by an other statistical figure, the relation between "milk and beef production". In Germany about 15 kg milk are produced by 1 kg beef, whereas in the Netherlands and Denmark 25 kg and 20 kg resp. are produced. Certainly, France and U.K. have a similar relation between milk and beef as Germany, however, both countries dispose of large, extensive herds specialized on beef production whereas in Germany a specialized beef production do not exist really.

Direct comparison between countries

Germany/Netherlands: The Dutch milk industry is much more intensive with respect to fertilizer and concentrate use, which is expressed by the higher yields per cow and the considerable higher number of cows per ha.
The significant different herd size indicates a considerable difference of the production technique of the average milk producer in the two countries.
Taking into account that both countries do not dispose of large herds specialized in beef production the relation between milk and beef output indicates that the German dairy farms are less specialized than the Dutch farms.

Germany/U.K.: The most obvious difference between the milk producing farms in both countries is the herd size. All other measure indicate that - on a national average - there do not exist extreme differences with respect to intensity of feeding and specialisation in spite of the immense size difference.

Germany/Denmark: Although the farm size in Denmark and Germany do not differ significantly there exist remarkable differences with respect to the milk production. Denmark's dairy farms seem to be slightly more specialized and more intensive.

Germany/France: The milk production in France seems to be much more based on roughage than in Germany. Furthermore there exist considerable differences with respect to the concentrate input.

1.2 Development of the milk production in Germany (F.R.) over time

From the early sixties until 1975 the German milk production remained almost unchanged. During the 12 years period 1963/1975 the total volume of milk produced fluctuated around a level of 21 million tons a year with a negligible average growth rate of 0.8 p. c. per year. Only in 1975 a considerable acceleration of the milk production can be stated. From 1975 to 1978 the average growth rate raised to 2.5 p. c. per year (see table 2).

However, the stability of the total volume of production had been accompanied by a continuous change of the structure of production. The number of dairy cows had been reduced by an annual rate of 0.7 p. c., whereas the milk yield is marked by an annual increase of 1 p. c. After 1975 considerable changes in both trends are to notice. The annual growth rate of the milk yield per cow run up to 2.5 p. c. during the period 75/78; in 1975/76 the average milk yield increased even with a rate of 3.8 p. c. Furthermore, the negative trend in the number of cows had been finished in 1975. Since 1976 a slight increase of the number of cows can be stated.

The whole period under consideration is characterized by a continuous reducement of the number of farms with dairy cows whereby the rate of reducement had been considerably higher than the negative growth rate of the number of cows. The number of dairy farms reduced with an annual rate of 4.7 p. c. It is to emphasize that this trend did not change in 1975. The rate of reducement during 1975/77 had been exactly 4.7 p. c. From the diverging trends of the number of cows and the number of dairy farms follow that a pronounced concentration of milk production has taken place. The average number of cows per farm increases from 5 cows/farm in 1960 to more than 10 cows/farm in 1978.

The relation between milk and beef produced in Germany - given in table 2 - indicates that contemporarily with the concentration process of the milk production the dairy farms tried to equalize this specialisation by an enlargement of the beef production. From 1961/63 until 1974 the beef produc-

Table 2: Development of the milk production in Germany (F.R.) from 1961/63 to 1978

	1961/63	64/66	67/69	70/72	73	74	75	76	77	78
Milk prod. in million t	20.5	21.2	21.1	21.3	21.3	21.5	21.6	22.2	22.5	23.3
Milk yield/cow kg	3460	3610	3740	3860	3910	3950	3960	4110	4140	4260
Dairy cows in 1000	5875	5844	5864	5548	5466	5446	5391	5399	5412	5415
Farms with cows in 1000	1132	1001	884	714	630	n.a.	572	n.a.	519	n.a.
cows/holder	5.2	5.8	6.6	7.8	8.7	n.a.	9.4	n.a.	10.4	n.a.
percentage of milk sales at total sales	28.0	27.0	26.3	23.9	22.2	23.4	23.8	23.7	24.8	25.6
relation: milk prod. to beef prod.	20.0	20.6	18.7	17.4	16.4	15.6	17.2	15.8	16.8	n.a.
price of milk (3.7%fat)	37.7	37.6	38.1	38.7	43.9	48.5	53.3	55.3	56.2	n.a.

Sources: Statistisches Jahrbuch für Ernährung, Landwirtschaft und Forsten, Hamburg und Berlin 1965 - 1979 .

tion had been extended with an annual rate of about 2.3 p. c. per year. From 1974/75 to 1978 the total volume of beef production remained more or less constant whereof a slight increase of the relation between milk and beef is caused by the increasing volume of milk.

Simultaneously with the shrinking number of cows and the shrinking number of dairy farms the portion of milk sales at the total sales of the agricultural sector decreases from 28 p. c. in 1961/63 to 22.2 in 1973. This portion increases again beginning with 1974 to a level of 25.6 in 1978. In the first two years (1974 and 1975) this increase is mainly caused by the high raise of the milk price whereas in the latter three years the price increase and the increase of the milk production as well contributes to the income growth. It can be summarized that the German dairy sector is characterized by a shrinkage process during the sixties and the early seventies. In this period the total production of milk remained stable as a consequence of the increasing yields per cow. About 1975 the negative trend had been changed tremendously and raised rapidly upwards. However, the trend of the concentration process which can be described by the number of cows per holder remained unbroken. Without any further analysis the change in the trends can be regarded as the consequence of a considerable change in the milk price policy. After a relative long period with almost constant milk prices in 1972 a period with considerable price increases started. The production followed this incentive obviously with a time-lag of two or three years.

1.3 Regional distribution of the milk production

The milk production is one of the most important farm enterprises in almost all regions of the Federal Republic. However, there exist considerable regional differences with respect to the production volume, to the intensity, and to the development trends. In 1978 about 44 dairy cows per 100 ha farmland are kept. From table 3 it can be seen that this figure is varying from 54 in Bavaria to only 31 in Rheinland-Pfalz. The big variety becomes more obvious if smaller areas are taken as a statistical basis as Doll (1975) has done it. Map 1 indicates that in the most southern part (Voralpengebiet) and in the most northern part (Coastregions) a density of more than 60 dairy cows per 100 ha had already been reached in 1971, whereas in the hilly regions of the middle part only less than 40 dairy cows per 100 ha are kept. Map 2 shows that, furthermore, the regions with a high density have a positive

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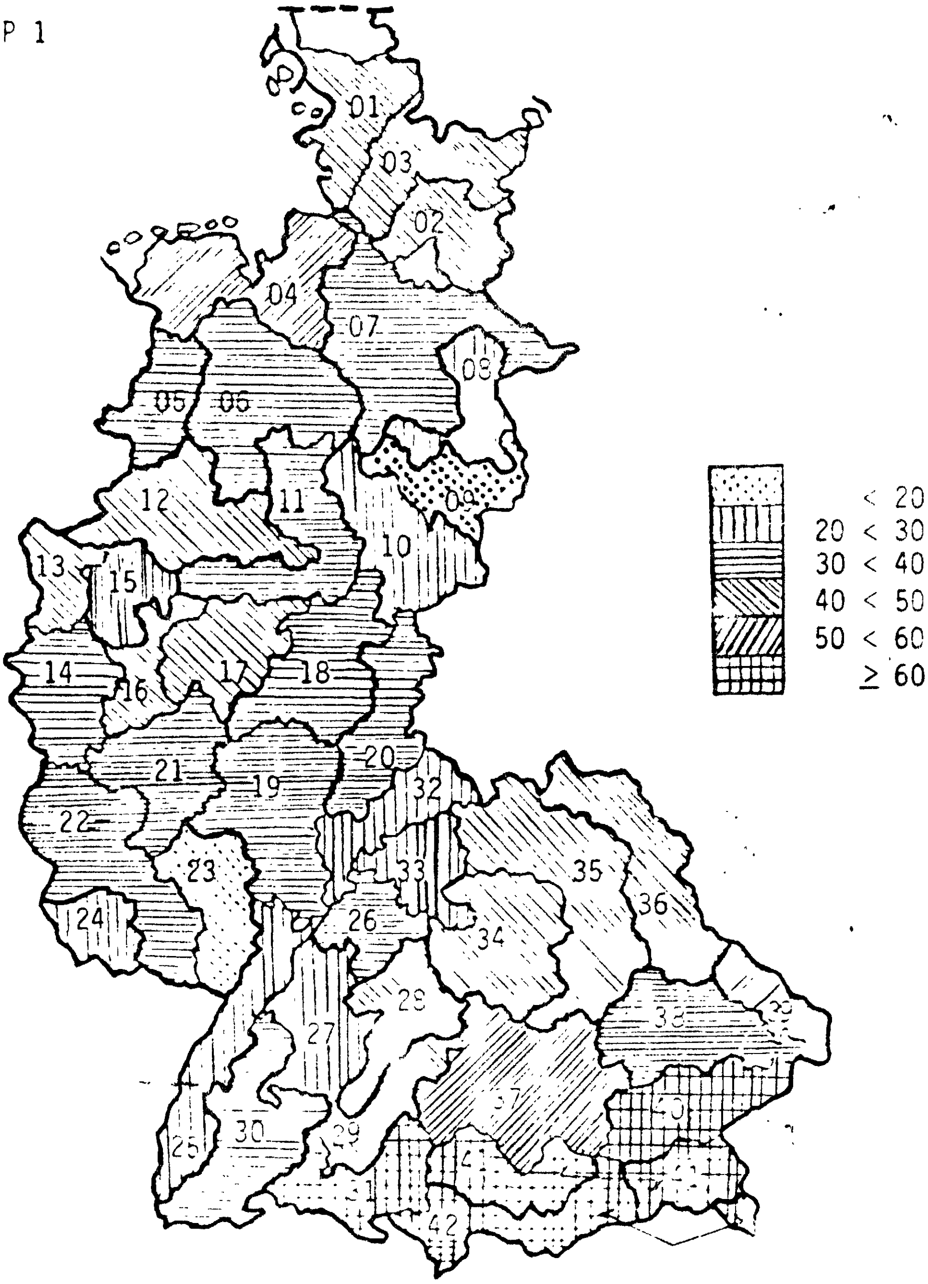
Table 3: Regional differences in the milk production of Germany (F.R.)

		FRG	Schleswig-Holstein	Niedersachsen	Nordrhein-Westfalen	Hessen	Rhld.-Pfalz	Baden-Württ.	Bayern	others
Dairy cows / 100 ha	1978	44	46	37	39	38	31	45	54	n.a.
Milk production of the Länder in p.c. of the total milk production	1978	100	10.4	22.2	12.5	5.6	3.9	11.5	33.2	0.7
	1958	100	8.8	19.4	15.1	6.0	4.2	12.5	31.5	2.2
level of milk yield in the Länder in p.c. of the highest level (Schleswig-Holstein)	1978		100	96	98	91	83	83	85	n.a.
	1958		100	98	97	76	62	69	71	n.a.
Regional price variation in p.c. of the FRG price	1978	100	101	101	100	99	105	99	99	n.a.
seasonal price variation: relation between minimum and maximum price	1978		0.80	0.85	0.87	0.95	0.95	0.95	0.95	n.a.
seasonal production variation: relation between minimum and maximum yield / month	1978	0.74	0.48	0.54	0.63	0.71	0.76	0.89	0.84	n.a.

Sources: Stat. Jahrbuch für Ernährung, Landwirtschaft und Forsten, Hamburg und Berlin 1979.
ZMP BILANZ 78 Milch, Bonn-Bad Godesberg 1979.
Statistisches Bundesamt, Reihe 3, Viehwirtschaft, Wiesbaden 1970 - 1978.

Dairy cows per 100 ha farmland 1971

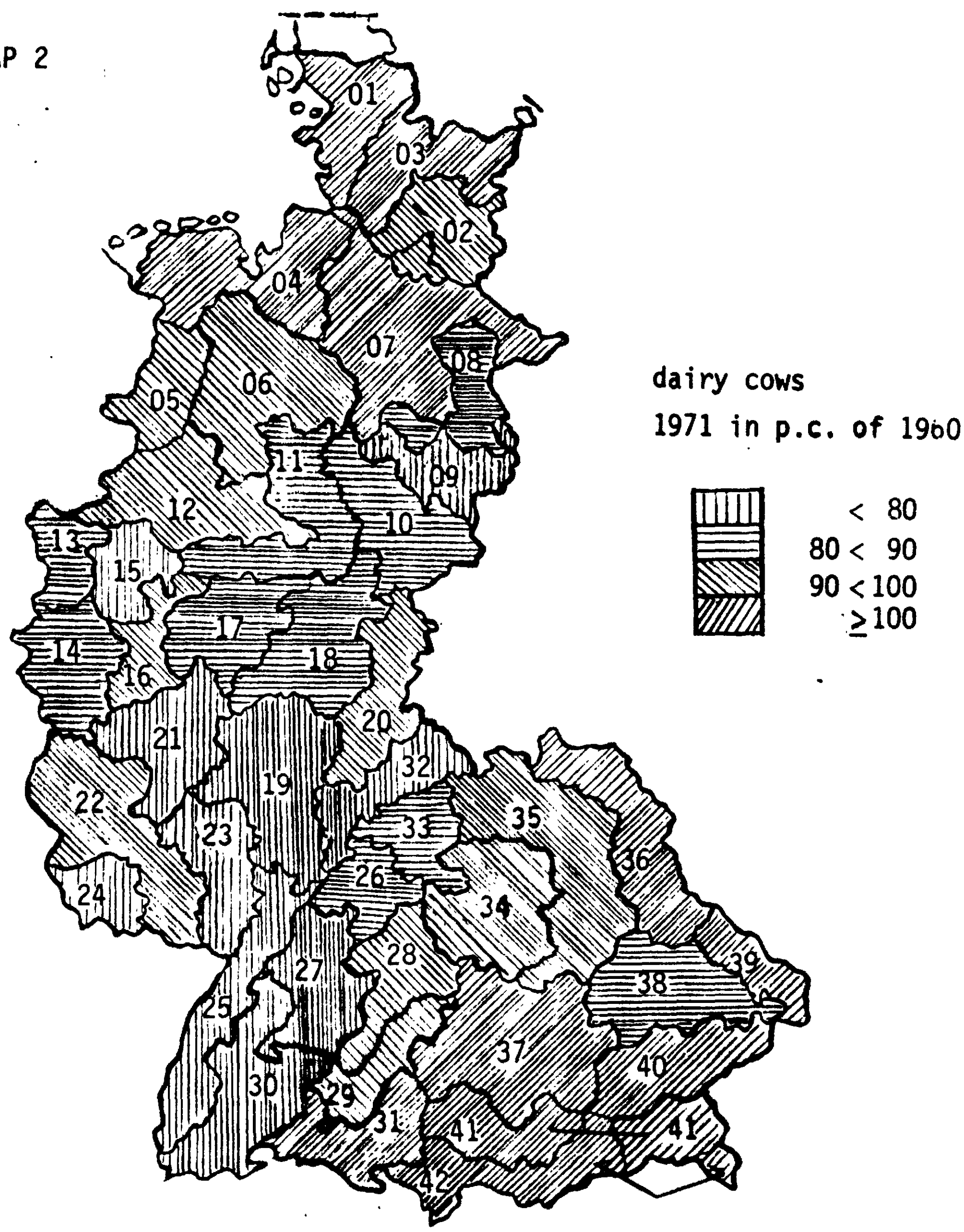
MAP 1



Doll: Analyse und Prognose... a.a.O.

Change in the number of cows 1960/1971

MAP 2



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trend with respect to the regional number of cows, whereas the regions with less than 40 cows/100 ha are characterized by a decreasing number of dairy cows.

This regional concentration becomes also obvious by the comparison of the percentage of milk production on the "Länder" basis as given in table 3. The portion of Bavaria and Schleswig-Holstein increased from 1958 to 1978, whereas the Länder like Hessen, Rheinland-Pfalz and Nordrhein-Westfalen lost production shares.

Furthermore a considerable slope in the milk yield per cow is to mention from the north to the south. Schleswig-Holstein reached an average yield per cow of 4685 kg in 1978 whereas Baden-Württemberg only 3900 kg recorded; this is a difference of 17 p. c. Nevertheless, it is to state that the regional differences in the milk yield are diminishing over time. In 1958 there had still been differences of 38 p. c. and 31 p. c. resp. between Schleswig-Holstein and Rheinland-Pfalz and Baden-Württemberg (see table 3), which is now reduced to the mentioned 17 percent difference.

A further regional difference within the milk producing sector is to be seen in the seasonal variation of the production. The northern regions are characterized by remarkable seasonal peaks, whereas, the milk production in southern Germany is more or less constantly distributed over the year. The milk production of Schleswig-Holstein in October runs up to only 48 p. c. of the production in May. The milk production in November (minimum) in Baden-Württemberg comes to 89 p. c. of the May production. According to these differences in the seasonal production the seasonal price variation differs considerably from north to south (see table 3).

1.4 Change in the structure of milk production

The present structure in dairy farming

Table 4 shows the present structure (1977) of dairy farming. The average herd size in 1977 was not more than 10.4 cows per holder. Only 7.6 p. c. of all cows stood in herd sizes of 40 and over. More than one quarter of all cows (25.9 p. c.) were held in herd sizes of 9 cows and under. Given the present state of technology and economic environment milk production can be

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Table 4: Structure of dairy farming, FRG, 1977

Number of cow holders and number of milk cows in holdings with ... milk cows

	total	1	2	3	4	5	6	7	8	9	10-14	15-19	20-29	30-39	40-49	50 and more
holder absolut in 1000	519.5	32.4	41.5	39.7	40.1	35.0	33.4	28.0	29.7	22.0	93.2	53.1	48.1	15.1	55.0	3.1
percentage of total	100	6.2	8.0	7.7	7.7	6.7	6.4	5.4	5.7	4.2	18.0	10.2	9.3	2.9	1.0	0.6
milk cows absolut in 1000	5417.3	32.4	82.9	119.2	160.5	175.0	200.2	196.3	237.5	198.3	1092.4	885.9	1120.1	501.8	214.4	200.4
percentage of total	100	0.6	1.5	2.2	3.0	3.2	3.7	3.6	4.4	3.7	20.2	16.3	220.7	9.3	3.9	3.7
average cows per holder	10.4	1	2	3	4	5	6	7	8	9	11.7	16.7	23.3	33.2	42.9	64.6

Source: Statistisches Bundesamt Wiesbaden (Ed.), Land- und Forstwirtschaft, Fischerei. Fachserie 3. Reihe 4.1.1 Bestandsgrößen der Viehhaltung 1977. pp.6. - Own calculations.

regarded as efficient with herd sizes of at least more than 40. If this is accepted only 1.6 p. c. of all milk producers in Germany fulfil the necessary condition for efficiency in milk production. It is very likely that a very high share of milk cows are milked by part-time farmers. If we assume that full-time farmers own herd sizes of more than 9 cows can conclude that 58 p. c. of all milk producer do not earn their main income out of milk; nevertheless, these farmers have 25.9 p. c. of all cows.

The data give a strong evidence of the inefficiency of the present milk industry in Germany. However, what matters from the dairy policy point of view is not so much the present structure of the dairy industry as it is more or less determined by historical facts and policy activies of the past. It is of even more interest how the structure of the industry did change over time. Of special interest e.g. is the question whether the actual herd size increased over time more or less than the efficient herd size.

Structural change in milk production over time

The development of the average herd size gives empirical evidence about the change in the production pattern of the German dairy sector. The growth rate in the average herd size was 4.8 p. c. p. a. for the period 1959 to 1977; there is only a slight difference in the growth rates for the sub-periods, for 1959 to 1969 it was 4.5, for 1973 to 1977 4.6 and for 1975 to 1977 5.1. These facts support the strong hypothesis that the actual average herd size increased much less than the efficient herd size.
Table 5 and 6 give a deeper insight in the structural change in dairy farming. The number of farms with 1 - 4 cows decreased considerably, from 798.100 in 1959 to 153.700 in 1977. In 1959 64 p. c. of all farms with cows had 1 to 4 cows whereas in 1977 only 29.6 p. c. Concerning the farm size in acreage table 5 says that up to 1973 there was only a decrease in the number of farms with 1 to 9 cows. Since 1973 there is also a decrease in the number of farms with 10 to 19 cows.
Having in mind that structural change in dairy farming consists of two components the giving up of milk production on the one hand and the stocking up of herd sizes on the other hand we may state that the farms which stopped milk production become larger over time. As a consequence the percentage of farms with over 20 cows increased from 0.8 in 1959 to 13.8 in 1977.
The process of specialisation within agriculture may be seen from the last column of table 5. Those farms which provided alternatives in income earning for the farmer ceased milk production to a very large extent. This holds especially true for large farms over 50 ha in size and small farms with less than 5 ha arable land. The latter farms mainly belong to part-time farmers who are not dependend on milk production as the main source of income. The same argument holds for farms with 50 ha and more. The situation is quite different for farms which cultivate 5 to 10 ha or 10 to 20 ha. As at least in the past most of the owners of these farms where full-time farmer they had to rely on milk production to earn a sufficient amount of income. Consequently, the percentage of farms of 5 to 10 ha which produced milk only decreased from 98.5 in 1959 to 67.2 in 1977. Concerning the farm size 10 - 20 ha the decrease in the number of farms with milk production was even smaller, from 85.3 p. c. in 1959 to 80.1 p. c. in 1977. Hence, the figures indicate that the relevance of the milk price for farm income is the greatest for farms of the size 10 - 20 ha. The farm size 5 to 10 ha seems to be less important: These farms have mainly 9 cows or less per farm which

Table 5: Dairy farms classified with respect to herd size and farm size, FRG.

Year	Dairy farms with ... cows						Dairy farms	
	1 - 4	5 - 9	10-19	20-29	30 and more	total	in p.c. of all dairy farms	in p.c. of all farms
	Farmsize - 5 ha LF							
1959	492,2	10,6	0,2	0,0	0.0	503,1	40,3	53,0
1969	209,3	14,3	0,6	0,1	0,0	224,3	26,8	34,9
1973	120,6	11,4	1,4	0,3	0,1	133,7	21,2	27,4
1975	100,2	10,9	1,1	0,1	0,1	112,5	19,6	25,1
1977	81,0	10,5	0,7	0,2	0,1	92,5	17,8	22,5
	Farmsize 5-10 ha LF							
1959	232,0	105,6	1,3	0,0	0,0	338,9	27,1	98,5
1969	107,2	96,0	5,6	0,1	0,0	209,0	25,0	82,5
1973	72,0	63,1	8,6	0,1	0,0	143,7	22,8	73,7
1975	61,0	57,2	8,8	0,1	0,0	127,0	22,2	70,9
1977	50,3	51,8	9,0	0,1	0,0	111,3	21,4	67,2
	Farmsize 10-20 ha LF							
1959	66,3	191,8	15,3	0,3	0,0	273,7	21,9	85,3
1969	29,0	173,0	49,6	3,0	0,1	254,7	30,4	90,7
1973	22,6	97,3	67,4	6,7	0,5	194,6	30,9	84,2
1975	20,1	82,3	64,4	7,6	0,6	175,0	30,6	82,7
1977	17,2	69,9	62,8	8,9	0,9	159,8	30,8	80,1
	Farmsize 20-50 ha LF							
1959	6,8	63,3	43,2	3,3	0,2	116,8	9,4	98,4
1969	5,1	44,0	70,4	13,8	2,6	135,9	16,3	91,1
1973	5,1	21,5	81,1	28,4	8,3	144,4	22,9	83,3
1975	5,4	18,6	76,3	32,0	11,2	143,6	25,1	81,5
1977	4,5	15,6	71,0	34,9	10,8	144,2	27,2	79,3
	Farmsize 50 and more							
1959	0,8	1,8	6,4	4,2	2,6	15,7	1,3	96,9
1969	0,7	0,9	3,8	3,6	3,7	12,7	1,5	70,6
1973	0,7	0,5	3,3	3,9	5,2	13,6	2,2	57,1
1975	0,7	0,4	3,0	4,0	5,9	14,1	2,5	53,8
1977	0,6	0,4	2,7	4,0	7,0	14,6	2,8	51,6
	Farms total							
1959	798,1	373,0	66,4	7,8	2,8	1 248,2	100,0	72,5
1969	351,3	328,2	130,0	20,5	6,4	838,6	100,0	62,3
1973	220,3	193,7	161,7	39,4	14,2	630,1	100,0	56,7
1975	187,5	169,5	153,4	43,8	18,5	572,1	100,0	54,9
1977	153,7	148,1	146,3	48,1	23,2	519,4	100,0	53,0
	All Farms in p. c.							
1959	64,0	29,9	5,3	0,6	0,2	100,0		
1969	42,0	39,2	15,5	2,5	0,8	100,0		
1973	35,0	30,7	25,7	6,3	2,3	100,0		
1975	32,7	29,6	26,8	7,7	3,2	100,0		
1977	29,6	28,5	28,7	9,3	4,5	100,0		

Source: Statistisches Bundesamt Wiesbaden and own calculations .

Table 6: Dairy cows classified with respect to herd size and farm size, FRG.

Year	Dairy cows in farms with ... cows					cows	
	1 - 4	5 - 9	10-19	20-29	30 and more	total	in p.c.of all cows
	Dairy cows in farms up to 5 ha LF						
1959	955	58	2	1	1	1 057	18,6
1969	457	83	7	2	2	551	9,4
1973	266	66	18	7	5	362	6,6
1975	224	63	15	3	2	307	5,7
1977	184	61	9	4	4	262	4,8
	Dairy cows in farms with 5-10 ha LF						
1959	734	613	16	0	0	1 363	24,0
1969	335	601	72	1	0	1 009	17,3
1973	215	392	100	2	1	711	13,0
1975	182	359	102	3	1	647	12,0
1977	179	328	106	3	1	587	10,8
	Dairy cows in farms with 10-20 ha LF						
1959	225	1 270	197	6	1	1 699	30,0
1969	93	1 274	672	70	5	2 114	36,2
1973	69	685	852	151	18	1 776	32,4
1975	60	583	822	171	21	1 657	30,7
1977	51	498	812	200	30	1 591	29,4
	Dairy cows in farms with 20-50 ha LF						
1959	20	503	597	77	9	1 207	21,3
1969	13	370	1 024	336	93	1 836	31,4
1973	12	164	1 126	658	296	2 255	41,1
1975	12	142	1 073	745	404	2 375	44,0
1977	10	118	1 010	816	562	2 516	46,4
	Dairy cows in farms with 50 and more ha LF						
1959	2	14	101	103	127	347	6,1
1969	2	7	60	93	174	336	5,7
1973	2	3	50	95	231	381	6,9
1975	1	3	46	96	263	410	7,6
1977	1	3	41	98	320	462	8,5
	Dairy cows in farms total						
1959	1 976	2 459	913	187	138	5 673	100,0
1969	898	2 335	1 836	501	275	5 846	100,0
1973	563	1 311	2 146	914	552	5 486	100,0
1975	479	1 150	2 056	1 018	692	5 395	100,0
1977	395	1 007	1 978	1 120	916	5 417	100,0
	All dairy cows in farms in p.c.						
1959	34,8	43,4	16,1	3,3	2,4	100,0	
1969	15,3	40,0	31,4	8,6	4,7	100,0	
1973	10,3	23,9	39,1	16,6	10,1	100,0	
1975	8,9	21,3	38,1	18,9	12,8	100,0	
1977	7,3	18,6	26,5	30,7	16,9	100,0	

Source: Statistisches Bundesamt Wiesbaden and own calculations.

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indicates that the owners are either part-time farmers or have anyway their main labor input on other economic activities.
Table 6 informs about the number of milk cows which stand in farms with 10 - 20 ha arable land, these were 812.000 in 1977 or 15 p. c. of the total number of milk cows. This shows clearly that milk price policy is not very efficient in achieving the income objective: To increase the income of those who are in need of the positive milk price variations has to affect 85 p. c. of cows where the owners get an income increase which is not necessary from the income objective point of view. At the present time structural change in the dairy sector is considerably influenced by expectations concerning prospective policy activities. Many farmers expect the introduction of a quota system in some form. Consequently, they accelerate their growth in the herd size at present. Thus, they may be not so much hurt by production restrictions which may freeze the quantity of a base period.
Table 7 gives some evidence about the present growth rate of those farms which want to stay in milk production.

Table 7: Present and planed herd size in Schleswig-Holstein

Region	herd size	
	1977	3 to 5 years later
Marsch	27.3	41.5
Geest	31.2	45.0
Hügelland	30.0	43.3
Schleswig-Holstein	30.0	43.9

Source: C.H. Thamling, 1979, p. 53.

The figures highlights the well-known fact that anticipation of policy activities may provoke expected policy action as they tend to worsen the situation.

1.5 Structural change, milk supply and income distribution

The effect of structural changes on the supply of milk are twofold:

a) Those farms which stop with milk production have, in general, below average milk yields per cow and below average efficiency in the production activity. Hence, the giving up has the effect that the average yield per cow in the country increases and averages as well as marginal production costs decreases.
b) Structural change implies a stocking up of herd sizes on some farms. Due to the technical change in milk production it is possible to realize considerably economics of scale. Hence, this component of technical change leads to a decrease in average and marginal costs in the dairy industry.

Figure 1 indicates the potential for decreasing costs by increasing herd sizes. The data represent the situation in 1977. Given factor prices of this year, total cost per cow and year comes up to 1.500 DM for a herd size of 40 cows and goes down to 780 DM for a herd size of 200 cows which indicates a decrease in costs by 50 p. c. The increase in efficiency and profitability may be even greater as the increase in herd size leads, in general, to an increase in the yield per cow.

Figure 2 highlights the relationship between labor input and herd size. The relative decrease in labor input with increasing herd size is less than of total cost. This shows that new technologies in milk production decrease more capital than labor input which may be a positive effect evalued from the macroeconomic point of view and the weak labor market at present. Furthermore, it is to assume that there exist a positive relationship between herd size and milk yield per cow. F. i. in the FRG we have an average herd size of 10.4 cows and yields per cow of 4.142 kg, whereas the corresponding figures for the region Geest in Schleswig-Holstein are 31.2 for the herd size and 5.067 kg yield per cow. This clearly shows that an acceleration of structural change on the one hand is able to mobilise an increase in productivity but on the other hand it may increase the problem on the milk market with given market prices. Consequently, the need for a reduction in market prices may be the more urgent the greater the structural changes in the dairy sector are.

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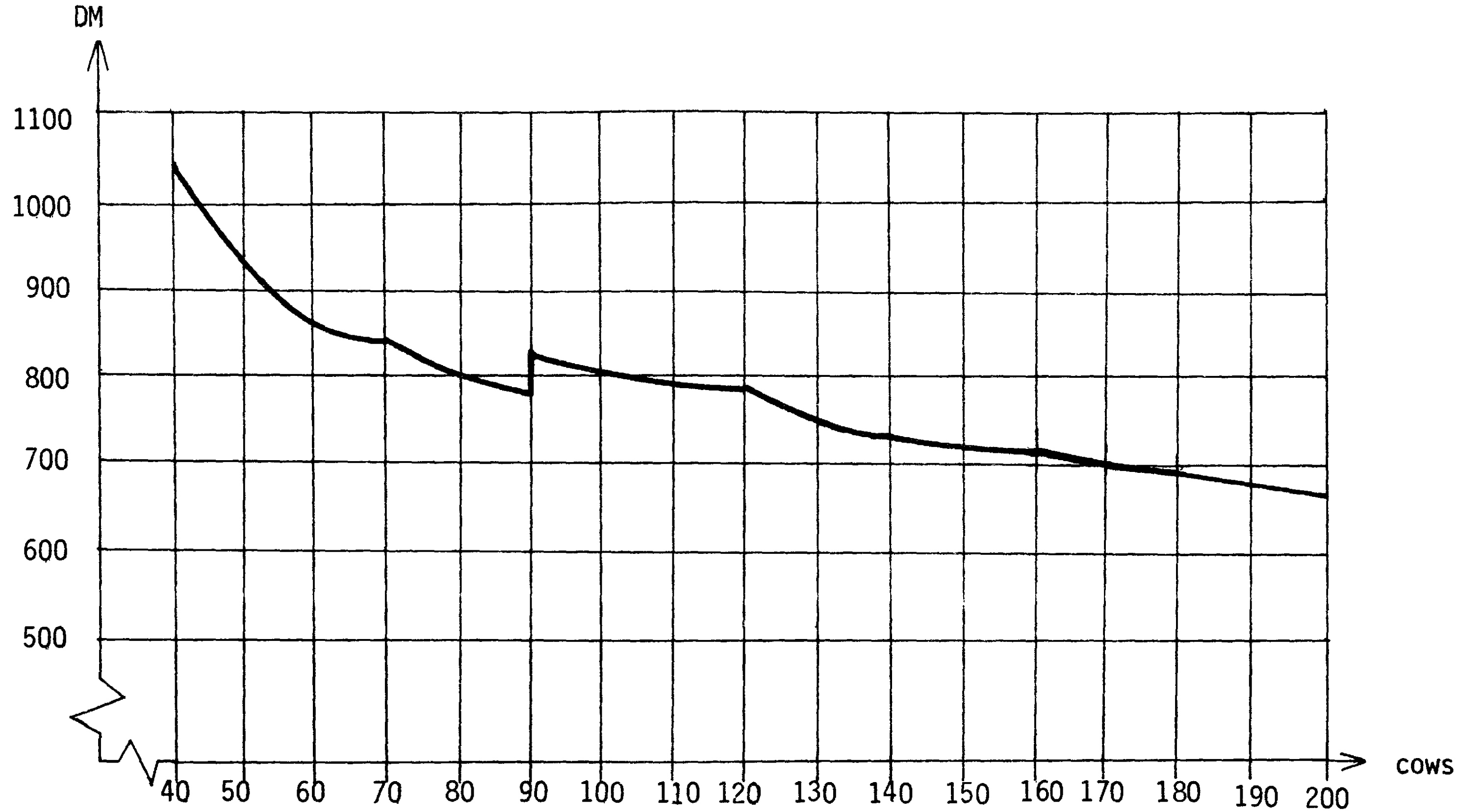
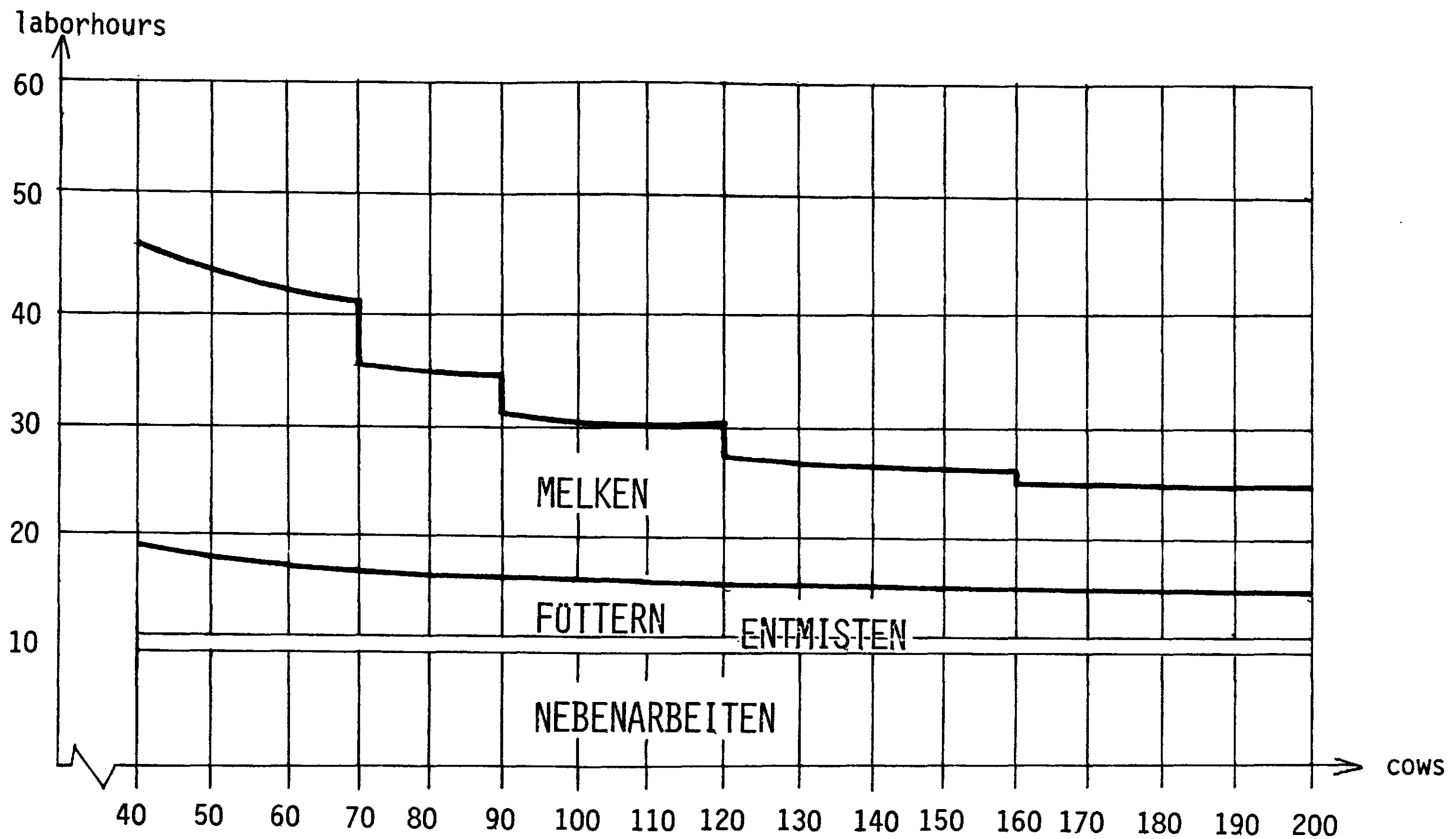
Figure 1: Total cost of milk production in GM/cow and year



Source: Höper (1977), p. 34.

Figure 2: Labor costs in milk production in GM/cow and year



Source: Höper (1977), p. 34.

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Structural change in the dairy sector has also some implications for intrasectoral income distribution and the efficiency of price policy as an instrument of income policy. At present it is much easier for large farms than for small farms to introduce new technologies in milk production. Hence, productivity increases are greater for large farms than for small farms. Consequently, income changes over time with constant product prices are greater for large than for small farms. If, on the other hand, price changes are supposed to guaranty sufficient income for poor dairy farmers more and more milk producer will get an income increase which is not necessary from the income objective point of view. Structural change tends to increase the heterogeneity in the dairy sector. Price policy will be less efficient in steering production and realizing the income objective at the same time. Consequently, it seems more and more worthwhile to ask for the effects of negative price variations on milk production and income in the dairy sector.

2 Analysis of the volume and of the structure of milk production in Germany

2.1 Objectives of the studies and methods applied

In the previous section it has been demonstrated that the milk production has played a central role in the development of the agricultural sector in Germany during the last two or three decades. The total volume of production remained almost unchanged over a period of 25 years, nevertheless, the structure of the dairy sector has changed considerably within this period. There are to consider remarkable changes with respect to the farm sizes and the herd sizes, to the regional distribution and with respect to the intensity and the technique of production. In spite of the fact that the milk production is the most important enterprise within the sector and that this enterprise had been influenced by many factors, there exist only a relative small number of research studies concerned with this topic. This abstinence of German analysts may be explained by - at least - four reasons, which render difficulties in analysis:

1. The degree of specialization of the farms in Germany is relatively low and most of the dairy cows are raised in mixed farms. Hence, it is rather difficult if not impossible to isolate the dairy sector. In addition, special methodological difficulties are connected with interrelationship between milk production and beef production. These enterprises are partly competing,

partly of a complementary character.
2. Most of the factors which have mainly influenced the development of the dairy sector are characterized by relative stable trends during the period 1960 to 1975. This makes it almost impossible to determine the special impact the different factors have had on the change of the production structure.
3. Milk production is based on long term investments. Hence, any adjustment at a changed data configueration needs an according time period. The time lag of adjustment causes additional complications in modelling and especially the "verification" of the parameters of econometric models is comlicated.
4. The impact of some factors vary considerably from region to region and from farm to farm. Especially aggravating is the fact that even the sign of a parameter can differ,according to the region, to the time period or to the price interval which is investigated. So it is possible that increasing beef prices cause a reduction of the milk production in some farms because of the competition with respect to land and labor. Contemporarely other farms will enlarge their dairy herds to receive more calves for fattening. Taking into account the mentioned difficulties it is not surprising that most studies aimed in substance at a projection of the milk production where the main stress has been layed upon the projection of the changes in the structure of production and in the regional distribution.

Trend extrapolation, markovian processes and similar techniques are applied in these studies. Some of them are briefly reported in section 2.2 .

In a small number of studies it is tried to quantify the influence of divers factors on the milk production. Of special interest in this context are those investigations which try to determine price response functions for milk. The leading features and the most important results of the different econometric studies are outlined in the following sections 2.3 .

In view of the remarkable difficulties which arose estimating parameters of price response functions for milk in econometric approaches some authors have calculated price supply function or price response relations by using a normative marginal cost curve. The marginal cost curve has been derived from linear programming models with profit maximizing objective functions. The model framework, the model differenciation and the results of some of these studies are given in section 2.4 . In section 2.5 another normativ approach is described in which the normative results of the single farm models are combined with empirical information in a dynamic procedure.

2.2 Models extrapolating the German milk production

2.21 Differencies in the approaches

As mentioned above a considerable number of studies has been carried out in which the milk production has been projected by extrapolating the underlying trends has number of these studies shall be briefly reported in order to characterize the different approaches, as the data were used and the results received. The studies can be classified

- by the applied extrapolation technique (linear and nonlinear trend, markov chains, logistic curves)
- by the degree of disaggregation of the production variable,(number of holders x number of cows per farm x yield per cow),
- by the regional differenciation and
- by the consideration of size classes etc.

The consideration of the regional distribution and of the size structure of the herds and the farms resp. will be used as a grouping criterion in the following short outline.

2.22 Extrapolation of regional trends

R. Müller (1971): Müller's study on the regional development of milk production is based on simple trendcalculations, for the 544 Kreise of the Federal Republic of Germany. Data are used from the period 1960 - 1968. As he calculates separate trend functions for the number of cows and the milk yield - or any Kreis,he gives a very differenciated picture of the German dairy sector and its recent development. He could show that there exists a relative narrow positive correlation between the regional level of production (number of cows/ha) and the growth rate. Later studies on a much higher aggregated level give an indication that this regional concentration process of the sixties can be suspected to maintain until today.

E. Schmitt, L. Kersten and D. Manegold (1977): This study uses the same method as Müller (1971), however on a much more aggregated level. The authors calculate also separate trend function for the number of cows and the yield per cow. The data basis are the recorded data on the level of the Bundesländer during the period 1960 - 1976. A comparison of the results of this study with Müller's results demonstrate that trend values are very sensitive with respect to the regional level used.

R. EL-Saaday (1972): EL-Saaday investigates the development of the milk production in the Land Hessen. For his projection he uses a combination of trend extrapolations, a markovian model and a single factor regression. He estimates the number of cows per ha as a function of the farm size. The farm size distribution is projected by a markov chain on the basis of the changes within the Kreise of Hessen. The average milk yield per Kreis is projected by a simple trend function.
Besides the projection of the milk production in Hessen EL-Saaday investigates the main factors influencing the differences of the production level in the Kreise by using a principal component analysis. His main results are:
1.) The number of cows per ha are mainly influenced by the natural conditions (67 p. c.). Further factors are the land-man-ratio (12 p. c.) and the individual managerial ability of the farmer (15 p. c.).
2.) The milk yield is depending on the farmer's ability to 60 p. c. and on the land-man-ratio to 22 p. c. The natural conditions contribute only 5 p. c. to the variance of yields.

2.23 Extrapolation of regional trends under consideration of structural changes

G. Müller (1968): Müller estimated the number of dairy cows in the Länder whereby the calculations are based on a classification of the farms by their acreage and their herd size. The distribution of the farms to size classes has been estimated by homogeneous markov chains with constant transition probabilities. In a second step he analysed the distribution of cows with respect to the herd size in any farm size class during the period 1949 - 1965 and thereof he estimated the future distribution by assuming a monotonous change of the distribution. Taking into account the estimated number of farms in any size class and the average number of cows in any size class which had been derived from the estimated distribution to herd sizes he computed the number of cows per region and size class. For estimating the milk yield he used a simple regression model where the annual increase of the milk yield had been considered as a function of the level of yield reached in the year before.

H. Doll (1976): Doll projected the number of cows in 42 regions of the Federal Republic with relative homogenous natural conditions. Because of the chosen regional differentiation he must be satisfied with the very short reference period 1965 - 1974. He split up the variable "number of cows" in the three components:

- the average number of cows per dairy farm
- the percentage of dairy farms at all farms and
- the number of farms.

By multiplying the three variables he results in the number of cows per region. The number of farms and the number of cows per farm are projected by using simple linear trend functions and logistic functions, whereas the percentage of dairy farms has been estimated by applying markov chains.

2.24 Comparison of the projection results

In table 4 the resulting projections of eight studies are summarized. All the projections are based on the extrapolation of the development trends in the dairy sector. The study of Ruf (1967), Plate and Neidlinger (1971), the Niedersachsengutachten (1971) and the Agrarbericht (1971) are based on aggregated national data, whereas the other studies consider data on the regional level as described below.

A comparison of the projection results with the actual figures of 1975 and 1978 resp. allows the following conclusions:

1. The studies of 1967 and 1968 tend to overestimate the milk yield, the number of cows and the milk production for 1975. It can be argued that these studies were not able to include the fact that the price of milk remained stable within the projective period whereas the milk price has increased during the analysis period.
2. The studies published in 1971 tend to underestimate the actual milk production of the year 1980. The level projected for 1980 had been reached already in 1978 (see table 8).

Table 8: Projections of dairy cows, milk yield and milk production and actual data+)

author	published in	number of dairy cows in million 1975	1980	milk yield (kg/cow/year) 1975	1980	milk production (mio t) 1975	1980
R. RUF, p. 30	1967	5.60 - 5.90	-	4 100	-	22.96 - 24.19	-
G. MOLLER, p. 232	1968	5.50 - 5.94	-	3 949 - 3 954	-	21.73 - 23.48	-
R. MOLLER, p. 377 f.	1971	-	5.50	-	3 950-4 350	-	(23.1)
R. PLATE und G. NEIDLINGER, p. 74	1971	5.08	4.77	4 100	4 250	20.84	20.29
NIEDERSACHSEN-GUTACHTEN, p. 5	1971	-	5.00	-	4 200	-	(21.0)
AGRARBERICHT, p. 372	1971	5.60	5.60	4 035	4 200	22.60	23.50
L. KERSTEN, p. 134	1974	5.50	5.50	-	4 320	22.44	23.76
H. DOLL, p. 218	1975	5.31 - 5.42	5.02 - 5.21	3 948-3 986	4 261-4 391	20.97-21.61	21.40-22.88
+ actual data of the FRG		5.35	5.42 (year 1978)	3960	4260 (year 1978)	21.6	23.3 (year 1978)

Source: H. Doll (1975), p. 218.

It can be argued that this underestimation is caused by the fact that the projections had been based on data with a relative stable price level whereas the actual milk price raised considerably in the projection period.

From these projection errors it can be concluded
a) that there exist a positive price elasticity and
b) that the adjustment needs a considerable time period.

If the studies are compared on the regional level with the actual data then an additional feature becomes obvious:
c) The tendency to over- and underestimate differs considerably with the Länder. E. g. the projections of Schleswig-Holstein and Nordrhein-Westfalen show a remarkable bias whereas the projections of Bayern and Baden-Württemberg seems to be reasonable. Hence, it might be argued that there exist considerable differencies in the price elasticities of the regions.

2.3 Analysis of the milk production in Germany by econometric models

2.31 General features of the approaches

The econometric studies which will be reported in the next sections aim at a reasonable prognosis of the development of the milk production in West Germany by taking into account the impact of some exogeneous variables. Four studies are reported which analyse the milk production by using one or two independent equations in which several exogeneous variables are included. This approach is also often named a multiple regression analysis. Furthermore, two large econometric models of the cattle sector are outlined and discussed briefly. As in all the studies the milk price is regarded to be one of these exogeneous variables, all the models can be used to appraise the impact of a milk price change on the dairy sector of Germany.

All the four multiple regression studies use price responce functions as the analytical tool and do not take into account the demand for milk. However, this model limitation seems to be reasonable in the case under consideration as the EC milk price is (at least in the short run) politically determined and there exists obviously no relation between the consumption at the EC market and the national production of milk. Although the four studies mentioned make use of relative similar models and are based almost on the same data set, the resulting information differs considerably, especially the large variation of the estimated price elasticities leaves a considerable margin for the interpretation and the valuation of any milk price policy.

As mentioned there will also be outlined two large econometric models of the cattle sector of West Germany in which the farmers' supply response to milk price changes are integrated. By interpreting these model results and by comparing these results with the simple regression models it is to take into account that the large models aim at the analysis of all the interrelationships which exist within the whole dairy/beef sector. In addition, the models have a recursive structure which consider only the most direct interrelations explicitely. Hence, the elasticities of the special equations of the model in which the milk price is explicitely involved do not indicate correctly the total impact of a change of the price variables to on the dependent varialble. The direct price elasticities of these models are usually smaller than the elasticities derived from single equation models. The total impact of a price change can be derived by the calculation of the whole system with varying price assumptions.

2.32 Analysis of the milk production by multiple regression models

E. Ryll (1973): The analysis carried out by E. Ryll (1973) is based on time series data of 1959 - 1971. He estimated separate supply response functions for the eight Länder of the FRG and for the Federal Republic of Germany as an aggregate. He divided the variable "milk produced" in its components:

- the milk yield per cow (YC)
- the average number of cows per dairy farm (ADF) and
- the number of dairy farms (NDF).

The following equations were estimated independently by the ordinary least square technique:

(1) $NDF = \alpha_1 + \beta_1 \cdot MP_{t-3} + \vartheta_1 t$

(2) $ADF = \alpha_2 + \beta_2 \; MP_{t-3} + \gamma_2 \; BP_{t-3} + \vartheta_2 t$

(3) $YC = \alpha_3 + \vartheta_3 t$

with t = time and MP = milk price and BP = beef price and $\alpha, \beta, \gamma, \vartheta$ = regression parameters.

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By this model Ryll came to the following elasticities of the number of cows with respect to milk price changes taking into account eq. (1) and eq. (2):

Federal republic	: 0,25
Schleswig-Holstein	: 0,25
Niedersachsen	: 0,13
Nordrhein/Westf.	: 0,30
Hessen	: 0,47
Rheinland/Pfalz	: 0,49
Saarland	: 0,31
Baden/Württ.	: 0,17
Bayern	: not significant at the 90 % level.

The elasticities of the number of cows with respect to the beef price had been significantly negative in the Länder Schleswig-Holstein, Niedersachsen and Nordrhein/Westfalen, whereas all other country equations and the equation for the FRG do not have significant regression parameters.

It should be emphasized that Ryll has experimented with different time lags of the price variables; the best results from the view point of statistical significance he received by implementing a 3 years'lag.

In order to find some explanation for the differing price elasticities he investigates additionally supply response functions in Schleswig-Holstein on a more disaggregated level. He separates groups of farms by the natural conditions (Marsch, Geest, Hügelland), by the size of farms and by the percentage of permanent grassland. The resulting elasticities of the number of cows with respect to milk price changes are presented in table 9.

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Table 9: Price elasticities in groups of farms in Schleswig-Holstein (Ryll 1973)

	permanent grassland in p. c. of agr.land	milk price elasticity
Marsch	58	0,23
Geest	45	0,19
Hügelland	25	0,33
10-30 ha	<30	0
	>30	0
30-50 ha	<30	0,30
	>30	0,17
50-100 ha	<30	0,45
	>30	0,15

It is to be emphasized that the elasticities derived from the calculations on the group level give only partly a meaningful exploration of the differing elasticities of the Länder. The small co-efficients of Bayern and Baden/Württemberg might be explained by the small average farm size of these Länder and by the high percentage of permanent grassland. However, the highest elasticities are estimated for Hessen and Rheinland/Pfalz which are countries with an extreme small farm size and a medium percentage of grassland.

H. Doll (1977): The study of H. Doll is based on the annual data of the Federal Republic and on annual data of groups and regions within the FRG. For the FRG he estimates diverse supply response functions taking into account the milk price index, the price index of calves and of beefcattle, in addition a trend variable and some other exogeneous variables. The resulting parameters of the regression equations are given in table 10. He used the same time lag of three years like Ryll (1973). However, his calculations are distinguished from Ryll's calculations by:

a.) the direct estimation of the number of cows in one equation instead of two equations

b.) his reference period was 1965 - 1974 (Ryll's period has been 1959 -

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Table 10: Parameters of linear price response functions for the FRG (Doll 1977)

Number of equation			P_{1t-3}	P_{2t-3}	P_{3t-2}	t	X_{5t-1}	X_{6t-1}	Y_{3t-1}
34.1	a	5692.9	28.207	-15.844	-9.681				
	b		10.006	4.803	4.079				
	c		0.541	-0.331	-0.215				
34.2	a	2505.4	23.518	-5.600+)					1.478
	b		6.667	3.161					0.275
	c		0.451	-					
34.3	a	8443.3	28.707	-6.824		-73.581			
	b		7.090	3.100		13.902			
	c		0.552	-0.149		-			
34.5	a	9137.2	33.198	-9.210			-1.634		
	b		6.106	2.423			0.244		
	c		0.636	-0.201					

a = regression coefficient. b = standard ewor. c= elasticity. +) = not signigicant at 95 %
Y: number of cows   P: price index with 1 = milk; 2 = calves; 3 = beef; t: time variable (years)
X: other variables

1971) and
c.) he includes more exogeneous variables.

As it can be seen from table 10 he resulted in considerably higher price elasticities (between 0.451 and 0.636) than Ryll (0.25 for the FRG). Taking into account that a splitting of a variable in its components usually results in a higher elasticity, and taking into account that the reference periods overlaps considerably, it can be argued that the consideration of the additional factors - especially the prices of calves and beefcattle - in the response function are mainly responsible for the different and the higher elasticities.

In addition to the analysis on the FRG level he carried out equivalent estimations on a very disaggregated level. For 42 regions of the FRG he estimates supply response functions whereby in any region 5 groups of farms were distinguished, they have been differenciated by the farm size in ha. The elasticity coefficents of four typical regions are given in table 12. The four regions are characterized by the percentage of permanent grassland and the possibilities to get jobs outside of the agricultural sector (see table 11).

Table 11: Characterisation of the regions reported in table 12

Region	percentage of permanent grassland	working possibilities outside of agriculture
4	72.4	poor
9	12.0	good
17	60.5	good
35	29.3	poor

The group results received by Doll (1977) confirm Ryll's group results to some extent and complete them partly. The elasticity of supply response is obviously strongly dependent on the working conditions of the regions. On the other hand no distinct tendency towards higher or smaller elasticities

Table 12: Elasticities of the number of dairy cows with respect to changing milk prices in regions and size groups (Doll 1977)

Region No. (see table 11)	Equation No. (see table 10)	Farmsize from ..... to ..... ha 5	5-10	10-20	20-50	50	all farms
		P r i c e e l a s t i c i t i e s					
4	34.1	– +)	–	1.919	–	–	0.744
	34.2	1.168	0.780	1.290	1.260	–	0.584
	34.3	1.499	0.578	2.069	–	1.505	0.542
9	34.1	–	–	–	0.647	–	–
	34.2	2.185	2.041	1.801	1.027	1.542	1.368
	34.3	1.561	–	1.529	0.693	–	0.437
17	34.1	–	–	1.765	–	–	–
	34.2	1.046	0.584	1.262	0.912	1.004	1.077
	34.3	1.069	0.854	2.273	–	1.309	1.144
35	34.1	–	–	1.083	–	–	–
	34.2	0.423	0.516	0.958	–	–	0.475
	34.3	0.463	0.583	1.150	1.375	–	0.521

+) not significant at 95 % level

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with respect to the farm size can be concluded from Doll's group results. Furthermore, it seems to be that the elasticities becomes the higher the less aggregated the involved groups are; it seems that varying reactions are to be expected to be wiped out by aggregating.

H. O. Aeikens (1979): Aeikens constructed a model to forecast the milk production of the whole EC. For this purpose he estimated independent supply functions for any of the EC countries and he distinguished between a function for the number of cows and one for the milk yield. For Germany he presents the following two regression functions:

(1) $DC = 7403.27 - 16.53\ CP_{t-1} - 6053.23\ X_{t-1.5} - 191.27\ SD$

(2) $YC = 2866.58 + 349.88\ MP/FP_{(t+t-1)12} + 12.62\ AI$

with

DC = number of dairy cows
CP = cereal price
MP = milk price
FP = feed price
X = industrial wages/income from dairying
SD, AI = dummy variables

The price elasticity of the milk yield per cow can be derived from equation (2) directly and it is 0.08. The total price elasticity of the milk production cannot be derived directly as in equation (1) the milk price is implemented in the variable X. Therefore, it is tried to calculate an approximate figure for the elasticity by using the results Aeikens presents for different scenarios for which he has calculated a projected development path. He has used 6 different price scenarios, where the scenarios of the variants A, B, C and the scenarios of the variants D, E, F are comparable with respect to all prices except the milk price. In table 13 the approximated elasticities derived from his results are presented.

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Table 13: Model results of Aeikens (1979) and price elasticities derived

		milk yield		number of cows		total milk production
Variants compared	milk price difference	difference within 2 years in p. c.	elasticity derived	difference within 2 years in p. c.	elasticity derived	elasticity derived
A,B	-1.5	0.17	0.09	0.77	0.39	0.47
B,C	-3.0	0.17	0.09	0.68	0.34	0.42
D,E	-1.5	0.18	0.09	0.55	0.28	0.37
E,F	-3.0	0.19	0.10	0.54	0.27	0.37

The results are not very different from Doll's (1977) results. However, it should be emphasized that Aeikens used only a very small time lag of one and a half year with respect to the number of dairy cows and of only half a year with respect to the milk yield. Hence, it can be argued that his estimates neglect the long run effects at least to some extent.

H. Becker (1979): Becker's study is mainly concerned with the income effects which are to be expected if the intervention of butter and skim milk is stopped. He used two approaches to estimate the recent price elasticity of milk. One of his estimations is based on a production function analysis. He derives indirectly the price elasticities from the factor shares and the price elasticities of the factor input:

$\eta = \sum_{i=1}^{4} K_i \eta_i$ with

K_i = factor shares

η_i = price elasticity of the factors and

i = 1,...4 with 1 = labor; 2 = capitalinvestment; 3 = land; 4 = variable input factors

The author used crude guesses for the factor elasticities and he came to a short run elasticity of 0.2 and to a long run elasitcity of 0.74.
By using a time series analysis with a double logarithmic function he results in a price elasticity of the milk production within the range 0.75 - 0.80.

2.33 Analysis of the milk supply response within multi equation models of the cattle sector

J. Haimerl (1969): Haimerl described and analysed the German cattle sector by an econometric model which consists of 39 equations. The model had been constructed in a bloc recursive form and the 39 structural equations are subdivided in six submodels. Some of the submodels have also a recursive structure so that ordinary least square estimators could be used. The estimation of the model parameters had been based on the half-year data between 1953/54 and 1966/67.

The first of the submodels is describing the milk production. The number of cows are explained in the first place by an autoregressive process; the number of cows in the period before are used as a lagged endogeneous variable. However, in addition other explaining variables are considered, e. g. the labor capacities, the acreage of foddercrops and the beef prices. The milk price which had been included in some of the variants did not show significant parameters. However, it is to emphasize that Haimerl used the milk price with a time lag of only half a year so that it would be very surprising if a significant coefficient could be established. In opposite, the milk yield equation brought a significant positive price elasticity with respect to the milk price. This elasticity calculated with no time lag had been approximately 0.08.

W. Rüther (1978): Rüther's model is much less disaggregated than the Haimerl (1969) model and is limited to 11 equations. Rüther based his calculation on the quarterly data of the period 1960 - 1976. He applied a three stage least square procedure to estimate the parameters of the model. Hence, he had not been forced to formulate all interdependencies in a recursive manner.

The relationship between milk production and milk price is implemented in

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his model in the equation explaining the variable "number of cows in t". The following variables are used as explaining variables in this equation:

- number of cows in t
- number of cows (t-1)
- relation milk price/beef price (t-2)
- number of young females (t-4)
- relation milk price/beef price (t-8)
- number of dairy farms (t)
- time variable and some dummy variables.

As quarterly data are used a time lag (t-8) means a two years' time lag a. s.o. From this formulation it can be seen that Rüthers model has also a strong autoregressive form. Futhermore, it is to see that the milk price influences the development of the number of cows with two different time lags. Hence, two different direct price elasticities are to calculate. In this model the milk price shows a short run elasticity of 0.06, the long run elasticity lies between 0.14 and 0.21.

However, these elasticities do not consider that the milk price influences the milk production indirectly by the following interdependencies included in the model:

a.) The autorecursive relationship of the number of dairy cows effects that any change of the number of cows caused by a price change in one period is transmitted to the next and all following periods if even with decreasing rates.

b.) Another equation of the model says that the number of young females is depending on the milk price with a time lag of 2 years. According to this equation and taking into account that the young females are a time lagged explanatory variable of the number of cows a further indirect, however lagged influence is to be to consider. Hence, it can be expected that

1.) the total impact of a milk price change is considerably higher than the direct elasticity of 0.14 to 0.21 indicates and
2.) that (because of the autoregressive structure) the price elasticity will increase with the time horizon taken into account and the elasticitiy will adjust asymtotically a certain level.

2.4 Supply analysis by linear programming models

Supply elasticities resulting from normative approaches are very difficult to interpret as there do not exist any comparable and simple measure like the "significance level" of the econometric parameters. Hence, the confidence given to a normatively derived "elasticity" is exactly equal to the confidence which is given to the model and, hence, this is completely subjective.

However, it should be emphasized that "econometric" elasticities are just as much subjective as "normative" elasticities for "econometric" elasticities are accepted if and only if the model is subjectively considered as a suitable and a sufficient picture of the (unknown) reality. With other words "normative" results are either better or worse than "positive" results. In both cases it depends on the model and its special specification.

The usefulness of a linear programming approach for estimating farmers' response to price variations depends mainly on how the following model components are formulated and implemented:

a.) Formulation of the objective function: Most of the models applied are based on pure "net income maximization", although it is generally accepted that at least some farmers behave risk averse a.s.o.
b.) Number of farm models: The aggregation error can be regarded as one of the most serious errors in normative models. It is to state that a high level of aggregation does not only cause instabilities in the response function but also biases. The aggregation bias is not directly depending on the number of farm models, however, the aggregation bias is at least correlated with the number of models. Hence, a large number of models seems to be desirable.
c.) The size of the farm models: A linear programming model can only reflect the probable response of a group of farmers sufficiently if the multiple possibilities of adjustment to new data configuerations are actually implemented in the model. A large size of the LP-models is no guarantee for a suitable formulation of the adjustment possibilities, however, if the model is too small and too aggregated it is sure that the model cannot well reflect the response to price variations.
d.) The time horizon: It is necessary to determine in any LP-model the production factors which are to be regarded as fixed and the factors which can be sold or bought from outside the farm. As the proportion of the fixed factors vary with the time horizon taken into account the model results reflect the supply response within a given exactly defined time period.
e.) Interfarm relationships: Furthermore, it is very important if and in how far the interdependencies between the farms are taken into account. In this context, it is to distinguish between the so called "representative farm approach" and the "simultaneous sector model". In the first case the price supply response is calculated for any farm model independently and than aggregated to a sectoral response function, whereas

in the second type the sectoral response is calcualted simultaneously for all farm models.

In the last two decades a considerable number of studies using the linear programming approach had been carried out to investigate the supply response to changing milk prices. However, no study satisfies all the requirements given. Hence, the resulting elasticities have to be interpreted very cautiously and it should not be given too much confidence in the values obtained. Nevertheless, some of the studies are outlined very briefly as they show interesting features with respect to some aspects.

Meinhold and Dieterich (1971): Meinhold and Dieterich have used a representative farm model approach. Their calculations are based on about 100 LP-models which reflect the production conditions of the Landkreis Hildesheim in Niedersachsen. The different farm models are of a size of about 50 x 50 columns and rows resp. and include a sufficient number of activities to reflect possible adjustments. Special investment activities allow to adjust the number of cows to increasing milk prices; the factors "labor and land input" are considered as fixed at the farm level so that the time period being investigated is to be assumed as 5 to 10 years.

As all farm models are based on the special data of only one Landkreis the results on the level of the FRG may not be regarded as very representative. Hence, the differing results of the different farm groups seems to be the more interesting outcome. Meinhold and Dieterich show that there exist a relatively strong dependency between price elasticity of supply and the land-man-ratio. It is to conclude that the more land per labor unit is available the more elastic is the milk supply function; or with other words:

- large farms react more elastic to milk price changes than small ones and
- part time farms react more elastic than full time farms.

Ifo-Institute (1976): The Ifo-Institute München carried out in 1976 a study about the possibilities to establish an equilibrium at the milk market and the beef market of the EC. Their argumentation had been based on the hypothesis that the price elasticities of milk and beef are so small that a price policy cannot be regarded as a suitable instrument. Hence, they propose "special regional instruments". The discussion is based on LP-calculations of only three models for the FRG. The models used do obviously not include a broad variety of adjustment possibilities, hence, the models react with unrealistic adjustment steps. If the results received by these models are converted to "elasticities" the "average" elasticity account to be about 1 or even more (see table 14); what is obviously contradictory to their political argumentation.

Table 14: LP-Model calculations by the Ifo-Institute (1976)

	Reduction of milk production in p.c. by a milk price change of ... p. c. -10 %	-20 %	- 30 %	corresponding elasticities -10 %	-25 %	-30 %
model 1	-12.5	-12.5	-37.5	1.25	0.7	1.2
model 2	0	-15.4	-92.3	0	0.75	3.0
model 3	-17.6	-17.6	-41.1	1.8	0.9	1.2

Henze and Zeddies (1979): Henze and Zeddies have also carried out a normative study of the German milk market by using the representative farm model approach. Their quantitative results with respect to the milk supply response are based on only 14 static linear programming models which should represent the dairy sector of Germany. The models are distinguished by the farmsize and by the production pattern. In addition, there is dinstinguished between full time and part time farmers. The 14 models are computed with different assumptions with respect to the time horizon of adjustment and with different price relations. For the short run (1 year) they come to very small elasticities (see table 15), whereas the medium range elasticities (3 years adjustment) are calculated to be about 0.4 if a 25 % price decrease is assumed.

Table 15: LP-Model results of Henze and Zeddies (1979)		
Decrease of milk price	Corresponding change of production (short term)	Short term elasticity
10 %	-0,13 %	0,013
20 %	-1,38 %	0,069
30 %	-8,50 %	0,28

Bauersachs and Niebuhr (1978): In opposite to the other studies mentioned, Bauersachs and Niebuhr used a simultaneous model of the agricultural sector of Germany. On the production side they use a differenciation by four size groups of farms. Any group model is producing nine different products with a given maximum market potential. The adjustment to variations of the price relations is calculated starting from the year 1971. As it can be seen from table 16 they result in a long term elasticity of about 1 and this in the case of increasing and decreasing milk prices as well. The short term elasticities of this model had been less than 0.1, whereby short term means "response within one year".

Table 16: Model results from Bauersachs and Niebuhr (1978)				
model variant	milk price change in p.c.	change of milk production annual	total	elasticity
I	+ 14,37	+ 1,0	+ 14,94	1,04
II	- 2,76	- 0,2	- 2,76	1,0
III	- 22,0	- 1,8	- 22,5	1,0
IV	- 22,5	- 1,8	- 22,5	1,0

2.5 Supply response of the German dairy sector with respect to changes in the EC-milk-price policy - A normative approach

2.51 Objectives and basic assumptions of the study

The model of Hanf and Koester (1980) which will be outlined in the next sections has been constructed in order to study the probable effects of a change in the price policy on West-Germany's agricultural sector; the analysis puts a strong emphasis on the impact of decreasing milk prices.
The choice of the model type and the construction of the computational procedure as well were considerably influenced by the fact that different objectives were pursued by carrying out the analysis. The main objectives of the study were:

1. To analyse the probable reduction of milk supply due to a certain change in the development of milk prices over time.
2. To analyse the adjustment in the overall production pattern and in the structure of factor use caused by a change in milk price policy.
3. To estimate the loss in income of West German farmers due to a decrease in milk prices and especially the potential to compensate these losses by an optimal adjustment to the change in price ratios.
4. To receive information about the probable impact on the structural development of the sector, mainly to quantify approximately the number of farmers and farm workers who are forced to leave the sector due to a change in price policy.

Furthermore, the model should provide the information mentioned above on a regional level and for specific types of farms as well.

The decision to accept a normative approach was based on the following reasoning:

a) Statistical informations about production and supply are obtainable only on a very high aggregated level (FRG) and with some reservation on the regional level (Bundesländer). This is especially true if data on the farm group level over a period of 15 to 20 years are to be considered.

b) Adjustment processes in milk production, especially adjustments to decreasing prices, take a long time, as some of the most important factors used in milk production are fixed on farm level for a relative long time period and there exist only limited employment alternatives. Hence, it would be necessary to estimate a very wide spread distributed lag function.

This would reduce considerably the chance for estimating significant coefficients of cross-price-elasticity due to the relative small number in degrees of freedom.

c) In fact, there have been some negative price changes in the last twenty years if deflated (relative) prices are considered. Nevertheless, in the last two decades West Germany did not have a considerable negative shift in the milk price development, which is the problem under consideration. Hence, it seems justified to doubt the usefulness of the price elasticities estimated by econometric methods as these methods usually estimate under the assumption that the annual price variations are independent.

The authors used a representative farm model and they defended the applied 'representative farm approach' by the following arguments:

a) It may be agreed that 'representative farm models' have to assume a constant market price which implies an infinite price elasticity of demand. This is obviously an overestimation of the market potential at a given price. However, on the other hand 'simultaneous models' are forced to assume a fixed demand capacity; this is certainly a relative artificial assumption, especially if we take into account that the relevant market for West German agriculture is the EC-market and that EC-policy may affect the market potential.

b) The only simultaneous constraint with respect to intermediate products which is of crucial relevance for the problem under discussion is the balance of calves within the FRG. Indeed it has to be assume that import and export elasticities for calves are not so high, that a constant price assumption can be justified. However, this problem can be solved: It will be applied an iterative procedure in the calculations of the individual farm supply functions that an approximate balance of calves can be guaranteed.

c) The land constraint can be met in 'representative farm models' if no trade in land is allowed. In this case the mobility of land will be underestimated. On the other hand, simultaneous equilibrium models assume full competition on land market. This assumption will certainly lead to a unrealistic land transfer within the regions. It might be argued that the mistake with respect to the land market in representative models can be reduced at least to the same level as in simultaneous models if a respective additional land distribution model is attached to the representative model (see Hanf and Doppler (1972)).

To sum up, it has to be agreed that representative approaches show some slight shortcomings as compared to simultaneous approaches. However, there exist some remarkable advantages by applying the representative approach. This concerns mainly model formulation:

1) Representative models can consider any operational objective function, e.g. it is possible to allow for a risk aversive behaviour.
2) The models can be based on incomplete information about future.
3) Temporary incompleteness of the markets can be taken into account adequately.
4) Dynamic adjustment processes can be approximated more adequately than in large simultaneous models.

The most important difference and advantage resp. may be seen in

5) representative models are not influenced by aggregation errors if the representative farms are drawn as a random sample from a large sample size and the sample error connected with the approach is a diminishing disturbing factor.
6) Finally, the necessary computer time of large and relatively differenciated representative farm models' is considerably smaller than the necessary computer time for simultaneous models, as the computer time is proportional to the number of farm models involved whereas in simultaneous models the time required increases with a potential factor of 2 to 3, even if efficient algorithms are applied.

2.52 Outline of the model

In order to achieve the objectives mentioned a disaggregated and dynamic approach has been applied. Taking into account the limited computational and working facilities and the given data information a four stage model has been used.

Stage 1: Definition and construction of an artificial sample of representative farms and their respective linear programming models.
Stage 2: Computation of diverse price supply response curves of the individual farm models by parametric programming .
Stage 3: Calculation of adjustment curves for individual farms to changes in price relations.

Stage 4: Aggregation of the individual adjustment curves to sectoral, dynamic response functions.

In the following sections the basic features of the model stages are described very briefly. A more detailed description is given in Hanf and Koester (1980).

"Stage 1"

As no sufficient information about the data on farm level had been available an artificial sample of representative farms had to be constructed. In order to represent the West German dairy sector 200 farm models were constructed for every of the 42 agricultural regions of the FRG. The necessary input data for these representative farms were produced by a random computer program which guaranteed that any of the regional sample of 200 models reflects the known statistical proportions of the dairy farms in the respective region. The program took into consideration the known distribution of farms with respect to size classes, the average input and output coefficients and their variances and covariances as far as they are obtainable from official statistics and research reports. On the basis of the mentioned information about 40 data were assigned to every of the models by a random process. The remaining data have been assumed to be identical for all farms.

The data assigned to the models can be grouped as follows:

a) Prices: Regional differences are considered and an individual variation are caused by the random process taking into account information about variances and covariances gained from the analysis of book keeping data.
b) yields: the same as prices
c) production capacities (acreage, permanent grassland, labor force and buildings) are assigned randomly taking into account the distribution of these factors to farm size group and to groups of farms with different number of cows and others.
d) Dynamic data.
   - The year in which the owner of the farm will retire has been assigned to the models by using the age structure of farm owners in West Germany.

- Furthermore, it was assigned a special year to any of the farm models in which the existing buildings and dairy equipments will have to be reinvested. This year has been assigned by a random generator which was based on a rough guess of the age structure of buildings and dairy equipment considering the development of investments in the past.

For all of the "representative" farms a linear programming model has been constructed. The model involved a deterministic and a stochastic part.

The latter one was added in order to take into account adequately the variances in the fodder economy. The approach used can be described as a "penalty cost" model, where missing quantities of roughage causes costs which were derived from the necessary substitution of roughage by concentrates, whereas overproduction in a special year does not result in any positive value.

The input-output matrices of all representative farms have identical structures and vary only with respect to the values of the variables,which are assigned individually to any model as mentioned in the previous section. The matrix is extremely detailed with respect to dairy, beef, and fodder production, but cropping activities are highly aggregated to only two crop production activities. Accordingly, constraints required for crop rotations were not considered, whereas limitations in fodder production and conservation and in diet requirements of dairy cows and other livestock are represented in detailed constraints. Specification of milk production is based on a milk-yield function with decreasing marginal returns with respect to an increase in input of concentrates. This non-linear function is approximated by six linear segments.

"Stage 2"

In the second stage a set of price supply functions are calculated by parametrizing the milk price for every representative farm model. The computed price supply functions differ with respect to the factors which are assumed to be variable, hence the marginal cost curves differ.

The basic function is the so called "long term" supply function S_0 which is marked by the assumption that all factors are variable with the exception of the available acreage.

This price supply function S_0 is assumed to be a good approximation of the adjustment path in the case of an increase in milk prices, however, the production adjustment of an increase in prices may follow this path with a time lag of at least one or two years.

In the case of a price decrease, it is ovviously not rational to follow this supply function as some of the input factors have to be regarded as fixed. Hence, a set of different supply functions has to be calculated which differ with respect to the factors being assumed as fixed. In table 17 the respective supply functions are indicated. Furthermore, it has to be kept in mind that the adjustment process in the case of a decrease in prices depends on the initial price level. Hence, a further set of supply functions has to be calculated for every type of the mentioned situations in accordance to different initial price levels.

The factors assumed to be fixed for a certain period have been taken from the "long term" function S_0 accepting the price from which the period of decreased prices starts. Theoretically there exists an unlimited number of short term price supply functions, however it might be regarded as sufficient to compute this functions only for certain points. The intermediate functions can be derived with sufficient accuracy by interpolation.

The relation between these supply functions is indicated in figure 3 and 4. In figure 3 the function S_0 refer to the socalled "long term" supply response function. S_I, S_{II}, S_{III} are supply functions which indicate supply response to a decrease in prices with an increasing number of factors becoming variable over time.

Supply functions in figure 4 have the same underlying assumption with respect to the factor mobility but they differ with respect to the price level from which the price decrease starts. The function $S(II|p_1)$ indicates a supply response function where the factor $f_1 \ldots f_n$ are fixed and the price decrease starts from price level p_1. $S(II|p_2)$ indicates the respective function starting from a price level p_2. Supply response functions $S(II|p_i)$ with $p_1 > p_i > p_2$ can be derived by interpolation between the function $S(II|p_1)$ and $S(II|p_2)$ as indicated by the dotted lines.

Table 17: Alternative price supply functions

Function	Production factors: predetermined	Production factors: variable	possible adjustment	assumed period
S_0	arable land perm. grassland	all factors except land	complete	max 20 years min 2 years
S_{IVa}	arable land grassland labor capacity	buildings, machinery and equipment	as in S_{III} + buildings	max 15 years min 2 years
S_{IVb}	arable land grassland buildings	labor, machinery and equipment	as in S_{III} + labor	max 20 years min 2 years
S_{III}	arable land grassland labor capacity buildings	machinery and equipment	as in S_{II} + investment in machinery and equipment	max 8 years min 2 years
S_{II}	arable land grassland; labor; buildings; machinery and equipment	–	as in S_I + reorganisation of production	in the 2nd and 3rd year
S_I	as in S_{II} in addition main features of the production pattern	–	concentrate feeding, special intencity in grass production; number of cows (reduction only)	during the 1st year

Figure 3:

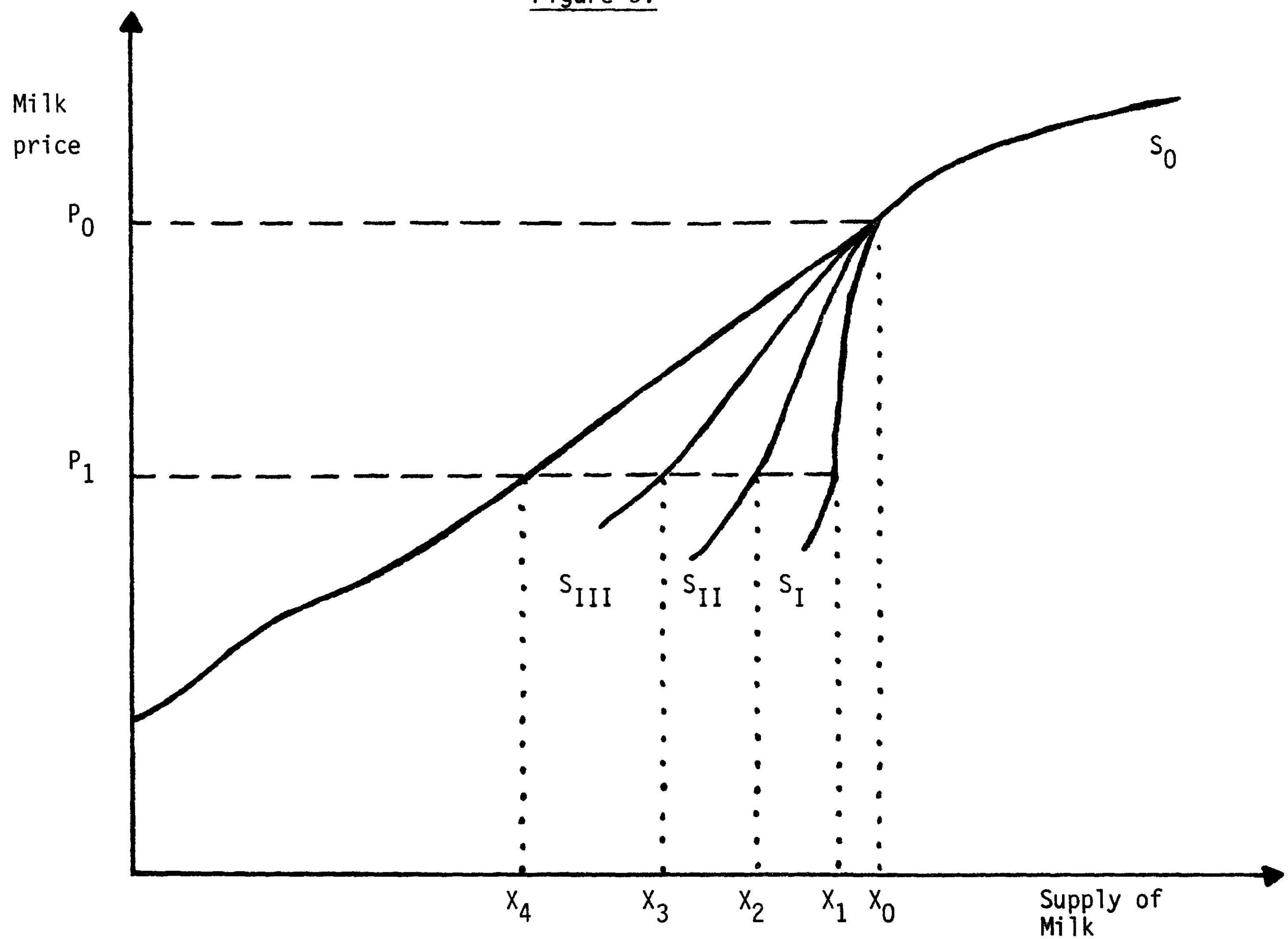
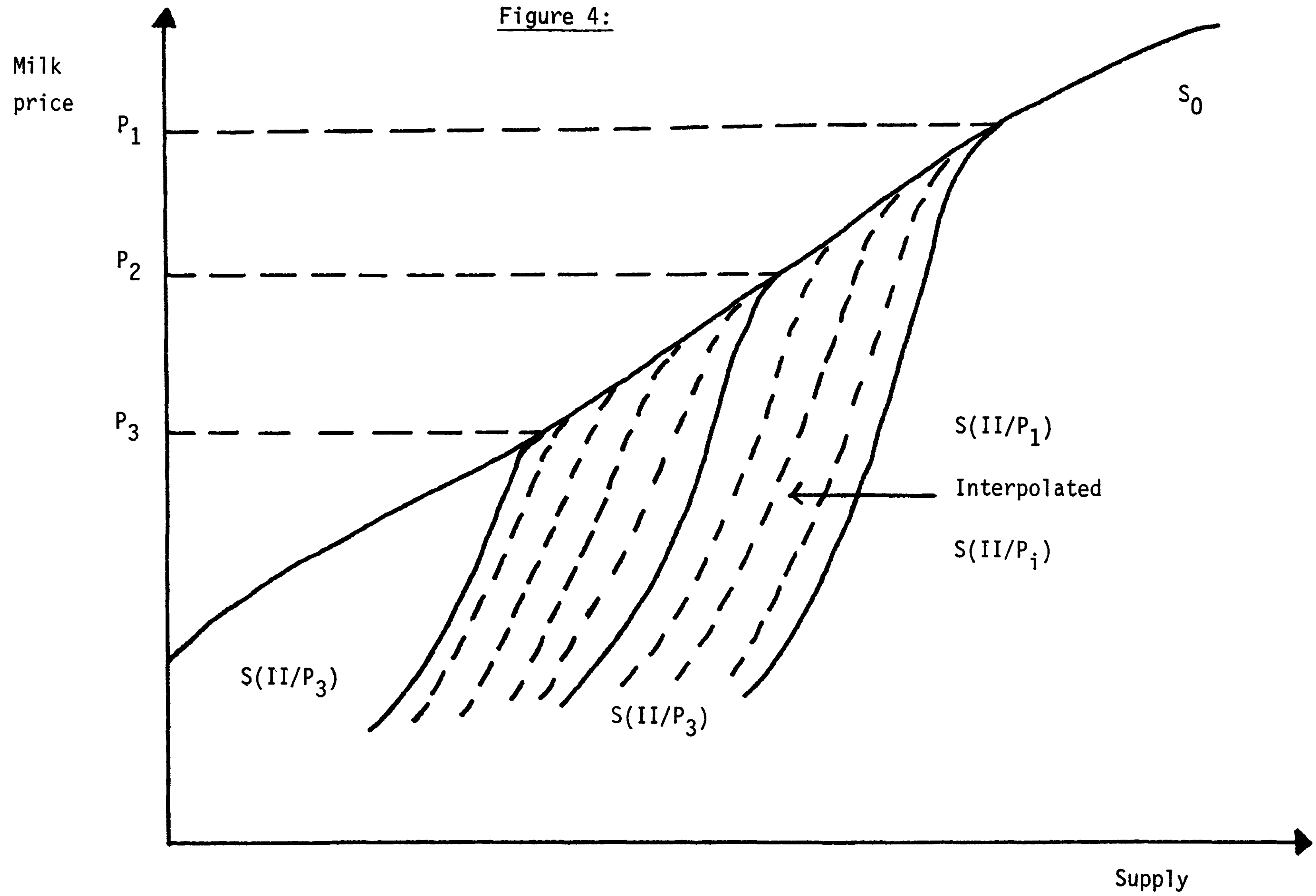


Figure 4:


Milk
price
P1
P2
P3
S0
S(II/P1)
Interpolated
S(II/Pi)
S(II/P3)
S(II/P3)
Supply

"Stage 3"

In the previous stage of the procedure a set of supply response functions are calculated which differ with respect to the underlying assumptions concerning the fixity of factors. In stage 3 these functions are used to define an adjustment process for every farm model.

The procedure which is used in order to convert the set of static functions to a dynamic adjustment process can be explained easily by interpreting figure 3 as follows:

Assume that S(I) refers to a response function where only those factors are assumed to be variable which are disponible in a very short period, whereas in S(II) more factors are assumed to be variable. Hence, function S(II) refers to somewhat longer period than S(I). In this case figure 3 may be interpreted as follows:

If the price of milk decreases from p_0 to p_1 the supply will be reduced from x_0 to x_1 more or less immediately. After a period which depends on the special situation of the investigated farm the supply will be reduced from x_1 to x_2, when a set of other factors become variable. After some time further factors will become variable, hence the supply will be reduced from x_2 to x_3 and then finally to x_4.

If the points of time are known at which the different factors become variable (have to be replaced) the adjustment process to the new price level can be derived easily. As mentioned above, assumptions about the age structure of the dairy equipment and the buildings have been set. Hence, the point of time can be determined at which reinvestments are necessary, respectively the points of time where these factors become variable. Furthermore, we have assumed that the labor force becomes variable at the time the farmer will retire. Hence, an adjustment process can be defined for every farm model.

D

"Stage 4"

In stage 4 of the computation procedure the different adjustment processes are aggregated to a sectoral adjustment function. This aggregation process has to consider that the farm models are constructed by using a stratified sample procedure, hence respective weighting factors have to be considered.

The adjustment process of the milk production to a change in the price level is accompanied by different changes in the production output of other products and in the input of variable factors. Furthermore, any price change and any adjustment process causes changes in the income situation, which are of a considerable interest. As linear programming models are used as the basis of the determination of the supply response, all changes in other variables connected and caused by this adjustment process are determined simultaneously. Hence, the corresponding development process of all other variables - presupposed they are endogenously considered - can be calculated by the same procedure as it has been outlined for the milk supply response.

2.53 Model variants computed

The dynamic procedure described above had been run over a 20 years calculation period in several variants. The variants differ in the following aspects:
- the milk price strategy investigated,
- the level of milk price decrease
- the assumed rate of technical progress and
- the model assumptions considering the labor mobility.

It is assumed in all model variants
- that the change in the price strategy is set in action in 1980/81 and
- that the price change considered is a relative price change, relative to the prices of all other agricultural products.
- Furthermore, it is assumed that no additional factors are working which change the competition power of the milk production versus other enterprises (c.p. assumption) and

- that the technical progress is neutral with respect to all agricultural commodities.

Four different milk price strategies are investigated:

A: The price shall decrease over a 5 years period with an annual rate of x percent. After this five years the milk price is assumed to be stable over time and no further changes in the price relations will occur.
B: The price shall decrease only in the first year and then the price relations should be stable.
C: A five years continuous price decrease is assumed, after this period the price will be raised again so that after further 5 years the original price relations will be obtained again.
D: Only one price decrease in the first year, then, like in strategy C, a continuous increase to the original price relations.

The assumed strategies A and C were calculated with annual price changes of 1, 2 and 3 percent, whereas B and D were computed with rates of 5, 10 and 15 p.c.

2.54 Price supply elasticities calculated under varying model assumptions

As already mentioned the model describes an adjustment process of the milk production over a 20 years period. As the adjustment during the first 5 or 10 years are certainly of a higher interest as the adjustment in the second phase, the tables give only the price elasticities until the 10th year after starting the price change. It should be mentioned that Hanf and Koester (1980) present only "dynamic elasticities" which express the total reduction of the milk production during the whole period under consideration in relation to the price change. These elasticities are not comparable to the elasticities usually derived from econometric studies, hence, the usual elasticities had to be calculated indirectly from the "dynamic elasticities" which may have caused some minor errors. The elasticities are given in the tables 18 - 22 and the most important features can be summarized as follows:

D

1. In the short run there do exist obviously only few possibilities to react on the price change. The elasticities are 0.2 and 0.4 resp. for a two years adjustment period (see table 18).
2. After an adjustment period of about 5 years an elasticity of about 1 is reached (see table 18).
3. In the long run the price supply elasticity is about 1.5 - 2.0 if a 10 years adjustment is considered (see table 18).
4. It can be recognized that the elasticity is depending on the extent the price level is changed. As it can be seen from table 18 the average elasticities become smaller with increasing price steps. This becomes still more evident by considering the "marginal" elasticities.
5. The labor market conditions have a considerable impact on the long run elasticities as it can be seen from table 19. Depending on the off-farm job situation the medium term elasticities may vary between 0.5 and 1.2.
6. The effects of a changed price policy are more or less independent of the special treatment of the policy as it can be concluded from the comparison of the elasticities caused by policy A and policy B (see table 20). However, the supply response will be considerably smaller if the price will be again increased after a certain period.
7. Differences in the elasticities of different groups of farms are to consider only in the medium and the long run as it is shown in the tables 21 - 23. The elasticity of supply increases with the size of farms and the size of herds. With respect to the percentage of permanent grassland table 23 shows that a minimum elasticity is given in farms with about 50 - 70 p.c. grassland, whereas farms with a high percentage of arable land and pure grassland farms as well show a higher elasticity. The latter may be caused by the larger average size of those farms.

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Table 18: Supply elasticities of milk under the assumption of price policy A (Hanf and Koester (1980))

Price policy A+ Price change	average supply elasticity in year t ... after the price change 1	2	3...	5...	7...	10
- 5 %	0.1	0.4	1.0...	1.1...	1.8...	1.9
- 10 %	0.1	0.2	0.9...	1.0...	1.7...	1.9
- 15 %	0.1	0.2	0.8...	0.9...	1.4...	1.6
	"marginal" supply elasticity					
- 5 %	0.1	0.4	1.0 ..	1.1...	1.8...	1.9
5 - 10 %	0.1	0.1	0.6 ..	1.0...	1.6...	1.9
10 - 15 %	-	0.1	0.5 ..	0.5...	0.8...	1.0

+The price is assumed to be decreased over a 5 years period and the off farm working conditions are assumed to be relative good.

Table 19: Supply elasticities of milk under varied off farm working conditions (Hanf and Koester (1980))

off-farm working conditions	Supply elasticities in ..... year t after the price change 1	2	3...	5...	7...	10
bad	0.1	0.2	0.5 . . .	0.6 ...	1.0 ...	1.1
good	0.1	0.2	0.9 . . .	1.0 ...	1.7 ...	1.9
excel-lent	0.1	0.2	1.2 . . .	1.4 ...	2.4 ...	2.8

- Price policy A (see table 18) with a 10 % price decrease

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Table 20: Supply elasticities of milk under varying price strategies (Hanf and Koester (1980))

Type of price policy*) (10 % decrease)	Elasticities in the year t after the change of the price policy 1	2	3...	5...	7...	10
A	0.1	0.2	1.2...	1.4...	2.4...	2.8
B	—+)	0.1	0.9...	1.6...	2.6...	3.0
C	0.1	0.2	0.8...	0.9...	(1.3)**...	(1.3)**
D	—+)	(0.1)**	(0.5)**...	(0.5)**...	...	...

*) for a detailed description of the policies see section 2.53
**) the direct effect of the price re-increase is not considered
+) smaller than 0.05

Table 21: Supply elasticities of milk in different size groups (Hanf and Koester (1980))

Size groups in ha LN	Elasticities in year t after the change of price policy 1	2	3...	5...	7...	10
less 10	0.1	0.4	0.5...	0.5...	0.5...	0.5
10 - 20	0.1	0.1	0.2...	0.5...	0.8...	1.1
20 - 50	0.1	0.3	1.0...	1.0...	1.5...	2.0
50 and more	0.1	0.1	0.1...	0.6...	2.5...	4.3

assumptions: price policy A; 10 % price decrease; bad off-farm working conditions

D

Table 22: Supply elasticities of milk in farm groups with different herd sizes (Hanf and Koester (1980))

herd size (no.of cows)	Elasticities in year t after the change of the price policy					
	1	2	3...	5...	7...	10
- 20	0.1	0.4	0.4...	0.4...	0.4...	0.4
20 - 50	0.1	0.2	0.4...	0.5...	0.9...	1.4
50 and more	0.1	0.2	0.6...	1.6...	2.5...	3.5

assumptions: price policy A; 10 % price desrease; good off-farm working conditions

Table 23: Supply elasticities of milk groups with different percentage of permanent grassland

Permanent grassland in p. c.	Elasticities in year t after the change of the price policy					
	1	2	3...	5...	7...	10
- 20	0.1	0.2	0.3...	1.2...	1.7...	2.2
20 - 50	0.1	0.2	0.7...	1.0...	1.3...	1.6
50 - 70	0.1	0.2	0.6...	0.7...	0.8...	0.8
70 - 100	0.1	0.4	0.9...	0.9...	1.3...	1.4

assumptions: price policy A; 10 % price decrease; good off-farm working conditions

3 Summary and conclusions

In the previous section a number of studies have been briefly outlined which are concerned with the development of the German dairy sector and which are investigating the factors influencing the milk production. There had been involved in the discussion studies using statistical methods and studies with a normative character as well. Because of the different approaches applied, the differences with respect to the time horizon considered and because of the different ways of describing the results it is rather difficult to compare directly the studies outlined and to come to an "average" result of all studies. In spite of the difficulties mentioned it should be tried to come to a result which includes all the information given by the diverse studies. In any case, such a "weighted" result must be subjective as there do not exist and there cannot exist any "objective" weighting system.

As the probable response of the dairy farmers to a decrease of the milk price is in the focus, it shall be tried in the following to derive an "elasticity figure" which may be regarded as a "weighted average" of all studies.

The price elasticities estimated in the different investigations are summarized in table 24. From this table it can be seen that the elasticities vary considerably from study to study. The smallest elasticity coefficient is recorded by Haimerl (1969) who result in a coefficient of only 0.1. On the other hand Hanf and Koester (1980) result in elasticity coefficients of 1 and more. All the other studies are lying within this range.

In order to come to a more precise statement some common features should be outlined:

1. The normative approaches tend to result in higher elasticities than the econometric models. The long term elasticity is usually estimated to be around 1.

Table 24: Elasticities estimated by different authors and methods

Author		data	time lag	elasticities
Ryll (1973)	regression model	1959/1971	3 years	FRG: 0.25 Länder: 0-0.49
Becker (1977)	prod. function	74/75		short term: 0.2 long term: 0.74
Becker (1977)	regression model	50/51 - 74/75		0.75 - 0.80
Doll (1977)	regression model	65 - 74	2 1/2 years	0.21 - 0.66
Aeikens (1979)	regression model		1/2 year-1 1/2 y.	short term: 0.08 long term 0,37
Haimerl (1969)	rekursive econometric model	53/54 - 66/67	1/2 year	very short term: 0.08
Rüther (1978)	simultaneous econometric model	1960 - 1976	1/2 y.; 2 years	short term: 0.06 long term: 0.14 - 0.21
Henze/ Zeddies (1971)	14 LP-models			short term: 0.01 - 0.28 long term: 0.4
Bauersachs/ Niebuhr (1978)	simultaneous LP-sector model			short term: 0.05 long term : 1.00
Hanf/Koester(1980)	dyn. representative LP-model			short term: 0.2 long term > 1

D

2. Within the econometric models the simple regression models come to stronger statistical dependencies between milk price and milk production than the large sectoral models.
3. The calculated elasticities increase obviously with the time lag considered.
4. The more recent studies result in higher elasticity coefficients than the former studies.

The higher elasticities of normative models can be explained by the fact that these models are based on an ideal decision maker who reacts immediately and without error on any change in the relevant data set. Hence, it is not considered that in the reality at least some farmers do not realize that the price changes or that they do not react on the price change correctly or that they have objectives which lead to a controverse or at least to a mildered reaction. Hence, normative models must have a tendency towards an overestimation of farmers' response.

On the other hand it is to argue that econometric models tend to underestimate the impact of price variation on the production. As it can be seen from the diverse econometric approaches mentioned the impact of the price is obviously distributed over several years. However, for statistical reasons most of the models include only one price variable with a certain time lag. Usually, a 2 1/2 or 3 years time lag is used as this time lag produces the coefficients with the best statistical test values. Doubtless, there exist further supply reactions with another lag structure and these effects of changing prices are neglected by the approaches.

The very small elasticities of the multi equation models are caused by the fact that in recursive models with seasonal data only the very direct impacts can be considered. The long term decisions are hidden behind the autocorrelative calculation of the development path of the decision variables. Hence, the long term impact of an exogenous variable on an endogenous variable can only be settled by alternative computation of the whole model. Therefore, it seems to be more meaningful to orientate the statement about the elasticities at the results of the simple regression models.

The higher elasticities of the more recent studies might be interpreted as the expression of an improved adjustment behaviour caused by the structural changes of the last two decades.

Taking into account these arguments it seems to be reasonable to assume that the probable response of the German farmers to a milk price decrease will be between the normative model results and the results of the more recent positive approaches. Furthermore, it is to consider that the supply response will follow a price change with a considerable time lag and that in time the possibilities to react will be improved the following time path of reaction may be regarded as a "weighted" result of all studies mentioned:

immediate response;	within the first year;	$\eta_1 \approx 0.1$	$\begin{cases} \text{min } 0.0 \\ \text{max } 0.2 \end{cases}$
short term response;	two years;	$\eta_2 \approx 0.3$	$\begin{cases} \text{min } 0.2 \\ \text{max } 0.4 \end{cases}$
medium term response;	three - five years;	$\eta_3 \approx 0.6$	$\begin{cases} \text{min } 0.4 \\ \text{max } 0.8 \end{cases}$
long term response;	seven and more;	$\eta_4 \approx 0.9$	$\begin{cases} \text{min } 0.7 \\ \text{max } 1.1 \end{cases}$

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DK

PART TWO : D E N M A R K

DK

CONTENTS

1. Structural and regional development of the milk production

1.1 Development of milk production

In the fifties milk production increased steadily in Denmark, reaching a peak in 1959. That year 5.43 million t of milk were produced. For the next eight years the volume of production remained at roughly that level, ranging during the period from 1959 to 1966 from 5.52 million t in 1961 to 5.09 million t in 1963. From 1966 onwards there was quite a marked decline in milk production. This phase lasted about five years, production falling from 5.31 million t in 1966 to 4.41 million t, its lowest point, in 1971. Since then milk production has again increased steadily: in 1978 production totalled 5.32 million t, roughly the same level as 20 to 25 years previously (see Table 1).

Three development phases in Danish milk production can thus be distinguished in the two decades from 1959 to 1978:

The first phase lasted from 1959 to 1966; during that time milk production remained more or less constant.

In the second phase, from 1966 to 1971, production fell by 3.6 % annually.

The third phase was marked by another substantial increase in production, at the rate of 2.7 % per year.

Corresponding distinctions can be made between the phases of development in respect of the individual components of milk production, i.e. the number of cows and the milk yield per cow. The milk yield per cow increased steadily over the entire reference period in Denmark - as in all West European countries - the annual rate of increase averaging about 1 %. Two distinct periods can be traced, however: from 1959 to 1971 the annual increase in yield averaged about 0.37 %, with quite minimal differences between 1959/66 and 1966/71. Since 1971 the milk yield has risen substantially and in 1978 reached 4 550 l per cow per year, compared with 3 970 l in 1971. This corresponds to an annual increase of nearly 2 %.

As regards the trend in the number of cows, the three abovementioned subdivisions of the reference period are again significant. The first phase from 1959 to 1966 saw a slight decrease in the number of cows: from

Table 1: Development of milk production in Denmark from 1959 to 1978

	Total milk production (million t)	Number of farms with cows (thousand)	Number of cows (million)	Milk price øre/kg
1959	5.43	169	1.43	40.8
1960	5.40	167	1.44	41.2
1961	5.52	164	1.49	38.6
1962	5.36	158	1.46	38.0
1963	5.09	151	1.41	44.8
1964	5.23	142	1.37	46.7
1965	5.37	136	1.35	48.2
1966	5.31	130	1.35	50.3
1967	5.19	122	1.33	51.7
1968	5.12	115	1.29	51.4
1969	4.88	107	1.23	55.1
1970	4.48	96.5	1.15	62.4
1971	4.41	88.6	1.11	69.4
1972	4.64	83.4	1.12	75.2
1973	4.73	78.9	1.16	93.0
1974	4.82	76.7	1.19	103
1975	4.92	72.9	1.18	110
1976	5.05	69.0	1.19	122
1977	5.14	64.9	1.18	138
1978	5.32	60.0	1.17	150

1.43 million in 1959 to 1.35 million in 1966, a drop of 0.7 %. From then on the decline accelerated: from 1966 to 1971 the average decrease was 3.8 % per year. During that period cow numbers fell from 1.35 million to 1.11 million. After 1971 they rose steadily, although the growth rate was only 0.8 % per year, bringing the total to 1.17 million in 1978.

The decline in the number of cows in the Danish countryside in the time up to 1971 can be attributed almost entirely to farms giving up milk production. Over the whole period the number of farms keeping dairy cows dropped steadily, while the average number of cows per farm constantly rose. This applies both to the phases in which milk production as a whole stagnated or decreased and to the time from 1971 to 1978 when milk production increased.

The details are as follows: in the first phase from 1959 to 1966 the number of dairy farms fell by 3.2 % per year, from 169 000 in 1959 to 130 000 in 1966. During this time the average herd size per farm rose from 8.5 to 10.4 cows, i.e. a 2.6 % annual increase. The second phase, during which milk production declined, was also marked by larger average herd sizes. It was during this phase that the highest rate of decrease in the number of dairy farms was recorded: 6.3 % per year. In 1966 there were still 130 000 farms with dairy cows, whereas five years later, in 1971, there were only 89 000. Over the same period the average herd size increased from 10.4 to 12.5 cows per farm, an increase of 3.8 %.

Even during the period from 1971 to 1978 when milk production rose substantially, at the rate of 2.7 % a year, the decline in the number of farms with dairy cows continued. From 89 000 in 1971 the total number of dairy farms fell to 60 000 over this seven-year period; this amounts to a rate of decrease of 5.5 % per year. Against this marked reduction in the number of farms, however, there was an above-average increase in the number of cows per farm, the average herd size rising from 12.5 in 1971 to 19.5 in 1978, i.e. at the rate of 6.6 %.

1.2 Change in the production structure

A number of interesting aspects of the trend in milk production in Denmark emerge when one considers the breakdown of cows and dairy farmers by herd size. For reasons of data availability this examination is restricted to the last two periods mentioned, i.e. 1966 to 1971, during which time

Danish milk production declined by 3.6 % a year, and 1971 to 1977 when production rose at an annual rate of 2.7 %.

As mentioned above, the number of dairy farmers dropped substantially during both those periods, in the first at an average rate of 7.3 % per year, somewhat more than during the second period (in this case only 1971-77), when the annual rate was 5.1 %. As regards the structural breakdown of farms ceasing dairying, the picture is roughly the same for both periods (see Table 2); in both periods the number of farmers in the herd size category up to 20 cows fell sharply, while in the over 20 cows category the number of farmers rose. The decrease in the smaller size categories was about the same for both periods: 10 and 9 % per year respectively. There are marked differences, however, in the herd size categories 30-50 cows and over 50 cows per farm. In the 30-50 category the number of farms keeping dairy cows rose by 8.8 % during the first period but by 14.7 % during the second. The differences were even greater in the over-50 size category: here there was an annual growth rate of 7.4 % during the first period, whereas during the second period (1971-77) the annual increase soared to 22.7 %.

As can be seen from Tables 1 and 2 in the period 1966-71, the number of cows fell substantially less than the number of dairy farmers, and between 1971 and 1977 the number of cows in fact rose while the number of farmers was falling. Consequently, the average herd size increased.

If, on the other hand, the annual rates of change in the number of dairy farmers are compared with those for the number of cows in the respective size categories (see Table 2), it can be seen that the rate of decrease in the number of cows by and large corresponds to the drop in the number of dairy farmers. This also applies to the categories with positive growth rates. This correlation between rates of cessation of dairy farming and growth rates means that the average number of cows per farm in the individual herd size categories remains almost constant, while for the sector as a whole there is a marked change in the average herd size. The increase in the average number of cows per farm in Denmark can, therefore, be attributed primarily to the fact that a structural change has taken place. The average herd sizes in Denmark have increased because the number of farms in the small herd size categories has dropped while at the same time the number of farms with over 50 cows has risen sharply. The

Table 2: Number of holders and dairy cows in size classes in Denmark

	Number of cows per farm															
	1 - 4		5 - 9		10 - 14		15 - 19		20 - 29		30 - 49		50 and more		total	
year	holders	cows	holders	cows	holders	cows	holders	cows	holders	cows	holders	cows	holders	cows	holders	cows
1966	22025	57817	48888	354678	34880	400814	12699	210056	8128	186970	2673	94436	612	45443	129905	1350214
1967	21137	53198	41820	297394	33981	397397	12921	215078	8950	205860	3104	110577	678	49017	122591	1328521
1968	19933	48583	35808	254868	33197	387295	13472	224248	9021	208666	3361	120690	660	47910	115452	1292260
1969	18965	45425	30723	218576	30531	358128	13265	208666	9231	221544	3627	132380	644	47885	106986	1232604
1970	16655	38107	25917	179882	26804	307232	12634	204984	9739	227164	3942	138116	837	57196	96528	1152681
1971	15888	37043	22514	160126	23953	282246	11851	198085	9456	220025	4076	147561	875	60327	88613	1105411
1972	14299	32964	18940	134910	21766	256917	11861	198626	10445	244102	5005	181460	1084	73656	83400	1122635
1973	13522	30956	16426	116498	17679	209160	11818	197951	11602	272882	6430	234379	1455	99708	78932	1161534
1974	13626	31481	14987	106325	15983	189665	10688	179769	11947	282297	7553	276378	1885	127818	76669	1193733
1975	13051	29301	13631	96636	14357	170404	9880	166136	11615	275792	8176	300094	2155	145914	72865	1184277
1976	11886	26333	12149	86160	12722	151068	9127	153634	11405	271137	8950	330089	2577	173009	68816	1191430
1977	11242	24862	10840	76720	11349	134698	8160	137436	10955	261140	9269	343830	2987	201967	64812	1180653

Source: Aeikens op.cit., p. 276

Table 3: Average annual rates of change in the number of dairy farmers and the number of cows in Denmark by herd size

Average annual rates of change (%)

Herd size	Dairy farmers 66 - 71	Dairy farmers 71 - 77	Cows 66 - 71	Cows 71 - 77
1 - 4	- 6.4	- 5.6	- 8.3	- 6.4
5 - 9	- 14.4	- 11.5	- 14.7	- 11.5
10 - 14	- 8.9	- 10.4	- 6.7	- 11.6
15 - 19	- 7.8	- 6.0	- 1.2	- 5.9
20 - 29	+ 3.1	+ 2.5	+ 3.3	+ 2.9
30 - 49	+ 8.8	+ 14.7	+ 9.4	15.1
50	+ 7.4	+ 22.7	+ 5.8	+ 22.4
Total	- 7.3	- 5.1	- 3.8	+ 1.1

conclusion can therefore be drawn that the expansion of dairy farming in Denmark is attributable not so much to a steady increase in herd sizes as to major changes in the herd size of individual farms following farm development in the form of new building. The significance of this for the analysis of Danish farmers' reactions as regards supply is that it must be assumed that this process is not easily reversible. In other words, the increases in production as prices rise can be reduced again only in the very long term because of high overheads. Adjustment to falling prices will take considerably longer than adjustment to equivalent price rises.

1.3 Development of dairy farming by farm size category

If the total number of farms in Denmark is compared with the number of dairy farms, it is seen that the decline in dairy farming resulted notonly from the general structural change but that the structural change in the milk sector was considerably more marked than in agriculture as a whole (see Table 4). During the period from 1966 to 1971 the number of farms in Denmark fell by 4 % annually, while the number of dairy farms declined almost 80 % faster: by 7.3 % per year. During the period from 1971 to 1977, when milk production increased, even more marked differences are to be seen. The total number of farmers ceasing farming each year was 1.5 % in this phase, while the number of departing dairy farmers was more than three times this rate: 5.1 %.

The rate varied from one farm size category to another. In the category up to 30 ha the decline in dairy farms was double the drop in the total number of farms. A contrasting development occurred in the size category over 30 ha. Particularly during the phase of strong growth of the group, from 1971 to 1977, the rate was quite close to the figure for agriculture as a whole. It can therefore be concluded that the importance attached to dairy farming differs greatly today from one size category to another, whereas in 1966 dairy farming played roughly the same role in all five categories, with the exception of very small farms under 5 ha. In 1966, 86 % of all farms in the 10 to 30 ha size category were engaged in dairy farming. This percentage has now dropped to 60 %. In 1977 dairy farming was most prominent among farms of over 30 ha: two thirds of those farms still produced milk. There has been a radical change in the size category 5 to 10 ha also, where the percentage of dairy farms fell from 78 % in 1966 to 38 % in 1977. A similar development, but starting from a lower level, can

Table 4: Number of farms, holders and cows in different size classes

	0,5 - 5			5 - 10			10 - 30			30 and more			total		
year	farms	holders	cows	farms	holders	cows	farms	holders	cows	farms	holders	cows	farms	holders	cows
1966	21779	9866	42604	40102	31391	198355	79001	68379	707413	25424	20269	401842	166306	129905	1350214
1967	19700	8859	30269	36831	28281	181892	76607	64663	694793	26161	20788	421567	159299	122591	1328521
1968	18130	7583	26034	33908	24908	161426	74196	62453	683305	26474	20508	421495	152708	115452	1292260
1969	16309	6872	23780	31396	22255	144847	71390	57644	648408	27116	20215	415569	146211	106986	1232604
1970	14528	5101	16334	29510	18901	119171	68625	52841	594923	27534	19685	422253	140197	965528	1152681
1971	14487	4312	13961	27679	16065	101269	65849	48965	563651	27573	19271	426530	135588	88613	1105411
1972	14387	3952	13265	26990	14417	93648	64506	45904	563328	28137	19127	452394	134020	83400	1122635
1973	15040	3481	11546	26214	12799	93787	62771	42995	561645	28975	19657	504556	133000	78932	1161534
1974	14490	3350	10976	25448	12083	80238	61275	41678	570762	28655	19558	531757	129860	76669	1193733
1975	14061	3057	9888	24401	10916	72294	59362	39108	546249	29330	19784	555846	127154	72865	1184277
1976	13492	2538	8067	23453	9886	66649	57577	36730	536584	29709	19662	580130	124231	68816	1191430
1977	13239	2275	7211	23152	8754	58902	56719	34346	515431	30113	19427	598830	123223	64802	1180653

Source H.-O.: Aeikens 1979 op. cit., p. 276

Table 5: Structure of dairy farming by farm size category

Farm size in ha	Percentage of farms keeping cows			Percentage change all farms		Percentage change farmers	
	1966	1971	1977	66/71	71/77	66/71	71/77
0- 5 ha	45	30	17	- 7.8	- 1.5	-15.4	-11.1
5-10 ha	78	58	38	- 8.1	- 2.9	-12.6	- 9.4
10-30 ha	86	74	60	- 3.5	- 2.4	- 6.3	- 5.7
over 30 ha	79	70	65	+ 1.6	+ 1.4	- 1.0	- 0.2
Total	78	65	53	- 4.0	- 1.5	- 7.3	- 5.1

also be traced among the smallest farms, i.e. up to 5 ha. Almost half of these kept cows in 1966, whereas today only one in six farms in this size category is engaged in dairy farming.

1.4 Regional distribution of milk production

The regional breakdown of dairy farming in Denmark and developments between 1955/56 and 1970 are shown in Tables 6 and 7. The regional percentages of the total number of cows shown in Table 7 indicate distinct tendencies towards concentration in particular regions. The production regions of the Jutland Peninsula, Viborg, Nordjylland, Sønderjylland and Ribe stand out as having experienced an increase in the percentage of milk production. In absolute terms, however, the number of cows has increased only in the regions of Sønderjylland and Ribe.

The greatest reductions in milk production in absolute and in relative terms are found in the regions close to industry and in regions with a relatively high percentage of arable land or relatively high yields. The regions in which dairy farming has declined most are to be found mainly in the western part of the island of Sjaelland and on the island of Fyn. For instance, over the 15-year reference period the percentage of Denmark's dairy farming in the region round Copenhagen dropped from 5.4 to 3.2 %; in absolute figures this means that the number of dairy cows in this region dropped from 77 000 to about half that number, 38 000. A correspondingly marked reduction in the absolute number of cows has occurred only in the Vestsjaelland region, where the number of dairy cows fell from 114 000 in 1955/58 to 59 000 in the period 1967/70. The regional trends outlined here show a definite correspondence to the regression analyses of the effects of factors on production management dealt with in Section 2. The investigations undertaken by Aeikens come to the conclusion that wages outside agriculture and the competitive position of pig farming are of particular importance for the size of dairy farming. The regional breakdowns shown in Tables 6 and 7 indicate that it is precisely in the areas surrounding the conurbations and in the regions where pig farming is combined with fruit-growing that the number of dairy cows has fallen.

Table 6: Reginonal number of dairy cows

Region*	A1**	A2	A3	A4	
NØS	77405	72356	60525	50415	38891
VES	114392	105029	88519	76182	59458
STS	105178	93453	78262	65365	50946
FYN	151242	147132	134410	125761	110242
SØJ	117751	122097	120677	122455	120690
RIB	100584	104991	106475	109658	109936
VEJ	88149	89580	86439	82915	74325
RIN	131748	139378	138191	138507	133007
ÅRH	180610	185111	177275	169692	148250
VIB	171990	182171	180530	178951	163930
NOJ	218784	229135	228130	224732	205125
Hele landet	1457833	1470433	1399433	1344633	1214800

*) NOS Kobenhavn, Frederiksborg
Roskilde og Bornholm
VES Vestsjaelland
STS Storstrom
FYN Fyn
SOJ Sonderjylland

RIB Ribe
VEJ Vejle
RIN Ringkobing
ÅRH Arhus
VIB Viborg
NOJ Nordjylland

A1 .... 1955/56 - 1957/58
A2 .... 1958/59 - 1960/61
A3 .... 1961/62 - 1963/64
A4 .... 1964/65 - 1966/67
A5 .... 1967/68 - 1969/70

Table 7: Breakdown of cows by region during different periods

	A1 (x)	A2	A3	A4	A5
NØS (x)	5.4	4.9	4.3	3.7	3.2
VES	7.8	7.1	6.3	5.7	4.9
STS	7.2	6.4	5.6	4.9	4.2
FYN	10.4	10.0	9.6	9.3	9.1
SØJ	8.1	8.3	8.6	9.1	9.9
RIB	6.9	7.1	7.6	8.2	9.0
VEJ	6.0	6.1	6.2	6.2	6.1
RIN	9.0	9.5	9.9	10.3	11.0
ARH	12.4	12.6	12.7	12.6	12.2
VIB	11.8	12.4	12.9	13.3	13.5
NOJ	15.0	15.6	16.3	16.7	16.9

(x) For key see Table 6

1.5 Structural development in the milk processing industry

Milk production in Denmark has been affected by considerable structural changes, not only at farm level but also in the milk processing industry. Table 8 contains some of the most important data relating to the structure of milk processing. In this section again a distinction has to be made between a phase of falling production of milk overall and a phase of increasing milk production. The first phase lasted from 1965 to 1971, followed by an upturn between 1971 and 1978.

For the three main products processed from milk the following picture emerges for the period from 1965 to 1971:

Butter production fell during this period by 4.8 % annually, while manufacture of milk powder rose at the rate of 3.0 %. Cheese production remained more or less steady; it rose slightly towards the end of the period, so that over the entire period from 1965 to 1971 the annual growth rate was 0.8 %.

The drop in milk production during this period can be attributed primarily to the decline in butter exports. These fell by 6.6 % per year during this period, while domestic consumption fell by only 1.7 % per year.

The 3 % annual increase in milk products was due primarily to the expansion of production of fat milk powder; this branch of the processing industry showed a 9.3 % expansion a year during the reference period. Skimmed milk

Table 8: Butter, cheese, milk powder and other preserved milk 1980 - 1978

	Butter mill. kg			Cheese mill. kg			Milk powder and other preserved milk mill. kg production			
	produktion	export	consumption	production	export	con-sumption	milk powder	skim milk powder	others	Total
1960	168.7	118.3	49.8	113.4	74.6	40.5	26.4	3.7	33.8	
1965	166.3	115.8	47.8	114.2	73.5	42.3	25.9	17.0	34.9	
1968	159.5	107.4	45.7	106.5	64.8	45.6	47.7	21.3	30.4	
1969	144.3	100.2	44.9	106.7	60.0	45.3	49.8	15.8	26.6	
1970	131.2	87.2	44.6	111.0	66.2	46.3	38.1	18.9	24.5	
1971	123.5	77.2	43.2	119.6	69.0	46.9	44.2	24.3	24.1	
1972	135.9	87.4	42.6	130.6	73.8	53.2	38.6	47.6	21.7	
1973	146.4	100.0	40.5	127.8	82.4	46.6	37.6	52.0	23.1	
1974	137.4	102.2	41.6	149.7	93.0	50.4	45.0	52.0	20.2	
1975	134.7	98.4	39.8	152.2	99.4	48.7	46.0	69.0	19.9	
1976	139.3	92.0	39.1	156.9	114.5	45.5	56.8	63.4	20.5	
1977	131.0	89.0	41.0	177.3	123.6	48.5	71.8	53.2	14.2	
1978	140.3	84.6	42.3	182.5	130.8	48.2	72.4	54.2	14.6	
				growth rates						
65/71	- 4.8	- 6.0	- 1.7	0.8	- 1.0	2.4	9.3	6.1	- 6.0	3.0
71/78	0.7	2.0	-0.3	6.2	9.6	- 0.2	8.7	14.9	- 5.5	8.0

production also contributed to the increase in output of preserved milk with an average growth rate of 6.1 % during this period. By contrast, output of other preserved milk products fell by 6 % a year during this period.

The slight increase in cheese production was attributable solely to the growth of domestic consumption. The home market consumed 2.4 % more a year, while exports fell slightly: by 1.0 % per year.

During the period from 1971 to 1978 there was an upward trend for all the products processed from milk. Rates varied considerably, however. Butter production expanded by a relatively small 0.7 % a year, while manufacture of cheese rose by 6.2 % a year and manufacture of preserved milk rose by 8.0 % a year.

The modest increase in butter consumption during the period 1971/78 resulted from an expansion of exports, while domestic consumption during this period remained unchanged or fell slightly, from 43.2 million kg to 42.3 million kg.

The growth rates for cheese production are similarly attributable solely to the expansion of exports. Exports grew during this period by 9.6 % a year, while cheese consumption on the domestic market fell slightly by 0.2 % a year.

The large increase in the manufacture of milk products can be attributed mainly to the expansion of milk powder production, manufacture of skimmed-milk powder far exceeding that of fat milk powder during this period: a rate of increase of almost 15 % as compared with 8.7 %. Manufacture of other preserved milk declined (- 5.5 %) as in the previous period, and today accounts for only a very small percentage of the total of preserved milk.

Although the percentages exported and the rate of self-supply did not change much during the reference period for individual products, Danish milk production remained very dependent on the export market throughout the period. Domestic consumption of butter, although increasing during the butter export crisis, was still only a relatively small percentage of total production in 1971 (35 %). In 1978 the percentage of butter consumed in Denmark had again fallen to roughly the level in 1965 and previously: 30 %.

The picture is similar for cheese production. Domestic consumption of cheese amounted to 37 % of production in 1965. Export difficulties and an increase in domestic consumption then brought it to 41 %. Since 1971, however, the percentage of total production consumed in the country has steadily fallen and in 1978 was only 26 %.

1.6 The most important trends in development

The development of the milk sector in Denmark over the past 15 to 20 years can be outlined as follows.

1. Milk production rose until the end of the fifties and then remained at more or less the same level until 1966. From 1966 to 1971 milk production fell sharply, reaching its lowest point in 1971. From 1971 onwards milk production in Denmark again showed a distinct upward trend.
2. During the periods of both decline and increase in milk production a far-reaching structural change took place in the Danish milk sector. The number of farms producing milk dropped steadily and a change in average herd sizes occurred as many farms with fewer than thirty cows ceased production while the number of farms with thirty or more cows rose considerably.
3. The milk yield per cow rose over the period as a whole, although annual increases varied considerably. During the period 1959 to 1971 the annual increase in yield was less than half of one percent, whereas after 1971 annual rates were almost 2 %.
4. The change in the structure of herd sizes was accompanied by a tendency for milk production to be concentrated increasingly on farms with more than 30 ha.
5. There are also marked regional differences in milk production. Dairy farming is concentrated mainly in regions with relatively favourable production conditions (grassland regions) and regions in which medium to large-sized family farms predominate.
6. In the milk processing industry there are clear trends towards increased manufacture of preserved milk (particularly skimmed-milk powder) which has doubled since 1965. A similar upward trend can be seen in the manufacture of cheese. Here too production increased steadily over the entire period, although up to 1971 the increases were only very small.

The manufacture of butter declined between 1965 and 1971 by about 20 % and then rose again slightly. The 1965 level has not been achieved since, however.

2. Analyses of milk production in Denmark

2.1 Introduction

We know of no specialized investigations into the price/supply relationship in Danish milk production and no such studies have been undertaken in recent years to the knowledge of various Danish economists. The following comments are therefore based on three works of considerably broader scope but which deal with Danish milk production as an integral part. These are two studies written in the Federal Republic of Germany, one of them undertaken on behalf of the EEC Commission by the Institute for World Economics of the University of Kiel and a dissertation dating from 1979 from Göttingen. The third work is the sectoral model produced by the Copenhagen Institute of Agricultural Economics.

2.2 Study: Projections relating to production and consumption of agricultural products - "1977" (Denmark)

An analysis of agricultural production in Denmark and demand for agricultural produce in the country was undertaken by the Institute of World Economics at the University of Kiel in 1971/72. Since this study examines all branches of agricultural production, the development of milk production and the factors determining it naturally represents only a relatively small part of the investigation. In it the analysis and prognosis of milk production are confined to changes and trends in cow numbers; the milk yield per cow is regarded as a trend value. The following variables were taken into account in considering dairy cow herds:

- butter exports
- price of milk
- price of oilcake
- price of heifers
- producer price for pigs for slaughter
- cost of barley.

To quantify the effect of the abovementioned factors linear models were calculated using the least-squares method. A clearly significant relationship between the development of dairy cow herds and butter exports emerged (see Table 9; equation 53a). From this regression equation it was calculated that the elasticity of the dairy cow herd in relation to butter exports was + 0.7. The close connection between the export elasticity of the dairy cow herd and exports as a percentage of total butter production is noted. This indicates that at least during the period 1957 to 1971 Danish agriculture reacted very elastically to changes in market conditions.

The drawback of the approach described above, however, was that no variable expressing the competition between cattle farming and pig farming could be successfully incorporated into the equation. For this reason the export variable was replaced by a simple trend variable. Where a trend variable is used (see Table 9, equation 54a) or where this trend variable is modified (see equation 55a) the deviations around this trend can be determined significantly by the competitive relationship between pig farming and dairy farming. An attempt was made at first to represent this competitive relationship by profitability figures for the individual branches of production. It was found, however, that only the ratio between pig prices and feed barley prices gave a significant coefficient in the regression function, whereas the milk price/feed quotient was not significant. The reason for this is probably that the milk price/oilcake price ratio altered only slightly during the period and fluctuated very little.

If it is assumed that the fluctuations in feed costs are synchronous in both branches of farming, the change in profitability ratios can also be presented in the form of a direct price comparison. Having regard to a modified, split trend variable the direct price relationship between heifers and pigs was incorporated into the regression equation in equation 55a. In this case reliable regression coefficients resulted and the elasticity of the dairy herd in relation to the heifer/pig price ratio was calculated as + 0.1.

The investigations by Tewes show that Danish agriculture reacts very elastically to market changes, which points to very high price elasticity. A direct price elasticity of dairy herds or milk production could not be quantified, however, mainly because during the period prices developed with relatively minor deviations around the trend.

Table 9: Investigation of cow numbers in Denmark by T. Tewes (Institute World Economics, Kiel)

Period: 1957 - 1971 (mid-year)

(53a) $$B'_M = 441.08 + \underset{(5.8)}{1.5572} \sum_{i=5}^{8} Ex_{Bu_{-1}}$$

$$R^2 = 0.718 \quad \frac{\hat{6}}{\bar{B}'_M} = 4.6 \text{ vH} \qquad D.W. = 0.91$$

(54a) $$B'_M = 1848.4 - \underset{(6.1)}{19.987}\, t - \underset{(1.9)}{37.402} \left[\frac{1}{4} \sum_{i=5}^{8} \left(\frac{P_S}{P_G}\right)_{-\frac{i}{4}} \right]$$

$$R^2 = 0.837 \quad \frac{\hat{6}}{\bar{B}'_M} = 3.7 \text{ vH} \qquad D.W. = 0.70$$

(55a) $$B'_M = 1406.3 - \underset{(5.2)}{15.390}\, t - \underset{(4.5)}{60.390}\, t_1 + \underset{(1.0)}{147.64} \left[\frac{1}{4} \sum_{i=5}^{8} \left(\frac{P_F}{P_S}\right)_{-\frac{i}{4}} \right]$$

$$R^2 = 0.931 \quad \frac{\hat{6}}{\bar{B}'_M} = 2.5 \text{ vH} \qquad D.W. = 0.69$$

B'_M = Number of cows in the middle of the year
t = Trend (1957 = 1, ..., 1971 = 15)
t_1 = Trend correction (1957 - 1968 = 0, 1969 = 1, ..., 1971 = 3)
P_F = Producer price for heifers 1st class (including compensatory payment)
P_S = Producer price for slaughter pigs class A (incl. compensat. payment)
P_G = Purchase price for barley

Table 10: Analysis of cow numbers in Denmark

	Constants	Slaughter pig price $X_{5\ 2}$	Milk price / Pig price $X_{7\ 2}$	Hourly wage / Turnover from milk production per cow per day $X_{14\ 2}$	PM
Dairy cows Y_{12} 1961-1977	1812.45	- 0.27 t-2 - 5.29 +++		211.93 t-1.5 - 15.69 +++	0.98 +++ 279.59 1.68
Dairy cows Y_{12} 1961-1977	1771.74	- 0.27 t-2 - 4.65 +++		-197.05 t-0.5 - 10.43 +++	0.95 +++ 95.47 1.61
Expansions Y_{42} 1966/67 1976/77	- 81725.74	-141.74 t-2 - 2.41 ++	1456348.95 t-1 4.46 +++		0.75 +++ 11.85 1.15
Expansions Y_{42} 1966/67 1976/77	- 91601.38	-211.42 t-3 - 5.51 +++	1709867.23 t-1 8.60 +++		0.91 +++ 40.02 2.50
Reductions Y_{52} 1966/67 1976/77	79892.27		- 811992.89 $\frac{(t-1)+(t-2)}{2}$ - 3.38 +++	28664.43 t-0.5 1.72	0.64 ++ 7.26 1.55

Source: H.O. Aeikens loc. cit., p. 105.

Table 11: Analysis of milk output in Denmark, the Federal Republic of Germany, the Netherlands and the United Kingdom

	Constants	Milk price X_1	Milk price / feed price X_2	Feed price X_3	Hay harvest X_{16}	Insemination % X_{19}	PM
Output Denmark $Y_{6\,3}$ 1961-1977	3422.89	9.39 t-0.5 8.66+++					0.83+++ 74.95 1.39
Output Denmark $Y_{6\,3}$ 1965-1977	3685.54	9.62 t-0.5 9.06+++		-2.59 t-0.5 -2.32+++			0.90+++ 47.51 1.34
Output Germany $Y_{6\,4}$ 1961-1977	2776.59		332.12 $\frac{t+(t-1)}{2}$ 1.86+			14.38 t-3 15.85+++	0.96+++ 163.84 1.07
Output Germany $Y_{6\,4}$ 1965-1977	2866.58		349.88 $\frac{t+(t-1)}{2}$ 2.43++			12.62 t-3 13.14+++	0.96 113.24+++ 1.92
Output N'lands $Y_{6\,8}$ 1961-1977	3244.33	30.11 t-0.5 9.73+++					0.86+++ 94.59 1.18
Output N'lands $Y_{6\,8}$ 1965-1977	3009.67	35.81 t-0.5 9.54+++					0.89+++ 91.07 1.15
Output U.K. $Y_{6\,9}$ 1961-1977	2248.63	163.67 t-0.5 7.98+++			0.11 t-1 1.83+		0.83+++ 33.98 0.79
Output U.K. $Y_{6\,9}$ 1965-1977	-1199.07	178.76 t-0.5 9.51+++			0.11 t 2.64++	60.44 t-3.5 2.65++	0.92+++ 32.35 1.62

2.3 Study: Development of milk production in the Member States of the Community

2.31 Analysis of dairy herds

A comprehensive study of milk production in the EEC Member States, covering, among other things, developments in Denmark, was recently produced by Aeikens. In it the empirical analysis of milk production in the individual Member States is divided into two parts: an analysis of increases and reductions of cow herds and of total cow numbers and an analysis of milk yields per cow per year.

Aeikens chose a differentiation of the change in the number of dairy cows because he considered that although increases and reductions occurred simultaneously they were influenced by different factors. Since statistics are lacking in Denmark, as in other Member States, regarding the number of cases of expansion and reduction of herds, Aeikens had to find a special method for estimating these values. He experimented with a number of such procedures before deciding on a modified Markov model.

The major factors determining the number of increases from year to year proved to be variables representing the competitive relationship between dairy farming and beef farming on the one hand and between dairy farming and pig farming on the other. The competitive relationship between beef farming and dairy farming was denoted by the price of beef animals and that between dairy farming and pig farming by the price relationship between milk and pigs for slaughter. Both variables show a significant regression coefficient with the expected signs. According to Aeikens' investigations, however, the reduction of dairy herds is largely influenced by the competitive relationship between non-agricultural activity and milk production; in addition, the milk price/pig price relationship proves to be significant with a 1 1/2-year time lag.

Since the results of the regression analysis did not entirely meet expectations as regards multiple correlation, Aeikens also calculated direct regressions between the number of dairy cows and the various influencing factors. This yielded substantially higher multiple correlations. The significant influencing values were identified as the price for beef cattle and the relationship between hourly wages outside agriculture and turnover from milk production per cow per day.

The high significance of the variable "hourly wage in non-agricultural sectors versus turnover from milk production per cow per day" shows that the attractiveness of employment outside agriculture compared with milk production is one factor determining the volume of dairy farming in Denmark also. The 1 1/2-year time lag points to relatively quick reaction to changing income relationships (Aeikens, page 105).

Aeikens' division of dairy cow herds into those which are expanding, those which are being reduced and the unchanged remainder seems at first sight, from the theoretical standpoint, to be meaningful and promising. The fact that Aeikens has not corrected the results or made any amendment to the interpretation is probably because a considerable number of errors of classification occur in an artificial calculation of changes in herds. In his study (Aeikens, page 109) he compares the actual dairy herd in the reference period with the figure he calculates from expansions and reductions. Deviations of up to 3 % per year result. Such a discrepancy between the actual and the estimated value would not in itself be decisive, but this discrepancy must be seen in relation to the deviations around the trend in the reference period. Such a comparison shows that the discrepancies arising from the method of calculation are significantly larger in almost all years than the changes in the total number of cows in Denmark. The significance of this error also becomes visible if one considers that the expansions and reductions calculated by Aeikens averaged about 5 % of the total number of cows; this means that a 3 % difference between estimated and actual cow numbers must be a 60 % error in relation to the variable "expansion" or "reduction".

The investigation undertaken by Aeikens into the development of the dairy cow herd and the influencing factors may not be entirely satisfactory as regards the results, but it does show clearly that Danish agriculture reacts exceptionally elastically to changes in the economic situation. The main influences would seem to be the following:

- the competitive power of beef farming and pig farming, and
- the possibilities and attractiveness of employment outside agriculture.

The regression equations presented by Aeikens for the dairy cow herd indicate a very high price elasticity for milk production, which he calculates to be 0.4.

2.32 Analysis of milk yield per cow per year

Aeikens incorporated the milk price, the feed price (soya meal), the size of the hay harvest and the insemination rate into the empirical analysis to determine the milk yield per cow per year. For the milk price he was able to determine a significant negative coefficient when he reduced the reference period by four years. Direct and cross price elasticities for the milk yield were not established.

It can however be assumed from rough calculations that the average direct price elasticity of the milk yield is about 0.15 and the cross price elasticity about - 0.05.

2.4 A recursive linear programming model for Denmark

A few years ago a recursive programming model for Denmark differentiated by region and farm group was produced by the authors Stryg, Andersen, Hansen and Pilgaard. This programming model was recently revised and projected for subsequent dates. It contains an exceptionally differentiated description of the dairy sector and the competing branches of beef and veal production.

This model is very well designed for investigating long-term adjustments; short-term adjustments cannot be dealt with because the individual recursively concurrent sub-periods cover three or five years each.

The model was used for the first time in 1974 to forecast the development of Danish agriculture, for a prognosis up to 1980. In its new form the period extends to 1985 or 1990.

In addition to prognosis on the basis of probable data changes a series of simulation calculations has been made to examine the effects that can be expected from future changes in the relationship between data. A change in milk prices was not included, but the investigations give some indication of the elasticity of milk production because the extent of dairy farming and thus total milk production in the model surveys react very strongly to changes in data in other branches, particularly in the event of changes in the relationship between prices for beef and milk and between wages outside agriculture and potential income from dairy farming.

The results obtained in this study from the normative approach are thus largely congruent with the empirical investigations undertaken by Aeikens and Tewes.

3. Additional studies on the timing of adjustment to changes in the milk price

3.1 Preliminary remarks

The analyses of the milk sector in Denmark carried out by Aeikens and Tewes show that in Danish agriculture there is a high degree of adaptability to changes in general conditions, including, in particular, a change in milk prices. These results achieved with econometric models are supported by the normative surveys of Stryg et al. The Aeikens study concludes that dairy cow herds show a direct price elasticity of 0.4 with a time lag of 1 or 1 1/2 years. Tewes' study also is based on a time lag of 1 1/2 years for the price variable.

Surveys in other countries and examinations of the cost structure tend to suggest, however, that changes in prices in the milk sector cause not only short-term one-time adjustments but that they lead also to longer-term adaptation processes. This applies in particular when milk prices drop because here the necessary adjustments are often made only following major alternative investments or when farms pass from one generation to the next.

Below we investigate whether it is to be assumed for Denmark also that in addition to the relatively short-term reaction established by Aeikens and Tewes longer-term effects on production can be expected when there is a change in the milk price. In view of the relatively short time-series available, which are moreover characterized by a strong trend sequence, the special procedures of time-series analysis are out of the question here. The investigation is therefore confined to simple linear models.

A second question should also be touched on: whether it is to be expected that where there is a fairly strong disaggregation of the dependent variables the reliability of empirical models with regard to direct price elasticity can be increased. As the studies available for Denmark and for other countries show, there are clearly major differences in the significance of the factors influenced in respect of the components of total supply. A distinction must be made here between yield per cow and the number of cows kept. This division is also made by Tewes and Aeikens. Aeikens attempts also to disaggregate further the variable "number of cows", by endeavouring to isolate increases and reductions of herds from the section remaining unchanged. On account of the problems of estimating in determining the variables he does not manage to improve reliability in this way.

One possibility of differentiation along different lines would be a division of the variable "number of cows" into "number of farms keeping dairy cows" and "average herd size"; an investigation is therefore to be made into whether such a differentiation does improve reliability, particularly with regard to the direct price elasticity and the time taken for adaptation.

3.2 Investigation of the time structure of adjustments to changes in the milk price

3.21 Aim of the analysis

The following regression analysis aims to answer two questions only:

1. How can adjustments to a change in the price of milk be expected to be distributed over time, or in other words: can the inclusion of a single price variable reflect the overall reaction of milk producers to changes in prices?

2. Does the effect over time and its distribution over the individual components of milk production (milk yield per cow; cows/farm; number of farms) differ so much that a differentiation is necessary and promising?

The following are included in the investigations as dependent variables corresponding to the possibilities of disaggregation:

Y_1: Milk production in Denmark

Y_2: Number of dairy cows

Y_3: Milk yield per cow per year

Y_4: Number of dairy farmers

3.22 Selection of model variables

In view of the relatively short time-series, as few other variables as possible should be incorporated into the model so that the number of the degrees of freedom is not too small when price variables with varying time lags are considered. On the other hand, such close stochastic relationships are found between a series of potential influencing factors and the milk price that it can be supposed that if these factors are ignored in the equations misinterpretations may result.

For this reason it was checked whether in the case under investigation the multicollinearity led to a marked bias of the regression coefficients of the price variables and of the price elasticities. A series of regression models with the following variable structure was used:

1. $y = a + bp + cx$ where

y: dependent variables see above

p: milk price, with 1 1/2-year time lag

x: variables which probably influence the volume of milk production.
The individual variables are listed in Table 12.

a,b,c: linear regression parameters.

The results of these model calculations were exceptionally unsatisfactory; some of the coefficients were not sufficiently different from zero, and in addition a series of significant negative coefficients occurred which could not be accepted as plausible if rational reaction on the part of the producer was assumed (inverse reaction).

The time variable was therefore incorporated into the equation as a permanent feature alongside the price variable, so that the parameters of the following model were calculated:

2. $y = a + bp + ct + dx.$

Here t denotes the time variable, otherwise the symbols are the same as in equation 1. above.

Table 12: Regression coefficients of the milk price variable from regressions* with different dependent variables

Independent variable	Milk production	Number of cows	No. of farms with cows	Cows/ farm	Milk/ farm
No. of farms	0.604	0.148	0.650	+ 0.571	0.116
Labour force	0.395	0.598	0.871	+ 0.816	0.110
Total number of pigs	0.941	1.553	1.712	1.809	0.296
Prices index for agricultural products	0.462	0.748	1.085	0.281	0.147
Prices index for feed	1.020	2.080	2.018	2.241	0.201
Cattle excluding cows (head)	0.274	0.486	1.065	0.794	0.104
Labour force per farm	0.344	0.642	0.858	0.764	0.055
Milk output t-1	1.033	0.285	2.002	2.010	0.218

*) $y = a_0 + a_1x_1 + a_2x_2 + a_3x_3$ where x_1 = trend, x_2 = milk price, x_3 varying.

The results of these calculations are given in Table 12 although because of the survey only the regression coefficients b are shown in relation to the lagged price variable p. The parameters shown in Table 12 still show substantial deviations, varying according to which of the other potential influencing factors are taken into consideration at the same time. They do, however, have distinct advantages over the parameters which were calculated without regard to a trend variable:

(a) all the parameters are, as expected, positive;

(b) with a few exceptions, they are significantly different from zero for an error probability of less than 10 % and

(c) apart from a few extremes, they are all roughly of the same order of magnitude.

If the milk price coefficients from the regressions

3. $y = a + bp \; 8 \; ct$

are compared with the values shown in Table 12, it is seen that these are in the same or at least on the limits of the same regions, so that further investigations into the time structure of adjustments can be based on equation 3. The following parameters of the milk price variable resulted for the dependent variables:

total milk production:	0.398
number of cows:	0.454
number of dairy farmers:	0.288
cows/farm:	0.474
milk yield/cow:	0.630.

3.23 Time lag in adjustment

On the basis of the preliminary investigation described in 3.22 the following model was selected for investigating the time lag for adjustment:

4. $y = a + \sum_{i=1}^{n} b_i p_i$ for $n = 1,\ldots,5$

where i denotes the time lag in years and n the number of lagged milk prices included. The results of this calculation are given in Tables 13 to 17 for the different dependent variables. For a better view only the regression coefficients of the price variables were again given. The regression coefficients in Table 17 clearly indicate that the adjustment in milk output to changes in prices generally occur in the year following the change. The parameters of the milk price variables delayed by one year remain almost constant if in addition other delayed price variables are incorporated. Since the regression coefficients in the case of a two-year time lag are also always significantly different from zero, it can be inferred that certain adjustments occur even after two years, although these are not so extensive as those during the first period.

The regression coefficients of the delayed price variables in relation to the dependent variable "cows/farm" give a rather unclear picture (see Table 16). It can be distinctly seen, however, that the price variable delayed by two years has the strongest effect in absolute terms. This

Table 13: Regression coefficient of lagged milk prices to "milk production"

REGRESSION COEFFICIENT OF THE MILK PRICE VARIABLE*			
t-1	t-2	t-3	t-4
0.398			
0.073	0.381		
0.072	0.275	0.119	
0.122	0.220	0.243	-0.141

*) Dependent variable: total milk production
Additional independent variable: time variable.

Table 14: Regression coefficient of lagged milk prices to "number of cows"

REGRESSION COEFFICIENT OF THE MILK PRICE VARIABLE*			
t-1	t-2	t-3	t-4
0.454			
0.137	0.372		
0.137	0.343	0.033	
0.315	0.146	0.478	-0.504

*) Dependent variable: number of cows.
Additional independent variable: time variable.

Table 15: Regression coefficient of lagged milk prices to "number of dairy farms"

REGRESSION COEFFICIENT OF THE MILK PRICE VARIABLE*			
t-1	t-2	t-3	t-4
2.288			
0.398	2.217		
0.401	2.839	-0.707	
0.824	2.237	0.353	-1.195

*) Dependent variable: number of dairy farmers.
Additional independent variable: time variable.

Table 16: Regression coefficient of lagged milk prices to "cows per farm"

REGRESSION COEFFICIENT OF THE MILK PRICE VARIABLE*			
t-1	t-2	t-3	t-4
0.474			
-0.067	1.242		
-0.064	1.155	-0.587	
-0.315	1.432	-1.213	0.708

*) Dependent variable: cows per farm.
Additional independent variable: time variable.

Table 17: Regression coefficient of lagged milk prices to "milk yield per cow"

REGRESSION COEFFICIENT OF THE MILK PRICE VARIABLE*			
t-1	t-2	t-3	t-4
0.630			
0.513	0.136		
0.513	0.196	-0.037	
0.577	0.355	-0.107	-0.181

*) Dependent variable: milk yield.
Additional independent variable: time variable.

variable is significantly different from zero in all equations and also deviates within a relatively narrow range. The negative coefficients of the price variables delayed by three years similarly differ significantly from zero. This negative correlation can be explained in part. The following assumption is made: the number of farms ceasing dairy farming varies with changes in the milk price. Since farms ceasing dairying are on average smaller than those remaining, the average herd size calculated is less than the trend, without the herd on an individual farm necessarily being reduced. This would also tie in with the results shown in Table 15 regarding the development of the number of dairy farms. If the hypothesis is accepted, this would imply:

(a) The positive coefficient in the case of a two-year delay mainly reflects the internal increase (or decrease) of herds.

(b) The negative coefficient in the case of a three-year delay reflects the deviation in the herd size development caused by the structural change determined by the price.

In Table 15 the regression coefficients using the variable "number of dairy farmers" can be seen. It clearly emerges from this that this variable also reacts to price changes with a two-year time lag. The coefficients of the price variable delayed by one year are also significantly positive, although this effect is definitely less than the effect two years after the price change. In interpreting the results it must be borne in mind that a positive coefficient of the price variable in this case does not mean that the number of dairy farmers is rising, but only that the number of dairy farmers is declining less than the trend. This explains the exceptionally short reaction time in this matter (entry into or departure from milk production). This examination also gives significance to the negative coefficient of the latest lag ovserved; part of the decision to give up the dairy herd, postponed initially because of a price increase, takes place at a later stage.

The regressions given in Table 14 with the variable "number of cows" clearly shows a mixture of the lag structures of the two components discussed above. Overall, the present result is to be interpreted as maining that the development of cow numbers is better represented with two different delayed price variables.

The "milk production" variable should also, according to the coefficients we have calculated, be represented - if possible - with a time lag structure of two or three price variables. The most suitable approach proves here also to be the one and a half to two-year time lag used by Aeikens and others.

4. Summary of the results

In view of the large number of shortcomings, the coefficients given should not be taken too literally. If the overall parameter structure emerging is taken into consideration in the interpretation, however, the following conclusions may be drawn with some certainty:

1. The process of adaptation to changes in the milk price extends over a number of years, so that the inclusion of only one price variable systematically underestimates price elasticity.
2. The total time lag for adaptation was about three years; it should be borne in mind, however, that during the period from 1971 to 1978, which had a marked influence, prices rose in both absolute and relative terms. It is therefore difficult to specify the time needed for adjustments when prices fall; in any case, the time required for adaptation cannot be estimated at any less than three years, probably it is more.
3. The lag structure of the individual components of the "milk production" variable varies considerably, so that a differentiated examination promises better results than a finding based on an overall aggregate.
4. The inclusion of lag structures and the breakdown of total production by components considerably increases the price elasticity calculated.
5. Taking into account the results mentioned it might be argued that the Danish milk sector will response relatively strong and relatively fast on a price decrease in milk. A short term price elasticity coefficient (2 years) of 0.4 will probably be a good guess with respect to the Danish milk production; furthermore, the results of the different studies indicate that the elasticity coefficient will be at least 0.3 and it should not be assumed in any case a larger response than 0.5 within a two years period.
6. The hypothesis that the adjustment process last more than two years is strongly underlined by the different calculations. Hence, it can be assumed that the long term elasticity (about 5 years) will be remarkably higher than the two years elasticity. A figure of about 0.7 maybe regarded as an acceptable and even a little bit conservative guess of the level of the long term price elasticity. The long term elasticity seems to tend more to a level of 0.9 than to a level of 0.6.

F/IT

Relationship between milk production and price variations in France and Italy

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TABLES

CHAPTER I

Milk production conditions in France and in Italy

I - 1 : France 1/

These conditions have been described recently 2/ by a number of authors : ATTONATY (1979), CARLES and NANQUETTE (1979), JAFFRELOT (1979) and EVRARD (1979). BROUSSOLLE (1976) discusses some aspects of the milk production problems linked with the informations of risk on milk production. SOUTY (1874) gives some informations on the possible effects of mechanization in dairy parlours. A rather complete set of statistical data can be found in CNIEL (1979). ALPHANDERY *et al* give an interpretation of the present state of the dairy and milk herds. Their contention is that the present tendancy to increased intensification is not in the farmers' interest, although it is made necessary by the policy developped by extensions services and the dairy industry.

Milk production in France is concentrated in small and medium sized farms. Farms larger than 100 Ha represent only 2 % of the hard. However, the number of very small farms tends to decline, and the average milk herd is increasing (from 9.5 cows per dairy farm in 1972 to 13.1 cows per dairy farm in 1978 according to CNIEL, 1979).The production is spread over the whole country, although its density is significantly smaller in the south eastern regions.

1/ The author acknowledge the help of Mrs PERRAUD, MATHAL and HAIRY, all from INRA, in preparing this sections. He his nevertheless solely responsible for the contend of the section, especially for what concerns errors and omissions.

2/ In addition,two recent important contributions are Ministry of agriculture (1979) and INRA (1980). They were issued at the time this paper was under press.

The total number of milk cows is about constant, or slightly decreasing (7.68 million heads in 1974, 7.51 in 1978, according to the CNIEL). But the yield per cow is increasing (from 35.93 hl/cow in 1974 to 38.97 in 1978). The generalized practice of artificial insemination had reduced the genetic diversity of the herd. Most local breeds have virtually disappeared in recent years, to the point of raising problems of genes conservation.

A few technical innovations are likely to increase the supply of milk in France :

a - The possibility of getting two calves a year from one cow. Important research has been undertaken in France by the INRA in that field. The results however do not seem to be presently of practical use.If they were successful, the price of young calves could be considerably lowered. In fact, this is more important for meat than for milk. Such an innovation could also be a source of increased demand for milk, insofar as young calves, fed with milk, could be used for producing an increased quantity of meat.

b - The possibility of extensive use of silage as a basic feedstuff in cheese production areas. Presently, this is not everywhere allowed to farmers by the milk processing plants, because of alleged difficulties in processing is milk. Many people do not recognize this argument. The introduction of this possibility, principaly in the eastern part of the country, could increase the production by a large amount at constant prices.

c - Even more important is the possibility of fully exploiting the genetic potential of existing and futur breeds, by feeding animals with the so called "concentrate" feedstuffs. France (and Italy) are far from having reached the limits of their possibilities in that respect, so that a huge expansion of milk production is technically feasible in both countries.

d - The possibility of increasing the efficiency of dairy parlours could bring about a significant reduction of the share of labour in the total output (cf SOUTY, 1974).

Recent changes in general economic condition may also affect the level of milk production in France. This is the case, especially of the growing rate of industrial unemployement. It is likely to decrease the rate of migration from the agricultural to the industrial sector. Since milk production is often considered as one of the best way of making use of unemployed manpower resources in a farm, this decrease of the rate of migration could very well result in an increased overall milk production. On the other hand, it is true that farmers and farm workers are by now more demanding in terms of working conditions. Milk production is far from being ideal in that respect, because it implies late or early working hours and it is difficult to leave the farm for a holiday. These points are often raised by farmers' organizations. However it is not the opinion of the author that this fact alone could entail a significant reduction of milk supply in the next few years. To a large extent, these considerations are merely tied to the price of labour : It is always possible to find manpower for toilsome work if it is comparatively well paid. Therefore, the labour supply for milk porduction would be reduced only if the monetary productivity of labour in that activity would increase less than in other comparable activities.

Finaly, it may be interesting to indicate that the most striking change in the conditions of milk production in France during the last few years occured in the western provinces (especially Britany) where the production increased dramatically.

This evolution was initiated by two factors : The decay of the "Bretonne" breed, which was replaced by more productive ones, such as the "Française Frisonne Pie Noire", or the "Normande"-a replacement which,in its turn,was made possible by improved feedstuffs.The second factor is the fact that, partly because of their own dynamism, partly because they were obliged to find markets for their increasing production, the dairies of these regions begun to make new types of cheese, of the emmenthal type, which formely, was produced only in the eastern part of the country. Britton emmenthal is of second grade, but cheap, and was well received by consumers, with the consequence that Eastern producers now encounter increasing difficulties for selling their production 1/ . As a result of this "war" between East and West, the total market for "fresh products"(as opposed to milk powder and butter) has been significantly expanded during the last ten years.

I - 2 : Milk production conditions in Italy 2/

A recent study describing these conditions is INEA (1980) : Domanda e offerta di latte e latterio caseari in Italia. Although this document is mainly concerned with the demand side of the problem, it provides some interesting views on the milk supply in Italy. Other documents if interest are OCDE (1978) and MESSORI (1976).

The Italian milk production is far from being negligible, contrary to a common creed : Although its density is lower, because the country is relatively large, its overall total approaches that of the Netherlands. According to the studies referred to above, the main features of this production are the followings :

- Although the domestic production has grown significantly during the last few years, it has grown a moderate rate, and far less than domestic demand.

1/ See HAIRY and PERRAUD (1976) and EVRARD (1978) for a description of these problems, and a broader view of the French dairy industry.

2/ Thanks are due to professor DE BENEDICTIS, and to the staff of the INEA, for providing the author with an ample and underused documentation.

- This situation is explained by the fact that the comparative advantage of local production over imported milk is disappearing as the technology of milk conservation is progressing. Thus, local production tends to be restricted to fresh milk, or to milk which needs to be processed near the production location. This local production is paid more than imported milk, which is cheaper, even if transportation costs are taken in account.

- The milk production in Italy is mainly concentrated on small farms. About 50 % of the cows come from herds with less than 9 heads. There is a slight downward tendency of this figure, but at a very small rate. The yield per cow is also relatively small (about 3000 kg/head) which implies that the milk producing technology is still in a relatively primitive state. At the same time,some large herds (50 heads and over) exist mainly in the Northern part of the country. A surprisingly low proportion of the total supply comes from medium sized herds.

- The total number of dairy cows decreased recently by a large amount (from 3,3 millions in 1970 to 2,95 millions in 1977). But the production per cow is steadily increasing (from 24,00 hl in 1970 to 30,50 in 1977) so that the total production is increasing (from 80 millions of hl in 1970 to 91 in 1977).

- As a consequence of the small size of herds, the cost of collection and transportation of local milk is relatively high - a fact which explains the price differential between domestic milk and imported milk, with a farm gate price fixed at the EEC level.

- A modification of this situation is not very likely in the next few years, since large farmers have presently more profitable activities than milk production to invest in. However, it is clear that a rise of the milk price may change the picture in that respect. On the other hand, a lowering of the price is not likely to reduce supply through a more extensive feeding pattern since the feeding pattern is already extensive. However, it is not unlikely that a lowering of the price of milk could push an increasing number of small herds out of business.

- The real price of milk (current price deflated by the consumer price index) has been considerably increased : from 100 in 1970 to 152-6 in 1977 according to OECD (1980) 1/. The production is far from having grown at the same rate : the annual coumpound rate of growth of production as -0.3 for the period 1970/72, and + 0.2 for the period 1975/77. By contrast, the same rates of growth were + 2.5 and + 1.3 for France, and +1.2 and + 1.4 for the EEC. These figures are consistent with the assumption that the elasticity of milk supply with respect to price is about zero or even negative in Italy. Such a conclusion would be misleading, since many other economic determinants of the milk supply has changed at the same time. For instance, EUROSTAT indicates that the number of workers in the agricultural sector has increased in Italy between 1974 and 1977 (from 3.11 to 3.14 millions), whereas, it has decreased in France (from 2.45 to 1.97 millions). The relative evolutions of various agricultural prices have also been divergent : the real price of wheat (1976 = 100) was 112 in 1977,that of potatoes was 270, that of sugar beets 131. There is thus a possibility that the production of milk remained constant, even with an increasing real price of milk, and despite a positive elasticity of milk supply with respect to price.

- The major issue of the current debate pertaining to milk policy in Italy is : "How to convince Italian consumers to pay a little more for Italian rather than foreign milk ?".

- In addition, the INEA (1980) published recently an extremely interesting report on production costs in agriculture. It gives the breakdown of the total gross product between intermediate consumptions, machiens, manpower, and fixed costs, for various techniques of production in various regions, for the main agricultural commodities in Italy. Although these data came too late for being used in the present report, they could be of invaluable interest in the kind of study described in chapter III. These figures and a few additional ones, provided by IRVAM and ISTAT are published by the parliament (ORLANDO, 1979).

1/ As a comparizon basis, the same index for France reached the value 92.0 in 1977. It was 81.1 for the EEC in the whole.

CHAPTER II

Possible model approaches for estimating milk supply response in France and Italy

II - 1 : Overview of available models

A) - Comprehensive farm model in France

Three farm sector models were built up in France during the last years :

a) - The OMTR model (FARHI and VERCUEIL, 1969)

This was a large linear programing model of interregional competition built along the line defined by HEADY. The size of the current matrix was about 600 x 600. It used a significant amount of the existing agricultural economists labour supply during the sixties. It gave poor results, in the sens that it was difficult to check its predictive ability, so that it was finally dismounted and is no more in use.

b) - The SIMAGRI model (RUCH, MONTFORT and WINTER, 1974)

This model was built up by the "Direction de la Prévision" of the Ministry of Finance. It is an econometric model, based on a cross section analysis of the French agricultural sector, and a few time series. The farm sector is divided into only seven sectors : cereals, perennial crops, other crops, beef, veal, milk other livestock productions. The model is not "checkable" because its sole purpose it ot predict the state of the farm sector at only two precise dates in the future : 1980 and 1985 (starting from the situation in 1970). Nevertheless, since the milk price is among the exogenous variables, it is possible to investigate what kind of change would be induced by a change in the price of milk, by comparizon with the "central solution" (that is, the solution which correspond to the "most likely" value of the exogenous variable, as they stood in 1970). The model takes into account various mechanism which determine farm production. Especially, the ties between income and agricultural manpower are investigated. It is thus possible to relate the production capacity to changes in income.

c) - The "Modêle historico-statistique" of INRA (BOUSSARD, 1975)

The model was built in the Institut National de la Recherche Agronomique. It is also an econometric model, based on statistical inference It uses time series as an exclusive source of data with 20 observations from 1949 to 1969. This number of observations is too small for the number of coefficients to estimate so that the predictive power of the model, checked against the estimations period, was not so good as expected.

The farm sector is divided into 16 subsectors among which milk production (however, cow milk is merged with goat milk, and sheep milk). Althgouth the order of magnitude of the forecast for 1980 and 1985 are similar to that of SIMAGRI, the direction of changes (by comparizon with the "central solution") may differ in magnitude and even in sign, with those predicted by SIMAGRI.

The model was dismounted because it failed to catching the attention of French officials. It has been reactived for the present study, and reestimated over a largernumber of observations (from 1949 up to 1978).

B) - Other models for France

In addition a few other studies may cast light on the milk supply response problem :

a) - CORDONNIER prepared for the EEC commission a set of linear programming models of "typical" farms. Unfortunately, these models are too few to cover the variety of farm situations in France, so that the answers will be very partial in any case. Moreover, the farm structure is supposed to be fixed, thus preventing the investigation of a major component of milk supply response, i.e, the fact that a lowering of the price of milk would force a number of old farmers to retire, therefore changing the farm structure.

The models were tested on the situation of represented farms at that time. But no experiments were performed through time. This is a direct consequence of the difficulty of using these models in the framework of changing structures.

They were used by IFO who came to the conclusion that the elasticity of milk supply with respect to price is very small. This is surprising, from two points of view : First, because of preceeding consideration about the difficulty of using them for that purpose. And second, because even within the narrow framework in which they are built, they suggest a rather large elasticity, as indicated below.

b) - Several linear programming farm models were built in various regions, especially Southern France, for various purposes (For instance, BOUSSARD and BRUN, 1970). They include "safety constraints" and financial management, with the possibility for the farmer to go out of business if the safety constraints are not met. In principle, they could have complemented the findings of the Cordonnier's model. In practice, reactivating these models would have been a toilsome task, which was not attempted.

c) - In addition to the models already mentioned the FORMA (Fonds d'Orientation et de Modernisation des Marchês Agricoles) operates a demographic model of the French herd in order to prepare short run predictions of the milk supply. Unfortunately, the model, a description of which can be found in FORMA and RAULT (1979), does not use the price as an explanatory variable. It is therefore useless for the purpose of the present study, although it deserves a mention from a more general point of view.

C) - The case of Italy

Only one reference to an econometric model of the agricultural sector is made for Italy. (BERTELE and BRIOSCHI, 1975 quoted by NEUNTEUFEL, 1978). In fact, this is only a detailed input/output table of the agricultural sector. It is available only for 1972, which is a bit far in time. It is not suitable for projections, but once adaptated, it could be a starting point for the kind of approach described in chapter III below. Unfortunately the author, despite his efforts, was not able to get the original report on this model.

D) - Models at the EEC level

a) - The IIASA model

The IIASA (International Institute for Applied System Analysis) is presently engaged in the building of a large scale model of the world food economy. The model is coumpound with several regional submodels, among which an EEC submodel (de HAEN et al, 1978). Teh latter in its turn is decomposed into several national submodels (Benelux, France, Italy, Germany, Great-Britain, Denmark) which have been estimated during the recent month. In each national submodel, the agricultural sector is decomposed into about 10 commodities, among which milk. Although the production function used in these models is quite similar to that which was used in the third part of the present report, a great number of relationships which were ignored in this third part were incorporated into the IIASA-EEC submodel. Thus, the latter is recursive (the results of one year being used as a starting position for the following year) and testable. First results of the tests show a good adequacy between model and reality. Unfortunately, these results have not yet been published. If it were possible to make use of them, they would have provided us with reliable and comparable estimates of milk supply response in each country of the EEC. Unfortunately, for lack of time this has not been attempted in the present study.

b) - A German regression model of milk supply

AEIKENS (1978) recently presented an interesting model at a meeting of the German society for agricultural economics. It is based on the least square estimation of two equations by country; one for the number of cows, one for the yield per cow. The explanatory variables differ between countries, for various reasons, such as lack of data, or poor explanatory power. The main results are :

- The comparative advantage of work outside agriculture as against milk production is often a determinant variable for the number of cows. However, this variable is more important in countries having small herds and small farms, that in countries with better structures, where the influence of the competitiviness between various subsectors of the agricultural sector is more marked.

- The milk price affects the yields per cow in all countries. The price of feedstuffs behaves the same way in almost all countries.

The model was tested over the period 1965-1977, with fairly good results in the sens of THEIL's U-statistics, although the authors did not indicate if his test was performed within a recursive framework or not.

c) - An Italian study of milk supply in Italy and in the EEC

A book by DE STEFANO and SCANDIZZO (1971) gives some estimates of price elasticities for Italy and the EEC. Although this study is somewhat old, it deserves a mention here - the more as it seems to be the only reference available in this field.

The elasticity is estimated through a time series multiple regressions. of milk supply over a few explanatory variables, among which lagged prices and supply. Observations concern the period between 1953 and 1965 (13 points).

II - 2 : Some findings from the "modèle historico-statistique"

The coefficient of the equations of the "modèle historico-statistique" may be used for deriving some tentative estimates of the milk supply response with respect to price.

The basic relationship in this model is of the following form :

$$\text{(III.I)} \qquad \text{Log}\,\frac{y_t}{y_{t-1}} = a\ \text{Log}\,\frac{P_{t-\theta}}{P_{t-\theta-1}} + b\ \text{Log}\,\frac{X_{t-\theta}}{X_{t-\theta-1}} + c + \varepsilon_t$$

where :

y_t is the predicted variable for the equation considered (for instance, milk supply in year t).

p_t is the corresponding price in year t (for instance, the price of milk).

x_t is the values taken by other exogenous variables.

θ and θ' are "lag factors" (usually -1)

With such a function, the elasticity $e(t,\theta) = \frac{dy_t}{y_t} \Big/ \frac{dP_{t-\theta}}{P_{t-\theta}}$

is given directly [1/] by the coefficient a.

Table II.1 gives the results of the estimates pertaining to milk production, i.e, the milk production per ha of feed crops and the total surface of feed crops. Combining the two equations gives an estimate of the elasticity which is :

$$\frac{dq_t}{q_t} \Big/ \frac{dP_{t-1}}{P_{t-1}} = 0.27$$

However, this figure is deduced from the partial derivative of a set of equations such as (III.1). Now the variable X_{1t}, X_{2t}, ... X_{nt} depend upon P_{t-1} and also upon P_{t-2}, P_{t-3}... P_{t-T}.

1/ Notice that : $\frac{dy_t}{y_t} \Big/ \frac{dP_{t-\theta-1}}{P_{t-\theta-1}} = -a$

TABLE II.1

INRA'S "historicostatistique" MODEL

Estimated coefficients for milk production

Dependant variable	explanatory variable: nature	lag	coefficient
Yield (r_m)	Constant	0	-0.01373
	gross income from related production	-1	-0.09862
	meteorological index	-1	0.001359
	price of land	0	0.21282
	yields of meat	-1	0.767782
	rate : $\frac{\text{marketed cereals}}{\text{total cereals}}$	-1	0.031976
	price of milk	-1	0.269637
	manpower/ha	-1	-0.090844
Surface of feed crops (s_f)	constant	0	-0.0006
	production expenses	-1	-0.0105
	price of land	0	0.0202
	manpower/ha	-1	0.0467
	price of feed crops	-1	0.00086
	price of cereals	-1	-0.1215
	Almond degree 1	0	1.2156
	Almond degree 2	0	0.6344

From the list of variables displayed in Table II.1, it is clear that the "gross income from production related to milk" 1/ depends upon the price of milk, as well as the price of land (because the price of land is computed so as to have $\Sigma_i \; ds_i = 0$, where ds_i is the change in the surface of crop i between year t and year t-1). Moreover, although the manpower/ha is a completely exogenous variable in this model, it is clear that this quantity is not independant from the agricultural income during previous years.

Unfortunately, the magnitude and even the direction of the changes in the quantity of milk which could have been induced by these additional relationships are unpredictable from the coefficients of the model. Only a set of runs of the model, under various assumptions about the price of milk, would give some elements of answer.

Such runs have been performed with the results given in Table II.2.

Before interpreting these results, it is usefull to notice that the model was reestimated over the period 1949-1977. However, because of the lack of homogeneity of French statistical series, some of the explanatory variables were excluded from the new model, with the consequence that, despite the longer time span of the estimated series, the results of the estimation were not so good as the preceeding ones.(Another reason for this outcome is that, because of the new economic situation prevailing after 1972, the series used in the estimation were less homogenous than for the period 1949-1969). The elasticities derived from these experiments are therefore less reliable than those which were derived from the first version of the model for the years 1949-1969. Unfortunately because of the unavailability of some of the time series, it was impossible to run the model for the period 1978-1985 with the old coefficients.

1/ These productions are the following : cereals, potatoes, misceallenous hogs, poultry, sugar beet. They represent the set of agricultural productions normally associated with milk in productions systems.

Nevertheless, these results are instructive : They show, first of all, an increasing tendency of the French milk production. In fact, it is unlikely that the increase be so quick as shown by these results : It is likely that the constant term in the yield equation, has been overestimated. However, this constant does exist, with the consequence that a sustained increase in milk production is likely, all other things remaining fixed.

On the other hand, this model shows an asymetric elasticity with respect to price, according as the price increases or decreases : the elasticity is negative for a price increase, and positive for a price decrease.

The five years (long run) elasticity is - 0.44 in the first case and + 1.63 in the second one.

At the same time, the one year (short run) elasticity is practically zero in both cases. Notice that this is not inconsistant with the preceeding conclusion that the short run elasticity was 0.27 : Since other mechanismes than the increases of milk price are involved in this model, it is not surprising that the overall elasticity differs from that which is derived from the coefficient estimates of the model.

II - 3 : Some findings of the SIMAGRI model

This model was solved at first for a "central solution". This term does not mean that this solution is the most likely,although it was established with the most likely values for the exogenous variables. The central solution serves only as a comparizon for discussing the effects of such and such measure.

A change in the price of milk was among the measures which were examined. The central solution (C) assumed that the price of milk was

TABLE II.2

Production of milk (in 10^6hl) forecasted for France by the INRA's model under various assumptions. 1/

	price of milk constant (and everything else constant)	price of milk decreasing at a rate of -3% per year	price of milk increasing at a rate of +7% per year	price of milk increasing by 12% in 1978, and constant afterward	price of milk decreasing by 8% in 1978 and constant afterward
1977	305	305	305	305	305
1978	334	333	333	333	333
1979	366	358	363	381	350
1980	393	376	387	407	372
1981	429	397	415	436	400
1982	475	421	446	469	430
1983	534	448	480	506	464

1/ All prices are expressed in current values, assuming a rate of inflation of 10 % a year.

increasing at a rate of 7.3 % per year (undeflated) 1/. Solution A (lower hypothesis) assumed that the price of milk was increasing only at 5 % rate, all other things remaining equal, and the solution B (higher hypothesis) assumed a rate of 10 %.

The main conclusion (direction de la Prévision, 1974) is given in the table II.3 below :

1/ The rate of inflation was assured to be 8 % per year.

TABLE II.3 - SIMAGRI variants on milk price - Forecast for 1985, French National level

	VARIANT A (% with respect to the figure in the central solution	Central solution (value of the item in the central solution	Variant B (% with respect to the figure in the central solution
milk production in volume(10^6 Francs 1972)	-2%	12400	+2%
beef production in volume (10^6 francs)	-5%	10900	+7%
cereals in volume(10^6 francs 1972)	+2%	18700	-2%
gross added value of the sector (current 10^6 F)	-8%	140800	+14%
number of farms (10^6 units)	-0.0	766	+0.0
savings(current 10^6 F)	-11%	53100	+20%
need for external financing(current 10^6 F)	+11%	19700	-10%

It is surprizing that the price of milk has no effect on the number of farms. This result contradicts many previous qualitative observations. It suggests that the elasticity measured may have been underestimated. Keeping this restriction in mind, the figures displayed in table II shown that a repeated decrease of 2.7 % per year of the price of milk would lower the production of milk after 15 years by 2 %. Conversely, a repeated increase of 2.3 % would raise this production by 2 %.

This result is not easy to interpret in terms of elasticity :

P_a being the price of milk under hypothesis A, P_c under hypothesis B, then, $P_A/P_C = \frac{(1.05)^n}{(1.073)} = (1 - 0.021)^n$

In the average, over 15 years, one can admit that this corresponds to a 15 % change of the price of milk, (0 % for year 0, 30 % for year 15). Since the production in year 15 changes by 2 %, the 15 year elasticity is 0.13. However, this result must be taken with suspicion, as indicated previously.

At the same time, the results just presented show that the change in the price of milk could bring about more important changes in other productions (such as beef) than in milk production.

II - 4 : Results drawn from models at the EEC level

a) - Cordonnier's model

The set of linear programming models built by CORDONNIER was used in order to evaluate the impact of changes in the price [1/] of milk (-15 %, -10 %, -5 %, +10 %, + 15 %). The main conclusions are what farmers' reaction to these changes may vary considerably from one type of farm to

1/ No inflationary process is assumed in this model.

another. The systems for which milk is the major production do not change their supply very much. But their incomes are deeply affected by the change. For instance, in the Cambridge region in the U.K lowering the price by 15 % would reduce the number of cows by 16 %, and reduce the income by 33 %. On the contrary, for a typical farm in Northern France, this reduction in the price of milk would suppress the milk production, but reduce income by only 4 %.

b) - Aeikens' model

Aeikens presents in his table 7 a set of computations of the elasticities of milk yields with respect to milk price. Since the milk price does not affect the number of cows in this model, this amounts to an estimate fo the milk supply elasticity with respect to price. Aeikens' results are reproduced in table II.4.

TABLE II.4

Milk price elasticity of supply in Aeiken's model

Countries	Elasticity 1965 -1967	Lag
Denmark	0.17	-0.5
Germany	0.08	-0.5
France	0.11	-0.5
Ireland	0.27	-0.5
Italy	0.59	0
Netherlands	0.31	-0.5
Great Britain	0.20	-0.5

C) - Main results of the DE STEPHANO and SCANDIZZO model

The long term elasticities given by the authors is reproduced in table II.5 :

TABLE II.5

Long term elasticity of milk supply in various countries, as estimated by DE STEFANO and SCANDIZZO

	Elasticity of milk supply
GERMANY	1.802
FRANCE	0.943
ITALY	0.774
BELGIUM	0.375

These long term elasticities are derived from regressions, using a Nerlovian expectation scheme for computing a long run equilibrium supply equation from the observation of actual prices and supply relationships.

Assuming that Y_t^* is the long period equilibrium quantity for year t, P_t^* is the corresponding price, and X_t^* is the corresponding level of "other variables" explaining production, it is assumed that :

$$Y_t^* = \alpha + \beta P_t^* + \gamma X_t^*$$

But Y_t^* , P_t^* and X_t^*, by definition, are unobsvervable. What can be observed is Y_t, P_t and X_t , the quantities and prices actually realized on year t. Moreover, an additional assumption states that :

$$Y_t = Y_{t-1} + \lambda(Y_{t-1}^* - Y_{t-1}) + u_t$$

where λ is a "coefficient of adaptation and u_t a random variable, with $E(u_t) = 0$

From these equations, and with a few additional assumptions especially, about u_t and the magnitude of λ, it is possible to get an estimable equation, the form of which is :

$$y^t = a + b_1 Y_{t-1} + b_2 Y_{t-2} \dots + c_1 X_{t-1} + c_2 X_{t-2} \dots$$
$$+ d_1 P_{t-1} + d_2 P_{t-2} + \dots + \varepsilon_t$$

Moreover, it is possible to compute $\alpha, \beta,$ and δ from a, the b_i's the c_i's and the d_i's.

In practice, because the number of observations is limited it is hardly possible to estimate more than 3 or 4 of the b_i's, c_i's and d_i's. This is sufficient however, for a reasonnable precision, given the order of the values of λ, α, β, and γ.

From these estimates, the authors compute a long run equilibrium price at the EEC level. It is noticeable that, even at that time, the equilibrium price if far under the current price : For milk, the difference between the current price - in other words, the 1970 price of milk should have been reduced by 34 % in order to reach the equilibrium point.

The main advantage of such a drastic reduction in the milk price would be a very significant increase of the consumer rent, and a suppression of the cost of the Common Agricultural Policy. At the same time, the authors contend that it is feasible, ever from the point of view of the producers, provided it could be understood as a long run target rather than a proposal for the short run.

CHAPTER III

The production function approach for estimating supply elasticity

III - 1 : General consideration [1/]

Suppose we know a function $q = f(x)$ which relates the physical quantity of product, q, to the physical quantity of input x (x is a vector, the component of which is x_i for input i). If farmers were rational profit maximizers, the value x^* of the inputs used in agricultural production would be given by the solution of the problem :

$$\text{(III.1.)} \qquad \underset{x}{\text{Max}} \left[B = P_q \ f(x) - p \ x \right]$$

where p_q is the price of output, and p is the vector of the prices of inputs. Then $\frac{df(x^*)}{dp_q} \Big/ \frac{q}{p}$ will give us the desired elasticity.

The formal simplicity of this approach hides a number of difficulties among which :

i - the specification of the function f(x) and

ii - the relationships between x and p.

1/ This exposition relies upon professor Jones' contribution to the panel of experts. A bibliography can be found in GARDNER (1979).

In order to be tractable, f must not depend on too many parameters. In that respect, the most common production function used in literature is the so called CES production function :

(III.1.2) $$f(x) = \gamma \left(\sum_i \delta_i x_i^{-\rho} \right)^{-1/\rho}$$

γ is a scale parameter, ρ is the elasticity of substitution parameter (with elasticity of substitution $\sigma = \frac{1}{1+\rho}$) which indicates how easily an input can be substituted for another and the δ_i's are the factor intensity parameters.

If $\rho = 0$ ($\sigma = 1$) this function reduces itself to the famous Cobb Douglas production function.

(III.1.3) $$f(x) = \gamma \prod_i x_i^{\varepsilon_i}$$

which depends only upon I + 1 coefficients, if I is the number of inputs.

By choosing appropriate units, one may specific $q = 1$, $p_q = 1$, $p = 1...1$. Then, with the additional assumption that $x = x^*$, it is possible to show that $\delta_i = p_i x_i / p_q q = x_i$. At the same time $\gamma = 1$. Thus, if the x_i's are known, the only unknown parameter is ρ.

At the same time, the supply elasticity of input i with respect to price is given by :

(III.1.4) $$\beta_i = \frac{dx_i}{x_i} \bigg/ \frac{dp_i}{p_i} ,$$

Then it can be shown (JONES, 1980) that the elasticity e of the supply of the product with respect to price is given by :

$$(II.1.5) \quad e = \frac{df(x)}{dp_q} = \frac{\sum_i \frac{s_i \beta_i}{\sigma + \beta_i}}{\sum_i \frac{s_i}{\sigma + \beta_i}}$$

where s_i is the share of input i in the total output value.

The major advantage of this approach is that e depends only upon σ, the s_i's and the β_i's.

The results may not be very sensitive to σ . In fact it seems possible to take $\sigma = 1$ (i.e, $\rho = 0$), since this case corresponds to the Coob Douglas production function, which is commonly used in many econometric models.

The s_i's are more difficult to estimate. But the difficulty is not a diriment obstacle. In many studies of gross margin ,it is possible to find out likely estimates of the share of each factor in the final gross product. The constraint that $\sum_i s_i = 1$ makes this estimation easier.

The real trouble is with the β_i's . It is not inconceivable to estimate the β_i's both in the long term and in the short term, at the farm sector level : For instance, it is clear that the supply elasticity of land is practically null, in the short as well as in the long term. Labour is probably fixed in the short term, and rather elastic in the long term. Fertilizers and pesticides can be considered as infinitely elastic.

But the problem is not there. It is in the fact that the supply of inputs for the milk sector depends also upon the possibility of shifting inputs to the milk sector from other agricultural sectors (such as wheat or vegetables). To disregard this fact would be extremely misleading. However, it is possible to modify the preceeding approach, in order to take this consideration into account.

III - 2 : A multiple output version of the production function approach

In this approach, we shall keep the general setting of the preceeding section - especially the idea that the elasticities depend upon the supply elasticity of inputs at the farm gate. But we shall try to take account of the possibility of shifting resources from one farm activity to another, if the marginal product of a given input is higher in one activity than in another. In that way, the importance of a price estimation of the β_i's is smaller, since the main source of changes in production will be the changes in marginal productivities of each input with each activity. Thus, it will be necessary to write down the initial equilibrium between productions, by stating that, in the optimal situation, all marginal productivities, expressed in value, are equal. Then, we shall compute the changes in this equilibrium which will be induced by a change in the price of output. Relating the percent change in output quantities associated to a given percent change in output prices will provide us with the desired elasticities.

A) - Basic model

Suppose that for each agricultural product (denoted 1...j...J), the production function is of CES form :

$$q_j = \gamma_j \left[\sum_i \delta_{ij} \; x_{ij}^{-\rho_j} \right]^{-1/\rho_j} \qquad \text{(III.2.1)}$$

with :

q_j : physical quantity of product j.

x_{ij} : physical quantity of factor i used in the production of j.

γ_j, δ_{ij}, ρ_j : function parameters, as above.

In addition, p_j denotes the price of output j, and p_i the price of input i. β_i is the elasticity of supply of input i (cf equation III.1.4). There are I inputs, and J outputs. $x_i = \Sigma_j \; x_{ij}$ is the total quantity of input i used in the production of all outputs. N is the number of coefficient x_{ij}.

The choice of measurement units is arbitrary. Without loss of generality, it is possible to set $q_j = 1 \; \forall \; j$. Then p_j is the value of the total production of output j. Again, this value is arbitrary, because the monetary unit is not yet fixed. Choosing it in such a way that $\sum_i p_j q_j = 1$, amounts to the same thing as defining p_j as the share of output j in the total value of production.

Similarly, on the factor side, because the production function is homogenous and of degree 1, the value of outputs equals the value of inputs. Thus $\sum_i p_i x_i = 1$. Then it is possible to choose the measurement units of the quantities of inputs so as to get $x_i = 1 \; \forall \; i$. In that case, p_i is the share of factor i in the total value of input, which equals the total value of outputs.

Recalling that ${}_i p_i x_{ij} = p_j$ and denoting by s_{ij} the share of input i in the total value of output j, then $s_{ij} = \frac{p_i x_{ij}}{p_j}$ and thus $x_{ij} = \frac{p_j s_{ij}}{p_i}$. Therefore, the four sets of parameters x_{ij}, x_i, p_i, p_j depend only upon the s_{ij}'s and the share of output j in the total production.

Each input belongs to one of three mutually exclusive sets :

S_1 : $\beta_i = \infty$ (the factor i is supplied at fixed prices)

S_2 : $0 \leqslant \beta_i \leqslant +\infty$ (increasing the demand of i increases its prices)

S_3 : $\beta_i = 0$ ($x_i = X_i$, fixed).

n_1, n_2 n_3 represent the number of inputs i belonging respectively to S_1, S_2, S_3 with $n_1 + n_2 + n_3 = I$.

then,

$$\frac{dp_i}{p_i} = 0, \quad i \in S_1 \tag{III.2.2}$$

$$\frac{dp_i}{p_i} = \frac{dx_i}{\beta_i x_i}, \quad i \in S_2 \tag{III.2.3}$$

(III.2.4) $$\sum_j dx_{ij} = 0 \quad , \quad i \in S_3$$

Under free competition between farmers, the marginal value product equal the price for each input. Therefore :

(III.2.5) $$\frac{\partial q_j}{\partial x_{ij}} = \frac{p_j}{p_i} \qquad \forall\, ij \,\middle|\, x_{ij} \neq 0$$

Moreover, from (III.2.1) :

(III.2.6) $$\frac{\partial q_j}{\partial x_{ij}} = \delta_{ij} \left(\frac{q_j}{x_{ij}}\right)^{1+\rho_j} \qquad \forall\, ij \,\middle|\, x_{ij} \neq 0$$

Combining (III.2.5) and (III.2.6) gives :

(III.2.7) $$p_j\, \delta_{ij} \left(\frac{q_j}{x_{ij}}\right)^{1+\rho_j} = p_i \qquad \forall\, ij \,\middle|\, x_{ij} \neq 0$$

Equation (III.2.7) holds whatever p_j, q_j, x_{ij} and p_i. In order to investigate what happens for small changes dp_i, dx_{ij}, dp_j and dq_j, it is possible to differenciate it. Thus :

$$\text{(III.2.8)} \qquad \frac{dp_j}{p_j} + (1+\rho_j)\,\frac{dq_j}{q_j} - (1+\rho_j)\,\frac{dx_{ij}}{x_{ij}} = \frac{dp_i}{p_i}, \ \forall\, ij \;\Big|\; x_{ij} \neq 0$$

Similarly, $\frac{dq_j}{q_j}$ is given by :

$$\text{(III.2.9)} \qquad \frac{dq_j}{q_j} = \frac{1}{q_j} \sum_i \frac{\partial q_j}{\partial x_{ij}}\, dx_{ij} = \frac{1}{q_j} \sum_i \frac{p_i}{p_j}\, dx_{ij} \;, \; j=1\ldots j$$

Recalling that equations (III.2.2) to (III.2.4) express the $\frac{dp_i}{p_i}$'s as linear functions of the dx_{ij}'s,and reporting (III.2.9) in (III.2.8), it is possible to define $\frac{dp_j}{p_j}$ as a linear function of the dx_{ij}'s. Thus, if we denote by :

G : a transfer matrix with N rows and I columns :

$$G = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & \\ & & 1 \\ \cdot & \cdot & \cdot \end{bmatrix}$$

P_j : the column vector of dimension J, the elements of which are dp_j/p_j

X : the column vector of dimension N, the elements of which are dx_{ij}

P_{S3} : the column vector of dimension n_3, the elements of which are dp_i / p_i, for $i \in S_3$.

M : a matrix of dimension $(N+n_3)$, $(N+n_3)$. The first n columns of M correspond to dx_{ij}, the last n_3 columns to dp_i for $i \in S_3$. The first N rows of M correspond to equation (III.2.8), in which $\frac{dq_j}{q_j}$ is expressed in function of dx_{ij} through equation (III.2.9), and the $\frac{dp_i}{p_i}$'s for $i \in S_1$, S_2 are expressed in function of dx_{ij} through equations (III.2.2) and (III.2.3). The last n_3 rows of M correspond to equation (III.2.4).

0 : A matrix with n_3 rows and I columns which is entirely filled with zeroes.

then :

(III.2.10) $$\begin{bmatrix} G \\ 0 \end{bmatrix} P = M \begin{bmatrix} X \\ P_{S3} \end{bmatrix}$$

Unfortunately, the matrix M can be singular because, since the production function is homogenous and of degree 1, $p_j q_j = \sum_i p_i x_{ij}$, hence :

(III.2.11) $$p_j dq_j + q_j dp_j = \sum_i p_i dx_{ij} + x_{ij} dp_i , \; j = 1 \ldots J .$$

Therefore, $\frac{dq_j}{q_j}$ depends linearly of the dx_{ij}'s through 2J equations (III.2.11) and (III.2.9) instead of J. Thus, there is a possibility that the M matrix defined in (III.2.10) be singular. In fact, it can be shown (BOUSSARD, 1980) that M is not singular if all inputs belong to the set S_2, but may be singular if all inputs belong to S_1 (which is evident), or if at least two activities consume the same input belonging to S_3. In order to avoid any difficulty of that kind, it has been assumed that certain inputs cannot be shifted instantaneously from one production process to another. For instance, cows cannot be replaced instantaneously by sheep, or pastures by arable land. Probably a certain fraction of each input can thus be shifted, but not the whole. Therefore, it is convenient to denote by $(1 - \lambda_{ij})$ the fraction of each input which can be shifted. Thus, λ_{ij} is the fixed share of each x_{ij}.

In that case, the decision variable is not x_{ij}, but x^*_{ij}, such that $x_{ij} = \overset{\circ}{x}_{ij} + x^*_{ij}$, with $\overset{\circ}{x}_{ij} / x_{ij} = \lambda_{ij}$ at equilibrium, and $\overset{\circ}{x}_{ij}$ is the fixed part of x_{ij}.

Then equation (III.2.1) is written :

(III.2.12) $$q_j = \gamma_j \left[\sum_i \delta^*_{ij} x^{*\,-\rho_j}_{ij} + \delta_{ij} \overset{\circ}{x}_{ij}^{\,-\rho_j} \right]^{-1/\rho_j} , \forall j,$$

With this new specification of the production function, equations (III.2.2) to (III.2.9) are still valid. It is only necessary to replace δ_{ij} by δ^*_{ij} and x_{ij} by x^*_{ij}. But it is no more true that :

(III.2.13) $$dq_j = \sum_i \frac{q_j}{x^*_{ij}} dx_{ij}$$

since $\sum_i p_i x^*_{ij} \neq \sum_i p_i x_i$. Therefore, the matrix M built from the x^*_{ij} 's is no more singular .

Thus, it is possible to compute X from (III.2.10) by :

(III.2.14) $$\begin{bmatrix} X \\ P_{S3} \end{bmatrix} = M^{-1} \begin{bmatrix} G \\ 0 \end{bmatrix} P$$

Now, from (III.2.9), denoting by Q the vector $\frac{dq_j}{q_j}$, it is possible to write :

(III.2.15) $$Q = E\ X$$

where E is again a matrix with J rows and I x J columns, the coefficients of which are given by (III.2.9).Thus, (III.2.13) and (III.2.14) give the $\frac{dq_j}{q_j}$'s corresponding to any specification of dp_j/p_j.

Especially, taking $dp_j/p_j = 0$ except for $j = j^*$, in which case $dp_{j*}/p_{j*}= 1$,gives the dq_j/q_j's which correspond to $dp_{j*} / p_{j*} = 1$, everything else remaining unchanged - i.e the elasticity and cross elasticities of the q_j's with respect to the price of j^*. Even more, replacing the vector P by a diagonal unitary matrix makes q the matrix of elasticities and cross elasticities of each output quantities with respect to each output prices. This matrix is thus given by :

(III.2.16) $$R = \begin{bmatrix} E & 0 \end{bmatrix} M^{-1} \begin{bmatrix} G \\ 0 \end{bmatrix}$$

III - 3 : Some further complications

a) - The problem of financing capital

Up till now, the problem of financing capital has been disregarded, or more rigorously, it has been assumed that the price of any input incorporated the price of financing capital associated with buying this input. But the financing capital is a specific commodity, the characteristics of which are different from the others. It is desirable to isolate it in the previous model.

This can be done by assuming that the input prices which have been used previously are made up of two elements :

(III.3.1) $$p_j = (p^*_i + t_i p_k)$$

where p^*_i is the original market price of the input, p_k is the price of capital (the rate of interest) and t_i is the lifespan of input i.

(III.3.2) $$\sum_{ij} t_i x_{ij} \quad p^*_i = K$$

where K is the total available capital.

Incorporating this analysis into the preceeding framework does not raise any problem. Only, one row and one column are added to the matrix M. The row corresponds to the equation :

(III.3.3) $$\sum_{j,i \in S_1 S_2} t_i \left(dx_{ij} p^*_i + \frac{dp_i}{dx_{ij}} x_{ij} \; dx_{ij}\right) = dK$$

with either dK = 0 (if the capital is in short supply) or dK = $\beta_k K_k$ if an elasticity β_k of capital supply with respect to price is assumed 1/.

The elements of the additional columns are obtained in replacing p_i by $p_i^* + t_i p_k$ and dp_i by $dp^*_i + t_i dp_k$ in equations (III.2.5). Thus, the elements of this column of matrix M are t_i.

Notice also that we are not free to choose the price of capital as we want, since the capital unit depends upon the units chosen for the inputs through equation (III.3.2). The actual rate of interest r must be used. Then from (III.2.3),

(III.3.4)
$$dK = \frac{\beta_k}{p_k} \left(\sum_{ij} t_i x_{ij} \right)$$

This value is reported with a minus sign, at the intersection of the last row and of the last column of matrix M.

b) - The income effect

Furthermore, the income effect, that is, the fact that dK depends upon the change in income generated by the change in price is disregarded here.

In order to incorporate this consideration into the model, let us define a set of inputs S_4. An inputs belongs to S_4 if a share x_i of the

---

1/ $i \in S_3$ is disregarded in this equation, because farmers do not have effectively to buy these factors. However, this assumption is discussable. Other models may take accounts of this effect of the price of one commodity upon the price of land and other fixed factors. This effect will disregarded for the moment.

income generated by this input is a part of the farmers' income. Thus, the components of S_4 are the family labour, the land owend by farmers, etc... Then the change of income generated by the new situations is, for each year :

(III.2.5) $$dI = \sum_{j,i \in S_4} \alpha_i (dp_i \, x_{ij} + p_i dx_{ij})$$

with dp_i being given by (III.2.2) through (III.2.4)

If s is the marginal propensity to save, and T is the time horizon over which the elasticity is computed, then :

(III.3.6) $$dK = \beta_k \quad K + L \quad T \quad s \quad dI$$

where L is the "leverage effect", that is, the coefficient which multiply saving through the self financing constraint imposed by banks.

However, it would not have been correct to incorporate this effect into the present model. This is a consequence of dynamic considerations : it is not possible to finance the current production by the current income. Otherwise, it would always be possible to finance an infinite production by an infinite income. A lag must be introduced in such a model, the dK of period t corresponding to the income of period t-1. Although it would have been useful to make use of such a dynamic model, this was not attempted, for lack of time. Therefore, in its present version, the model disregarded the "income effect" - with the consequence that the long term elasticities may be under-estimated. However, the preceeding reasoning allows for the computation of the elasticity of farmers' income with respect to any change in outputs prices, provided that the β_i's are known. This has been done tentatively in this study.

c) - The problem of joint production

Up till now, it has been assumed that each activity produces only one product. This is clearly not the case for milk, since this activity produces meat as well. A full treatment of this difficulty would not have been easy, because it would imply measuring the change in the ratio : production of meat/production of milk, which is induced by a change in the ratio : price of milk/price of meat. Clearly, the general approach which is chosen here is not suitable for that purpose. A possible alternative approach would have been to define a joint CES milk and meat production function along the line suggested for instance by MUNDLACK (1966) or by HASENKAMP (1976).

Another approach would have been to define a set of milk/meat producing subactivities, each with a fixed milk production/meat production. Then, it would have been possible to estimate the elasticity if each of these subactivities, and to compute the overall elasticity of milk supply as a weighed sum of the elasticity of each of the subactivities.

For lack of data, this was not attempted, and we limited our study to the measurement of the elasticity of only one milk producing activity in each region, with the consequence that the milk supply elasticity with respect to price if underestimated. In that context, we have :

(III.3.7)
$$q = q_1 + q_2$$
$$q_2 = \gamma q_1$$

where q is the production of the milk/meat producing activity.

q_1 is the production of milk

q_2 is the production of meat

γ is a fixed coefficient

Assuming p_1 is the price of milk, p_2 is the price of meat, and p is the price of the joint production, then :

$$pq = p_1 q_1 + p_2 q_2 = q_1 (p_1 + \gamma p_2)$$

and

(III.3.8)
$$p = \frac{p_1 + \gamma p_2}{1 + \gamma}$$

thus, assuming that only p_1, varies :

$$\frac{dq}{q} = \frac{dq_1}{q_1}$$

(III.3.9)
$$\frac{dp}{p} = \frac{dp_1}{1+\gamma} \Big/ \frac{p_1 + \gamma p_2}{1 + \gamma}$$

e denoting the elasticity $\frac{dq}{q} / \frac{dp}{p}$ as measured by the system of equations described in the previous section, one can derive from equation (III.3.10) from (III.3.9).

(III.3.10)
$$\frac{dq_1}{q_1} \cdot \frac{p_1}{dp_1} = e \quad \frac{1}{1 + \gamma \frac{p_2}{p_1}}$$

This equation shows that a correction coefficient, which is a function of γ and of $\frac{p_2}{p_1}$ must be applied to the result of equation (III.2.14) if we want to compute the elasticity of milk only, and not that of the joint production meat and milk.

Notice that, if $r_1 = p_1 q_1$, and $r_2 = p_2 q_2$ one has :

$$\frac{p_2}{p_1} = \frac{r_2}{r_1} \cdot \frac{q_1}{q_2} \quad \text{and because of (III.3.7)} \quad \frac{p_2}{p_1} \simeq \frac{r_2}{r_1}\gamma$$

thus (III.3.10) can be written :

$$\text{(III.3.11)} \qquad \frac{dp_1}{q_1} \cdot \frac{p_1}{dp_1} = e \frac{1}{1+\frac{r_2}{r_1}} = e \frac{r_1}{r_1 + r_2} = w\ e$$

$w = r_1/(r_1 + r_2)$ is the share of milk in the total output of the milk and meat producing activity. This coefficient has been used to correct the results obtained from equation (III.2.15).

More generally, let E be the matrix of supply elasticities pertaining to a set of activities, so that :

$$\text{(III.3.12)} \qquad \frac{dQ_J}{Q_J} = \frac{dP_A}{P_A}$$

Notice that E is not necessarily square. $\frac{dQ_J}{Q_J}$ is a vector, the elements $\frac{dq_j}{q_j}$ of which is the relative increment of the physical level of acticity j. $\frac{dP_A}{P_A}$ is also a vector, the element $\frac{dp_1}{p_1}$ of which is the relative increment of the price associated with activity 1. dQ_J, Q_J, dP_A, P_A can also be considered by those of V_2 as vectors, V_1/V_2 representing the division term by term of the elements of V_1 . The activity 1 produces several outputs (for instance, 1 is the "milk producing activity", but it produces also some meat). Let q_r denote the quantity of the output, and Q_R the vector corresponding to all q_2. Q_r and Q_A are related by :

(III.3.13) $$Q_r = A\ Q_A$$

where A is a matrix of technical coefficients (notice that A is not necessarily square). Q_A is a subset of Q_J, and P_A is the price vector associated with Q_A.

Hence :

$$dQ_R = A\ dQ_A$$

Similarly, P_R is the price vector associated with the outputs.

If units are chosen so as to have $Q_A = \left[1 \ldots 1\right]^T$, $P_R = \left[1 \ \ldots \ 1\right]^T$, the elements a_{jr} of A are such that $p_r a_{jr} / p_j = s_{jr}$, where s_{1r} is the share of output r in the total output of activity 1. Since $p_2 = 1$, $a_{1r} = p_1 s_{12}$, and $p_2 = \sum_j a_{1r}$. For the same reason:

$$P_R^T \; A = P_A^T$$

(III.3.14)

$$A^T P_R = P_A$$

Then, $Q_R = A \; Q_A = A \left[1 \ldots 1\right]^T$

Taking account of (III.3.14) in (III.3.12) gives :

(III.3.15) $$\frac{dQ_J}{Q_J} = E \quad \frac{A^T dP_R}{P_A}$$

Denoting by V_D the diagonal square matrix, the diagonal elements of which are those of vector V :

(III.3.16) $$\frac{dQ_J}{Q_J} = E \; (P_A)_D^{-1} \; A^T \; dP_R$$

Recalling that $P_R^T = \left[1 \ldots 1\right]$,the matrix of the elasticities of Q_J with respect to P_R is thus given by :

(III.3.17) $$\frac{dQ_J}{Q_J} \; / \; \frac{dP_R}{P_R} = E \; (P_A)_D^{-1} \quad A^T$$

Moreover, if we want the matrix of the elasticities of Q_R with respect to P_R, taking account of $Q_J = \left[1 \; \ldots \; 1\right]^T$ and starting from (III.3.16) gives :

(III.3.18) $$dQ_J = E \; (P_A)_D^{-1} \quad A^T \quad \frac{dP_R}{P_R}$$

Taking account of (III.3.13) gives :

$$\frac{dQ_R}{Q_R} \;/\; \frac{dP_R}{P_R} = (A\ Q_A)_D^{-1}\ A\ E(P_A)_D^{-1}\ A^T \tag{III.3.18}$$

In addition, if we want the supply elasticity of Q_R with respect to P_J, the price of the activities, then :

$$\frac{dQ_R}{Q_R} \;/\; \frac{dP_J}{P_j} = (A\ Q_A)_D^{-1}\ A\ E \tag{III.3.19}$$

III - 4 : Application of the multiple output production function approach

The model just described presents many features of a linear programming model. It relies mainly on the input/output coefficients. The effects of technical progress can be investigated (through a modification of the input/output matrix). Changes in credit policy, and in factor supply conditions, can be investigated as well. At the same time, this model is much simpler than a L.P model. The assumption of optimality of the existing situation guarantees the identity between the "initial situation" and the solution of the optimizing process. The main defect of the L.P model is precisely not to provide this guarantee.

In particular, all effects such as the risk and uncertainty are embodied into the coefficients of the production function, whereas they must be incorporated explicitely in a linear programming analysis.

The necessity of making assumptions with respect to fixed factors is not essentially different from the necessity, in linear programming, to define a right hand side which expresses the fixity of certain past decisions. The main difference is that, in linear programming, both the right hand side and the technical coefficients of the matrix prevent the elasticities from being infinite, whereas the set of fixed coefficients defined here play the same role in the present approach. Thus, this set of coefficients also expresses considerations pertaining to existing techniques, and even to risk and uncertainty - in a way which, in many respects, is similar to linear programming models with flexibility constraints.

The main shortcoming of this approach is that the results are not testable by comparing predictions to reality. This is,admitedly,a severe drawback .

The model was applied for estimating the milk supply elasticity with respect to price in France and in Italy. For the latter, it is the only recent source of information, in the absence of other model than that of DE STEFANO and SCANDIZZO,which is somewhat old. For the former it will supplement informations already available, as described in chapter II of the present report.

In addition, and since data were available for these countries in the same conditions as for France and Italy, it was applied to Great-Britain, Netherlands and Germany. The purpose of this exercise was not to overlap the reports of other experts in charge of these countries. It was rather to provide a basis of comparizon between estimates for France and Italy on one hand, and the three other countries, on the other. Thus, if the method which was used here were to be biased, an order of magnitude of this bias could be evaluated, by comparing the results described here with thoses which were obtained by the other experts for the three other countries. It should be noticed, however, that the accuracy of the computation is probably less good for Great-Britain (where no possibility of regionalization existed)than for other countries.

a) - Sources of data

The data required by the model come from various sources. Unfortunately, it was impossible to measure most of the key data which were estimated on a judgmental and discussable basis.

1) - <u>The list of inputs and associated parameters</u>

The set S_0 of the outputs defines the agricultural activities with which any particular agricultural product will compete for the use of fixed agricultural inputs. Clearly, the price supply elasticity of any agricultural product will depend heavily upon S_0. At the same time, S_0 varies among the regions.

For instance, it is impossible to grow wine in Northern France, so that wine production will be excluded from S_0 in this region, while it has to be included in S_0 in Southern France. For this reason, S_0 has been defined for various regions in each country, and the supply elasticity of milk is the weighted average of all regional supply elasticities. The weights used for this computation are the milk production in each region, for, if $q = \Sigma q_r$, where r represent the region i,then :

$$\frac{dq}{q} \quad / \quad \frac{dp}{p} = \sum_r \frac{q_r}{q} \quad \frac{dq_r}{q_r} \quad / \quad \frac{dp}{p} \ .$$

Table III.1 gives the list of countries and regions to which the preceeding analysis has been applied, and the corresponding S_0 sets. The classification of regions is discussable, as all classifications. It has been made on a judgment basis. However, the judgment has been helped by various studies on the regional typology of the EEC, especially RAINELLI (1978), JUDEZ and VELASQUEZ (1979) BAILLET (1968) and THIEDE (1968).

Two parameters of the model are associated with each j : the elasticity of substitution parameter $\sigma_j = \frac{1}{1 + \rho_j}$, and the price p_j - the latter being in fact the share of j in the total output of all outputs belonging to the same region.

TABLE III.1

Set S_0 and p_j's for each region 3/

	Great-Britain	Netherlands		Germany		
	(whole)	Northern provinces 1/	Sea provinces 2/	Bavaria	Renish Palatinat	Others lander
Weight of milk for the regions in the country	1.0	5151	3446	6590	754	13234
milk	0.254	0.595	0.384	0.465	0.215	0.016
open field vegetables	0.075		0.017	0.006	0.019	0.016
cereals	0.075	0.041	0.032	0.145	0.154	0.162
beef	0.135	0.021	0.004	0.035	0.046	0.075
poultry				0.028	0.034	0.051
hogs	0.285	0.305	0.376	-	0.106	0.274
potatoes	0.035	0.018	0.033	0.110	0.067	0.049
sheep	0.048	-	-	-	-	-
sugar bets	-	-	0.042	0.028	0.031	0.036

1/ Northern provinces : North Netherlands and East Netherlands

2/ Sea provinces : West Netherlands and South Netherlands

3/the sign "-" indicates that the commodity is not considered in the region. Otherwise, the content of the table indicates the corresponding p_j, or ε if p_j is too small.

TABLE III.I (cont')

ITALY

	North 1/	Center 2/	Southern plains 3/	Southern mountains 4/
Weight of the milk for the region in the country	3469	2870	390	91
milk	0.520	0.192	0.070	0.152
beef	0.124	0.073	0.039	-
cereals	0.140	0.134	0.114	0.234
maize	0.146	0.082	-	0.002
potatoes	0.039	0.046	0.079	-
sheep	0.001	0.004	0.009	0.195
hogs	0.075	0.080	0.025	0.065
olives	-	0.021	0.136	0.070
fruit	-	0.112	0.212	-
wine	-	0.118	0.090	0.102
horticulture	-	0.054	0.084	0.127
openfield vegetable	-	0.106	0.125	0.113
sugar beets	-	0.058	0.013	-
tobacco	-	-	0.029	0.004
total	1.000	1.000	1.000	1.000

1/ North : Valle d'Aoste, Piemonte, Lombardia, Friuli, Venezia, Trentino, Alto Adige
2/ Center : Lazio, Liguria, Veneto, Emilia, Romagna, Toscana, Umbria, Marche
3/ Southern plains : Abbruzi, Campagnia, Puglia, Calabria, Sicilia
4/ Southern mountains : Molize, Basilicate, Sardegna
5/ the sign "-" indicates that the commodity is not considered in the region. Otherwise the content of the table indicates the corresponding p_j.

TABLE III.1 (cont')

	Great-Britain	Netherlands		Germany		
	(whole)	Northern provinces 1/	Sea provinces 2/	Bavaria	Renish Palatinat	Others Lander
horticulture	-	-	0.111	0.111	-	-
hop	-	-	-	0.014		
wine	-	-	-	-	0.328	-
maize	-	-	-	0.009	-	-
Total	1.000	1.000	1.000	1.000	1.000	1.000

FRANCE

TABLE III.1 (cont')
Set S_0 and p_j's for each region 6/

	Southern provinces 1/	West 2/	North 3/	Mountains 4/	Plains 5/
weight of milk for the region in the country	1827	9462	4208	3049	2754
milk	0.148	0.501	0.289	0.442	0.293
beef	0.038	0.052	0.066	0.075	0.068
sheep	0.033	0.005	0.005	0.041	0.026
poultry	0.075	0.118	0.051	0.102	0.072
cereals	0.085	0.081	0.269	0.087	0.313
maize	0.065	0.011	0.035	0.034	0.066
fruit	0.089	-	0.016	0.046	-
wine	0.271	-	-	0.068	0.071
horticulture	0.062	0.054	0.075	-	-
open field vegetables	0.070	0.007	0.037	-	-
sugar beets	-	-	0.082	-	0.033
tobacco	ε	-	-	0.007	-
potatoes	0.017	0.023	0.069	0.029	0.018
hog	0.047	0.147	-	0.069	0.039
hop	-	-	ε	-	ε
Total	1.000	1.000	1.000	1.000	1.000

1/ Southern provinces : Provence, Côte d'Azur, Corse, Languedoc,Roussillon, Aquitaine, Midi-Pyrénées.
2/ West : Bretagne, Basse-Normandie, Pays de la Loire.
3/ North : Nord-Picardie, Région Parisienne, Lorraine, Haute-Normandie.
4/ Mountains : Auvergne, Rhône-Alpes, Limousin.
5/ Plains : Poitou-Charentes, Alsace, Bourgogne, Centre, Champagne.
6/ The sign "-" indicates that the commodity is not considered in the region. Otherwise, the content of the table indicates the corresponding p_j.

The parameter ρ_j has been fixed on a judgmental basis at the value 1 for all j - thus $\sigma_j = 0.5$, the elasticity of substitution in agriculture being small, but not negligible 1/.

The p_j's were estimated at the level of each region, using various data among which provisional data supplied by the DG 12 of the EEC and not yet published. They are listed in table III.1. It should be noticed that the significance of the p_j's is somewhat particular : For instance : the p_j associated with milk production does not represent the share of milk production in the total output of a particular region, but the share of milk, plus that of the meat production which is a byproduct of milk. Similarly, the p_j associated with meat reprensents only the share of the pure meat production of the total production. A large amount of judgment intervene in the determination of these proportions.

2) - Data tied with inputs

The set E_I of the inputs has been defined in the same way for each region. Inputs are broken down into 9 categories as indicated in Table III.2. This table also give the values of the parameters associated with each input, some of which (especially the t_i's) are not independant of the x_{ij}'s, since these data will be used in the computation of the share of input commodities with a long liftspan in the total gross product of each activity.

The t_i coefficients have been chosen on the basis of usual accountancy conventions assuming that the existing set of inputs is amortized by half.

1/ For an additional justification of this value, see below the comments of the sensitivity analysis of the results.

The α_i coefficients have been chosen rather arbitrarily, although it is likely that only the expenses on land, labour, and "others" can represent an income for farmers.

Two sets of β_i coefficients have been chosen, one for the short run, one for the long run, on a judgment basis. Intermediate consumptions are always infinitely elastic, land is always completely inelastic. But other commodities are inelastic in the short run, and moderately elastic in the long run.

The financing capital input raises a few special problems :

The supply elasticity of capital is difficult to measure. Various values were tried. The most likely value (i.e., that which gives results close from other estimates) is 0 in the short run, and 0.5 in the long run. In effect, an increase in the demand for funds from agriculture does not necessarily entail a rise in the funds supplied, nor a change in the rate of interest, because these variables are determined by other mechanisms. Perhaps, the correct way of coping with the difficulty would have been to consider dK as exogenous. However, estimating the correct value of dK in that context would have been even more difficult.

Finally, the λ_{ij} coefficients are crucial for the absolute magnitude of the resulted presented here. Unfortunately, they are difficult to estimate on solid grounds. Some reasonable order of magnitude can be obtained however. Intermediate consumptions, labour and financing capital can be shifted from one production to another instantaneously. Therefore, the fixed share of these inputs is zero. Land can be reallocated to each crop, but only partially. It has been assumed that 50 % of the land is fixed in the "long run" and 75 % in the "short run". Machines can be fully reallocated in the long run, but only 25 % of them have been assumed "shiftable", in the short run. Cattle and trees are not reallocatable in the short run, and are only partially reallocatable on the long run. Finaly, the proportions 0 % and 50 % respectively,for the short run and the long run have been estimated for "other" commodities.

Thus, the λ_{ij}'s are the same for all j, which is admittedly discussable. They are given on table III.2 for the long run and short run.

Furthermore, since the values of the λ_i's were obviously of the utmost importance, a sensitivity test was performed.Thus table III.2 also give the upper and lower limits of the λ_i vector used in this sensitivity analysis.

3) - The shares of inputs

The main source of information for the x_{ij} was the EEC document on the standard gross margins for agricultural product (GILES, 1975).This document gives the gross product, the intermediate consumptions, the expenses for machinery and specific buildings, and the number of working hours, for the main crops in the EEC, in 1972. The expenses for machinery and buildings have been broken down into expenses for machinery, and expenses for buildings on a judgment basis and information on typical costs for specific buildings. Expenses for land have been evaluated on the basis of a 3 % on interest applied to the average value of land in 1972 for the considered country. The value of cattle has been estimated using common prices for cattle as recorded in the EEC statistical census, and assuming that a beef last 3 years, and that a sow last 4 years 1/. Sources of information for these computations have been, among other, AUKEMA and OVERGAAW (1976), CHABRAT (1976), JONAS and FAASCH (1975) WILSON (1975), ADAMO (1976), FEURSTEIN, DEAN, DE BENEDICTIS et al (1974) FILANGIERI (1970) EUROSTAT, etc.

The set of prices which has been used is given in Table III.3 below.

1/ There is some inconsistency between these considerations about the life span of various types of cattle and the values of the t_i's given in Table III.2. This is a consequence of the aggregation of each category of cattle on only one input "cattle". The same difficulty occurs with the aggregated input "trees". A slight overestimation of elasticities may result from this aggregation.

TABLE III.2

Data pertaining to each category of input

			Intermediate consumptions	Machinery	Buildings	Cattle	Trees	Labour	Other	Land
	life span (t_i coefficients)	total	1	5	30	10	25	1	1	20
		average	0.5	2.5	15	5	12.5	0.5	0.5	20
	α_i coefficients	-	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5
	β_i coefficients	long term	0.0		1.0	1.0	1.0	2.0	1.0	0.0
		short term	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
	λ_i coefficients reference values	long term	0.0	0.0	0.75	0.5	0.75	0.0	0.5	0.5
		short run	0.0	0.75	1.0	0.9	1	0.0	1	0.75
values used for the sensitivity analysis	λ_i coefficients upper values	long run	0.0	0.5	0.9	0.75	0.8	0.25	0.75	0.75
		short run	0.0	0.8	1	1	1	0.5	1	0.8
	λ_i coefficients lower values	long run	0.0	0.0	0.0	0.5	0.25	0.5	0.0	0.25
		short run	0.0	0.6	0.75	0.6	1	0	0.5	0.6

TABLE III.3

Prices of land, labour and capital estimated for this study (Reference year 1972)

Countries	currency unit	Labour (per hour)	Land		interest rate %	w coefficient
			per ha	per ha/year		
ITALY	10^3 lira	1.555	1500	37.5	4	0.68
FRANCE	Francs	13.33	9400	235	6.5	0.61
GREAT BRITAIN	Pounds	0.852	1284	32.1	5	0.88
NETHERLANDS	Gulden	11.60	6047	151.175	8.25	0.70
GERMANY	Mark	11.54	15000	375	4.25	0.72

Since ther was not a one to one correspondance between the crops and livestock enterprises described by GILES, and the categories of activities such as "open field vegetables" or "horticulture" the x_{ij} coefficients have been estimated at the level of each crop in GILES, and then the x_{ij}'s of each category of activities have been computed as the weighted sum of these crops-the weights being defined on the basis of the actual corresponding production in the country or in the region (when known) in 1972. In principle, it would have been desirable to use different sets of x_{ij} coefficients for different regions. This was not possible except, in a few occasions ,for France and Italy, because, except for these countries ,GILES does not indicate the regions where his data come from. Similarly, it was in general impossible to make any distinction between types of farms, although this would have been highly desirable. However, in some cases ,regional differences between activities could be defined, mainly by changing the weights used in the averaging of several crops or livestock activities as described by GILES. For instance, the regional differences between the activity "milk" in France stem from the fact that each region contains a different proportion of "large" and "small" farms. The results of the computation of matrices S for each region considered in this study are given in annex A.

An additional shortcoming of the approach used here is that data pertaining to some important crop and livestock activities were not available.The activities used in this study represent 80 to 90 % of the agricultural production of each country.

4) - <u>The share of meat in milk production</u>

The w coefficient of equation III.3.11 foe each country are given in Table III.3. They were estimated from various sources of information among which GILES is the most important one. The value of milk production using average farmgate prices was substracted from the gross product indicated in GILES, in order to estimate the value of meat and of secondary productions, such as veal. Here again, different estimates for different regions would have been highly desirable. But lack of data precluded such a refinement.

The share of meat is obviously 1 - w.

b) - Preliminary results : sensitivity analysis

The major drawback of the approach is that the results can be sensitive to the parameters which are the most difficult to estimate. A sensitivity analysis was therefore needed. It was performed only on the data pertaining to England - mostly for reasons associated with early availability. Tables III.5 and III.6 give the results obtained for the milk supply elasticity in England for various values of the most uncertain paramters, that is :

- the elasticity of substitution
- the labour supply elasticity with respect to price (for the long run only, since in the short run labour is fixed).
- the capital supply elasticity
- the vector λ_i of the fixed share

Clearly the estimation is extremely robust with respect to the labour and capital supply elasticities. But it is extremely sensitive to the other assumptions - especially, those pertaining to the λ_i's. This is obviously a serious shortcoming, since there are few objective ways of assessing correct values for these data.

The same remark holds also for the ρ_i's values. Therefore, this method cannot be considered as a reliable one, and cannot be used independantly from more objective procedures. However, we are, in this study, confronted with the problem of estimating at least one elasticity coefficient for Italy a country in which there is no other reliable model. At the same time, it is obvious, from the preceeding chapters, that the elasticity we are looking for is extremely sensitive to the method of estimation. It is therefore wishable to apply the same method to every countries in order to get comparable results. Now, the method just described is suitable for such an exercise, provided it could be calibrated, by fixing the unknown coefficient at a value giving approximatively the same value as other methods whenever

TABLE III.4

Sensitivity analysis of the milk "activity" 1/ supply elasticity for the short run

fixed shares	capital supply elasticity	elasticity of substitution	Value of milk activity elasticity 1/
upper value	0.0	1	0.62
		0.66	0.41
		0.5	0.30
	0.5	1	0.62
		0.66	0.41
		0.5	0.30
reference value	0.0	1	1.00
		0.66	0.66
		0.5	0.50
Lower value	0.0	1	1.65
		0.66	1.10
		0.5	0.83
	0.5	1	1.65
		0.66	1.10
		0.5	0.83

1/ The milk "activity" supply elasticity means that the correction of equation III.3.18 has not been made. Thus, the results indicates the elasticity of the activity "milk supply", and not that of the commodity "milk".

such other methods are available. This is in fact the only rational way of choosing the values which have already been indicated for the λ_i's and for the ρ_j's. Actually, the elasticities thus obtained are still relatively high, and are probably slightly overestimated.

At the same time, it is interesting to notice that the method does not preclude the existence of negative elasticities. In effect, such negative values are obtained for extreme values of the parameters (low values of the λ_i's, high values of the capital supply elasticity). This may be explained by the fact that, in such conditions, the prices of some inputs, such as land, which are fixed at the sector level, but variable at the activity level, may be deeply affected by the price of milk, thus making other activities more profitable than milk. At the same time, these conditions are unlikely to occur in reality. Thus, this result support the conclusion that, under current conditions, the elasticity of the supply of milk with respect to price is positive.

c) - Application of the method to selected countries in the EEC

Tables III.6 to III.10 give the results obtained with the most likely assumptions, as defined previously.

Table III.6 gives the direct elasticities of response to price, for milk, and for a few selected commodities, in order to compare the magnitude of the milk elasticity with other supply elasticities. Milk is significantly more elastic than cereals, but less than beef or poultry.

Table III.7 gives the percent changes in income, and in supply of other commodities which will be induced by a 1 % rise of the price of milk in the short run. Results differs widely among regions. Especially, for what concerns income, it is striking to find that a 1 % increase in the price of milk would increase the income by almost 1 % in North Netherlands and by 0.03 %

TABLE III.5

Sensitivity analysis of the milk activity supply elasticity in the long run 1/

fixed shares	capital supply elasticity	Labour supply elasticity	elasticity of substitution	value of milk elasticity 1/
upper value	0	0.01	1 0.5	1.07 0.53
		2	1 0.5	1.07 0.53
	1	0.01	1 0.5	1.08 0.53
		2	1 0.5	1.08 0.53
medium value	0	0.01	1 0.5	3.41 1.71
		2	1 0.5	3.41 1.71
	1	0.01	1 0.5	3.48 1.76
		2	1 0.5	3.48 1.76
lower value	0	0.01	1 0.5	17.7 8.8
		2	1 0.5	17.7 8.8
	1	0.01	1 0.5	-51.04 - 5.3
		2	1 0.5	-51.04 - 5.3

1/ See note 1 of Table III.4 above.

TABLE III.6

Factors shares estimates of supply elasticities with respect to price by regions and countries for milk and other selected agricultural outputs

Countries	Regions	Short term: Milk commodity 1/	Short term: Cereals	Short term: Beef commodity	Short term: Poultry 2/	Long term: Milk commodity 1/	Long term: Cereals	Long term: Beef Commodity	Long term: Poultry 2/
Great Britain	All	0.45	0.29	1.48	1.77	1.72	1.1	3.88	3.75
Netherlands	North	0.27	0.3	0.20	1.10	1.04	1.17	0.56	2.74
	Sea	0.50	0.30	0.25	0.92	1.40	1.14	0.64	2.65
	ALL	0.38	-			1.22	-		-
Germany	Bav.	0.43	0.37	0.43	4.36	1.68	1.17	1.45	7.75
	Rh. Pal.	0.99	0.36	0.97	4.17	2.47	1.12	2.65	7.60
	Other	0.59	0.36	0.74	3.92	2.04	1.12	2.36	7.38
	ALL	0.55	-		-	1.94	-		-
France	South	0.94	0.44	0.74	1.94	2.88	2.03	2.96	3.69
	West	0.35	0.45	0.33	1.83	1.45	1.93	1.35	3.55
	North	0.61	0.39	0.56	2.09	2.23	1.61	2.31	3.80
	Mountains	0.53	0.44	0.45	1.89	1.73	1.87	1.73	3.61
	Plains	0.69	0.37	0.59	2.02	2.22	1.35	2.30	3.71
	ALL	0.52	-	-	-	1.87	-	-	-
Italy	Mountains	0.37	0.39	0.80	-	1.67	1.25	2.09	-
	Cent.	1.01	0.38	1.29	-	3.29	1.35	3.21	-
	South Pl.	1.33	0.87	1.69	-	4.34	3.35	4.09	-
	South Moun.	1.18	-	0.55	-	4.19	3.07	1.98	-
	ALL	0.71	-	-	-	2.54	-	-	-

1/"commodity" means that figure have been computed using the correction of equation III.3.18

2/ Hogs and poultry when these activities are aggregated together.

TABLE III.7

Short run cross elasticities of income, and of supply of selected agricultural outputs, with respect of the price of milk, 1/ by regions and countries

Countries	Regions	Short run quantities of :							
		Income	Cereals	Hogs	Fruit	Wine	Potatoes	Sheep	Beef
Great Britain	all	+0.41	-0.07	-0.28	-	-	-0.18	-0.18	-0.07
Netherlands	North	+0.97	-0.15	-	-	-	-0.08	-	+0.20
	Sea	+0.69	-0.12	-	-	-	-0.05	-	+0.48
Germany	Bav.	+0.28	-0.16	0.17	-	-	-0.26	-	+0.12
	Rh. Pal.	+0.23	-0.09	0.09	-	0.27	-0.13	-	+0.33
	Other	+0.34	-0.13	-0.12	-	-	-0.23	-	-0.39
France	South	+0.17	-0.06	-0.15	-0.6	-0.23	-0.25	-0.20	+0.52
	West	+0.73	-0.17	-0.42	-	-	-0.50	-0.78	+0.21
	North	+0.32	-0.10	-	0.19	-	-0.31	-0.52	+0.31
	Mountains	+0.53	-0.14	-0.37	-0.21	-0.96	-0.42	-0.60	+0.28
	Plains	+0.26	-0.09	-0.26	-	-0.93	-0.29	-0.44	+0.36
Italy	Mountains	+0.34	-0.20	-0.08	-	-	-0.51	-0.14	-0.10
	Cent.	+0.13	-0.09	-0.05	-0.19	-0.09	-0.21	-0.06	+0.22
	South Pl.	+0.03	-0.07	-0.03	-0.02	-0.01	-0.06	-0.02	+0.33
	South Moun.	+0.25	-0.15	-0.04	-	-0.02	-	-0.02	+1.18

1/ This price is that of the "commodity milk" and not that of the "activity milk"

TABLE III.8

Long run cross elasticities of income and of supply of selected agricultural outputs, with respect to the price of milk by region and countries

		Long run quantities of :							
Countries	Regions	Income	Cereals	Hogs	Fruit	Wine	Potatoes	Sheep	Beef
Great Britain	all	0.63	0.40	0.57	-	-	0.30	0.93	-0.22
Netherlands	North	1.44	-0.43	-	-	-	0.06	-	+0.82
	Sea	1.05	-0.38	-	-	-	0.10	-	+0.10
Germany	Bav.	0.63	-0.55	-0.17	-	-	-0.16	-	+0.84
	Rh. Pal.	0.26	-0.34	-0.03	-	-0.40	-0.04	-	+0.78
	Other	0.61	-0.46	-0.14	-	-	-0.13	-	
France	South	0.21	-0.24	-0.16	-0.01	-0.51	-0.91	-0.44	+1.44
	West	1.30	-0.65	-0.46	-	-	-2.66	1.31	+0.70
	North	0.53	-0.35	-	0.04	-	-1.67	-0.76	+0.92
	Mountains	0.90	-0.47	-0.33	-0.04	-0.04	-2.25	-1.09	+0.66
	Plains	0.42	-0.33	-0.30	-	-1.60	-1.65	-0.77	+0.90
Italy	Mountains	1.20	-0.51	-0.67	-	-	-0.97	-0.82	+0.48
	Cent.	0.44	-0.26	-0.26	-0.28	-0.64	-0.42	-0.38	+1.16
	South Pl.	0.01	-0.35	-0.01	-0.04	-0.02	-0.11	-0.10	+1.42
	South Moun.	0.10	-0.48	-0.11	-	0.0	-	0.14	+4.22

TABLE III. 9

Elasticities of the price of fixed inputs with respect to the price of milk

Countries	Regions	Short run capital	Short run land	Short run labour	Short run cattle	Long run capital	Long run land
Great Britain	all	+0.83	-0.74	+0.67	+0.32	+2.35	-0.61
Netherlands	North	+3.32	-1.28	+0.65	-0.15	+5.00	-1.39
	Sea	+2.03	-0.28	+0.50	+0.44	+3.95	-0.49
Germany	Bav.	+6.39	-2.49	+0.66	-0.35	+7.78	-2.38
	Rh. Pal.	+3.18	-0.98	+0.31	+0.60	+4.61	-1.21
	Other	+3.66	-1.32	+0.64	-0.10	+6.39	-1.94
France	South	+2.27	-0.99	+0.23	+0.07	+1.51	-0.31
	West	+3.65	-1.38	+0.54	-0.47	+4.29	-0.99
	North	+2.13	-0.98	+0.39	-0.47	+3.18	-1.48
	Mountains	+4.10	-1.77	+0.32	+0.61	+3.30	-1.00
	Plains	+2.63	-1.20	+0.27	+0.09	+3.05	-1.15
Italy	Mountains	+7.89	-3.23	+0.71	-1.15	+11.19	-4.10
	Cent.	+7.53	-3.07	+0.07	-0.63	+4.35	-1.02
	South Pl.	+4.41	-1.79	-0.08	-0.21	+1.16	-0.15
	South Moun.	+9.41	-4.02	-0.16	-1.45	+1.56	-0.25

TABLE III.10

Short run cross elasticities of milk supply with respect to the prices of other selected commodities

Countries	Regions	Percent increase in milk production induced by a 1% increase of the price of :						
		cereals	sugar beets	hogs 1/	fruit	wine	potatoes	sheep
Great Britain	all	-0.05	-	-0.28	-	-	-0.03	-0.04
Netherlands	North	-0.01	-0.01	-0.21	-	-	-0.01	-
	Sea	-0.01	-0.02	-0.27	-	-	-0.01	-
Germany	Bav.	-0.05	-0.04	-	-	-	-0.07	-
	Rh. Pal.	-0.07	-0.04	-	-	-0.43	-0.04	-
	Other	-0.06	-0.06	-	-	-	-0.03	-
France	South	-0.04	-	-0.04	-0.04	-0.43	-0.02	-0.04
	West	-0.03	-	-0.11	-	-	-0.02	-
	North	-0.10	-0.10	-	-0.07	-	-0.07	-
	Mountains	-0.03	-	-0.05	-0.02	-0.15	-0.02	-0.05
	Plains	-0.12	-0.02	-0.02	-	-0.23	-0.01	-0.04
Italy	Mountains	-0.07	-	-	-	-	-0.03	-
	Cent.	-0.07	-0.07	-	-0.12	-0.05	-0.05	-
	South Pl.	-0.16	-0.04	-	-0.07	-0.01	-0.08	-
	South Moun.	-0.29	-	-	-	-0.01	-	-0.03

1/ Or hogs + poultry when theses activities are aggregated together.

in Southern Italy. Within the same country, it can vary to a large extent : for instance, it is about 1 in Northern Netherlands and only 0.7 in Southern Netherlands. Similarly, the same increase of the price of milk would decrease the cereal supply by 0.2 % in Northern Italy, and by only 0.07 % in Southern Italy. Potatoes and sheep appear to be the agricultural commodities for which the cross elasticity with respect to the price of milk is the highest.

Table III.8 gives the same information as table III.8 but for the long run. The relative magnitude of the various items are the same for this table as for the preceeding one, except perhaps for income. Nevertheless, North Holland remains the regions for which the income effect of a change in the price of milk is the highest and Southern Italian Plains, the lowest.

Table III.9 indicates the percent changes in the price of fixed factors which would be induced by a one percent increase in the price of milk, in each region. These figures have the same general significance as shadow prices in linear programming. Therefore, they cannot be compared with market prices without caution : It is conspicuous that land prices tend to decrease everywhere in response to a rise in the price of milk. The reason is that milk production is on the average, less land intensive than competing crops : thus, rising the price of milk would result in less land requirement and consequently, in a lowering of land price. Conversely, milk is relatively demanding in financing capital and in labor. Thus the price of these commodities would tend to increase if the milk price increases except for labor in Southern Italy.

Table III.10 gives, for the short run (long run results would have been similar except that all elasticities would have been higher) the percent increase of milk supply which would be induced by a one percent increase of the price of selected agricultural commodities. These cross elasticities are weak, in general, so that there are few grounds for hopeing to be able to lower the supply of milk by increasing the price of other commodities.

Figures in these tables are subject to the restrictions already pointed out, due to defects in data, and shortcomings of the method used. They represent orders of magnitude, however, and are more accurate with respect to their relative than to their absolute magnitudes. They could be improved at the expenses of a very significant effort in terms of data collection.

CHAPTER IV

Recapitulation of results

All the results obtained in this study are summarized in table IV.1

Obviously, estimates of elasticities in various countries diverge widely, although they are positive, except for the "modêle historico-statistique" in France, in the special case of a price increase, for the long run. This last result is due to the fact that milk supply is in general negatively correlated with farmers income. Thus, raising the income would tend to lower milk supply, because it is more profitable to invest benefits from milk production in other agricultural productions. Since the "modêle historico-statistique" in the only one, in the set of models examined here, which allows for this kind of resource allocation, and since, in that case, the effect is striking, this fact must be taken into consideration. At the same time, it is difficult to assess to what extent the importance of the effect, as measured in this special model, is only an artifact of this model, or whether it is something important in reality. A comparison with other models would have been useful here.

Unfortunately, this is impossible within the framework of the present study. In any case, if the results of the "modêle historico-statistique" are accepted, the long run elasticity of milk supply with respect to a price increase is practically zero, whereas it is very significantly positive in the case of a price decrease.

Can we derive an overall estimate from these figures ? It is out of question to take certain (possibility weighted) average values of each model This would be meaningless. The only way to answer this question is to choose one of the models, in view of its supposed better quality. This is a pure matter of judgment, the basis for this judgment being assessment of the overall quality of the elected model.

TABLE IV.1

Summary of results - Elasticity of milk supply with respect to price

model	Scope	short run for price increasing	short run for price decreasing	long run for price increasing	long run for price decreasing
historico-statistique, INRA	France	0.27	0.27	-0.44	+1.63
Simagri Direction de la Prévision	France	-	-	0.13	0.13
Aikens	France Italy Netherlands Britain Germany	0.11 0.59 0.31 0.20 0.08	0.11 0.59 0.31 0.20 0.08	- - - - -	- - - - -
Factor shares INRA	France Italy Netherlands Britain Germany	0.52 0.71 0.38 0.45 0.55	0.52 0.71 0.38 0.45 0.55	1.87 2.5 1.22 1.72 1.94	1.87 2.54 1.22 1.72 1.94
Cordonnier	Cambridge-shire Northern-France	- -	- -	- -	1.06 infinite
De Stefano Scandizzo	France Italy Germany Belgium	- - - -	- - - -	0.943 0.774 1.802 0.375	0.943 0.774 1.802 0.375

Unfortunately, none of the models described here are free of reproaches.

The "mddèle historico-statistique" showed considerable discrepancies between the results of the model and reality. Moreover, in this model, manpower is exogenous. The effect on manpower of a lowering of price is therefore disregarded.

The Simagri model is not testable. It behaved somewhat oddly in various occasions. It is valuable only for the period 1972-1980.

The Aiekens model is a model of the milk sector only, whereas it is too obvious that the supply elasticity of an agricultural commodity should rely upon the examination of the whole agricultural sector.

The Cordonnier model was not tested. It disregard the manpower effect of lowering incomes. It gives extremes results, which are hardly credible.

The De Stefano/Scandizzo model is not testable. Data are somewhat old, and the study would have to be updated.

The factor share model is not testable. Data are discussable, a large amount of judgment having been incorporated in them at the time of their elaboration. The model is sensitive to various probable assumptions about the most uncertain coefficients.

Nevertheless, this last model gives results which are probably under reasonable assumptions. It has been calibrated by using results from other models. It gives a large amount of information about cross elasticities. Its results are comparable with that of other countries. The factor share estimates will therefore, be retained here as "the most likely", although is is clear that they are not precise.

In any case, that the mere idea of supply elasticity with respect to price is not extremely accurate. Nor are the notions of "long" and "short" term in elasticity computations accurate. Thus, the figure published here should not be considered with an illusory precision. The main results are that, in all countries, and whatever the method, the elasticity of milk supply with respect to price is positive in the short as well in the long run. It is certainly higher than 1 in the long run (5 years), and around 0.5 in the short run. It is relatively small for the Netherlands, medium for France, Germany and the United Kingdom and relatively high for Italy. There is a possibility of the response being asymetric. In that case, it would be greater for a price decrease than for a price increase.

Finaly, the elasticity of income with respect to the price of milk is probably of the same order of magnitude as that of milk supply in the short term, and probably significantly smaller in the long term.

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A N N E X E S

ANNEXE A

Matrices of S_{ij} coefficients for each region and country

Great-Britain (all regions)

Input	Share of inputs in the gross product of :						
	MILK	OPEN FIELDS VEGETABLES	CEREALS	BEEF	HOGS AND POULTRY	POTATOES	SHEEP
LAND	.076	.117	.165	.071	.000	.051	.020
INTERMEDIATE CONSUMPTION	.270	.325	.181	.687	.730	.281	.357
MACHINERY	.125	.156	.220	.063	.032	.084	.268
BUILDING	.027	.000	.000	.000	.044	.000	.000
CATTLE	0.51	.000	.000	.009	.044	.000	.089
TREES	.000	.000	.000	.000	.000	.000	.000
LABOUR	.266	.093	.081	.056	.089	.207	.160
OTHER	.044	.153	.147	.014	.007	.289	.016
FINANCING CAPITAL	.140	.155	.206	.100	.068	.088	.090

ANNEXE A (cont')

Netherlands (all regions)

Inputs	Share of inputs in the gross product of :							
	MILK	SUGAR BEET	POTATOES	CEREALS	BEEF	HOGS AND POULTRY	OPEN FIELDS VEGETABLES	HORTICULTURE
LAND	.022	.028	.010	.056	.068	.000	.001	.001
INTERMEDIATE CONSUMPTION	.323	.180	.113	.172	.595	.628	.374	.371
MACHINERY	.056	.112	.050	.114	.015	.007	.000	.000
BUILDING	.010	.000	.000	.000	.000	.019	.051	.018
CATTLE	.063	.000	.000	.000	.032	.019	.000	.000
TREES	.000	.000	.000	.000	.000	.000	.000	.000
LABOUR	.389	.227	.102	.125	.063	.123	.417	.340
OTHER	.019	.339	.637	.373	.066	.128	.055	.201
FINANCING CAPITAL	.118	.114	.089	.159	.161	.075	.102	.069

ANNEX A (cont') GERMANY (all regions, except for wine)

Inputs	Share of inputs in the gross product of :				
	Open field vegetables	Cereals	Poultry	Maize	Wine 1/
LAND	.064	.156	.000	.141	.014
INTERMEDIATE CONSUMPTION	.211	.235	.851	.348	.169
MACHINERY	.040	.137	.005	.176	.128
BUILDINGS	.000	.000	.031	.000	.003
CATTLE	.000	.000	.031	.000	.000
TREES	.000	.000	.000	.000	.006
LABOUR	.577	.107	.035	.156	.431
OTHER	.031	.203	.001	.030	.197
FINANCING CAPITAL	.077	.163	.046	.150	.052

1/ Only for rhenish palatinat

ANNEX A (cont') GERMANY (all regions

	Share of inputs in the gross product of :					
Inputs	Milk	Sugar beets	Potatoes	Hop	Beef	Hogs
LAND	.072	.071	.069	.017	.079	.000
INTERMEDIATE CONSUMPTION	.312	.252	.059	.255	.410	.565
MACHINERY	.070	.116	.065	.285	.084	.009
BUILDING	.014	.000	.000	.032	.000	.025
CATTLE	.017	.000	.000	.000	.000	.025
TREES	.000	.000	.000	.000	.000	.000
LABOUR	.428	.370	.320	.343	.335	.057
OTHER	.009	.101	.394	.008	.001	.273
FINANCING CAPITAL	.096	.090	.091	.077	.092	.047

ANNEX A (cont') FRANCE

1/ Activities common to all regions

Inputs	Share of inputs in the gross product of :						
	Potatoes	Open fields vegetables	Beef	Sheeps	Poultry	Cereals	Maize
LAND	.039	.041	.046	.053	.000	.072	.056
INTERMEDIATE CONSUMPTION	.476	.438	.473	.410	.753	.248	.256
MACHINERY	.167	.272	.199	.013	.020	.234	.214
BUILDINGS	.000	.000	.000	.008	.051	.000	.000
CATTLE	.000	.000	.030	.065	.051	.000	.000
TREES	.000	.000	.000	.000	.000	.000	.000
LABOUR	.200	.116	.121	.331	.029	.122	.126
OTHER	.017	.015	.011	.003	.001	.170	.215
FINANCING CAPITAL	.101	.117	.121	.124	.095	.154	.134

ANNEX A (cont') FRANCE

2/ Specific activities to certain regions

Inputs	Share of inputs in the gross product of :					
	Wine (southern)	Wine (plains)	Fruits (Southern)	Fruits (North)	Fruits (Mountains)	Hop (Northern)
LAND	.018	.013	.015	.013	.011	.011
INTERMEDIATE CONSUMPTION	.113	.076	.177	.164	.162	.227
MACHINERY	.058	.074	.071	.076	.104	.194
BUILDINGS	.011	.008	.000	.000	.000	.016
CATTLE	.000	.000	.000	.000	.000	.000
TREES	.024	.019	.028	.027	.028	.000
LABOUR	.659	.723	.341	.328	.323	.403
OTHER	.026	.009	.281	.304	.284	.064
FINANCING CAPITAL	.091	.078	.088	.087	.088	.086

ANNEXE A (cont') FRANCE

2/ activities specific to certain regions :

Inputs	Share of inputs in the gross product of :					
	Milk (Southern, Western, northern)	Milk (Plains, mountains)	Tobacco (Southern)	Hogs (West, plains, mountains)	Sugar beet (Northern)	Horticulture (Southern and Western)
LAND	.039	.040	.008	.000	.039	.002
INTERMEDIATE CONSUMPTION	.330	.335	.144	.623	.265	.027
MACHINERY	.110	.110	.000	.013	.139	.000
BUILDINGS	.015	.015	.000	.025	.000	.000
CATTLE	.029	.029	.000	.025	.000	.000
TREES	.000	.000	.000	.000	.000	.000
LABOUR	.378	.369	.674	.139	.350	.594
OTHER	.014	.014	.129	.106	.108	.332
FINANCING CAPITAL	.114	.116	.045	.067	.100	.045

ANNEX A (cont') ITALY

1/ Activities common to all regions

Inputs	Share of input in the gross product of :					
	Milk	Beef	Potatoes	Sheep	Tobacco	Wine
LAND	0.48	.050	.044	.106	.013	.019
INTERMEDIATE CONSUMPTION	.374	.674	.348	.081	.073	.035
MACHINERY	.103	.023	.092	.000	.009	.046
BUILDINGS	.009	.000	.000	.135	.000	.014
CATTLE	.018	.058	.000	.270	.000	.000
TREES	.000	.000	.000	.000	.000	.035
LABOUR	.369	.123	.281	.177	.837	.384
OTHER	.005	.003	.171	.005	.036	.397
FINANCING CAPITAL	.073	.070	.064	.226	.031	.070

ANNEX A (cont') ITALY

2/ Specific activities to certain regions

Inputs	Share of inputs in the gross product of :					
	Cereals		Maize		Open field-vegetable	
	Northern Central	Southern	Northern Central	Southern	Central	Southern
LAND	.096	.114	.063	.073	.029	.012
INTERMEDIATE CONSUMPTION	.212	.197	.188	.167	.175	.146
MACHINERY	.147	.217	.158	.130	.062	.035
BUILDINGS	.000	.000	.000	.000	.000	.000
CATTLE	.000	.000	.000	.000	.000	.000
TREES	.000	.000	.000	.000	.000	.000
LABOUR	.156	.355	.103	.121	.569	.777
OTHER	.279	.007	.399	.416	.117	.002
FINANCING CAPITAL	.110	.124	.088	.094	.049	.032

ANNEX A (cont') ITALY

2/ Specific activities to certain regions

Inputs	Share of inputs in the gross product of :								
	Olive			Horticulture		Sugar beet		Fruit	
	Central	Southern-Mountains	Southern-Plains	Central	Southern	Central	Southern	Central	Southern
LAND	.030	.044	.038	.002	.001	.044	.052	.023	0.16
INTERMEDIATE CONSUMPTION	.370	.094	.210	.171	.274	.229	.187	.092	.090
MACHINERY	.084	.000	.035	.004	.000	.115	.114	.043	.065
BUILDINGS	.000	.000	.000	.307	.128	.000	.000	.000	.000
CATTLE	.000	.000	.000	.000	.000	.000	.000	.000	.000
TREES	.046	.067	.058	.000	.000	.000	.000	.049	.045
LABOUR	.375	.726	.578	.284	.424	.373	.647	.519	.435
OTHER	.024	.015	.002	.035	.079	.174	.067	.206	.285
FINANCING CAPITAL	.071	.084	.079	.197	.095	.065	.067	.068	.064

A N N E X B

List of the function NEL

This APL function performs the computations described in chapter 3. The result R is the matrix R defined in equation (III.2.16), the parameter X is the matrix with I rows and J columns of the x_{ij} coefficients. The function requires the initialization of the following variables.

RJ : a vector of J elements containing the values of the ρ_j's of equation (III.2.1).

S_1, S_2, S_3, S_4 : four vectors giving the row numbers of X corresponding to the four sets S_1, S_2, S_3, S_4 defined after equation (III/2/3) for S_1 to S_2 and equation (III.3.5) for S_4.

TI : a vector with I elements, giving the duration of each inputs, as defined in equation (III.3.1).

ALPHA : a vector with I elements, giving the coefficients α_i as defined in equation (III.3.5) ALPHA k is a scalar, giving the same information for capital.

BI : a vector with I elements, giving the coefficients β_i defined in equation (III.1.4).

MC : a scalar giving the coefficient L defined in equation (III.3.6).

BK : a scalar giving the supply elasticity of financing capital defined in the comment of the equation (III.3.3).

PK : a scalar giving the interest rate of capital p_k (with $p_k \leq 1.0$) as defined in equation (III.3.1).

As a sideproduct of this function, one may obtain :

M : the product of the inverse of matrix M defined in equation (III.2.10) by the matrix G defined below.

G : matrix G defined in equation (III.2.10).

E : matrix E defined in equation (III.2.14).

XI : vector $x_i = \sum_j x_{ij}$

XIJ : vector containing all non zero elements x_{ij} of X.

IN : vector containing the i's corresponding to each cell of XIJ.

JN : vector containing the j's corresponding to each cell of XIJ.

NI : value of I (number of inputs).

NJ : value of J (number of outputs).

```
      ∇ R←NEL X;M
[1]   R←ρX
[2]   PIS←X+.×PJ
[3]   PI←PIS×(1+PK×TI)
[4]   NI←R[1]
[5]   NJ←R[2]
[6]   X←X×((NI,NJ)ρPJ)÷(⍉(NJ,NI)ρPIS+PIS=0)
[7]   XI←+/[2]X
[8]   X←X×⍉(NJ,NI)ρ(1-SF)
[9]   R←(,X≠0)/ιρ,X
[10]  XIJ←(,X)[R]
[11]  NIJ←ρXIJ
[12]  NN←NIJ,NIJ
[13]  N←ιNIJ
[14]  JN←(,((NI,NJ)ριNJ))[R]
[15]  IN←(,⍉((NJ,NI)ριNI))[R]
[16]  R←(1+RJ[JN])÷XIJ
[17]  SM←1+(ρS3)+NIJ
[18]  M←(SM,SM)ρ0
[19]  I←N∘.=N
[20]  M[N;N]←(I×(NNρR))+(NNρ(PI[IN]÷(BI[IN]×XI[IN])))×(NNρIN∊S2)×(IN∘.=
[21]  M[N;N]←M[N;N]-(NNρ(RJ[JN]+1)×PI[IN]÷PJ[JN])×(JN∘.=JN)
[22]  M[N;NIJ+ιρS3]←(IN∘.=S3)÷⍉((ρS3),NIJ)ρPI[IN]
[23]  M[NIJ+ιρS3;N]←S3∘.=IN
[24]  M[SM;SM]←-+/PIS[IN]×XIJ×TI[IN]×BK
[25]  M[SM;N]←(TI[IN]×PIS[IN]÷BI[IN])×IN∊S2
[26]  M[N;SM]←TI[IN]÷(1+PK×TI[IN])
[27]  M[SM;N]←M[SM;N]+((1,NIJ)ρPIS[IN]×TI[IN])
[28]  R←(NIJ-SM)↑(+/[1]M)≠0
[29]  M←((+/[1]M)≠0)/[2]M←((+/[2]M)≠0)/[1]M
[30]  SM←(ρM)[1]
[31]  E←(NJ,SM)ρ0
[32]  E[ιNJ;N]←(ιNJ)∘.=JN
[33]  E[ιNJ;N]←E[ιNJ;N]×(NJ,NIJ)ρPI[IN]÷PJ[JN]
[34]  G←(SM,NJ)ρ0
[35]  G[N;ιNJ]←JN∘.=(ιNJ)
[36]  M←(⌹M)+.×G
[37]  DP←M[NIJ+ι(SM-NIJ);]
[38]  SS3←(¯1↓R)/S3
[39]  DP←DP÷⍉(⌽ρDP)ρPI[SS3],PK
[40]  DR←(((IN∊S2)×PIS[IN]÷BI[IN])+PIS[IN])×(IN∊S4)×ALPHA[IN]
[41]  DR←(DR,((¯1↓R)/((S3∊S4)×ALPHA[S3]×XI[S3])),ALPHAK)+.×M
[42]  R←(+/ALPHA[ιNI]×XI×PIS×(ιNI)∊S4)+ALPHAK×PK×PIS+.×XI
[43]  R←(E+.×M),[1](DR÷R),[1]DP
      ∇
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Relationship between milk production and price variations in United Kingdom and Ireland

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Contents

Tables

CHAPTER ONE

Introduction

Our main purpose is to assess the effect of reduced milk prices on milk production. If the cut were large enough it would clearly eliminate most milk output: some unmarketed production would remain especially in milder grazing areas in association with raising cattle. Over a large enough price range the elasticity of supply downwards must exceed one. In the context of an E.E.C. surplus which may be of the order of 17%,* and tending to grow (if real prices are held constant) no one is envisaging such extreme measures. We might consider price changes sufficient to reduce or eliminate the surplus, but even then we would argue that it is more important to prevent the surplus rising to 19% or to reduce it to 15% than it is to reduce it from 7% to 5%. The accent will tend to be on estimating marginal effects of price changes often assuming by implication that the effects of price changes are similar in different circumstances unless they are shown to differ.

The price may be cut directly or by default in an inflationary situation and the effects are always in a sense unique to each situation. But a degree of continuity is to be expected and we would even argue that price effects measured in periods of rising milk prices were partially relevant. Upward trends due to technical change and other factors have been experienced and are still anticipated and these are doubtless the main reason for confusion about the upward and downward effects of price changes. But it is equally difficult to be certain that these trends are continuous and again each situation is somewhat special.

* This was reported as the view of the Commission and others (19 vol. I, paras 19 and 20). We do not think it meaningful prior to the analysis to attribute this surplus to member countries either in a static or dynamic sense. Taking a fair competition viewpoint we would suggest that the local supply and demand schedules must be known and the "proper" price differentials between regions before the "proper" net trade for any country or region can be specified. The local surplus is merely a gap between local observed supply (less local consumption) and what is considered "proper" whatever normative viewpoint is adopted.

After consideration of long term changes in table 3 it is difficult to attribute much increase in production to increased prices in the U.K. or Ireland. Indeed it may be argued that prior to E.E.C. entry the rise in production led to reductions in price. Over 1960-65 and 1973-77 the higher growth rate in Irish output might be attributed to higher growth rates in prices. One might expect a higher growth rate at given prices in Ireland as the technological basis was originally less intensive, but the data is difficult to interpret. The time series for dairy cows has been revised (see table 3A) and we may point out that the milk deliveries per creamery cow (which is perhaps a firmer statistic than some others) has risen substantially while the estimated milk production per dairy cow has not risen much until recently.

We might loosely interpret the effect of a fall in milk prices as taking other prices constant except to the extent that they are expected to fall consequent to the fall in milk prices. This distinction seems necessary as the price of milk is a reward for all factors engaged in milk production, it is not merely a reward for the dairy farmer. If the price of any factor is held constant while the milk price falls (dairy cows, land etc) then by implication the supply of that factor is being regarded as highly elastic. It is easier to envisage this at an individual farm level than in a competitive industry. Proceeding to a higher degree of aggregation by county, by country and for the E.E.C. as a whole we expect the elasticity of supply of inputs to fall because there is less room for arbitrage. In like manner the supply elasticity over time is affected by similar considerations. As the period shortens the supply elasticity for inputs falls, the effect of a price cut in milk on inputs will be greater and more obviously the effect on the shadow price of committed inputs. Apart from any slowness on the part of the farmer to respond he may properly respond slowly at first. Situations or analyses in which prices of inputs are regarded as constant tend to produce larger elasticities of supply than situations where the quantities of these inputs are supposed constant.

The same principle applies to prices and quantities of alternative products. If price levels of these products are regarded as fixed at protected levels the diversion of resources from milk is not limited. But if production of (say) sugar or potatoes is limited by quota or inelastic demand the resource transfer is also restrained. We accept the idea that the price elasticity of supply for milk may be estimated as if other product prices were being held constant on the understanding that in particular circumstances it would not be possible to achieve this. For instance if

E.E.C. prices for milk were reduced some alternative product prices for say beef and cereals may be held through support arrangements, but they might be weakened a little and it is difficult to envisage rigid prices for all alternative products.

It is useful to have a price signal that works quickly to reduce a (milk) surplus. We will subsequently be summarising our view in terms of a sequence of effects leading up to what is substantially an estimate of a long run elasticity of supply. But in practice these effects must depend upon farmers' expectations in a specific situation. Some may regard the existence of a surplus as grounds for pessimism. Some farmers may take a reasoned view that others will have to drop out first and plan to remain in production albeit at reduced prices. A sustained change in price should carry with it a similar change in expected price. But in some measure the knowledge that prices will be used to reduce a surplus is critical. If price is to be used as a major instrument expectations may run ahead of price cuts. If it is possible that other instruments are to be relied on - especially quotas - the price expectations may well lag behind the price cuts and the effect may well be delayed.

A General Review of the Literature

Relevant literature is by no means confined to studies which provide an explicit estimate of the supply elasticity. For instance the experimental studies (1,2,3,4,15,16,37,38 and 44) do not provide estimates even when associated with a full economic appraisal (44) but they become relevant to estimation of the effect of milk prices on cow yields because they consider the (curvature of the) effect of concentrate inputs on yield. Viewed in a particular normative manner they produce price-elasticities for yield. In like manner "neutral" evidence about the breakdown of production costs into fixed and variable elements (9,17,28,36) handled in a particular way with assumptions about the form of the production function can be used to draw normative conclusions about the elasticity of supply. According to the method of analysis used by Holmes (18) any frequency distribution of milk costs is relevant to supply analysis enabling an opinion to be formed of the manner in which farmers may be edged out of production as prices fall. Studies of the elasticity of demand for inputs like feed (8,26,42) and fertiliser (41) are somewhat relevant even when it is not always possible to identify exactly the dairying element in these studies.

It is not our purpose to establish the relevance of bibliography here. It will be considered step by step as different methods are considered in

Chapter II. We can point to two linear programming examples (7 and 26) which suggest the overall supply response might be of the order of 1.3, but the implied time horizon is rather unclear. There are rather a lot of econometric studies for the U.K. based upon time series analysis (12, 13, 14, 21, 22, 23, 24, 45, 46) which usually use methods which enable the short and long run effects of a price change to be distinguished. The long run effect of milk prices on dairy cow numbers does vary somewhat from study to study as the time series unfolds and as methodology changes, but we think it would be misleading to stress conflicts in the estimates. We would regard them as supporting a long run elasticity for dairy cows of .7 or even more and as a result of the most recent analysis (46) we are inclined to put the question of the existence of a substantial response as beyond doubt. For Ireland estimates of the order of .3 for the elasticity of (dairy) cow numbers with respect to prices appeared quite firm and quite consistent across many studies (5, 6, 13, 25) but no great effort was made to separate short and long run aspects of price changes. Revised data and new analyses (10) have if anything made the results seem less certain and drawn attention to the intrinsic difficulty in separating the effects of price and the effect of trend in Irish time series.

Analysis of the effect of price on yields from times series in the U.K. by Wildgoose (quoted in 24) and Rayner (45) led to estimates of price elasticities which are not very strong but they are consistent with analysis of experimental results (table 6A) and we again consider it would be misleading to stress differences between them. The results suggest that the yields may respond to prices with an elasticity of the order of .25 but the range of uncertainty is quite wide. Comparison of European data by Williams (39 diagram 4) suggests that a rather greater elasticity of yield in relation to the milk feed price ratio may prevail but clearly this relationship is not intended to be very precise.

To my knowledge no attempts have been made to isolate the downward effect of price changes on production from time series. The linear programming studies (7 and 26) indicate somewhat sharper responses to price cuts than to price rises, but we do not regard the differences as very significant.

Structural Arguments and Recent Events

There are several obvious features relating to dairying in both countries which could affect the response to price. In Gt. Britain the market has been strongly integrated: very similar prices have prevailed everywhere with minimal regard to transport costs and utilisation. Prices have varied

Table 1 Regional Variation in the % of Winter Milk E & W 1978-9

Northern	North-west	Eastern	East Midlands	West Midlands	North Wales	South Wales	Southern	Midwest	Far West	South East
47.8	48.3	50.8	49.6	47.2	43.8	43.4	50.7	48.5	46.2	50.3

Variation in % Winter Milk within the UK 1977-8 / Ireland

England & Wales	Scottish M.M.B. (South/West)	Aberdeen & District (North East)	North Scotland	Northern Ireland	Ireland: Creamery Supply	Ireland: Total Supply
48.2	47.4	48.3	46.7	42.4	19.5	(24.3)est.

Calculated from data in the Milk Producer and quoted from "Dairy Facts and Figures" 1978.

Ireland Creamery supply from C.E.C. Monthly "Meat and Dairy Produce" total % winter milk for Ireland estimated approximately.

Table 2

Distribution of Dairy Herds in U.K. and Ireland

Herd SIZE	U.K. June 1975 % of herds	U.K. June 1975 % of cows	Ireland Dec. 1973 % of herds	Ireland Dec. 1973 % of cows	Ireland Dec. 1977 % of herds	Ireland Dec. 1977 % of cows	England & Wales 1972/3 % of herds	England & Wales 1972/3 % of cows	England & Wales 1976/7 % of herds	England & Wales 1976/7 % of cows
under 10	14.8	1.4	63.9	22.3	58.5	16.3	Not quoted		Not quoted	
10-29	29.9	13.4	26.9	44.7	30.8	40.8	43.4	31.8	31.8	12.2
30-49	23.8	21.3	5.2	19.2	7.7	22.9	27.7	28.5	28.5	21.4
50-99	24.2	38.2	(	)	3.2	15.9	23.4	29.7	29.7	38.3
Over 100	7.3	25.7	(1.9	13.7)	.4	4.1	5.5	19.9	10.0	28.1

U.K. June Census Agricultural Statistics 1975 — Irish Statistical Bulletins March 1976 and December 1978 — England & Wales: Milk cost enquires Milk Producer July 1978

Distribution of Dairying by size of Farm in Standard Man Days England & Wales

Farm Size 1971 June Census	275-599		600-1199	1200-1799	1800-2399	2400-4199	Over 4200	175 and over	
Specialised Dairying	28)		26	19	11	6	2	13	
Mainly Dairying 1975 June Census	13)	as % of holdings in size group	16	18	17	12	6	8	% of dairy cows
Specialised Dairying	24))		30	26	18	10	4	14	60 (out of 97%)
Mainly Dairying	9)		12	15	16	14	8	7	26 " " "
% of dairy cows all types	15	as % of "all dairy cows"							
Dairy cows as % of standard man days all types	21	as % of "labour needs" in each size group	25	23	20	15	7	18	

% Contribution of Dairying to Farm Output by Farm Size (Hectares) in Ireland

Farm size	2 - 6	6-12	12-20	20-40	40-80	80 and over
1966/7	39	32	36	38	40	30
1976	29	27	38	47	46	28

Farm Classification England & Wales 1971 and 1975

Farm Management Survey, Dublin quoted Kearney

Table 3

Measures of Production of Milk in UK and Ireland

	Dairy Cows: Dec '000s UK	Dairy Cows: Dec '000s Ireland***	Dairy Cows Milk Production UK	Dairy Cows Milk Production Ireland '000 tonnes	Yield/Dairy Cow UK Kg/cow/year	Yield/Dairy Cow Ireland Kg/cow/year	Dairy Deliveries UK '000 tonnes	Dairy Deliveries Ireland '000 tonnes	Out-put (ex feed) UK '000 tonnes	Out-put (ex feed) Ireland '000 tonnes	Output per dairy cow Ireland	Index of Real Price* UK	Index of Real Price* Ireland
1959	3175	757										130	92
1960	3283	774	11454	2746	3608	3627	10470	1672	11156	2382	3147	125	99
1961	3364	791	11966	2862	3645	3698	10937	1743	11651	2441	3154	120	96
1962	3410	833	12266	2963	3646	3746	11254	1838	11973	2533	3202	114	93
1963	3368	861	11904	2979	3491	3576	10937	1904	11605	2543	3052	109	95
1964	3260	916	11647	3091	3458	3590	10713	2038	11402	2629	3053	114	97
1965	3271	995	12019	3236	3687	3533	11188	2196	11773	2718	2967	116	94
1966	3251	1029	11868	3329	3628	3346	11083	2304	11648	2696	2622	112	93
1967	3301	1085	12236	3565	3764	3465	11486	2567	12034	3030	2945	111	98
1968	3358	1164	12532	3781	3796	3485	11812	2799	12344	3226	2973	108	95
1969	3309	1152	12650	3795	3767	3260	11953	2835	12438	3222	2768	103	88
1970	3337	1124	12870	3742	3889	3248	12202	2791	12667	3159	2742	99	83
1971	3347	1180	13204	3853	3957	3428	12557	2891	12998	3244	2886	102	84
1972	3482	1182	14067	<u>4054</u>	4203	<u>3436</u>	13433	3062	13829	3402	2883	102	94
1973	3545	1389	14316	3566	4111	3017	13693	3149	14121	3466	2932	98	105
1974	3387	1344	13913	3436	3925	2474	13315	3045	13733	3366	2423	106	107
1975	3249	1300	13856	3699	4091	2752	13324	3308	13755	3591	2671	117	114
1976	3318	1353	14384	3858	4427	2968	13831	3608	(14261)	(3858)	2967	115	108
1977	3327	1484	(15200)	(4151)	(4581)	(3069)	(14644)	(3890)	(15074)	(4152)	3068	113	128
1978	(3389)	1513	(15920)	(4673)	(4785)	(3148)	(15329)	(4463)	(15759)	(4673)	(3148)	102	130
% trend per annum												Trend for prices over last two harvest years**	
1960-77	.1	3.8	1.7	2.4(3.4)	1.4	-1.0(0.2)	2.0	5.0	1.8	3.3	-.1	-.6	1.2
1960-5	-.1	5.0	1.0	3.3	.4	- .5	1.3	5.5	1.1	2.6	-1.2	-2.0	1.0
1965-73	1.0	4.2	2.2	1.2(3.2)	1.4	-2.0(-.4)	2.5	4.5	2.3	3.0	- .1	-1.7	-.8
1973-77	-1.6	1.6	1.5	3.8	2.7	.4	1.7	5.3	1.6	4.5	1.1	3.3	5.5

Irish data contains a large discrepancy - between 1972 and 1973, bracketted trends exclude it.

Data is mainly from EEC dairy statistics "Milk and Milk Products" 1977, recent figures are spliced from other sources or estimated. It seems possible that the output of Irish milk cannot all be attributed to dairy cows from 1960-68. Yields are related to cows last December. Deliveries per cow trended upward (see table 3(A)).

* Price in harvest year ending in current year ÷ retail price index of last year. Trends are for last two harvest years, e.g. 1975-6 and 1976-7 assumed to affect cows in Dec. 1977. Figures for Ireland relate to current calendar years.

** Last two calendar years for the Irish Data.

*** Revised series (see Table 3(A)).

Table 3A

Adjusted Estimates of Cow Numbers and Their Components in Ireland in '000s in June

Year	Policy* Variables	Beef	'House'	Liquid	Creamery	Dairy Cows	Total Cows	Creamery Supply Gallons Per Creamery
1953		120	170	130	754	1,054	1,174	308
1954		132	165	135	772	1,072	1,204	311
1955		126	162	142	768	1,072	1,198	309
1956		109	157	137	784	1,078	1,187	333
1957		133	152	136	815	1,103	1,236	354
1958		153	150	140	817	1,107	1,260	337
1959	-.2	180	145	154	793	1,092	1,272	310
1960	-.6	201	142	143	798	1,083	1,284	351
1961	-.7	187	138	144	822	1,104	1,291	368
1962	-.6	190	134	143	842	1,119	1,309	382
1963	-1.0	177	130	146	870	1,146	1,323	385
1964	+.3	216	125	140	919	1,184	1,400	391
1965	+.8	300	123	140	984	1,247	1,547	398
1966	+1.0	293	116	149	1,024	1,289	1,582	401
1967	+1.0	221	109	149	1,089	1,347	1,568	428
1968	+1.0	230	103	145	1,129	1,377	1,607	455
1969	-.5	286	98	145	1,128	1,371	1,657	463
1970	-.5	387	92	150	1,084	1,326	1,713)	470
1971	-.2	450	90	150	1,104	1,344	1,794)	480
1972		490	85	150	1,195	1,430	1,920)	471
1973		651	82	150	1,255	1,487	2,138)	477
1974		732	80	150	1,246	1,476	2,208	459
1975		637	78	150	1,237	1,465	2,102	505
1976		547	76	150	1,274	1,500	2,047	530
1977		537	70	150	1,333	1,553	2,092	552
1978		502	66	150	1,378	1,594	2,096	618
1979		484	64	150	1,410	1,624	2,108	
Trend					Percentage per annum			%
1960-77					3.2	2.3	2.9	3.3
1953-79 (or 78 for last col.)					2.4	1.7	2.3	2.8

* Artificial policy variable Calved Heifer Scheme T.B. Eradication Two-Tier Milk Price

Source: Brenden Kearney

Policy variable constructed by me - see below footnote page (17) seasonally, but seasonal differentials have tended to fall over time especially since entry into the E.E.C. Taking season into account prices in Northern Ireland are roughly comparable, but the price trends have differed at times. Elsewhere in Ireland supplies for the liquid market have generally sold at a substantial premium, while producers in some outlying areas have probably been at a disadvantage through distance from (more profitable) creameries. The protection of the liquid milk market has been implicit in contracts within a milk shed, the protection of the manufacturing market has been explicit through state support and more recently through support of milk product markets within the E.E.C. Since 1969-71 the premia* on milk sold for liquid consumption has dropped substantially.

In Great Britain the bulk of the production is for liquid consumption and autumn calving tends to predominate (see Table 1).

The seasonal troughs tend to occur in July and August rather than in the winter months. By contrast spring calving predominates in Ireland and the proportion of winter milk is much lower. The relevance to the supply response for milk is two-fold. First there is a presumption (but little more) that milk yields over summer are less sensitive to price because there is less hand feeding to adjust.** Second there is a strong association between the % of winter milk, overall yields and the input of concentrated feed (35, page 32, and 49). The observed pattern is not only due to climate, current prices of milk by season and current feed prices, but depends also on a long history of prices and milk use. In the U.K. there may be a slight trend toward less winter milk. In Ireland without explicit (price) check one would expect to see less milk fed to livestock, more concentrates fed to dairy cows, more winter milk and higher yields.

There is a large difference in the typical herd size in the two countries and in both countries the structure is changing quite fast. Kearney (25) shows that dairying has not been very strongly associated with small farms in Ireland and is if anything becoming associated with medium to large

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* Following the apparent average implicit unit values from the Agricultural Output Series the premium dropped from 28% to 4% in 1976-8. More recently a premium of 10% was regarded as "inadequate" in the Dublin area.

** For summer milk there is more discretion about feeding to livestock;this is clear in the analysis of supplies per creamery cow given below in Table 5(C).

farms. In Table 2 the distribution of dairy "standard man days" by SMD per holding still appears to suggest that dairying is rather more important on smaller farms. But many more herds over 100 cows have been formed recently. The implications for supply response are none too clear. Where the larger farmers engage in dairying among other activities they may well be more flexible in their response to price. But the trends are not going that way - they are toward large scale specialisation involving a very heavy load of committed capital. The salient features associated with large herds are silage making, heavy nitrogen applications to grass and milking in buildings other than cowsheds (49 tables 7,18 and 19) with less labour per cow (28 table 2). These may introduce more of one factor (N) which might be regarded as somewhat flexible and a somewhat more flexible attitude to another (buildings); but perhaps the most remarkable point is that over time there has been a rapid pickup of these "large farm" practices. Half the cowsheds, which one conveniently thinks of as fixed and fairly specialised pieces of equipment, were being ignored or converted to a somewhat different use between 1972-3 and 1976-7 (33). The use of more of hired labour per cow is associated with larger herds cross sectionally but not over time. From 1960-78 the number of registered milk producers in the United Kingdom fell by about 4½% per annum. Even allowing that unhelpful weather may have accelerated this trend over 1973-6, there is no evidence of it moderating. A rather larger proportion leave each year and they are generally disbanding herds which are below the average size. But that does not mean that their establishments make little contribution to production. Before there was any question of incentives to get out of dairying (over 1963-4 to 1972-2 England and Wales) about 33% of the cows originally in the national herd were probably in herds whose producers subsequently dropped out of production (29 and 30). In relatively few cases did production start up on the same farm with a new producer in control. We may infer that by 1971-2 at least a quarter of the milk production depended on investment decisions to commit new capital to dairying and (to a lesser extent) new land and new labour. The distinction between the effects of a rise in price and a fall in price, or between expansion and contraction, is somewhat blurred. Any cut in production that policy might have required could in principle have been achieved by moderating the enthusiasm of producers who were starting up or expanding their herds. It is clear from recent data that the margin between the size of herds leaving and herds staying remains and that the order of magnitude of turnover of herds in terms of cows is similar. O'Dwyer (40) shows a rather sharper emphasis on small herds among producers leaving the Co-operative Creamery herd over 1960-65 with cows in outgoing herds near 10%. More recently the rate of decline in number of dairy herds* in Ireland was about 4% p.a. over 1973-7 compared with a decline in producers of 6% p.a. in the United Kingdom.

Expanding herds had rather less followers than other herds and were in a sense relying on replacements (and land) from other herds to expand (30). The perceived incentive for that sector to expand would not need to be so big as it would need to be for the national herd to expand in unison. This may in part explain one problem associated with the years 1974 and 75 where both inflow and outflow appeared to rise together in association with a contraction of the U.K. dairy herd.** Expanding herds may have preferred a heifer inflow and had little difficulty in getting it when it was difficult to finish young cattle adequately due to shortage of keep. A more common suggestion offered for the ease with which herds expand under pressure is that they are forced perhaps through difficulties to take up technological slack. A partial answer to this argument is given by the Production Division of the M.M.B. where they relate the financial overhead charges to technical performance, albeit over a rather small sample of 112 farms.

Table 4 Financial Charges per Hectare and Performance

charge £/Ha	0-29	30-59	60-89	90+
Herd Size	91	86	109	115
Concentrate/cow kgs	1818	1727	1743	1855
Yield/cow litres	4723	4613	4599	4697
Livestock Units/ha	1.81	1.98	1.99	2.01
Nitrogen/ha	146	198	215	174
Gross Margin/cow £	247	227	219	209
Gross Margin/ha £	447	450	435	420

M.M.B. "Breeding and Production" 1977-8, page 38.

* The drop in the number of creamery suppliers was 3½% over this period and nearer 3% over 1964-77 (10).

** Unfortunately some relevant inflow data was considered unreliable over the period due to statistical changes.

It is not a complete answer, there may be a two-way association between debt and efficiency, one in which inefficiency leads to debt and another in which debt leads to efficiency: there is also a probable association of both with age. But on the face of it the argument that a shortage of funds will produce efficiency looks rather weak. One might expect the effect of shortage of funds on investment to be more relevant in considering the supply response to price. I did try to approach the matter through tracing the consequences of unsystematic "windfall" income variation in an identical sample of farms in England and Wales over the period 1958-9 (23 especially table 6). I considered that a stream of £1 income on specialist dairy farms might lead eventually to a rise of £1.1 in capital stock, while on mainly dairy farms it might lead to a £1.6 rise in capital stock. About a third of this investment would be almost immediate and about a half of it would be in livestock. The method was chosen in order to try to separate the effects of income and price incentive. It was also shown that expenditure on fertiliser would be affected modestly by last year's income on dairy farms (much more than on farms in general).

The question of the role of income in modifying the role of price in affecting dairy cow numbers is considered generally by O'Connor (43 page 66). He regards the factors associated with additional income (per farmer) whether it is price, productivity or reduced agricultural population as responsible for a shift from an attitude of survival to one of expansion. While proposals were afoot to tax the agricultural sector more heavily the responses of creamery suppliers have been elicited (47). In the context the responses should not be taken at face value, but suggest that larger farmers may be less willing to expand dairying than other sectors as a result. One might infer that if it were only a question of more tax the implied effect of income on dairying would be positive. But it is also a shift toward taxing marginal income (from investments) more heavily compared with the old system which was more like a tax on potential income. The impact is no less apparent where farmers are paying off heavy debts. It is difficult to infer that Irish farmers would be squeezed into more dairying by lower prices. On the other hand family responsibilities would appear to be associated with larger herds.

Two other recent changes in the U.K. deserve some mention. First the reaction to the rise in feed prices from 1972-3 to 1974-5 appeared in aggregate to be a normal response of about .5 with respect to the milk-feed price ratio. This may have been an underestimate in that very many farmers appear to have increased concentrate use over the same period, many of them to compensate for inadequate supply of other feed or inadequate quality (49). Over two subsequent drought years 1975-6 and 1976-7 consumption of concentrates rose, especially in 1976-7 when yields and profitability recovered sharply. The present levels of concentrate use may be high enough to suggest a permanent change toward a more general use of concentrates in dairying. Changes do not in general look as though they can be tied simply into the milk/feed price ratio. Rather more general studies of the elasticity of demand for feed and fertiliser in Ireland suggest immediate elasticities of demand of the order of a half for feed and nitrogen given livestock numbers (41 and 42). Second, one may note that the commonly held belief that yields in the U.K. were tending to a saturation level or that upward trends were moderating can be discarded. Special considerations may be adduced to help explain the sharp recovery over the last few years. One is the unusually high outflow and replacement rates over 1973-76. Another the possible shift in feed practice referred to above. But the contribution of breeding to improved yields has by no means exhausted itself and may well have increased over time. The view taken here is that the changes in technology and the rapid structural changes make it more difficult to estimate and isolate the effects of price, but if anything they make the impact of price more relevant and more immediate.

CHAPTER TWO

Milk Supply Responses Estimated by Various Methods

Frequency Distribution of Costs

The main emphasis has been on econometric work on time series, but there are other methods. Perhaps the simplest(especially where a reduction of prices is involved) is to look at a cost distribution of producers given on a full cost basis and compare it with the milk price. If the milk price falls how many herds are made unprofitable and for what proportion of the milk supply are they responsible? The presumption is that only the herds with negative profits are on the way out or that any errors in this assumption balance out. This method was used by Holmes (18) as a part of his analysis of a milk supply schedule for Scotland. Applied to 1972-3 data (35, table 3.6) it gives the following kind of answer. Returns per gallon of almost 25 pence including the return on the calf have varied very little among producers. About 15% of the herds responsible for about 5% of milk production appeared to have no net margin. It is not unreasonable to assume that these herds were mostly on the way out, though "inadequate margins" are not usually quoted by outgoing producers as "the" reason for quitting. M.M.B. Breeding and Production Reports for 1976-7 and 1977-8 only report 3% of the farmers as giving this as the reason for leaving, but near 30% quoted a "change in farm policy" which could mean "inadequate in relation to opportunity cost". Arguably if the returns had risen to 30p per gallon these producers would have stayed in production and many more become interested in starting. About 10% of milk production was in the hands of producers with costs between 21 and 25 pence per gallon so that if milk prices had been cut by 4 pence a gallon on the average price of 20.7 pence one would expect an elasticity of supply of about .5. For these marginal farms the minimum average cost and the average cost must be very close unless farmers improve their technology under threat. Holmes also used some rather tenuous assumptions in sequence about the form of the cost schedules on individual farms to derive a supply elasticity of approximately 1.0. We would agree that there should be something to add for the supply response on non marginal farms but really the only thing that the cost information reveals is that the elasticity of supply should be somewhat more than .5 on the way down.

Obviously the method is subject to countless objections. The way costs are measured may fail to reflect the opportunity costs for individual farmers. The cost distribution for a single year may be far more extreme than the normal cost distribution: the random component of income distribution on specialist dairy farms could well be as high as 40% of the mean.* There is no allowance for normal profits in the estimation of cost. The method is essentially long term in that all costs are taken as perfectly variable, but only on farms where dairying is marginal. Assuming that over a span of years the price is not absurdly remote from the frequency distribution of full costs properly estimated, and given that that frequency distribution is somewhat denser than the one quoted for a single year, one might well

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* Over 1958-69 on an identical sample of farms who were classified as specialised dairy farms in 1970 we obtained a standard deviation of the random component of income equal to 44% of the mean but some of this variation could be due to a change in farm type over the period. It excluded variation of income between farms and between years (23).

well argue that the estimate of the long run elasticity quoted above would be too low and that this method should lead to an elasticity due to a reduction of the number of dairy farmers involved in excess of .5 for downward movements in price (holding costs constant). It may be a childish method, but are the others to be preferred?

Linear Programming

We are aware of two examples where programming techniques have been applied to estimate a supply reponse to milk prices in England and Wales and of one model which may be adapted to such a problem in Ireland (9) which has not yet (to my knowledge) been applied to a typical maximisation problem with or without variable milk prices.

The study by Cason (7) related to a specialised dairy region. Farms were grouped (A) by resource constraints specific to dairying at high and low productivity levels for labour; capital ceilings were determined after enquiry on borrowing limits considered reasonable by the farmers themselves. They were also grouped (B) by land-labour ratios. Six modal farms were used in both cases. The target period was a few years ahead but no reinvestment out of profits was allowed for so the elasticities derived might be considered medium term. At current prices and without special restraints on resource use dairying was reduced drastically in the optimal solution. The reason for this is not clear, labour was not specified seasonally but most of the alternative enterprises were livestock enterprises so this may not have been a serious error. Perhaps the farmers took a different view of the potential profitability of the other enterprises which suggests that elasticities should be derived in a range including a false milk price (P) necessary to call forth the current milk production. We quote three elasticities for a range of 6 old pence per gallon including P but fixed mainly below it. The observed price then was 37 old pence per gallon.

First without restraints on resource use, and with modal farms grouped as under A above, an elasticity of 3.0 is obtained with a value P = 44. Second with constraints designed to prevent the outflow of labour then in dairying for beef production, with modal farms grouped as under A, an elasticity 1.0 is obtained with a value of P = 40. The author appears to prefer this solution. Third with farms grouped as under B by labour-land ratios, an elasticity of 1.3 is obtained with P = 41. Any response of milk yield to price was ruled out by definition of the activities. The elasticities 1.0 and 1.3 might be regarded as medium run and restricted by a largely psychological preference for dairying.

Even though the author identifies sharp differences in labour productivity between his modal types, he uses normative improved labour productivity levels in his target period. Certainly for our purposes it would have been better if he had run the program with % or simple increases on the observed productivities in each modal type. In spite of some different comments by the author we consider that because the program specifies a fixed ratio between followers and dairy cows it is more like a supply elasticity for a nation rather than a region within a nation that can adjust its inflow policy independently. The author permits expansion by purchase of cows, but this only raises problems in the transition period which is not a part of the results quoted. For the target period the replacement problem solves itself.

The Newcastle model is a larger scale model covering a lattice of farm types across England and Wales. It was originally designed for medium-long period forecasting (13). The capital constraints especially were considered too binding and modifications were introduced to allow realistic borrowing and use of a part of farm income for reinvestment. The model now uses a two period time horizon where adjustment problems in the first period are cleared while maximising returns over the second, recurrent time period. The model can be used iteratively to produce an adjustment time path and it can also be used more statically to produce a single year solution. The main application relevant here is that by Longmire (26). The full model uses 48 farm types of which 42 might be considered relevant here. The parametric programming with prices appears to have been limited to 10 farm types only to save computer time - the extent of dairy farming in the optimal solution is increased substantially by this simplification. In the solutions in which the milk price varies from 50-150% of the 1970-1 level in graduated stages (26 page 395) the elasticity response of milk production over the whole range is 1.42 and the elasticity of cow numbers is 1.33. Yield variation is irrelevant except at very low prices. In the immediate neighbourhood of the 1970-1 price we have elasticities of 1.30 and 1.21 respectively. The % winter milk rises modestly from 43% at a price level of 50% through 46% at 100% to 52% at 150%. Beef production is reduced substantially over the wide range of milk prices (elasticity -.57) but scarcely at all within the range 80%-120%. But beef production appears to fall modestly if milk prices fall by 20% and again to fall modestly if milk prices rise 20%. By contrast milk production appears to rise steadily with beef prices(with an elasticity of + . 14.) What actually happens over period 1 (the adjustment period) is unclear as the solutions are not quoted.

It is assumed that prices of inflow heifers are raised proportionately in response to milk prices which increases both the capital load and the expense of adjustment in period 1.* The ratios of dairy cows to followers are again constant in the target period 2 so the long run replacement problem looks after itself. This price assumption is reasonable and implies that the supply elasticities of the rearing sector in response to heifer prices and the dairy sector in response to milk prices are similar. The major constraining factors for expansion of dairy production are family labour and medium term capital. Borrowing ceilings are fixed as 50% of tenants capital (and buildings) so the relationship between milk prices, beef prices, capital costs and availability are somewhat complex. These problems are probably linked to the paradoxical unsymmetry of the effects of beef prices on milk production and milk prices on beef production. Fortunately this paradox presents fewer difficulties within a realistic price range.

The insensitivity of yields to milk price (and their still great insensitivity to feed prices) suggests an error in the specification of the model. Activities with different yields are allowed, but the cost of securing higher yields appears to be merely the biological requirement in terms of feed: the same labour and other costs are involved, the same dairy cow price and capital costs albeit for a higher yielding cow. The programme will therefore tend to stick to the highest feasible yield almost regardless of price. This may also help to explain the relative insensitivity of cow numbers to concentrate feed prices. Almost certainly, with a long sequential run the model would tend to give even greater responses to price, weakening the capital constraint through annual reinvestment of income. The present solution for different milk prices is in the nature of a compromise between short and long term. Taken together with the earlier study by Cason we would regard the linear programming

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* The reduction in the number of farm types to 10 enables overall constraints on trade in store livestock to be made but these have not been enforced. The cost in computer time when 42 farm types are involved is prohibitive. A cheaper method of enforcing these kinds of restraint is by iteration on the price of store animals rather than by forcing it across many farm types.

approach as suggesting supply responses of more than 1.0 for dairy cows with respect to milk prices once the milk prices are firmly understood as permanent. The Newcastle model fits the data rather better than Cason's and approximates reasonably in an experimental run to an observed time path over 1970-75 giving trouble when other models* give trouble after 1973 when bad weather coincided with high feed prices.

Econometric Analysis of Time Series Cows (U.K.)

Econometric analysis of time series material has produced quite a number of estimates both for the United Kingdom and Ireland of the effect of milk price on the number of cows and fewer of the effect of price on yield. Because the effect of price on yield and yield on price are essentially simultaneous the econometric approach has been less convincing and no really convincing approach to solving the identification problem has been produced. There are also quite a number of lesser identification problems lurking in the analysis of cow numbers and again they have been passed by rather than solved. We might start with analysis of post war time series in the U.K. Control of feed supply continued in some form up to 1953 and this sets a natural boundary to relevant time series. Earlier data can be made relevant but only with a selective and constructive effort. My own analysis of total cow numbers over 1924-39 and 46-58 combined (21) suggested an elasticity with respect to real milk prices of .46 and rather bigger effects of feed and cattle prices in the long run. The effect in the short run was .06 with a standard error of .03 and the rate of adjustment .12 with a standard error of .06. Whether one accepts the Nerlovian model or not one may merely reflect that even if the theory were right the result merely suggests that the long run elasticity of supply had a 95% confidence range from near zero to near infinity. But two additional considerations would suggest that milk price had a more certain positive effect on milk supply. There should be some effect on yield, but for much of the period yield statistics had to be invented. There should have been an effect of milk price on the proportions of cows being milked, but this kind of distinction escaped the statistics. It is very clear that an autumn calving dairy herd was established over this period and that the milk price, the Milk Marketing Board and guidance from the Government over the rationing period all had something to do with it.

My second published effort (22) to estimate an elasticity of supply for cow numbers over the period 1955-64, using two observations a year, was not much more conclusive. The short run effects of milk price were rather higher, even when the cow numbers six months ago were specified in the equation,

* Except Rickard (46) and table 5 which allow for specific effects of E.E.C. entry.

but they were not more significant statistically. The long run elasticity of supply was estimated at .47 (in association with two lagged dependent variables whose coefficients were inconsistent with any conventional Nerlovian adjustment process) and 1.05 with a single adjustment rate of .22 (with a standard error of .19). Again the long run elasticity of supply might lie somewhere between (a little under) zero and infinity. The 1955-1964 period (and some untidy extrapolations for Scotland and N. Ireland) also provided sufficient evidence to establish a plausible relationship between milk prices and the proportion of cows primarily intended for beef production. The combination of this equation with the elasticity of supply for cows in general suggested a "best estimate" of a long run elasticity of supply for dairy cows of .70 or more. The short run elasticity of supply implicit in the analysis might be unplausibly high at .30 or more with a year's delay. Direct and indirect analysis suggested that both the inflow and outflow of all cows was responding positively to the milk price.

There are two obvious points of criticism of the 1955-64 analysis. Using a desk computer I never bothered to examine the problem of autocorrelation explicitly even though the time interval for successive observations was short enough to suggest that it might be quite important. The prices used were all undeflated. Over this particular period there was some reason to assume that with a fairly stable agricultural price index, and a fairly steadily increasing retail price index, the effects of inflation could be balanced by technical trends of a cost saving nature or subsumed in the general trend (or lack of it). At the time I defended this view by saying that the choice of a deflator prejudged the kind of supply response that was involved (more effort from the farmer to produce a real profit to be spent suggests deflation by a retail price index, exchange of milk for competing products implies deflation by the price of farm products, use of new factors purchsed at a price suggests deflation by input prices). Even over the period in question this did not amount to a sufficient argument for doing nothing. Over later (and earlier) periods when the impact of inflation was more acute and more variable it becomes very difficult to ascribe a consistent meaning to an undeflated price. In the absence of a suitable deflator the time series analysis should tend to compensate by giving sufficient weight to almost any (input) price to give a result which is not very sensitive to inflation. The use of any neutral deflator does not prevent the inclusion of other real (opportunity) cost changes (deflated) in the model.

In more recent analysis over 1960-78 I have deflated by a mixture between the all farm products index and the retail price index. The simplest results exclude beef prices though it is clear that inclusion of real calf prices would have improved the fit in some years:-

$$Y = \text{constant} + \underset{(.23)}{.85Y_{-1}} + \underset{(.05)}{.14M_{-1}} - \underset{(.04)}{.13F} + \underset{(.0017)}{.003T}$$

and

$$Y - \text{constant} + \underset{(.22)}{.93Y_{-1}} + \underset{(.05)}{.15M_{-1}} - \underset{(.04)}{.11F}$$

where Y is the logarithm of the number of dairy cows in December and M and F are logarithms of milk and concentrated feed prices for the preceding harvest year, T is a time trend in years and subscript -1 denotes a lag of one year. The timing of the impact of F and M has been fiddled to give a more convincing effect that when they are synchronised (24). The predictive power of the model is not good but the effects of milk and feed prices seem fairly clearcut. Feed prices clearly carry the effect of some adverse weather conditions and shortage of home produced feeds. Although the trend term is not significant statistically in the first result it is significant economically as it equates to 2% per annum as a long run trend at constant prices. The long run impact of milk prices is .95 in the first result and 2.33 in the second. But both models are statistically consistent with any long run elasticity in excess of .1. One may also note that it is difficult to explain both inflow and outflow into and from the dairy herd in terms of milk prices over this period.

Earlier analysis by Wildgoose (50) had also failed to relate inflow and outflow to end product prices satisfactorily, except perhaps in a seasonal sense for inflow. But at least the effects of the milk price were of the right sign. The long run elasticity of cow numbers to price is quoted as .7 and the rate of adjustment over one year .3 with an initial delay of one year. That is to say prices of milk in the previous calendar year affected the cows in December of this year. The short run elasticity of supply with this lag would be .21 with a standard error of .07. The standard error of the adjustment rate of .11. No estimates of the range of the long run elasticity are given. The result is in terms of money prices but the time series was corrected for autocorrelated errors and to that extent a correction for (autocorrelated) inflation is implicit in the solution.

Other regressions were run with prices deflated by retail prices and by farm product prices which yielded very similar short period responses and some very different long period responses to the milk price. The statistical properties of these other equations with or without adjustment for autocorrelation appeared somewhat inferior.

Over 1960-75 the University of Louvain (27) appears to have a delayed elasticity of milk cows with respect to the milk/barley ratio of .07 with any further long run effect subsumed into the trend term. There is no provision for graduated adjustment.

Evans (12) analyses the period 1955-1969 and builds up a rather complete looking model for the U.K. beef and milk sectors. He deals with three models which differ in accordance with the extent to which the beef and milk sectors have been allowed to be integrated in the equations of the model. The basic equations as they relate to the effect of milk price on milk supply are in terms of <u>net</u> inflow into the cow herd and the proportion of cows in the dairy herd. The first relates significantly to the <u>guaranteed</u> price of milk deflated by the "All Farm Products" price index in models A and B and to the average producer price in model C - deflated by lagged feed prices. The primary delay is between milk prices lagged one year and December's cow herd. Model A uses the money value of the recent output of molk at <u>guaranteed</u> prices to determine the proportion of dairy cows in the herd. Models B and C use the calf rearing subsidy and the beef cow subsidy and no price variables. The total long run effect of milk prices on production is given by elasticities 1.43, 1.09 and 1.49 in models A, B and C respectively. The implicit rate of adjustment is rather more than 20% in all cases and seems especially high in case A. At times the model is careless about the specification of inflow. For instance the variable used as a proxy for inflow into the cow herd is the heifers in calf the previous December - excluding <u>all</u> autumn calvings! In spite of the apparent attention paid to breeding decisions up to the heifer in calf stage and to equations determining outflow it is clear that none of these really enter into the estimation of the cow numbers, and merely provide comment on what is going on.

The econometric approach used by Newcastle (13, page 47) in analysis of the effects of milk price on dairy cows considered the effect of gross margin per cow (calf and milk less concentrated feed cost) on dairy cow numbers. This subsumes the effect of milk yields, milk prices, feed costs and calf prices into one parameter. One expects a greater degree of statistical significance than when each has to justify its own conclusion in the equation. The results suggest an elasticity with respect to milk supply of .81 with a rate of adjustment of .42. These allow last year's gross margin to have a primary effect on this year's dairy cows in June. If the cull cow price is omitted from the equation (it is less sensible as a curb on cow numbers in the long run) then the long run elasticity with respect to milk prices falls to .41 and the rate of adjustment to .34.

Gardiner & Walker (14) analyse the total response of all cows to associated returns and derive a lagged response of .23 over two years and .66 in the long run.

A very important contribution to supply analysis was made by Rickard (46). His model and work related mainly to beef but included a model for the December dairy herd which produced a surprisingly close fit. The price variable was simply the milk feed price ratio and its effect estimated from a (first) differenced series subject to a third order Almon-type polynomial spread over lags 1 to 5. The overall elasticity of supply was probably of the order of .67 but is subject to confirmation as he has not supplied us with these details of his model yet; and the error is 1%. The result was mainly due to the first differencing procedure which I had been reluctant to adopt due to the problem of induced (negative) autocorrelated errors and their effect on the estimated Nerlovian adjustment rate. Because of the lack of a published result a rather similar model is recalculated in table 5.

It is clear from the table that the lagged price pattern is strong enough to be estimated without Almon-type restraints even over a five year period. Rickard's model used a dummy variable to allow for a jump of expectations associated with 1973. We have allowed for equal successive jumps for 1972 and 1973 and run alternative series for June which show lower overall elasticities and a worse fit. The closeness of fit in the first line is so good that it is almost ridiculous. The implied jump in the size of the U.K. December dairy herd due to E.E.C. entry is 11% which is rather high and even if valid at the time might logically be subject to modification if expectations were not justified ex post. The overall elasticity of 1.0 may in a sense be an underestimate as there is no reason to expect all the adjustment to materialise over 5 years. But the equation for the average dairy herd is perhaps best regarded as an average of the June and December equations.

The Nerlovian approach seems to produce rather lower elasticity estimates which are nevertheless quite robust. They are clearly sensitive to the

Table 5 U.K. Effects of Milk/Feed Price Ratio* on the Dairy Herd 1960-79.

Estimated from First Differences and expressed as elasticities

Dependent Variable	cows lag one year	price lag one	price lag two	price lag three	price lag four	price lag five	% trend p.a.	% error	EEC Entry 1972-3 dummy	Total Elas-ticity
Cows December	X	.24 (.024)	.27 (.023)	.28 (.035)	.14 (.022)	.11 (.033)	1.12 (.18)	.66	+ 5.45 (.53)	1.03 (.10)
Cows June	X	.11 (0.4)	.12 (.035)	.23 (.056)	.04 (.035)	.11 (.06)	.85 (.33)	1.27	3.65 (.98)	.60 (.15)
Cows December	.37 (.23)	.26 (.063)	.16 (.044)	.10 (.05)	X	X	long run .55 (.60)	1.37	long run 4.98 (1.20)	long run .76 (.22)
Cows December (adjusted for ½% random measurement errors in undifferenced dependent variable)	.69 (.13)	.28 (.03)	.17 (.02)	.12 (.02)	X	X	1.63	[ex measurement error] .71	7.88	1.82
Cows December	X	.18 (.07)	.23 (.06)	.19 (.09)	.10 (.06)	.04 (.09)	.80 (.47)	1.84	X	.74 (.26)

* Price ratio for first lage = $\frac{\text{price of milk}}{\text{price of feed}}$ = previous harvest year e.g. 70-1 for dec. (1971)

$= \frac{\text{price of milk previous calendar year (e.g. 1970)}}{\text{price of feed previous harvest year (e.g. 70/1)}}$ for june (1971)

Standard errors of fourth line exclude any provision for uncertainty in assumed random measurement errors.
All standard errors are in brackets below the relevant elasticities.
Elasticity estimates assume a herd size of 3300 cows. The price variables in the equations were logarithmic differences and the dependent variables absolute differences.

possible effect of (uncorrelated) measurement errors in cow numbers. These affect the variance of current and lagged first differences positively and their covariance negatively. The result of subtracting this error pattern from the information matrix is seen as increasing the long run elasticity very substantially. The results as a whole tend to confirm our earlier assumption about the long run impact of price. The first difference approach bypasses or de-emphasises some problems associated with variable trend in yields and other costs. It also gives less weight to observed differences between more distant years with more accent on getting a good fit in the short run.

All the models (except 27) suggest a cumulative build up in response to price both in the dairy and beef herd (usually using a Nerlovian approach). Indeed whatever the statistical objections it is difficult to escape the significance of the number of cows at the beginning of a decision period in considering the likely number at the end of it and, having got so far, the long run effect follows whether one approves of the method or not. The analysis in table 5 does serve as a check that the long run elasticity is not simply produced by the Nerlovian approach. But a complete model showing the difficulties that expansion causes for itself in terms of grazing densities and so forth has not really been attempted. We have a few dynamic equations but no truly dynamic model. As they are all run on largely overlapping time series we should not be too surprised if some elasticities look similar.

Econometric Analysis of Times Series Cows Ireland

By contrast most of the equations run for the Irish dairy herd (or more usually the Irish creamery herd as the dairy herd has to be invented retrospectively) avoid the use of a lagged dependent variable in the analysis. For some time the money prices for milk and the creamery herd increased more or less proportionately. Buttimer and McAirt, Buttimer, Hickey & Kearney, Lucy & O'Callagan (contributing to 13) all give elasticities of supply in relation to price of approximately .3 in relation to the money price and broadly similar supplementary variables. But some studies drop an explicit trend. Generally the money price is used, where Buttimer uses deflated prices he appears to get a rather similar but slightly less significant effect. Buttimer and McAirt do quote some equations where the lagged dependent variable is used. Its significance depended very much upon the manner in which the effect of the Calved Heifer Scheme was introduced into the equation. If it was introduced as a slope variable with a permanent effect upon the creamery herd which was not eroded after the scheme ended then the introduction of the lagged dependent variable did not help much. But if it was introduced as a simple dummy intercept variable whose effect (like that of a price rise) would be eroded after it had been discontinued then the lagged coefficient rises to .72 (with a standard error of .10) and the short run elasticity with respect to price (as of 1970) is .27 and the long run effect about 1.00. Personally I consider the slope treatment as implausible and regard the equation with the intercept variable as more correctly specified for this reason and also because it does include a lagged dependent variable.*

My own analysis (24) of the total cowherd suggested a very large effect of the lagged dependent variable and a short run elasticity of about .3 with respect to deflated milk prices and an infinite long run elasticity. This was clearly implausible.

Killen (Irish Journal of Agricultural Economics & Rural Sociology) 1976 follows the effect of money prices and returns on the total cow herd. He considers the total returns per cow as a possible variable affecting the size of the breeding herd. With no other variables he appears to get an implicit elasticity with respect to milk prices of about .5, rising over time to nearer .7. Specifying other factors than price separately he again gets a supply elasticity of almost .3 by 1975 presumably concentrated on dairy cows. His main contribution is to relate the inflow and outflow to the ratios of store heifer prices and cull prices to returns per cow. The

* The Calved Heifer Scheme was not the only relevant policy variable to operate. The T.B. eradication scheme preceded it (with some overlap, and it was followed briefly by a two-tier milk scheme which discouraged milk production at the margin (given the average price). It was also followed by a Beef Incentive Scheme. The sequence of policies probably contributed to the observed statistical significance of the Calved Heifer Scheme and is reflected in the artificial policy variable quoted in table 5(B). This is constructed from data presented by Conway et alia and a comparison of the negative effects of one with the positive effects of the other. The comparison with the effects of the T.B. scheme assumed that rather more than a quarter of the cows culled under this head were effectively removed from the herd. The effect of the Beef Incentive Scheme was presumably negative but more difficult to compare.

Table 5(A) Some Elasticities etc from Irish Data: Dairy Cows December*

	Lagged Deflated Prices**					Beef***		
	Lagged Cows	MILK	FEED	CATTLE	Calved Heifer Scheme	Incentive Scheme	Annual Trend	% Error
1960-78	.33	.18	-.45	+.04	3.3%	-1.7%	2.2%	2.9
	(.18)	(.20)	(.17)	(.14)	(2.9)	(3.6)	(.7)	
1964-78	.40	.21	.53	.02	6.8	X	2.2%	3.2%
	(.22)	(.23)	(.21)	(.16)	(4.5)		(.8)	
1964-78 Long Run	X	.35	-.89	-.04	11%	X	3.7%	
		Milk/Feed est.						
Restricted	.35	.37(.20)		+.03	5.0	X	2.1%	
Long Run	X	.57		.05	7.7	X	3.3%	

* For estimates based on revised values of the dependent variable, see discussion of analysis of Conway et alia and table 5(B)

** Deflated by G.M. of Retail Price Index and Agricultural Output Price Index.

*** The Beef Incentive Scheme was running when the Calved Heifer Scheme wasn't. The distinct effect over 1964-78 is barely calculable.

Table 5B Further Elasticities from Irish Data

	DC_{-1}	Z_{-1}	MP_{-1}	X_{-1}	G	% Trend	% Error
1955-78	.46	.15	.11	-.01	2.9%	.75	.5
	(.14)	(.09)	(.09)	(.04)	(.7)	(.25)	
1955-78	.80	.23	.19	-.09	2.1%	assumes	1.9
	(.09)	(.11)	(.11)	(.04)	(.8)	nil	
1960-78	.42	.07	.07	-.06	2.7%	.97	1.6
	(.15)	(.13)	(.11)	(.07)	(.8)	(.33)	
1960-78	.87	.02	.21	-.13	assumed		2.4
	(.13)	(.16)	(.15)	(.09)	nil		

DC is the dependent variable log dairy cows

DC_{-1} is log dairy cows lagged one year

Z_{-1} is last year's weighted sum of the logarithms of milk supply per creamery cow last year, hay and silage available ÷ grazing livestock unit* and real calf price; the weights are inversely proportionate to the standard deviations of each variable. The variable measures the keep situation and other short run influences giving equal importance to each factor qualitatively. The weights sum to 1.00.

MP_{-1} is the mean logarthm of the deflated price of milk over the last two years. Deflator as in table 5A.

X_{-1} is the mean logarithm of the deflated price for grain and fertiliser last year.

G is a synthetic variable for government policy whose values are given in table 3(a) and whose elements consist of the supposed effects of T.B. eradication, the calved heifer scheme and tier pricing of milk, all expressed in terms of a unit corresponding to C.H.S. in table 5A. The effects are the % effects of C.H.S. in the short term.

* Referred to in text as HY/GL and in table 5C.

elasticity of supply for cows holding inflow prices constant would be .48 at the start of the period falling to near .18 at the end of it with average near .30. The elasticity of cows wrt milk prices from inflow alone cannot be as high as this, but could be .15 or more into the dairy herd. The elasticity for outflow to returns per cow is of a similar order of magnitude .20 on average according to one equation and .40 according to another. Hence we assume that both inflow and outflow responses are responding to price in a manner not merely induced by inflation. His estimates for inflow are derived from his estimates for outflow. The heifer calf statistics are not used. The variation of elasticities over time merely arises from the linear form of the model. The Louvain study (27) suggests two effected of deflated beef prices on dairy cow numbers in Ireland but no more. We are inclined to regard the short run elasticity of supply as rather less than .3 and the long run elasticity substantially higher. We do detect a difference in approach between the U.K. and Irish analysts which probably has something to do with the more rigorous and classical statistical training in Ireland. A renewed effort to fit the Irish analysis into the context of a graduated adjustment model is attempted in Table 5(A). This uses data from Table 3 consistent with E.E.C. series for Irish Dairy Cows in December. The size of the effect of feed prices appears large in relation to the size of the effect of milk prices. When these are constrained to equality then the short run elasticity is .35(with implicit time lag of 1½ years) and the long run elasticity is .57. Variables involving beef cattle are not helpful.

Essentially different data is used by Conway et alia (10) to revise the estimates of the response of dairy cow numbers to price. These are given earlier in Table 3A. They screen many variables according to their statistical significance in explaining the level of the dairy herd and changes in the level of the dairy herd. These can be seen as corresponding to extreme values of the rate of adjustment in a Nerlovian model, and the long run effect is infinite in the second case unless constrained by the nature of the variables involved. Several of the variables used would of themselves change when the dairy herd changes (e.g. by more than the hay production or more fast than customary) and a subtle check is often introduced into the expansion in their model. Some equations lay stress on the influence of non-price variables. It is very difficult to quote any representative price elasticity of milk supply but we consider it could be of the order of .1 or a little less in the short run with the long run effect well delayed.

In order to try to get a better view of the possible time path of response, we considered some variables considered by Conway et alia combining them rather arbitrarily as in table 5B for dairy cows. One may point out that the long run estimates of the elasticity of supply of milk vary from about .2 to over 1.0 according to the emphasis put on trend. The emphasis put on the complex variable Z_{-1} is probably misplaced but the sign is consistently correct. Conway found the element (HY/GL) relatively more useful. The immediate effects of milk prices, feed and fertiliser prices are of plausible magnitude in the absence of trend.

Regional Elasticities (Time Series U.K.)

An essentially different kind of analyses for the U.K. is presented by Rayner (45). It relates to individual regions within England and Wales and although it introduces no explanatory variables other than weather variables which vary from region to region it does produce what might be regarded as an essentially local elasticity of supply by introducing the national price of yearling heifers as an explanatory variable for every region. By implication the milk supply response is as if an unlimited inflow could be purchased from other regions for service. Arguably the flexibility should have been somewhat greater if the price of more mature dairy heifers had been specified. The supply response is for the dairy sector excluding the rearing sector. Alternative crop prices are specified as well as the calf price whose effect is almost uniformly positive. After weighting and adding the responses the long run elasticity is 1.25, the (unweighted) elasticity after a delay of two years (more strictly one year and 9 months) on dairy cow numbers in June is .74 and the (unweighted) rate of adjustment is .64. The high short run impact has something to do with the implicit ease of acquiring new stock and also the slightly greater delay in the primary impact. Nevertheless it is surprisingly high.

Rayner's study is an interesting test of whether the supply response in different regions might differ. If for policy reasons it were considered appropriate to price regions differently - say with a view to pricing lowest in the most elastic regions in order to reduce product without reducing overall farm incomes - then it would be these kind of elasticities which would be relevant. No one is going to introduce supplementary measures to ban the trade in livestock. But although Rayner certainly obtains equations that look good statistically using a regional approach, it is difficult to argue that the good fit is due to the different elasticities with respect to milk price. If one follows the standard deviations expected on the individual equations one would expect a standard deviation among regions of .20. What one gets is a standard deviation of .10. The difficulty is to explain why the elasticities for different regions are so similar! One explanation may be that there is a strong common element in all regions whose size is in doubt and that the larger expected error in every region owes its origin to a common problem (say) in multicollinearity or in the placing of common errors. There is much more variation in the regional response to yearling heifer prices. High values are found both in outflow regions and in inflow regions. The variation of adjustment rates and calf prices is just about what one would expect from the individual standard errors.

Econometric Analysis: Yields

It is also convenient to follow Rayner's study for evidence of the effect of milk prices on milk yield. Our main reservation is that the way trend is introduced into the analysis is crazy. The logarithm of yield is related to the logarithm of time without any prior justification for measuring time from the first year (1957) of the quoted time series. Clearly one would obtain a very different curvature if time was measured with 1945 or even 1954 as 0 and if one uses A.D. like most Europeans one gets a more or less steady % trend. The trends introduced for cow numbers are equally crazy but they are rather less numerous. Retrospectively the attempt to introduce falling percentage trends in yield was ill-judged anyway. It is rescued by inserting a supplementary term in log T for the last two years of the series. This may have troublesome implications for the effects of price and local weather. The overall yield elasticity with respect to milk price is .26 when weighted by milk production. The regional variation is just what one would expect from the standard errors given. If anything it is high in regions where one would expect the grazing to be good and often where one would expect hand feeding to be low. We are inclined to dismiss any evidence of variation of yield response by region as non-proven. The extent to which the national yield response is improved by splitting it into regional components first seems rather doubtful and depends inter alia upon the extent to which the three local weather variables used (April soil temperature, June sunshine and rain in June-August) do in fact identify exogenous factors affecting yield. We have no reason to suppose there is a serious aggregation bias. It is not clear that disaggregation will of itself solve the identification problem.

Wildgoose (50 quoted in 24) also estimated the effect of price on yield as of a similar order of magnitude in one of his equations, but only by using autocorrelation in lieu of trend in the equation. When simple trends were specified the effect was very unclear. The "yield" measured in both cases was the milk deliveries per cow rather than the biological yield of milk cows.

An indirect attempt to measure the effect of price on yield was followed by Louvain (27). A variable corresponding to the instantaneous change in dairy cow numbers is used with trend in the equation for the level of yields. Roughly the result for the U.K. suggests that where the farmers are seeking to raise numbers by 1% (more than usual) they will try to raise yields by 1 1/4%. This approach implicitly deals with several problems under one head and creates problems in interpreting the result. One is that the inflow of heifers and the outflow of cows would not normally have an above average yield, so that if yields were measured in relation to the average number of cows the coefficient should be negative.* Another is that the incentive evaporates rather quickly - if economic conditions create a rise in cow numbers which then reaches saturation the yield then drops back to its prior level. There is no lasting effect. Arguably less efficient cows or farmers have by then been encouraged (to remain) inducing a relapse in yield. Finally it assumes that all the prices which affect cow numbers affect yield in like proportions and with similar initial degrees of delay. In spite of these drawbacks the method does seem to work quite well statistically. So far as the implicit effect of milk price is concerned it says "look for the short run effect of milk prices on dairy cow numbers (or on dairy cow yields) and try doubling it to get the effect on milk production". But again it comes short of solving the identification problem because both could well depress prices, indeed both may do in like measure. It is consistent with the analysis to date in that a short run elasticity for cow numbers may well be .20 and the elasticity for yields may well be .25, but the second elasticity may well be more immediate. The corresponding elasticity for Ireland with respect to this variable appears to be rather lower and associated with a negative effect of the current real milk price on yield. It is scarcely worth pointing out that the more likely relationship goes the other way round. Anyone analysing the supposed yield series

* Given the bias in the E.E.C. yield time series through the use of last year's December cow numbers as a base, the intention may only have been to correct for bias in which case the elasticity should have been lower (say .35 to .50).

Table 5(C) Yield - Some Elasticities for Deliveries per Creamery Cow 1954-1977

Y_{-1}	(HY/GL)	MP	CP	PF	% trend	% error
.43	.18	.02	-.05	-.09	1.2	3.8
(.24)	(.14)	(.25)	(.03)	(.15)	(.7)	
set 0	.27		-.03	-.07	2.2	N A
set 1	.07	.08	-.08	-.11	.2	N A
.82	.12	.17	-.08	-.22	Set 0	4.0
(.11)	(.14)	(.24)	(.03)	(.14)		

Coeff of milk/feed price in line above .20 (.09)

Y is log delivery per creamery cow

Y_{-1} is lagged Y

MP is log deflated price of milk in current and previous year

CP is long deflated calf price

PF is log feed price deflated, spliced with grain price in early years (before 63)

HY/GL see table 5B

Deflator is again as in Table 5A

estimated for Ireland per supposed dairy cow does so at their peril (see table 3).

It is perhaps a little less crazy to estimate the factors affecting the more consistent series for deliveries per cow as the biological yield under conditions in which much of the milk was fed to cavles is barely assessable directly from year to year. Table 5(C) is the logical counterpart to Table 5(B). The economic variables again appear more helpful in the absence of trend. Clearly the significance of the feed element is enhanced by regarding it as responsible for trend in yields. The overall results suggest that there could have been a substantial long run elasticity with respect to the milk feed price ratio and some competition between milk for sale and milk for feeding to calves. But given the statistical weakness of the results it is difficult to give them much emphasis.

The effect of price on yield across some European countries is considered by Williams (39). The influence would appear to be consistent with an elasticity of supply of well over a half. Williams also compares the apparent effect of concentrated feed input levels on yields in certain countries over time. The very different rates discovered (for example) for the U.K. and the Netherlands which suggests that different relationships were involved. Where the effect is lower as in the Netherlands the implications are that feed inputs are acting more often in a causative manner. Where the effect is high as in the U.K. the presumption is that the feed requirement is being dictated more often by yields. The relevance of these relationships to analysis of the yield response to price is that it is only when feed inputs act in the former causative manner that any consequences for price elasticity of supply can be inferred. Although feed output models of a rather more complex type can be used to estimate the effect of milk price on yield in a normative manner there are great difficulties in trying to do this from time series. We may however try to do it from experimental evidence where the causal framework is present by design.

Technical Evidence Relating to Yield Response

But these technical studies were not designed to estimate the price response. Blaxter's results (1 and 2) are mainly designed to show that on the feed levels then conventional it was profitable to feed the better cows more heavily because they had a higher marginal product. Hence we should get some trend to more fed per gallon over time with breeding improvements. There is an established relationship between "Metalysable Energy" and increasing cost per unit provided that bulk feeds are a cheap source of energy, but it is not self-evident that this is very important at recent prices. Broster (3) also presents evidence of increased yield with increased feed but the change in the apparent marginal product as feed rises is very haphazard. Some is associated with an increase in lactation length, but it is not clear that this is sufficient to cause an acute problem within the range of the data. The data which is easiest for a layman to analyse is taken from equations calculated by Gordon (15) which give yield per cow as a quadratic function of feed intake in terms of feed per kg. of milk. There are 4 feed reduplicated over 6 cows for 3 levels of % protein (12%, 18%, and 24%). The data on feeding of hay indicate little or no displacement of hay by extra concentrate. Data is also given on weight gains by livestock. The data can only provide a reasonable estimate of the normative elasticity of milk yield with respect to the milk/feed price ratio in the neighbourhood of a concentrate input of .4kg per kg of milk produced. Derived elasticities are given in table 6. Alternative estimates are given for the elasticity if live weight gain is valued at 4 times the value of milk - as it might be if the cow was in the final year of its milking life. One may note that the implicit elasticities of demand for concentrated feed are quite high, around 1.0 or more with 18 or 24% protein and the elasticities of production with respect to price ignoring incidental costs are near .50. The elasticities for the year as a whole may well be less.

Perhaps it is necessary to balance these results with others derived from experimental evidence that has been available for some time from various countries - assuming that cows remain just about as inflexible in their requirements wherever they may be. The essential components of the normative elasticity of supply at a particular point are the level of output y, the first differential of output with respect to feed input y_x and the second differential y_{xx}. In the absence of refinements the supply elasticity is then $(y_x)^2 \div (y\, y_{xx}) = -e$. Refinements arise because milk is not the only output from extra feeds and quality may vary. Published data on short run experimental results summarised by Broster in 1972 and again by the OECD in 1969 suggest an average value of .26 for e. This is derived by estimating the elements of the above formula for e for each quoted result, taking unweighted averages and then estimating e. One may note that y_{xx} is not always negative and when it is positive e is not negative but unbounded unless further constraints are known, If one divided by y_{xx} first and then averaged one might expect both the value of e and its sampling variance to be infinite. For almost all experimental results available we

Table 6 Elasticities from Experimental Data after Gordon (15)

Only milk valued	Feed Kgs	Milk per day	Price Ratio Feed/ Milk	Elasticities of Produce wrt concentrate input	Milk wrt milk price	
Protein 12%	6.3	15.8	.83	.33	.23	
Protein 18%	6.8	16.9	1.05	.42	.49	
Protein 24%	7.1	17.8	.92	.37	.39	
Milk & Liveweight Valued				Both beef and milk		Meat & Milk wrt price of both
Protein 12%	6.3	14.7	1.03	.44	.22	(.30)
Protein 18%	7.1	17.4	1.17	.48	.52	(.68)

can almost certainly say that the experimental error on y_{xx} is either not available from the published material or that it is too high for e to be inferred precisely. We are better off if we take a view on many results.

The longer run results quoted in the same sources are probably not "long" in the normal economic sense of the word and merely indicate that we are dealing with months rather than weeks. The general view is that the longer the run the greater the response to feed input. This matters quite a lot for practical farmers but it will not affect the value of e unless the numerator rises proportionately more than the denominator - or to rephrase it unless $(y_x \div y)$ rises proportionately more than $(y_{xx} \div y_x)$. Although this is not the kind of question that experiments have often been designed to answer it is quite probable that the residual effects are especially heavy on y_{xx} in that it is more easy to envisage bad feeding having an acute residual legacy on summer milk production and the next lactation than to believe that heavy feeding has a beneficial legacy enough to balance higher maintenance requirements. This view is consistent with some evidence incorporating residual effects by Gordon (16) which does in fact produce a much lower estimate of e nearer .04 than .40.

To return to the "longer run" estimates of e (quoted in 3). These include Jensen's results analysed by Heady and others, which appear to

Table 6A — A Synthesis of Elasticities from Various Sources

Source	Value	Comment
Broster 1972	.26	short run, average, individual results often wild
Heady & Jensen 1962	.29 or less	critical parameters subject to substantial error
Blaxter 1966	.48	feed variable
	.20	feed ratio variable
Gordon 1977	.22) .54) .52)	see table 6
Gordon 1977	.04	different trial
Broster 1972	.03	longer run results
Van Boven (OECD 1964)	.39	summary of other detailed evidence
Vestergaard 1961	.31 +	without reference to data rising with feed prices
Ostergaard 1979	.06 to .40	lower elasticities for weeks 0-24 of lactation
Brown et al. 1978	.15	with respect to quality improvement in the feed
Conway *et alia* 1978	.50 to 1.00	the lower elasticity of supply relates to the concentrate feeding period, the higher to the whole lactation. The average yield is not quoted and is set at 3 gallons per day which may be too low. The experimental data is from Moore park and was presented at their dairying conference 1976

produce a value of e of .29 from the observations quoted or perhaps rather less (.22) estimated from the derived function at the start of the lactation with grain value at the same price as milk and hay valued at half that price. The three other results (Hvidsten, Therne and Larsen & Larsen) all appear to be consistent with low values of e of the order of .03.

Other results (quoted in 37) relate to the Netherlands where 6 indexed observations are quoted and to Denmark where several productions functions are quoted. The first is more easy to interpret although the functional form used by Van Boven is not appropriate to estimate e (because it has only two parameters it cannot independently measure curvature). The results are consistent with a value of e of .39 (but an infinite value is just about possible!). The Danish results are more difficult because the basic observations are missing. The quadratic form given by Vestergaard can be analysed to derive a value of e = .31 when S.E. and milk are priced equally. If marginal feed costs are higher as seems probable then e rises sharply.

The work of Blaxter referred to earlier was based on experiments with alternative feeding regimes over a 5 year period administered to the same cows - chosen deliberately to be of heterogeneous types. The values of e can be inferred for two groups one in which seven cows were given more or less starch equivalent (e = .48) and another in which they were given different feed inputs in relation to milk produced (e = .20).

Osterguaard's results from experiments for weeks 0-24 suggest an elasticity of .06 with respect to milk price through varying the grain input only when about two-thirds of its marginal product is in the form of milk (i.e. over the first 24 weeks of lactation and at an input of 6 kgs per cow). The discussion for the lactation as a whole suggests a substantially higher price elasticity due to choice of systems.

Brown et alia derive a quadratic response curve to quality of dry matter intake which suggest prima facie a response of .15 with respect to milk price in relation to whatever the cost of improving the % protein and the % of concentrates might be. The authors intend to develop their own economic interpretation but we have not seen it.

Conway et alia adapt experimental data to consider the profitability of feeding concentrates in Ireland. Their results suggest a large elasticity of yield - perhaps an abnormally large one.

The results are summarised in table 6A. The impression presented is that the elasticity of supply could well be of the order of .25 with a very considerable band of uncertainty from around zero to as much as .50. From the point of view of the effect of a cut in milk price on yield several comments are in order. The idea that there is well know systematic variation in the value of e is probably wrong. If feed prices rise relative to milk prices and there is a quadratic function of y in relation to x then y_{xx} is constant y_x rises and e rises sharply. But this is purely due to the assumption that the relationship is quadratic. The experimental results shed a little light on the second order terms in f, on the third order terms they shed no light at all.

Another point is that there is a presumption that the metalisable energy is linearly related to the energy requirement in all forms (for milk, meat and maintenance). For some purposes that may be adequate e.g. if extra milk yield is expected because non-feed constraints are raised. Even then curvature in the economic costs are expected provided more concentrated sources of energy are more expensive, but this is unlikely in itself to make the search for high yields unprofitable. But when the stimulus is economic extra milk is produced which involves secondary demands for feed due to the extra weight, extra feed while the weight is being put on and (perhaps?) less efficiency in conversion of given feed mixtures which render this linear relationship unhelpful. It is the production function that is relevant not the function for "required" feed. The experimental evidence available is for hand feeding, which barely covers half the life of cows in any country in the E.E.C. (except Denmark). The understanding of the effect of milk prices on (over)provision of summer keep with grazing would involve entirely new considerations especially the variable slack that is appropriate to support yields with more certainty under variable weather conditions. This cannot be isolated from decisions on cow numbers.

The Demand for Feed Approach

As we indicate earlier there are long term aspects of the response to the milk/feed price, which involve reorganisation of the calving pattern over fairly long periods of time - how long I would not like to guess - as the changes are quite large. Meanwhile it is possible to use information on the first order estimates of elasticities of demand for feed to produce an estimate of yield response to price. Given livestock numbers one may infer from Colman's work (8) that there is a price response for feed as a whole - perhaps as high as .5 with respect to livestock product prices. Other evidence from U.S.A. and Ireland may support such a figure. What is lacking is good evidence of a relevant series for feed used by dairy cattle - even a series of cattle feed can be very misleading - which can be linked to price. Given a demand elasticity of .5 for feed per cow and a yield elasticity of about .3 with respect to concentrates one would expect an elasticity of .15 in the U.K. For dairy herds in Ireland one might expect a production elasticity with respect to concentrates nearer .15 and an elasticity of yield with respect to price of .07. Concentrated feed is not the only thing to affect yield and it is arguable the adverse pricing may affect yields favourably by selection, but on balance, given that entry into dairying is competitive at any price level the expected effect in the long run seems likely to exceed these indirect estimates.

A Production Function Approach to total elasticity of milk supply

A more general approach to milk supply response on specialised holdings may be developed from a single product approach. The essential component is a production function which provides in some measures evidence of the degree of substitutability between factors, especially between factors with a low elasticity of supply and factors with a high elasticity of supply into the dairy sector. More customarily production functions assume that the elasticity of substitution between factors is known *a priori*. The C.E.S. function which has just one elasticity of substitution does provide the simplest function that provides evidence of the second order effects of changes in factor input which are relevant to the estimation of an elasticity of supply. It is possible to run different C.E.S. functions with very similar first order elasticities with respect to each input and very different elasticities of substitution between inputs in general. The results given in Table 7 are derived from the following form of function

$$Y^r = d_i X_i^{\ r} + u_r \quad \cdots\cdots \qquad (1)$$

where u_r is an error term. There is no constant.
The values are expressed per dairy cow across 711 dairy farms in 1974-5 and the observations are weighted by dairy cow numbers. There are several objections to running and using such a function, but here we mention only one. The production function is run on the assumption that there is sufficient uneconomic behaviour or sufficient variations of opportunity cost from the given prices for the variation of the inputs to identify their effect on production. But immediately we assume that the producers in general respond by bringing in resources in response to price either at the marginal product value or at least with a constant proportionate gap between

Table 7 Production Function calculated from 711 specialised dairy farms - England and Wales 1974-5

Factor	Elasticities of Substitution 1.25	Production with Elasticity(s) of 2.5	% of gross product	d_i Arbitrary Values	b_i Elasticity of SR	Supply LR
Labour hired and attributed cost	.14 (.02)	.13	19%	.17	.15	1.5
Purchased feed, vet bills	.27 (.014)	.29	37%	.30	2.5	5.0
Crop costs including those in Home Fodder	.12 (.012)	.14	10%	.12	.45	3.0
Land and general incl. building rent	.19 (.023)	.17	12%	.18	0	.15
Machinery costs	.09 (.013)	.10	12%	.10	.10	1.5
Livestock Inventory	.19 (.024)	.17	10%	.13	.10	.50
Total	1.00	1.00	100%	1.00		
	(unconstrained sum!)	at 15% discount				

Substitution elasticity	Elasticity of supply	of output
.6	.34	1.14
.8	.38	1.24
1.25	.46	1.40
2.50	.57	1.66

Table 7(A) **Supply Elasticity Derived from Cost Structure**
Full Time Farms Ireland 1976

	Mainly Creamery Milk d_i	Liquid Milk d_i	Assumed Elasticity supply (b_i) of each Factor. Short Run	Long Run
Labour (mainly family)	(.35)	(.27)	.05 creamery milk .15 liquid milk	1.0 1.5
Purchased Feed & Livestock Expenses	.14	.18	2.5	5.0
Direct Crop Costs incl. fertiliser	.10	.13	.45	3.0
Land & Buildings (rent at 4% of land price)	.19	.23	0	.15
Machinery Costs (incl. depreciation & transport excl. interest & car)	.09	.08	.10	1.50
Livestock Inventory (10%)	.13	.11	.15 creamery .10 liquid	.75 .50

Adapted from Farm Management Survey 1976. Interest rates implicit in that survey for Land and Livestock have been doubled. The original estimates for labour costs have been changed from .37 & .22 respectively to sum coefficients to 1.00 and include management.

Elasticity of Supply of Product

	Creamery Herds		Liquid Milk	
Substitution Elasticity	S.R.	L.R.	S.R.	L.R.
.6	.17	.91	.24	.96
.8	.19	.96	.26	1.03
1.25	.23	1.05	.31	1.17
2.50	.29	1.19	.38	1.36
% Milk in Output		73%		76%

Table 7B **Various Estimates of Production Elasticity and Substitution Elasticity 1974/5 England and Wales**

	Specialist Dairy Farms	A	B	Mainly Dairy Farms	B
Labour	.14	.12	.05	.16	.15
Purchased feed etc.	.27	.29	.27	.26	.22
Crop costs	.12	.21	.07	.21	.10
Land and Buildings	.19	.16	.11	.20	.07
Machinery Costs	.09	.13	.08	.08	.05
Livestock Inventory	.19	.09	.42	.09	.41
Substitution* elasticity	2.5	1.1	1.25	2.5	1.4
Observations	711	239	711	365	365
% error of output	17	14	22	15	25

A restricted sample limited to herds whose output and or input was not lower than 50% of the average and not higher than 170% of the average (for any input or the output).

B dependent variable covers milk output only and livestock inventory dairy cows only.
52% of output was milk for mainly dairy farms, 70% on specialised dairy farms.

* Estimated from best % error estimate at the weighted mean value of product per dairy cow weighted by square root of cow numbers in each herd.

Table 7(C) Estimates* Using Multiproduct Production Functions

Values of d_i	Irish Creamery Farms: Milk Calves etc.	Irish Creamery Farms: Non Milk	England & Wales Mainly Dairy: Milk Calves etc.	England & Wales Mainly Dairy: Crops	England & Wales Mainly Dairy: Other livestock
Labour	.37	.24	.21	.25	.07
Purchased feed	.16	.04	.30	0	.40
Crop costs	.08	.20	.09	.30	0
Land	.18	.22	.12	.25	.04
Livestock	.14	.10	.18	0	.40
% all output	.85	.15	.70	.20	.10
Substitution Elasticity wrt milk price "short run"	2.08	-10.0	18.6	-24.5	-64.6

The supply elasticities for inputs are given in tables 7 and 7A and the short run elasticities with respect to milk price are reduced by multiplying by the assumed proportion of milk in the enterprise milk, calves, etc. which includes a normal sale of cull cows. Substitution elasticity s is set at .6 for all activities.

* More realistic estimates are derived using a multi-product approach in appendix table 1 for England & Wales Mainly Dairy Farms. For a more complete multiproduct model covering the relationship of milk product to six other activities see appendix tables 2 and 3.

Table 7D Production Function Derived from Analysis of 1977-8 Data for Specialised Dairy Farms

	All Farms Costs in £ per dairy cow		Elasticities of Production with respect to Inputs			
	A	B	C	D	E	
Labour	110	111	.06	.08	.11	(.02)
Purchased Feed	220	241	.29	.31	.30	(.013)
Crop Costs	60	66	.06	.12	.06	(.01)
Land & Buildings	73	78	.25	.24	.24	(.02)
Machinery Cost	95	102	.08	.07	.07	(.005)
Livestock Inventory	55	59	.27	.19	.27	(.02)
Total Cost	622	656	Total 1.0	1.01	1.05	(.01)
			% error 14.1	11.9	13.9	
Returns	674	723	Substitution Elasticity		2.5	

A Weighted by square root of number of cows

B Weighted by the number of cows;% errors are estimated at this level

C Calculated from all data without provision for economies of scale

D Calculated from screened data as in table 7B

E Calculated with constant cost per farm to denote provision for economies of scale (when divided by dairy cows); the bracketted figures are standard errors which are omitted under C and D (those under C are similar, those under D are bigger due to reduced sample). The value of the estimated % error estimated at £723 were lowest for a substitution elasticity of 2.5 for C, D and E,

Table 7E — Supply Elasticities from Gross Margins: Standardised with S = 1

E.E.C. Farm Accounts "1977" Milk Producers

Farm Size	Ireland+	Northern Ireland	Wales	Scotland	Northern England	Western England	Eastern England	U.K.
10-20 Ha	.38	.95	X	X	1.51	1.92	X	1.46
20-50 Ha	.54	.92	1.05	1.21	1.19	1.38	1.33	1.18
Over 50 Ha	.54	.74	1.06	1.03	1.08	1.11	1.21	1.10

Ireland 1976 (17)	Connault	Leinster	Munster	Ulster	Liquid Milk (mainly Leinster)
Creamery Milk Farms	.21	.28	.38	.43	.46

U.K. 74/5 and 75/6 Specialised Dairy Farms (36)	Wales	Northern England	Western England	Eastern England
(Variable inputs limited to feed, seed and fertiliser)	.76	.76	.75	.74
(Variable inputs including machinery ex depreciation and misc.)	1.30	1.34	1.39	1.35

Costs of Milk Production (allocated to milk enterprise)	Specialised Dairy	Mainly Dairy	Livestock*	Cropping, Pigs, ** Poultry, etc.	Mixed	Under 275 man days	All kinds
	.99	.99	(.78)	(1.37)	1.03	1.01	1.0

Cows in herd	10-19	20-29	30-39	40-49	50-59	60-69	70-99	100-199	200 +
	.94	1.03	1.11	1.06	.99	1.02	.93	.95	1.11

Ireland 1976 gross margin taken as equal to gross output less "direct costs"

* 3 farms in sample ** 10 farms in sample + Farms 5-10 Ha = .43

the marginal product and the price. Then the cost structure approach or the production function approach leads to an elasticity of supply of the output which is simply a weighted sum of the elasticities of supply of the inputs. These supply elasticities may be greater over time. In like manner the elasticities of substitution* which can be estimated with some difficulty cross sectionally may rise over time and those calculated may be largely generated by relatively long run differences among farmers and farm structure. In table 7 we use only one set of elasticities of production with response to factors which are given by the arbitrary compromise between calculated elasticities and budget shares. The weights are

$$\frac{d_i}{s + b_i}$$

and with values of s as high as 1.25 and 2.5 the values of the supply elasticity of the output in relation to output price are derived. With lower values of s which are not supported by the cross-sectional but may well be truer such as .6 and .8 we get somewhat lower supply elasticities. With the particular value of the input elasticities of supply suggested the results are not quite so sensitive to the value of s as one might expect from examples where the demarcation between fixed and variable costs is rigid and the elasticity of supply is simply proportional to s (s multiplied by variable costs $\div$ fixed costs).

In practice it is difficult to fix the input supply elasticities by analysis. One might in a sense simply interpret the elasticities of supply in relation to a farmer's reluctance to change that particular element regardless of incentive. Obviously purchased inputs like concentrated feed could be regarded as having a supply elasticity of infinity, but this does presume a readiness to change. This confusion between supply and demand elasticity for factors is illogical but very similar to the easy separation of factors into fixed and variable in conventional economic analyses. The

* The best estimate of r depends on criteria for selection. If u_r is the standard error of Y^r and v_r its standard deviation, one might wish to minimise $u_r \div v_r$ giving r = .1 approx. More consistently we prefer to minimise e the expected proportionate error in Y which we estimate as $u_r \div \bar{Y}^r$ giving r = .65, to the first order in u. If higher order terms in u^r are allowed for the best estimate of r is reduced somewhat. The substitution elasticity $s = \frac{1}{1-r}$. The results given in table 7(B) assume that $\bar{Y}$ was evaluated as if it were weighted by the square root of the number of dairy cows. Further analysis has suggested that a better fit would be obtained with a higher value of r and s at least for specialised dairy herds.

idea that the short run production function itself has a lower elasticity of substitution is probably correct but difficult to establish except by reference to short run demand elasticities (where the problem of farmers' inertia comes in).

There is no actual need to run a production function at all provided that the substitution elasticity can be assumed to hold a particular value. The table 7(A) is constructed for creamery herds in Ireland (17) creating fairly comparable cost structures after allowing for a rise in the notional values attached to capital items (land and buildings, livestock). The derived elasticities of supply are substantially lower, essentially because of the reduced importance of purchased feed. It was assumed that extra cows were somewhat easier to "supply" in creamery herds because of less difficult building problems - clearly land and buildings should have been separated. Meanwhile it was assumed that labour would be more elastic on liquid milk farms because alternative employment would be more available in the vicinity.

It is possible to simplify this approach considerably if all factors can either be regarded as fixed ($b_i = 0$) or variable (with b_i infinite). The supply elasticity for output is then the value of variable inputs divided by the value of fixed inputs multiplied by the elasticity of substitution between fixed and variable inputs. Regarding profit as a part of the reward for the fixed factors this formula for the elasticity of supply corresponds to $(1 - g)\ s \div g$ where g is the share of the "gross margin" in the final output. Several sources may be considered from which internally consistent definitions of the gross margin are available. Assuming $s = 1$ standardised values are given in table 7E. These "elasticities" may also be affected by the fact that a good year will produce a gross margin which is temporarily high. In the E.E.C. data the definitional differences within the regions of the U.K. and between the U.K. and Ireland are presumed to have been reduced. Given farm size there is a rough ordering of region, but within Great Britain there is some doubt about it being very important, and it would be very difficult to infer any substantial difference between the supply response on all farms in major regions. One may note that two "natural" dairying regions Munster and Western England do not have cost structures that suggest relatively low supply elasticities. Arguably there are fewer alternatives to dairying, but there is enough room for cost adjustment in dairying. With the the U.K. size measured by hectares per farm reduces the standardised elasticity; the position of smaller farms may again be that they have less alternatives to dairying but room for cost adjustment. But the grouping by herd size does not suggest a similar relationship. This is not really surprising as the extra cows may be pressing on land resources. The fact that all regions of Great Britain are fairly heavily committed to winter milk (table 1) is maybe sufficient reason not to expect very great variation in supply elasticities due to cost structure. In Northern Ireland the supply elasticity could well be lower and more obviously throughout Ireland.

Production functions for England and Wales were run for 1974/5 when the weather conditions were rather poor and for 1977/8. The results are given in tables 7B and 7D. They are all of Constant Elasticitiy of Substitution. There is a shift of emphasis away from labour and toward livestock and land. Taken at its face value this would reduce the elasticity of supply especially in the long run. For instance the pattern of inputs suggested by the last column E of table 7D* would lead a reduction of 15% and 25% in the short and long run elasticities compared to those estimated arbitrarily in table 7 with S = .6 and similar supply elasticities. The rise in the importance of the livestock inventory may be due to the improved keep situation which clearly affected its coefficient adversely on mainly dairying farms in 1974/5. One definitional problem linked to its estimation is that unlike other cost variables the opening livestock inventory is a negative part of output; the coefficient is perhaps depressed and an average of opening and closing inventories might be a more suitable variable. Regressions were not run on the enterprise cost studies directly (28) and some attempt was made to approach the milk enterprise more directly in columns B of table 7(B). The approach may be regarded as somewhat dubious as only one input is specific to dairying and the rest are subject to specification errors. For this reason and because the definitional link with output is removed the rise in importance of the livestock inventory is no surprise. The possibility of economices of scale were also investigated in the 1977/8 analysis by adding a constant term to represent overhead costs per farm regardless of the number of cows. This was significant and associated on average with economies of scale relating to listed inputs of 5% (col. E in table 7D) although this would clearly be

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* Scaled down to make the sum = 1.00. The suggested economies of scale would increase the elasticity of supply by an uncertain amount but this is not germane to the comparison.

greater at low herd sizes. We may note that larger herds did have a higher output per cow and a higher input level also by comparing lines A and B of table 7(D). A similar pattern for specialised dairy herds was observed in the 1974/5 sample. The higher output appears due to a positive attitude associated with expansion and better use of given resources, it does not merely arise from spreading labour over more cows even though this is suggested by the enterprise cost studies (28).

The problem of estimation of the best fitting r may now be reconsidered. The best level of Y at which to compare estimated % errors associated with different r in equation (1) is not altogether clear. The level used in table 7(B) was the value weighted by the square root of the number of dairy cows because it was conveniently available. In fact the large farms are over-represented in the sample so this could be closer to the universe mean than the obvious and consistent choice which is the value weighted by the number of cows. Taking the latter value we reestimate r at .85 for specialised dairy farms in 1974/5 and estimate r at .6 for all the lines in table 7(D). Because the C.E.S. function does not discriminate between necessary and optional inputs it can stricly only be valid within a range unless $s > 1$. To allow for the possibilities that $s < 1$ in a range the samples were screened for outlying values and the associated estimate of s was reduced in table 7(B) but not in table 7(D). The screening reduces the sample size markedly but does not indicate that a value of $s < 1$ would fit better over a limited range. The more fundamental problem is that the different values of r and their associated parameters are estimated assuming different errors u_r are to be minimised. A priori each function should fit its own error pattern the best. Rather surprisingly it was found that almost the same value of r minimised weighted variances of u_t for values of t = .1, .5 and 1.0. For 1974/5 specialised dairy herds this value was almost 1.0, for 1977/8 it was between .5 and .6. Given the weighting pattern adopted we took it as proven that these values of r must fit best without further search into the correct error pattern. This leads to high estimates of s but the r are only a little different from the short cut estimates based on estimated proportionate errors using the simple weighted mean. The statistical search for the correct values could easily have been more difficult. We assume that the best estimate values are 2 or more for 1977/8 and anything up to infinity for 1974/5 with a considerable range of uncertainty.

Given that one production function is not being estimated unambiguously in a relationship in which inputs are clearly predetermined (feed inputs may be based upon yields) there are grounds for expecting some bias in measuring s. Farmers would have different functions and we anticipated that we would be tending to measure a more flexible envelope around these functions. For instance a farmer using more fertiliser and less concentrate would tend to have some reason in his local function. The production function of a typical farmer would probably have a lower value of s. We anticipated some upward bias but having done the calculations we have doubts about whether the estimated value of s are very useful even as upper bounds.

A further problem arises in the estimation of the appropriate correction in a multiproduct situation. Even with so called specialist farm types several other products are involved. The supply elasticities of all inputs always presume divertion from other uses but where these uses are in agriculture or on the same farm they become more immediately relevant. Where strongly complementary outputs are involved they can be treated as one activity. For instance, if specialist dairy farms had to produce a fixed proportion of their output in milk then the elasticity of supply estimated in 7 or 7A must be multiplied by that proportion. Similar problems were involved in table 6 where extra concentrate obliged dairy cows to put on extra weight. But normally the constraints are not so strong and the scope for specialisation is not exhausted. It is much more difficult to set the upper bound to the supply elasticity with competing products. A generalised approach to the C.E.S. function across many products is given in the Appendix. It suffers from unreality in that there is no provision for complementary use of inputs or rotational benefits (except by defining rigid bundles of products in one activity). Some input supply schedules like feed and rearing may themselves be affected by the other inputs used in dairying. The mathematics leads to a reasonably simple result. The problems come when it is put into effect with facile definitions of the inputs. In table 7(C) two simple estimates of the effect of milk prices are made. One with two products for creamery herds in Ireland, another with three products for mainly dairying farms in England and Wales. The first gives very high estimates of the short run elasticity by comparison with table 7(A) and the second impossibly high estimates. Even though they are valid only in a limited range the implications are that the supplementary activities would disappear quickly with a modest rise in the milk price. The method used to meet this problem is to specify the inputs in detail so that the transfer of resources is restricted. Shepherds cannot be turned into cowmen nor can sheep become cows except through the supply schedule for cowmen and cows. In the Appendix we present two examples in which the inputs are specified in great detail, one for the three product case in table 7(C) and another for a 7 product case as for the U.K. as a whole to compare with Professor Boussard's estimates. Because the method is somewhat less restrictive about the transfer of resources between products it tends to give rather higher supply elasticities for milk. Arguably the elasticities of substitution could be reduced in the 3 product case especially on the dairy cow activity. But it does provide a path toward more realistic estimates. In the 7 product example the elasticity of supply for milk is not strongly affected by the value of s chosen. There is nothing authoritative about the structure of the assumptions; even the division of costs among products is somewhat arbitrary. It would be wrong to consider either the single or the multiproduct approach developed here as anything more than a way of thinking about the connection between supply elasticities of inputs and products. But in any normative approach using profit maximising behaviour the kind of questions underlying the assumptions in Appendix tables 1 and 2 have to be met. How detailed is the input list and how special are the inputs to the products? How readily are inputs substitutes in each activity? How easily are inputs discouraged?

CHAPTER III

A Note on the Inflence of Factors other than Milk Prices

Three factors claim attention as likely to affect milk production at Constant "real" prices: trend, especially in association with rising yields, prices of feeding stuffs and the prices of other farm products. The effect of each is to some extent interdependent with the meaning attached to the real price. For instance in the analysis in table 5 one notes that feed prices take a dominant role and when the real price is regarded as the milk/feed price ratio the trend in cow numbers appears to be of the order of 1% per annum. To this we may add expected yield trend of the order of 1% or more giving a total trend of over 2%. But this trend takes into account upward external pressures on other costs (and opportunity costs) such as wages and rents (and shadow wages and shadow rents) which have generally risen faster than milk or feed prices. If the real price had to allow for these the upward trend "at constant prices" would have been higher. From a normative standpoint one might look at the trends in yields in a rather different manner. Assuming that the yield trend put up full costs at about half half the rate at which it put up trends in output value one might at first glance suggest that it put up productivity of resources half as fast. But in association with price elasticity of supply of 1.0 or more for milk in the long run the implications of productivity gains specific to milk are approximately doubled. We may therefore consider yield contributes to trend at about its face value even though it is partially offset by rising costs. If it had been a costless increase it would have been necessary to double its effect because it would act in two senses - first to raise the productivity of all factors by (say 1%) and second to reward those factors 1% better just like a price rise. With the rise in cow numbers a major part is associated with rising productivity of grassland and other forage crops. These differ in a sense from the yield increases because they also put up the productivity of sheep and beef cattle which may be regarded as alternatives to milk. One might again note obvious cost increases like fertiliser associated with such a trend. Another element may be economies of scale. Noting the upward trend in the size of the cowherd may be of the order of 5% per annum (similar to the rate of decline in dairy farmers) and given a coefficient of economies of scale of .05 (as in table 7D) this might provide a trend in productivity of .25% per annum and a trend in product of .5% or more. We do not intend to provide a complete account of the elements of trend in terms of itemised productivity changes for factors. A great deal depends upon which enterprises are considered alternatives and one might point out that some technical improvements for sheep and cattle have not been very impressive. But coupled with substantial elasticities of supply for factors/products a trend in milk production at constant real prices of the order of 3% is not unreasonable for the U.K. Given that there remains some scope for increased output in relation to product in Ireland we would be inclined to put the trend there rather higher.

The normative approach would suggest that exogenously determined shifts in feed should be more important than exogenously determined changes in other prices. But using the methodology implicit in table 7 we would not expect a shift of 1% in the supply schedule for feed to have more than 70% of the impact of a 1% change in the milk price in the short run and not more than 50% of the impact in the long run when other factors become more elastic in their supply. The time series analysis probably gives a misleading impression of its importance especially in the longer run; when the appropriate deflator would change to emphasise other costs. As more stress is given to competition with other livestock products for resources less stress can be given to feed.

Time series analysis has given a very unclear impression of the role of other farm product prices. Usually they enter into analysis arbitrarily as a deflator or partial deflator without much verification. But if the results give virtually equal weight to real feed and real milk prices there is little room left for any deflator to have any effect. The effect of beef cattle prices has often been stressed. In appendix table 3 it clearly acquires great significance because the assumptions were loaded in that direction. But in time series analysis it is becoming increasingly difficult to give it clear and special significance. Doubtless its effect at different intervals and with special kinds of expectation differ and would enter into the development in milk production in an unclear manner. We might stress that given the uncertainties implicit in each method we do not consider they give a sharply different view on the kind of effects that milk prices have on milk production; but they give a very different view of the way that non-milk prices affect milk production and we do not think this conflict can be easily resolved. We may point out here that the implicit deflator in table 8 below and especially table 8(B) is probably overweighted toward long run considerations and more stress should be given to feed prices in the immediate future - or more strictly on factors other than the E.E.C. milk price that may influence them.

A Summary of Evidence relating to the Effect of Milk Prices on Milk Supply

The structural discussion in Chapter I was directed toward evidence of continuous change casting doubt upon the view that the upward and downward effects of price changes can be distinguished. Doubt was also cast on the view that the income effect of a price cut would lead to (more) effective action to raise product to compensate. The changed structure does of course cast doubt on whether effects that have been estimated will continue to be valid. For the U.K. we considered it possible that large specialist producers may be more unpredictable in their short run decision making and perhaps more rigid. In Ireland we thought that producers in Ireland would be increasingly drawn in to less seasonal high cost production methods and become more sensitive to price. We had little support for this view from those better placed to understand their situation.

Firmer evidence of the cumulative effect of milk prices on dairy cow numbers in the U.K. has been obtained from time series; with effects building up quite quickly over the first few years following a price change (table 5) with an elasticity as high as .6 after 3½ years, .8 after 5½ years and perhaps more in the long run. The evidence from Ireland is more difficult to summarise, but taken as a whole it indicates less response to price and a considerably greater range of uncertainty.

A new look at experimental evidence confirmed our prior view that the elasticity of supply of milk yield to price could well be of the order of .25. The range of uncertainty surrounding the derived estimates is very large especially for individual experiments; the evidence is not very relevant to grazing cows, otherwise there is no reason to suppose the response in Ireland would be lower than in the U.K. or elsewhere.

A generalised Constant Elasticity of Substitutes model was developed to provide a vehicle for discussing normative estimates of the effects of price on milk production. This is generalised still further in the Appendix to cover a multiproduct situation. With the kinds of assumptions made about the elasticity of substitution and the elasticity of supply of factors the results confirmed the results from Time Series; but because it stresses competitive aspects the multi-product models lead to rather higher estimates of the elasticities. But the estimates are rather sensitive to assumptions. Efforts to estimate a characteristic elasticity of substitution for factors on dairy farms from cross-sectional evidence in the U.K. gave rather high estimates (in excess of 2.0) but this is considered as an upper bound to an unknown true value. The size of this parameter is critical in considering conventional fixed cost and variable cost situations for a single product. With more moderate assumptions about the elasticity of supply of factors and in multiproduct situations this parameter is still important but it is less critical. The multiproduct case is highly sensitive to the specification of the inputs involved.

Within Great Britain and especially within England and Wales the evidence to support the view that very different elasticities of supply are to be expected in different regions is almost entirely absent. If anything the evidence points to conformity plus unclear variations. Lower and more variable elasticities may well apply in N. Ireland and in different regions of Ireland.

Taking the evidence as a whole it is perhaps more consistent than one might have expected. There are difficulties in comparing "short run" results from time series and cross-section partly because there is no evidence which effectively separates the expectational element of delays and the technical reasons for delay in time series analysis. If anything we are surprised that the time series responses to price are not found to be slower. It should be stressed that the time series estimates are not strongly dependent upon the view of the farmer as a "profit maximiser". The normative estimates are. It was not possible to develop a more realistic Linear Programming approach or to develop dynamic modifications to the profit maximising principle. The relevance of the time series analysis in the U.K. may be limited by the fact that it related to a period in which dairy cow numbers did not in fact change by very much. None of the models have been tested for their predictive ability on (new) data in such a manner that we could state that the price effects are clearly confirmed or clearly denied.

A Scheule for the Effects of Milk Price Changes

There are essentially two elements of a projection of the effect of a change in money prices for milk. One is the effect of leaving the money price unchanged which of itself in present conditions would constitute a very serious policy measure against milk, which would lead to protest as other incomes and prices are rising sharply in money terms. The other is the effect of the proposed price changes themselves.

One of the critical problems arising in the no-change situation is to evaluate the impact of general prices, feed prices and agricultural product prices on production as well as any technical upward trends associated with milk deliveries per cow and cow numbers. In addition in the most recent accounting periods 1977-8 and 1978-9 there would seem to have been a fair margin which was more than sufficient to keep the bulk of dairy farmers in business. Against this we have a standstill in milk prices for 1979-80 which was to some extent offset in the U.K. by devaluation in the green rate for sterling. At present the margin must be much tighter both in Ireland and the U.K. If a major objective of this study was to forecast milk supply it would be necessary to spell out these elements in detail. In table 8B the forecast changes in the implicit deflator of milk prices rises rather more than 65% for Ireland and almost 55% for the U.K., the latter figure assumes that the strong level of sterling in 1979 would have been sufficient to eliminate the need for further adjustments in the green rate if only that amount of inflation had been in prospect. Notionally we consider feed prices, agricultural product prices and retail prices as equally important. The corresponding real price trend is allowed for in the supply forecasts in table 8(B), but we would not wish to defend this table strongly in an uncertain inflationary situation. Doing nothing or very little to raise milk price in money terms would almost certainly cut U.K. milk production (provided the U.K. government did not attempt to mitigate the consequences by trying to isolate the U.K. liquid market still further), and probably lead to stagnation of supply in Ireland at a rather higher level.

The impact of milk price changes is spelt out in table 8 from which any time path of effects can be constructed. It is assumed that a kind of graduated adjustment must occur for cow numbers and the rate of adjustment suggested is about 20% for the U.K. and 30% for Ireland. The long term elasticities assumed are .75 and .50. The primary response is .15 with a delay of rather more than a year from the date at which the price change is announced. For yields we consider that there is a fairly immediate response for the U.K. modified only by a little uncertainty about the price change itself, followed by no further change. For Ireland the proper response to feed prices may well be as high or even higher but as long as the level of feeding is low in aggregate it is difficult to credit a very high effect. We have not allowed for an immediate response through feeding more to rearing calves as milk prices drop because the calf price could well move down in line. The effect has been allowed to move up gradually so as to equal .25 after 5 years and to rise to nearer .30 thereafter.

The table 8(A) is merely an interpretation of the results by cumulating the effects of 4 similar price changes announced in 1980, 1981, 1982 and 1983 over their impact on the production in subsequence harvest years. The effects for calendar years are interpolated. The overall impact that might be expected from a sequence of price cuts of 5% would be 8% less milk from Ireland by 1983-4 and 12% less from the U.K. The ultimate effects would be 15% and 20%.

Several comments may be in order. First that there is a fairly wide band of uncertainty about the overall effects (in the long run), and perhaps even more about the step by step procedure. In my opinion there is more uncertainty on the upward bound, but it would not be very helpful to spell out possible errors at each stage and how they interact. We would be prepared to accept the possibility that the long run effects might be 30% lower for the U.K. and 50% lower for Ireland, but would be unwilling to go lower in view of the total evidence submitted. Second, the uncertainty would be much reduced if the permanence of any cut in prices were stressed. In this context the inflationary background does not help; nor does it help to have the prices changes dependent on trigger mechanisms, which may only be effective for one or two years; whose meaning has to be explained to farmers as individuals (who know that the only relevant reaction is collective). Third, a collective action by the E.E.C. to reduce milk prices may have rather less consequence proportionately on production in the U.K. and Ireland than a national price change holding all other E.E.C. prices. The main reason is that such an important change in milk prices would

Table 8 Elasticities for a permanent change in prices effected from April 1980

	On milk production U.K.	Ireland	On yield/cow U.K.	Ireland	On Dairy cows U.K.	Ireland
1980	.14	.10	.10	.05	.05	.05
1980-1	.35	.25	.20	.10	.15	.15
1981-2	.55	.37	.25	.12	.30	.25
1982-3	.70	.47	.25	.15	.45	.32
1983-4	.80	.54	.25	.17	.55	.37
1984-5	.90	.62	.25	.20	.65	.42
1985-6	.95	.70	.25	.25	.70	.45

Table 8A Percentage Changes associated with a 1% trend in price over 4 years effective from April 1980 through to 1983-4

	Milk Production U.K.	Ireland	U.K.	Ireland
	for each 1% change		for a 5% change	
1980	.15	.10	.75	.50
1980-1	.35	.25	1.75	1.25
1981	.65	.45	3.25	2.24
1981-2	.90	.62	4.50	3.10
1982	1.30	.85	6.40	4.25
1982-3	1.60	1.09	8.00	5.45
1983	1.95	1.35	9.65	5.75
1983-4	2.40	1.63	12.00	8.15
1984	2.65	1.81	13.25	9.05
1984-5	2.95	2.00	14.75	10.00
1985	3.05	2.16	15.25	10.80
1985-6	3.35	2.33	16.75	11.55
1986-7	3.65	2.60	18.25	13.00
1987-8	3.90	2.83	19.50	14.15
1988-9	4.10	3.00	20.50	15.00

These changes assume that national average milk prices rise or fall in proportion to announced E.E.C. prices. There is some doubt whether this would occur especially in the U.K. and especially when the cut in production exceeds 10%. Otherwise the effects are proportionately independent of the size or direction of any change.

scarcely be possible without some consequent effect on feed prices - especially the prices of oilcakes and cereal substitutes. Fourth, in the even of a severe price cut in E.E.C. prices the greater the importance of local liquid milk sheds and local premia. This would be more important in the U.K. even with a degree of E.E.C. competition for its milkshed. Fifth, the elimination of any E.E.C. surplus may affect the price expectation - assuming the price cut is big enough. Finally, if more local price changes are envisaged for subregions within Ireland or for regions within the U.K. then the local elasticities of supply will almost certainly be greater on average than these quoted because of the possibilities offered by trading in store animals. The difference may well be as much as .3 in the long run effect.

Table 8(B) Assumed Effects of Stationary Money Prices for Milk from 1980 onward) taking Account of the Freeze over 1979-80 Effective up to 1983-4

	Real Effective Price base 1977-8			Level of Milk Supply Base 1978	
	U.K.	Ireland		U.K.	Ireland
1978-9	100	95	1979	(103)	
1979-80	90	85	1980	100.5	108.4
1980-1	80	75	1981	97.8	107.2
1981-2	75	70	1982	96.6	107.4
1982-3	70	65	1983	94.1	106.6
1983-4	65	60	1984	91.7	106.0
1984-5	65	60	1985	91.7	106.2
1986-7	65	60			

Trends in supply should be taken to exclude animal feed. The underlying trends at constant real prices are assumed to be + 3% for the U.K. and + 3½% for Ireland. The base price for Ireland is relatively high. Changes in production observed after 1978-9 are not taken into account. The U.K. prices are notionally adjusted for green rate changes.

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We would like to acknowledge assistance in supply of information from Robert O'Connor of the Economic & Social Research Institute, Dublin. Many references to this information have been inserted in the text under"Conway et alia" as we understood much of it to relate to working documents on that text. We have also been assisted by Dr. Crabtree of the School of Agriculture at Aberdeen, especially in the search for experimental data relating to feed and milk. Any misleading quotations, calculations and conclusions remain my responsibility. There are a few additional references unnumbered in the text, especially those relating to source material.

George Jones

The Multiproduct Case

Supply Elasticities derived from Independent

C.E.S. Production Functions: Appendix

For the j^{th} product

$$Y_j^{-\rho_j} = \sum_i \delta_{ij} X_{ij}^{-\rho_j} \tag{1}$$

where X_{ij} is the input of factor i into the j^{th} product and Y_j is the output of the j^{th} product. Without loss of generality we may refer to an initial situation in which all Y_j and X_{ij} are equal to 1 in which δ_{ij} represents the share of factor i in the j^{th} product's returns so that $\sum_i \delta_{ij} = 1$. We note that the X_{ij} cannot be added up directly across products without weighting. If X_i is the input of the i^{th} kind with initial value 1.0 it is convenient to denote shares λ_{ij} of the j^{th} output in the i^{th} factor in the initial situation so that

$$dX_i = \sum_j \lambda_{ij} \, dX_{ij} \tag{2}$$

for small changes near it.

$\sigma_j = \frac{1}{1 + \rho_j}$ is the substitution elasticity for the j^{th} product and the δ_{ij} and the λ_{ij} are linked by

$$\frac{\lambda_j}{\lambda_k} \frac{\delta_{ij}}{\delta_{ik}} = \frac{\lambda_{ij}}{\lambda_{ik}} \tag{3}$$

where λ_j and λ_k are the shares of the j^{th} and k^{th} product in the value of all inputs and all outputs in the initial situation.

From (1) we can derive the effect of proportionate changes of product and (shadow) factor prices of dP_j and dP'_j on the ratio of X_{ij}/Y_j because for each factor the price ratio must correspond to the marginal value product in terms of the output. Hence after successive differentiations of (1)

$$\sigma_j(dP'_i - dP_j) = -dX_{ij} + dY_j \tag{4}$$

We also note that if the supply elasticity for each input with respect to its own price (or shadow price) is β_i then using (2)

$$\beta_i \; dP_i' = \sum_i \lambda_{ij} \; dX_{ij} \qquad (5)$$

Finally we note that the differential form of (1) is

$$dY_j = \sum_i \delta_{ij} \; dX_{ij} \qquad (6)$$

From (4) we can substitute for dX_{ij} in general in terms of dX_{ik} for a particular product k for instance

$$\sigma_j \; dP_j + dY_j - dX_{ij} = \frac{\sigma_j}{\sigma_k} (\sigma_k \; dP_k + dY_k - dX_{ik})$$

or $$dX_{ij} = \frac{\sigma_j}{\sigma_k} (dX_{ik} - dY_k) + dY_j + \sigma_j \; (dP_j - dP_k) \qquad (7)$$

Also from (4) and (5)

$$\sum_i \lambda_{ij} \; dX_{ij} = \frac{\beta_i}{\sigma_k} (dY_k + \sigma_k \; dP_k - dX_{ik}) \qquad (8)$$

Multiplying (7) by λ_{ij} for each j including k the sum of the LHS of the versions of (7) equal the LHS of equation (8) equating the corresponding RHS values we have after multiplying by σ_k

$$\sum_j \lambda_{ij} \; \sigma_j \; (dX_{ik} - dY_k) + \sum_j \lambda_{ij} \; \sigma_k \; (dY_j + \sigma_j \; dP_j - \sigma_j \; dP_k)$$

$$= \beta_i \; (dY_k + \sigma_k \; dP_k - dX_{ik})$$

or $$dX_{ik} = dY_k + \sigma_k \; dP_k - \frac{\sum_j (dY_j + \sigma_j \; dP_j) \; \lambda_{ij} \; \sigma_k}{\left(\sum_j \lambda_{ij} \; \sigma_j + \beta_i\right)} \qquad (9)$$

We may now substitute in (6) with j = k to eliminate dX_{ik} by multiplying (9) by δ_{ik} for each i and summing and recalling that $\sum_i \delta_{ik} = 1$

$$dY_k = dY_k + \sigma_k \; dP_k - \sum_i \sum_j \frac{(dY_j + \sigma_j \; dP_j) \; \lambda_{ij} \; \delta_{ik} \; \sigma_k}{f_i}$$

where $f_i = \beta_i + \sum_j \lambda_{ij} \; \sigma_j$

cancelling dY_k and σ_k we get

$$\sum_i \sum_j \frac{\lambda_{ij}\ \delta_{ik}}{f_i} (dY_j + \sigma_j\ dP_j) = dP_k \tag{10}$$

If we denote $w_{ijk} = \frac{\lambda_{ij}\ \delta_{ik}}{f_i}$

and $W_{kj} = \sum_i w_{ijk}$

then with j and k running over all products up to n

$$\sum_j W_{jk}\ (dY_j + \sigma_j\ dP_j) = dP_k \tag{11}$$

Provided the determinant $|W_{kj}|$ is non-singular then the matrix of elasticities for the products is derived from the vector equation

$$W\ (\underline{dY} + \hat{\sigma}\ \underline{dP}) = \underline{dP}$$

or $$\underline{dY} = (W^{-1} - \hat{\sigma})\ \underline{dP} \tag{12}$$

where $\hat{\sigma}$ is diagonal derived from elements σ_j and W has typical element W_{kj} and $\underline{dY}$ and $\underline{dP}$ are vectors of (proportionate) changes in quantity and price of outputs.

It is clear that as the number of products builds up if it exceeds the number of factors m then the matrix W will in fact be singular. Moreover the singularities of W depends essentially on each product's cost structure being independent of any linear combination of the cost structure of other products. Especially relevant are those costs for which f_i and β_i are low. As the prices change the cost structures will change and the probability is that at intervals singular W <u>will</u> occur with changes in product structure as in Linear Programming. The formulae are for a limited neighbourhood in which they are only approximately valid. For the Cobb-Douglas function the matrix $\hat{\sigma}$ in (12) is I the identity matrix. The single product case is derived from (10) putting $\lambda_{ij} = 1$ $f_i = \sigma + \beta_i$ $w_i = \delta_i \div f_i$ and putting $dP = dP\Sigma\delta_i$

$$dY = dY \sum_i w_i = dP \sum_i \beta_i\ w_i \tag{13}$$

Appendix Table 1 **Multi-product example constructed to be consisted with data for U.K. mainly dairy farms - 1974-5 leading to supply elasticity estimates for 3 activity levels in relation to the prices of their outputs**

Activities → Factors ↓	Cows etc. δ_{i1}	Cows etc. λ_{i1}	Crop δ_{i2}	Crop λ_{i2}	Other Livestock δ_{i3}	Other Livestock λ_{i3}	β_i short	r_i short	β_i long	r_i long
Labour 1	.15	1	0	0	0	0	.15	1.15	1.5	2.5
Labour 2	0	0	.20	1	0	0	.15	.65	1.5	2.0
Labour 3	0	0	0	0	.03	1	.15	.65	1.5	2.0
Labour 0	.06	.75	.05	.18	.04	.07	.15	1.03	1.5	2.38
Feed etc.	.30	.86	0	0	.35	.14	2.5	3.43	5.0	5.93
Fertiliser Etc.	.09	.49	.30	.47	.05	.04	.45	1.30	3.0	3.75
Land 1	.09	.94	0	0	.04	.06	0	.97	.15	1.12
Land 2	.03	.28	.25	.66	.05	.07	0	.64	.15	.89
Livestock 1	.14	.95	0	0	.05	.05	.10	1.08	.50	1.48
Livestock 3	.04	.44	0	0	.35	.56	.10	.82	.50	1.22
Machines 1	.05	1	0	0	0	0	.10	1.10	1.50	2.5
Machines 2	0	0	.10	1	0	0	.10	.60	1.50	2.0
Machines 3	0	0	0	0	.02	1	.10	.60	1.50	2.0
Machines 0	.05	.61	.10	.35	.02	.04	.10	.91	1.50	2.31
Output Shares (λ_j)	(1.0)	.70	(1.0)	.20	(1.0)	.10				
Substitution Elasticities (σ_j)	1.0		.50		.50					

W short run

$$\begin{bmatrix} .6594 & .0957 & .0640 \\ .3349 & .8971 & .0447 \\ .4479 & .0859 & .3475 \end{bmatrix}$$

$(W^{-1} - \hat{\sigma})$ short run*

$$\begin{bmatrix} .809 & -.163 & -.313 \\ -.569 & 1.30 & -.045 \\ -2.165 & -.084 & 2.787 \end{bmatrix}$$

W long run

$$\begin{bmatrix} .3566 & .0456 & .0409 \\ .1600 & .3919 & .0260 \\ .2828 & .0494 & .2037 \end{bmatrix}$$

$(W^{-1} - \hat{\sigma})$ long run*

$$\begin{bmatrix} 2.467 & -.321 & -.655 \\ -1.114 & 2.20 & -.12 \\ -4.536 & -.209 & 5.347 \end{bmatrix}$$

* The final elasticity matrices: the elasticity of supply of the cow activity may be reduced by about 15% to derive the elasticity of milk supply.

ndix Table 2 **Seven product relationship for U.K. data. CES functions combined - assumptions and preliminaries**

	COWS	VEG	CER	BEEF	HOGS etc	POT	SHEEP		COWS	VEG	CER	BEEF	HOGS etc	POT	SHEEP	Values of β_i Short Run	Values of β_i Long Run	Long Run Values of f_i	NOTES
	Matrix of δ_{ij}								Matrix of λ_{ij}										
l	(.12)	(.20)	(.20)	(.20	(.01)	(.20)	(.20)												
1	.01	0	0	.04	0	0	.18		.153	0	0	.325	0	0	.521	0	0	.25	outby land incl. rough grazings
2	.07	0	.02	.14	.01	0	.10		.373	0	.070	.396	.06	0	.101	0	0	.25	inbye land mainly permanent grass
3	.04	.10	.18	.02	0	.10	.02		.184	.136	.549	.049	0	.063	.017	0	0	.25	ordinary arable
4	0	.10	0	0	0	.10	0		0	.682	0	0	0	.318	0	0	0	.25	high quality arable
ur	(.20)	(.20)	(.10)	(.07)	(.15)	(.25)	(.16)												
1	.14	0	0	.02	0	0	0		.929	0	0	.071	0	0	0	.15	1.0	1.25	cowmen
2	0	.13	0	0	.01	.05	0		0	.679	0	0	.199	.122	0	.15	1.0	1.25	vegetable/casual labour
3	.01	.03	.07	.01	0	.08	.01		.120	.106	.555	.064	0	.133	.023	.15	1.0	1.25	tractor drivers etc.
4	0	0	0	.02	0	0	.01		0	0	0	.849	0	0	.151	.15	1.0	1.25	stock handlers/marketeers
5	0	0	0	0	.09	0	0		0	0	0	0	1.0	0	0	.15	1.0	1.25	hog/poultry experts
6	0	0	0	0	0	0	.09		0	0	0	0	0	0	1.0	.15	1.0	1.25	shepherds
7	.05	.04	.03	.02	.05	.12	.05		.287	.068	.114	.060	.321	.074	.054	.15	1.0	1.25	general workers
inery	(.10)	(.20)	(.40)	(.06)	(.04)	(.15)	(.10)												
1	.05	0	0	.01	0	0	.02		.846	0	0	.090	0	0	.064	.10	1.50	1.75	cattle feed & milking equipment
2	0	.10	0	0	0	0	0		0	1.0	0	0	0	0	0	.10	1.50	1.75	specialised vegetables
3	.01	.02	.30	.02	0	.05	.02		.042	.025	.842	.045	0	.029	.016	.10	1.50	1.75	cultivation equipment
4	0	0	0	0	0	.03	0		0	0	0	0	0	1.00	0	.10	1.50	1.75	specialised potato
5	0	0	0	0	.03	0	0		0	0	0	0	1.00	0	0	.10	1.50	1.75	specialised hog/poultry
6	.04	.08	.10	.03	.01	.07	.06		.225	.133	.372	.090	.063	.054	.063	.10	1.50	1.75	transport/general
stock	(.18)	(0)	(0)	(.30)	(.05)	(0)	(.26)												
1	.14	0	0	.05	0	0	0		.84	0	0	.16	0	0	0	.10	1.0	1.25	cows (incl. "peu laitiers")
2	.04	0	0	.25	0	0	0		.23	0	0	.77	0	0	0	.10	1.0	1.25	cattle (incl followers & beef cows)
3	0	0	0	0	.05	0	0		0	0	0	0	1.00	0	0	.20	3.0	3.25	pigs and chickens
4	0	0	0	0	0	0	.26		0	0	0	0	0	0	1.00	.10	1.0	1.00	sheep
ding	(.05)	(.02)	(.05)	(.04)	(.05)	(.05)	(.02)												
1	.03	0	0	0	0	0	0		1.0	0	0	0	0	0	0	0	2.0	2.25	byres built in milking plant
2	.01	0	0	.03	0	0	.01		.359	0	0	.527	0	0	.068	0	2.0	2.25	sheds for livestock
3	0	0	0	0	.04	0	0		0	0	0	0	1.0	0	0	0	2.0	2.25	specialised pig/poultry
4	.01	.02	.05	.01	.01	.05	.01		.134	.079	.445	.071	.151	.092	.025	0	2.0	2.25	storage, machinery sheds & general
stock expenses Feed, Vets,etc.	.29	0	0	.24	.70	0	.10		.237	0	0	.104	.643	0	.015	2.5	5.0	5.25	
expenses fertiliser etc.	.06	.38	.25	.10	0	.40	.05		.133	.246	.363	.117	0	.121	.021	.45	4.0	4.25	
nded 1.00 = $\Sigma\delta_i$	1.00	1.00	1.00	1.01	1.00	1.05	.99	value shares	.254	.075	.168	.135	.285	.035	.048				

SPECIFIED ACTIVITIES

- **COWS** include calf production & output of culls
- **VEG.** mainly outdoor type of vegetables
- **CER** Cereals for sale or feed, ex silage etc.
- **BEEF** voluntary beef production not tied to milk
- **HOGS** etc include poultry activities
- **POT** potatoes all kinds

Values of σ adopted were .25 and .50 throughout the values of f_i quoted use σ = .25.

* **Subject to unintended error (potatoes)**

Appendix Table 3 **Seven-product relationship U.K. results**

Short run results $W_{kj} = \sum_i \delta_{ik} \lambda_{ij} + f_i$

W with σ = .25 (rounded)

COWS	VEG	CER	BEEF	HOGS ETC	POT	SHEEP
1.19	.07	.25	.39	.14	.05	.08
.25	1.02	.64	.12	.12	.40	.04
.38	.28	1.55	.20	.08	.18	.07
.73	.07	.25	1.01	.12	.04	.11
.12	.03	.05	.06	.80	.02	.02
.34	.64	.86	.16	.16	.41	.06
.44	.07	.26	.43	.10	.04	1.42

This section calculated from

$$v_{jk} = v_{kj} \frac{\lambda_j}{\lambda_k}$$

corresponding to symmetry constraint.

W with σ = .50 (rounded)

COWS	VEG	CER	BEEF	HOGS ETC	POT	SHEEP
.87	.05	.19	.29	.07	.03	.06
.18	.75	.46	.08	.08	.22	.03
.28	.20	1.16	.15	.06	.13	.05
.54	.05	.18	.76	.06	.03	.12
.06	.02	.03	.03	.51	.01	.01
.24	.47	.62	.11	.12	.30	.04
.34	.05	.19	.34	.07	.03	1.07

figures used to invert were to four decimal places.

W^{-1} - $\hat{\sigma}$ with σ = .25 gives elasticities

[Det W = .2477]

COWS	VEG	CER	BEEF	HOGS ETC	POT	SHEEP
.90	0+	-.11	-.40	-.12	-.04	-.03
.10	1.56	-.59	+.02	-.02	-1.08	.01
-.11	-.01	.47	-.05	.02	-.29	-.01
-.76	-.01	-.08	1.07	-.05	.01	-.06
-.10	0-	-.01	-.02	1.03	-.04	-.01
-.69	-2.82	.60	-.13	-.37	4.09	-.07
-.08	0	-.06	-.27	-.03	-.02	.49

0+ is a little over 0
0- is a little under 0

W^{-1} - $\hat{\sigma}$ with σ = .50 gives elasticities

COWS	VEG	CER	BEEF	HOGS ETC	POT	SHEEP
.95	0+	-.13	-.54	-.12	-.06	-.02
.01	1.95	-.02	-.02	-.01	-1.77	0+
-.19	-.01	.66	-.08	.01	-.46	-.02
-1.02	-.01	-.10	1.28	-.05	-.02	-.14
-.10	0-	.01	-.02	1.49	-.08	-.01
-.45	-3.80	-2.19	.08	-.69	6.58	-.03
-.11	0+	-.07	-.39	-.05	-.02	.49

If milk prices only change the elasticities with respect to "cow activity prices" must be reduced by 10 to 15%. Respectively the row and column involving potato prices/ quantities were approximately 5% too high in W and the proper elasticities may be 5% higher and the main elasticity 10% higher.

long run results

W with σ = .25 (rounded)

.45	.03	.12	.20	.07	.02	.06
.11	.49	.30	.04	.04	.19	.01
.17	.13	.62	.09	.17	.07	.03
.38	.02	.11	.47	.07	.01	.15
.06	.01	.01	.03	.23	.01	.01
.13	.40	.33	.05	.04	.21	.02
.31	.02	.11	.42	.05	.01	.70

W with σ = .50 (rounded)

.31	.02	.07	.12	.05	.01	.03
.07	.30	.18	.03	.03	.11	.01
.11	.08	.39	.05	.01	.04	.02
.23	.02	.07	.30	.05	.01	.07
.05	.01	.01	.02	.20	.00	.01
.09	.23	.21	.03	.04	.13	.01
.17	.02	.07	.22	.04	.01	.45

W^{-1} - $\hat{\sigma}$ with σ = .25 gives elasticities

[Det W = 00019359]

3.93	.08	-.42	-1.66	-.68	-.19	.03
.26	7.28	-.11	-.07	.09	-6.71	.02
-.64	-.05	1.84	-.07	.18	-.59	-.01
-3.12	-.05	-.09	3.71	-.18	.15	-.57
-.61	.02	.11	-.08	4.39	-.11	.01
-1.37	-14.36	-2.83	+.58	-.99	18.43	-.09
.15	.04	-.03	-1.60	.06	-.06	1.49

W^{-1} - $\hat{\sigma}$ with σ = .50 gives elasticities

COWS	VEG	CER	BEEF	HOGS ETC	POT	SHEEP
4.59	.09	-.48	-1.91	-.85	-.25	0-
.30	8.38	-.25	-.06	.02	-7.44	.03
-.72	-.11	2.79	-.16	.23	-.96	-.03
-3.60	-.04	-.21	4.78	-.23	.14	-.64
-.75	.01	.14	-.11	4.72	-.16	0-
-1.78	-15.93	-4.60	.55	-1.32	22.7	-.12
0-	.05	-.10	-1.79	0-	-.08	2.04

Some "complementary" products enter in even though there is no complementary use of factors. Lowest absolute cross effects of milk prices on beef production are when share of beef or cow output = 15%:

values -.39 & -.58 short run
and -3.3 & -3.81 long run

Corresponding effects of beef on milk:

-.27 and -.40
-1.07 and -1.22

Relationship between milk production and price variations in Belgium and the Netherlands

by

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CONTENTS

TABLES

FIGURES

Introduction

Milk production in the EEC is to be found in almost all regions of the Community. There is a large degree of concentration and specialisation (see Fig. 1).

In recent years milk production has risen in the Netherlands and other EEC countries, whereas in some countries such as Belgium, for example, it has tended to mark time. Total milk production in the EEC has risen, as shown in Table 1.

Table 1. Total EEC milk production (* 1000 tonnes)

Year	Nether-lands	Germany	France	Italy	Belgium/ Luxembourg	UK	Ireland	Denmark
1968	7 791	22 121	30 444	10 009	4 129	12 630	3 671	5 122
1969	7 915	22 216	27 486	9 617	4 132	12 747	3 684	4 878
1970	8 253	21 856	27 276	9 354	3 962	12 971	3 629	4 480
1971	8 399	21 165	27 639	9 312	3 819	13 305	3 742	4 406
1972	8 940	21 490	28 846	9 859	3 879	14 171	3 936	4 636
1973	9 313	21 265	29 291	9 690	3 850	14 402	4 153	4 729
1974	9 839	21 508	29 476	9 309	3 959	13 993	4 045	4 818
1975	10 286	21 6[illegible]	28 554	9 113	3 869	13 937	4 260	4 918
1976	10 563	22 455	30 801	10 233	4 003	16 659	4 678	5 227

Source: Eurostat

Various reasons have been suggested for these changes in milk production. For the purpose of this study, the significant question is to what extent the ex-farm price of milk has influenced production. In other words, the study is concerned with the price elasticity of the supply of milk

One starting point in economic theory is that the supply elasticity is determined by the (aggregated) marginal cost curve for milk (Fig. 2).

Fig. 1 **Dairy cows per 100 ha Agricultural land**

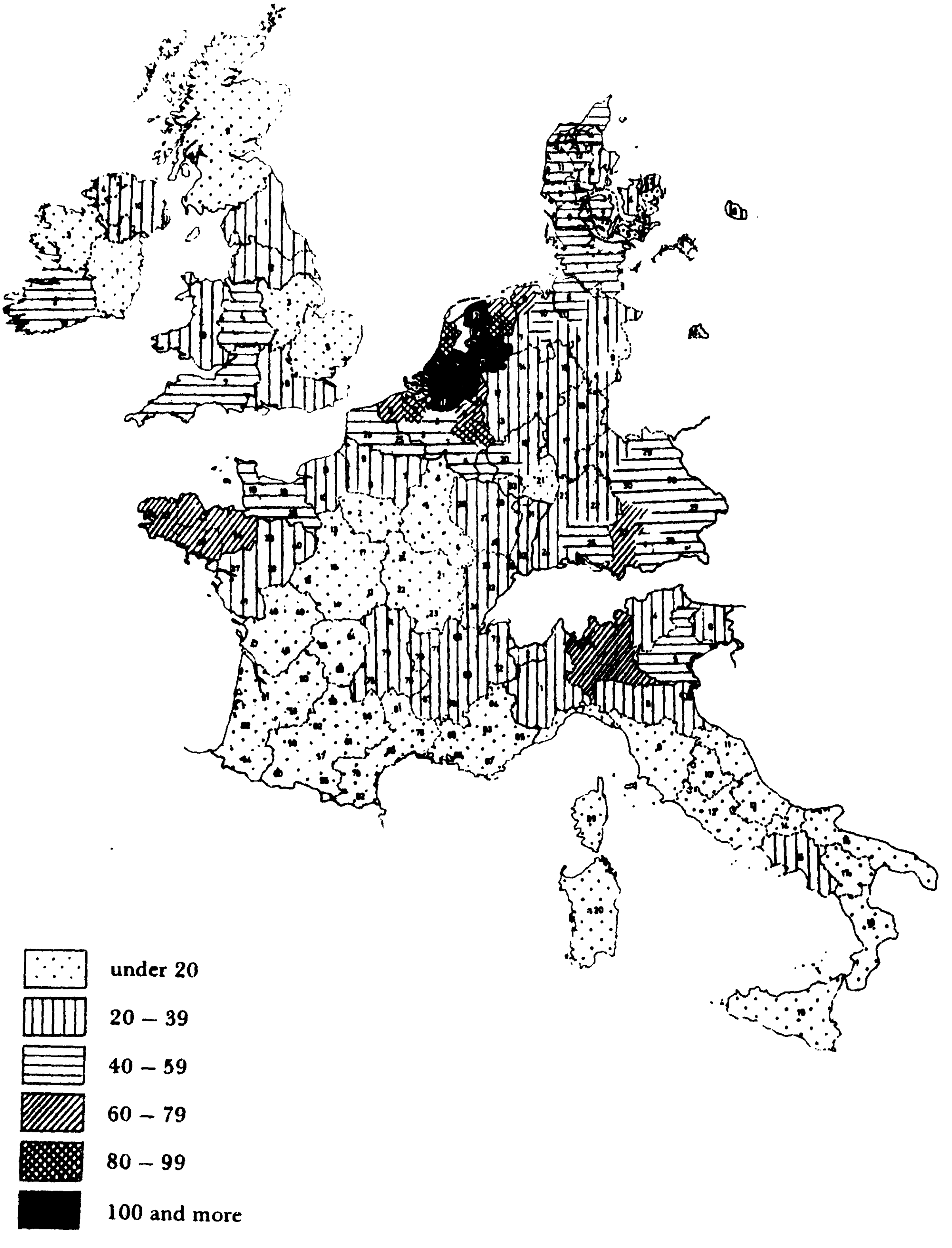
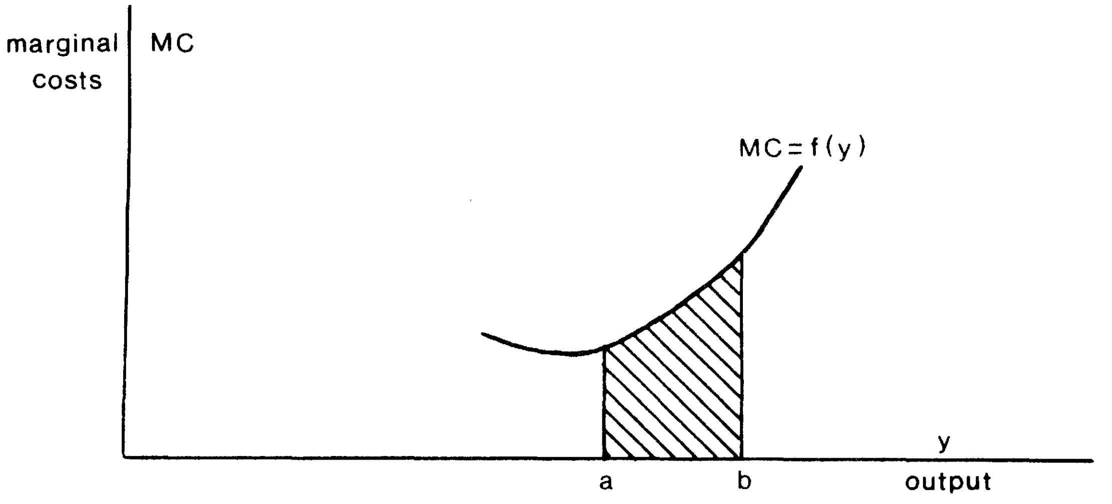


Fig. 2 Marginal cost curve



The curve depends on the trend in variable costs in milk production and accordingly also on the time-scale referred to (short-term, long-term).

Whan production increases from a to b in Figure 1, total costs increase with a variable cost element = $\int_a^b f(y)dy$.

The shape of the function f(y) from Figure 1 is as yet unknown, but the law of diminishing returns suggests a curve growing steadily steeper, and an exponential function would be an acceptable example. If MC = f(y) αy^β, then there is, for the whole distance ab, a constant price-elasticity of supply. At the same time it is supposed that β is positive. Doubt is often expressed whether these suppositions are in fact correct. The first assumption was questioned by Dijkstra in which he came to the conclusion that the production of milk was a lineair function of energy-input[1]. The second assumption concerns the problem of the so called inverse supply reaction.

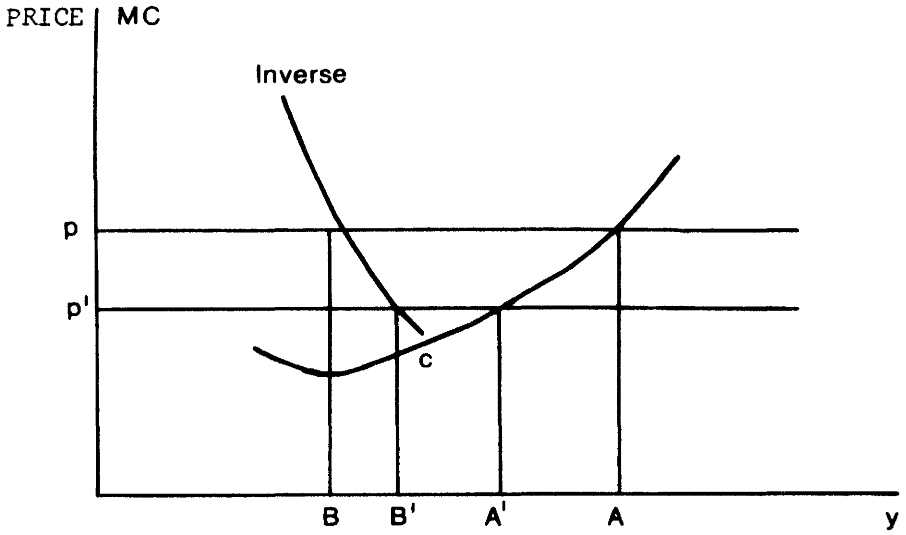
1) H. Dijkstra, de concurrentiepositie van Ierland op het gebied van de productie van gras en melk, Vakgroep Algemene Bedrijfseconomie, Landbouwhogeschool, Wageningen, 1978.

Inverse Price Reaction?

The backward sloping supply curve is familiar to agricultural economists.

It is possible that real supply behaviour is not in line with the basic idea of the first section of this paper, e.g. because farmers are tradition minded and not in fact profit maximizers, see fig. 2.

Fig. 3. Inverse price reaction of traditional farmers



If the price falls from p to p', production of the profit maximizer drops from A to A'.
The traditional farmer, who wants only to keep the same money-income, however, increases his production from B to B'. There is nothing irrational about this up to point C. It is only possible to do so if the farmer does not operate on the full intensity or the optimal way of production.[2)]

Sometimes it is said that the inverse reaction really happened in milk production, e.g. in Friesland in the 1920's and 1930's. The basic facts were as follows (Table 2).

2) This behaviour may be consistent with maximising utility rather than profit but only if the farmer can reach C by his own efforts. Of course he may not be maximising anything.

Table 2. Milk price and Milk production in Friesland

Year		M		P	Year	M	P
1925	=	100	=	100	1933	113	45
1926		197		80	1934	119	44
1927		109		86	1935	122	48
1928		114		90	1936	133	50
1929		110		83	1937	134	54
1930		110		66	1938	136	56
1931		109		48	1939	139	61
1932		114		45			

M = milk production P = milk price

This table suggest inverse supply behaviour, but only provided all other relevant factors were constant. And precisely this was not the case.

There were also drastic changes in technology, prices of alternative products (beef, grains, potatoes), prices of inputs (feed, fertilizer, labour, capital). Only a not ill-specified supply equation could lead so easily to the conclusion of a negative price-elasticity of supply in this case. For far production as a whole, however, we could not conclude that elasticity of supply[3)] was negative and there are no obvious reasons to believe that milk production were the exception. Empirical studies are needed to test this hypothesis.

The elasticity of supply of Dutch milk production estimated by the cost function

An important group of dairy farmers are to be found in Friesland. Professor Van Riemsdijk[4)] published some results of the estimation of

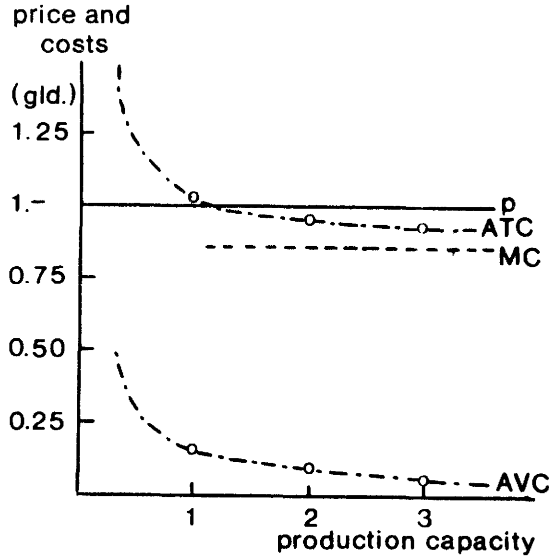
3) P.C. van den Noort, De averechtse aanbodselasticiteit bij landbouwproducten, Landbouwkundig Tijdschrift 74 (1962)-7,p.268-280

P.C. van den Noort & A.J. Oskam, An improvement of the supply-analysis of the farming industry, European Economic Review 5 (1974),p.187-192

4) J.F. van Riemsdijk, Economische aspecten van het bedrijfsgrootte vraagstuk als onderdeel van het structuurprobleem, 1960, p. 149.

the total cost function. In his opinion the total cost function would be of the type TC = c + vy (a linear curve). The average cost-curve would be AC = c/y + v (a hyoerbolic curve) and the marginal cost function would be MC = v (a horizontal linear curve (Fig. 4).

Fig. 4 Marginal cost curve for Frisian dairy Farmers



From this it follows that the supply-curve would be perfectly elastic that can be indicated as a all or nothing situation in which milk is either unconstrained by costs or absent on each farm. However it is also possible to use a curve of the type $TC = ay^3 + by^2 + cy$ and this gives an even better fit. The marginal cost curve in this case was

$MC = P = 7.5y^2 - 15.5y + 115.$

The flexibility of milk supply was for dairy farms with

2 men/26 ha (y = 2) : 0.24

3 men/39 ha (y = 3) : 0.65

on the average 0.50 so we can hardly say this is a perfect elastic supply. This is only one exemple of the great influence of the type of curve used on the results[5]. The choice of the type of cost curve is almost an arbitrary matter! For other regions such studies are not available.

5) P.C. van den Noort (ed.) Aspecten van agrarische sector economie, LH, Wageningen 1976, p. 31-40.

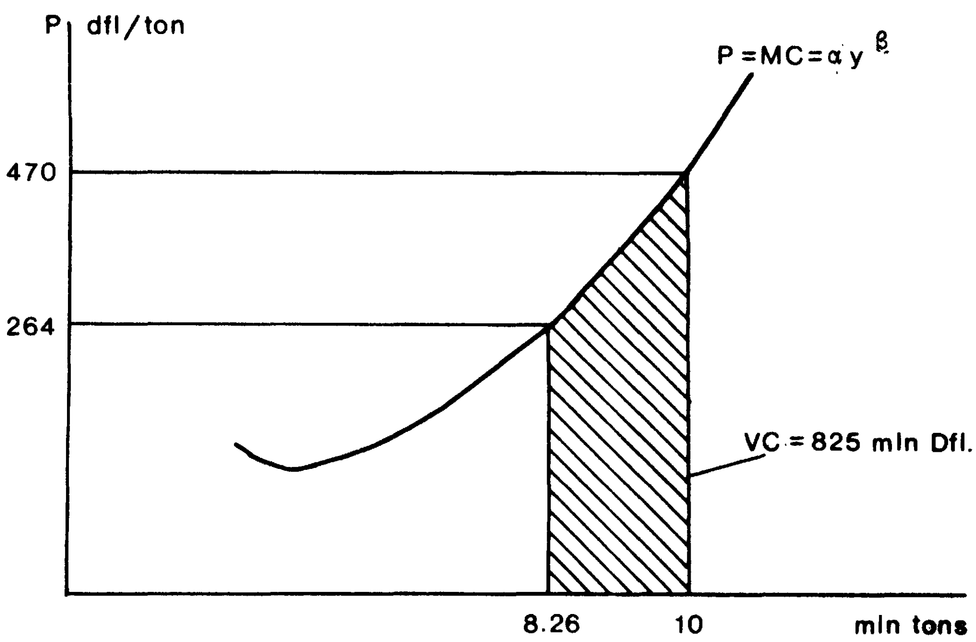
Another exemple is given in the Interim-Report[6)]

From a cost-study of Dutch milk production we could say that in 1974:

- total milk production was 10 m tons
- price for farmers: Hfl. 470 per tons
- variable costs of the last 17 per cent of milk production:Hfl.825 m.
- marginal cost for 8,26 m. tons was Hfl. 264.

We think that the exponential type of marginal cost curve is a realistic approximation. If we combine these points we get Fig.5.

Fig. 5. Marginal cost curve of Dutch dairy production in 1974.



Now remember that the increase in variable cost is $\int_{8,26}^{10} f(y)dy = 825$

From all this we can compute α and β, resulting in:

$$y = 0627 \times 10^6 . p^{0.45}$$

and the short-run price elasticity is 0.45 ex-farm.Elasticity of supply is somewhat lower ex-factory.

6) Interim-rapport EEG-zuivelbeleid FNZ,Den Haag,1978, Appendix B.

This conclusion is simple but not universally acceptable, since only a limited amount of data is available and a special supposition is made as to the shape of the curve, whereas many variations are possible. These limitations must be vorne in mind.

The production function method

In the absence of economies of scale CES production function can be written

$$Y^{-\rho}=\Sigma\delta_i X_i^{-\rho} \qquad (1)$$

where initial factor inputs $X_i = 1$, initial product = Y=1, initial prices of factors p_i are δ_i and initial product price = p = 1 and $\Sigma\delta_i = 1$ so price p_i = marginal product exhausts revenue 1.

In general all factors have a supply elasticity β_i so $X_i=(\frac{p_i}{\delta_i})^{\beta_i}$ (2)

Also in general all marginal products in value = price hence

$$p_i = p\delta_i(\frac{Y}{X_i})^{\rho+1} \qquad (3)$$

From (2) and (3) $x_i^{1/\beta}=p_i/\delta_i=(Y/X_i)^{1+\rho}p$ hence $X_i=(Y^{\rho+1}p)^{1/(1+p)+1/\beta_i}$ (4)

Substituting for X_i back in (1) $Y^{-\rho}= \Sigma\delta_i(Y^{\rho+1}p)^{-\rho/1+\rho-\rho/\beta}= Y^{-\rho}\Sigma\delta_i$ (5)

In neighbourhood of initial point Y = p = 1 all powers of Y and p = 1 hence

$$dy\ \Sigma\delta_i\ (\rho - \frac{\rho(\rho+1)}{1+\rho+1/\beta_i}) = dp\ \Sigma\ \delta_i(\frac{\rho}{1+\rho + 1/\beta_i}) \qquad (6)$$

cancelling ρ (which is strictly wrong if ρ = 0 as in Cobb-Douglas) and substituting the elasticity of substitution $\sigma=\frac{1}{1+\rho}$ (which = 1 in Cobb-Douglas)

$$dY\ \Sigma\ \delta_i(1 - \frac{1}{1+\sigma/\beta_i}) = \alpha p\ \Sigma\ \delta_i\frac{1}{(1/\sigma + 1/\beta_i)} \qquad (7)$$

The elasticity of supply (near Y = p = 1) $\frac{dy}{dp} = \frac{\Sigma\delta_i\beta_i}{(\sigma + \beta_i)} \div \frac{\Sigma\delta_i}{\sigma + \beta_i}$ (8)

this is a weighted average of the factor-supply elasticities with weights $w_i = \frac{\delta_i}{\sigma + \beta_i}$

The case where some factors are "variable" ($\beta_i \to \infty$) while other are "fixed"($\beta_i=0$) is special and elasticity leading to $\Sigma\delta_i \div \Sigma\frac{\delta_i}{\sigma} = \frac{\sigma\Sigma\delta_i}{1-\Sigma\delta_i}$ or in words:

The elasticity of supply = variable costs ÷ fixed costs x elasticity of substitution. The Cobb-Douglas is a special case with an elasticity of substitution = 1 so that

$$\text{supply elasticity} = \frac{\text{variable costs}}{\text{fixed costs}} .$$

Now starting from a CES-production function, a substitution elasticity $\sigma = 1$ and a situation in which costs = return and some factors of production are variable and some are fixed, we could show that the supply elasticity is variable cost ÷ fixed cost.
We get for four different regions in the Netherlands 1972/73.

		Per unit cost	Price obtained
I	Northern clay and peat pasture area	44.70	46.80
II	Western pasture area	44.10	43.90
III	Sand area (pasture farms)	44.20	44.85
IV	Mixed farms on sandy soil specializing in dairy	45.20	44.55

so that the requirement that costs equal returns is substantially satisfied. In subsequent years this is no longer true. Whether $\sigma \hat{=} 1$ cannot be tested[7]. The breakdown of costs and returns is given in Table 3.

Tabel 3. Costs and returns on dairy farms in the Netherlands, in 1972/73

Area	I	II	III	IV
Labour	0.34	0.35	0.31	0.32
Management	0.04	0.04	0.04	0.04
Feedingstuffs	0.22	0.28	0.26	0.26
Fertilizer	0.05	0.04	0.06	0.06
Rent	0.09	0.08	0.08	0.07
Equipment	0.09	0.08	0.08	0.08
Sundry	0.17	0.15	0.17	0.18
Milk	0.73	0.72	0.71	0.68

7) But $\sigma \hat{=} 1$ is not unlikely. See J.A. Wartna, Bouw en gebruik van econometrische modellen. Universitaire Pers, Rotterdam, 1974, p. 24.

Apart from a few small differences which are partly a matter of rounding, the proportions vary remarkably little. From this table we arrive at the calculations given in Table 4.

Table 4. Calculation of elasticity of supply of milk

Type of farm	Number of farms	Variable costs 1)	Fixed costs 2)	Proportion of milk in output	Elasticity
I	86	0.35	0.65	0.73	0.39
II	33	0.40	0.60	0.72	0.48
III	123	0.35	0.65	0.71	0.38
IV	54	0.41	0.59	0.68	0.47
Total	296	-	-	-	0.41

1) Feedingstuffs, fertilizer and 50% of sundries

2) Other elements

Source: LEI/CBS; Agricultural statistics 1975, page 145.

This suggests an average price-elasticity of supply of milk in the Netherlands of 0.41.

Assessment of price-elasticity depends substantially on what is included under variable costs and whether in fact $\sigma = 1$. Even quite small changes can have a significant influence on the result. Results in the range 0.20 to 0.60 are, indeed, arithmetically possible.

For a second, even more sophisticated method on formula (8) information on the elasticities of supply of the various production factors is required, but such information is almost entirely lacking, Boussard, nevertheless, came with wome estimates, resulting in a supply-elasticity of milk of +0.38 for the Dutch dairy sector[8].

Comparable calculations and observations may be made in respect of Belgian dairy farming, based on studies by Devisch and Hellemans[9]. Distinctions can be made in the year 1974-75. A breakdown of the variable and fixed costs is given in Table 5.

8) J.M.Boussard, Relationship between milk production and price variation in France and Italy, INRA, Paris, 1980.

9) N. Devisch & R. Hellemans, Economische aspecten en rendabiliteit etc., Landbouwtijdschrift nr. 6, 1977.

Table 5 . Structure of total cost of milk production in Belgium dairy farming 1974 - 1975

Area	Number of farms	Variable costs	Fixed costs including labour	Proportion of milk in total output	Elasticity
Campine	63	0.393	0.607	0.75	0.49
Liège	247	0.386	0.614	0.74	0.47
Upper Ardennes	33	0.321	0.669	0.69	0.34
Total	343	-	-		0.46

We should remember, however, that this sample is not quite representative for all Belgium dairy farming. Further data are available on the cost structure, depending on size of farm expressed in number of cows. (Table 6)

Table 6 . Estimates of supply elasticities of milk in three regions of Belgium

Area	Size	Variable costs[1]	Elasticity
Campine	< 20	0.257	0.34
	20-30	0.346	0.53
	30-40	0.386	0.63
	40-50	0.431	0.76
	> 50	0.481	0.93
Liège	< 20	0.306	0.44
	20-30	0.351	0.54
	30-40	0.378	0.61
	40-50	0.400	0.67
	> 50	0.445	0.80
Upper Ardennes	< 20	0.248	0.33
	20-30	0.309	0.45
	30-40	0.337	0.51
	40-50	0.371	0.59
	> 50	0.395	0.65

1) Share in the per unit costs of milk production

These calculations are even less representative or precise, but at least the trend is clear: the larger herds show a greater elasticity of supply of milk.

In order to get the best available estimate for Belgium agriculture I used also the sample of the Belgium Farmers' Union, consisting of about 1000 farms with an average of 28 ha and 26 cows. The share of variable costs was 0.32 and of the fixed costs 0.68; the proportion of milk in total output was 0.87. From these data of the Belgische Boerenbond for the year 1977-78 we can calculate a price-elasticity of supply of $\frac{0.32}{0.68} * 0.87 = 0.42$.

Linear programming method

A combination of cost analysis and production function-method can be found in the LP-models.

We can question the LP-model builders what will happen in their models with milk production in case of milk price reduction. The answer of LEI in the Hague was very simple, there would be no change in milk production if the price of milk went down from the present 64 cent/kg to 42 cent/kg in all their farm models. Conclusion: supply-elasticity almost zero in short run.[10)]

The model produces such answers because in the assumptions of the modelbuilder there were almost no alternative enterprises within the farm (no arable farming or pig farming) and no employment outside the farm (part-time farming) was considered. The assumption was also that there was a constant marginal productivity of feed to milk. Neither was there any variable included for reactions in the longer run. Also it is true that real farmers are often in different positions from those considered in the model. There is not an integrated series of LP-models for the whole of the Dutch farming industry, as is the case for West Germany in professor Hanpf studies. In Belgium there was no LP-model of this kind available.

Econometric methods for estimation of supply-elasticities for Dutch and Belgian milk production

There are various models available. One that covers various ideas on milk production is:

$$\dot{Q}_t = a_0 + a_1\dot{P}_{t-1} + a_2\dot{P}_{t-2} + a_3\dot{P}_{t-3} + a_4\dot{Q}_{t-1}$$

10) See also: L.B.van der Giessen, De invloed van de hoogte van de melkprijs op de melkproduktie, Landbouwkundig Tijdschrift 92 (1980) nr.6,p. 267-270

Estimation resulted in equations described in the Interim-Report from which the price elasticities could be figured out (Table 7)

Table 7. Price elasticity of supply of milk

Run in number of years	Price elasticity
1	0.28
2	0.34
3	0.66
4	0.85
5	0.99
.	.
.	.
	1.22

There are some variations, leading to similar price-elasticities. An important problem is the possibility to compute long series of more or less relevant equations. There often is no possibility for rational choice. Some observers are, therefore, somewhat sceptical about econometric approaches [11]. We will give some examples from the Interim-Report.

An attempt is made to determine the supply curve for the Netherlands dairy farming sector on the basis of a time-series analysis. Over the years many factors have combined to produce a shift in the curve. The question then arises as to whether the effect on the milk price and on the factors which have contributed to a shift in the supply curve has remained the same.

The most important factors determining milk production are:

- the price of milk
- the price of beef
- prices of calves
- prices of inputs (particularly fodder concentrates)
- the weather
- the state of production technology.

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11) P.C. van den Noort, Kwantitatief versus kwalitatief in de economie ? Landbouwkundig Tijdschrift (91) 1979, p. 304.

To make the number of variables manageable, the weighted prices of milk, beef and calves are combined in one price variable. Where a producer is also engaged in other branches of production, the overall price formation is the significant factor. In addition to fodder concentrates, other cost components are of significance in deciding the volume of milk production; these are not explicitly included in the equation but crop up in the trend variable, often because of gradual developments.

Technical progress, other things being equal, leads to a shift in the supply curve. It is difficult, however, to measure the extent of technical progress. For this reason a trend variable is often used. The rate of technical progress in the dairy farming sector is by no means uniform, however. Particularly in recent years there has been an acceleration (loose housing, market increase in the average size of dairy herds, etc.).

On the basis of the above factors the following supply equations are estimated[12]:

$$(1)\ Q_t = -47 + \underset{(0.20)}{0.37P_{t-1}} + \underset{(0.27)}{0.29P^v_{t-\frac{1}{2}}} + \underset{(0.21)}{0.15}\left[W_{t-1/2} - 0.84W_{t-3/2}\right]$$
$$+ \underset{(0.52)}{0.47T} + \underset{(0.98)}{2.74\ DT} + \underset{(0.2)}{0.84\ Q_{t-1}} \qquad R^2 = 0.994$$

$$(2)\ Q_t = 7.5 + \underset{(0.15)}{0.29P_{t-2}} - \underset{(0.24)}{0.16P^v_{t-3/2}} + \underset{(0.21)}{0.14}\left[W_{t-1/2} - 0.8W_{t-3/2}\right]$$
$$+ \underset{(0.5)}{0.05\ T} + \underset{(0.90)}{1.71\ DT} + \underset{(0.14)}{0.80\ Q_{t-1}} \qquad R^2 = 0.993$$

$$(3)\ Q_t = 25 + \underset{(0.14)}{0.30P_{t-3}} - \underset{(0.16)}{0.35P^v_{t-5/2}} + \underset{(0.19)}{0.27}\left[W_{t-1/2} - 0.74\ W_{t-3/2}\right]$$
$$+ \underset{(0.67)}{1.39DT} + \underset{(0.09)}{0.74\ Q_{t-1}} \qquad R^2 = 0.994$$

12) The reference period is 1958 to 1976 for all the equations. The figures given in brackets are the estimated standard deviations of the regression coefficients.

where:

Q = milk production (index; 1955 ≐ 100)

P = (weighted) price of milk, beef and calves (index; 1955 = 100; deflated by the purchasing power index for the guilder)

P^v = price of fodder concentrates (index; 1955 = 100; deflated by the purchasing power index for the guilder)

W = grassland weather index

T = trend variable: 1955 = 1; 1956 = 2, etc.

DT = trend variable: 1955 to 1966 = 0, 1967 = 1, 1968 = 2, etc.

Analogous equations were estimated for the same period, quantity and price variables being included in logarithmic form. The estimates as given in equations (1), (2) and (3) are fairly homogeneous. The estimated coefficients are not particularly reliable, however. In one case (price of fodder concentrate in equation (1)) the estimates coefficient as regards the sign, does not coincide with our expectations; the coefficient is, however, not significantly positive.

On the basis of the estimated equations, price elasticities of supply can be calculated (Table 8). Since the milk price makes up only part of the total price, the elasticities of a specific change in the milk price are also included. The elasticities of supply as determined by the price of fodder concentrates can be seen at the bottom of Table 8.

Table 8 · Short- and long-term price elasticities of milk production for two types of equation

Type of elasticity	equation	Short term: linear equat.	Short term: logarithmic equation	Long term: linear equat.	Long term: logarithmic equation
Total price elasticity	(1)	0.26 [a)] 0.15	0.31	1.6 0.9	5.8
	(2)	0.20 0.15	0.23	1.0 0.8	1.0
	(3)	0.21 0.14	0.28	0.8 0.5	1.0
milk price elasticity	(1)	0.19 0.11	0.23	1.2 0.7	4.3
	(2)	0.15 0.11	0.17	0.8 0.6	0.7
	(3)	0.16 0.10	0.21	0.6 0.4	0.7
fodder concentrate price elasticity	(1)	0.14 0.07	0.04	0.9 0.4	0.7
	(2)	-0.08 -0.04	-0.08	-0.04 -0.2	-0.3
	(3)	-0.18 -0.09	-0.23	-0.7 -0.4	-0.8

a) For the linear equations two elasticities are given in each case; the first figure is the average elasticity over the reference period (1958 to 1967); the second figure is for the 1976 price and quantity levels.

It is not easy to make out from the above equations how and over what time scale production reacts to the price of milk. It is thought, however, that a three-year time lag (see equation (3)) underestimates the flexibility of supply.

$$(4) \quad Q_t = 0.009 + \underset{(0.17)}{0.33\, P_{t-1}} + \underset{(0.14)}{0.02\, P_{t-2}} + \underset{(0.14)}{0.31\, P_{t-3}}$$

$$- \underset{(0.11)}{0.05\, P^{v}_{t-1/2}} + \underset{(0.11)}{0.024\, D} + \underset{(0.31)}{0.49\, Q_{t-1}} \qquad R^2 = 0.49$$

where : D is a dummy variable; D = 0 in the period 1958 to 1966, D = 1 in the period 1967 to 1976;

- All variables with a dot over them are relative changes over the preceding year (this implies that the coefficients concerned are elasticities).

Up to now real prices have been used; a more or less identical equation can be made for nominal prices:

$$(5) \quad Q_t = -1.25 + \underset{(0.11)}{0.37\, P_{t-1}} - \underset{(0.09)}{0.15\, P_{t-2}} + \underset{(0.09)}{0.37\, P_{t-3}} + \underset{(0.22)}{0.64\, Q_{t-1}}$$

$$R^2 = 0.63$$

The above equations lead to the total elasticity and milk price elasticity of supply shown in Table 9 .

From the results as a whole (Tables 8 and 9) a possible conclusion seems to be short-term and long-term milk price elasticity of 0.2 to 0.3 and 0.7 to 1.2 respectively. It is difficult to predict how dairy farmers will react to a deliberate change in policy. On the one hand, it seems that a more marked reaction is to be expected because over the reference period some of the price changes came about by chance and therefore had less effect on the volume produced. If, on the one hand, after a price change income remains constant, we then expect less reaction as regards supply.

Table 9. Price elasticities of supply depending on the term (in years)

Number of years	Total price		Milk price	
	Equation(4)	Equation(5)	Equation (4)	Equation (5)
1	0.33	0.37	0.25	0.28
2	0.51	0.45	0.38	0.34
3	0.90	0.88	0.67	0.66
4	1.10	1.14	0.82	0.85
5	1.20	1.32	0.90	0.99
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
oo	1.29	1.62	0.97	1.22

Table 10gives the elasticities for 1975 based on Belgian studies

Table 10. Supply of agricultural products: Number of dairy cows

Country	Producer Price Beef cattle		Ratio Prod.Pri. Cow milk/barley	Ratio Prod.Pri. Beef cattle/barley		Producer Price cows' milk
	P'	P'_{t-5}	$P_{3_{t-2}}$	P_4	$P_{4_{t-2,5}}$	$P_{6_{t-3}}$
D		0.08^{*}				0.26^{**}
F	-0.10^{o}	0.27^{**}				0.21^{x}
I		0.76^{x}				0.94^{x}
→ NL	-0.39^{**}	0.00				-0.18^{+}
→ BL	-0.28^{**}	0.11^{x}				0.23^{xx}
UK			0.05^{x}	-0.01^{+}	0.07	
IRL	-0.32^{+}	0.66^{+}				
DK	-0.22^{**}	0.08^{x}				0.49^{xx}
EZ	-0.17^{**}	0.24^{xx}				0.30^{xx}
EN	-0.12^{**}	0.23^{xx}				0.41^{xx}

xx, x, +, o, level of significance: 1%, 5%, 10%, 20% risk

Member States: price deflated by CDP-index 1973 = 100, BF 1973 (1973 average official exchange rate)

EUR-6 and EUR-9: weighted EEC price (physical production "74") - BF 1973 average official exchange rate)

Source: CLEO Schriften 29, Mei 1980, p. 7, Louvain

These data spplied by CLEO to the European Commission should according to professor Boddez not be considered as supply-elasticities, so we may not conclude that the Dutch dairy production (NL in table10) would have an inverse price relationship between production and price.

Another econometric study of the European dairy farms originates from the Institute of Agricultural Economics of the University of Göttingen.In this study H.C.Aeikens[13] found the following price elasticities for milk supply: in Belgium + 0.25 and in Holland + 0.38. Acoording to Mr. Viaene[14]

13) H.O.Aeikens,Forecasting milk production in the EEC-countries, Paper presented at the 20th annual meeting of the Society for Agricultural Economics and Social Science, Bonn, 1979

14) Prijsgevoeligheid van de Belgische melkveehouderij,Landbouw-tijdschrift, (Brussel), 1980.

econometric abalysis leads to supply elasticities of milkproduction in Belgium of 0.20 - 0.35 on short run and 0.45 on long run.

Public Opinion Polls

We can question the farmers directly how they would react on a price freeze or decrease for milk. In the Netherlands[15)]

45% of the farmers would not react

18% of the farmers would drease their production of milk

25% of the farmers would increase their milk production.

On balance the price reduction would increase milk production. This method is very direct. The answer depend a little on the effect the farmers expect them to have on politicians. There is also a gap between the idea to increase, decrease etc. and the realisation. Because the farmer propably will answerd such questions from a private economic point of view that is all other factors involved are constant. But if a lot of farmers start to buy cows, the price will increase and perhaps the price of feed and land will follow. This will bring a lot of farmers to different ideas again[16)].

15) Boeren geven hun mening over knelpunten in beleid en bedrijfsvoering. Bedrijfsontwikkeling 1979, p. 875 - 877.

16) P. Bos, Tussen voornemen en werkelijkheid gaapt soms een afgrond, De Boerderij, 1979, p. 12-13.

Conclusions

It is very difficult to estimate the supply-elasticities for agricultural products, milk is by no means an exception.

There are several methods available resulting in confusing results for the short run. Considering a period of two to five years as medium run and five to ten years as long we can say that the medium run elasticity for Belgium and Dutch agriculture was about + 0.4 and on long run + 1.0 resp. 1.2. The backward sloping supply curve or inverse price reaction seemed not very likely at least on medium run. This effect of milk prices on milk production, however, is not so strong as the one of technical progress and structural change, which are also not neutral for long run price-levels of the milk price. To give reliable estimates for the future is even more difficult. For these reasons a perfect estimate is not yet available.