ROYAL COMMISSION ON FARM MACHINERY

DEMAND FOR FARM MACHINERY - WESTERN EUROPE

Henry G. Scott
David J. Smyth

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by

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1. INTRODUCTION AND SUMMARY

This study analyzes the factors determining the use of farm machinery in Western Europe. The analysis is intended to provide a framework for making conditional forecasts, in which one variable can be predicted in terms of others. No unconditional predictions are made because the quantity and price of agricultural output in the western European countries are to a considerable extent determined by policy decisions which may be radically changed in the near future. It is hoped that the effects and implications of particular changes can be considered in the light of this analysis. Furthermore the study of the proportion in which the factors of production are used can provide insight into various aspects of agricultural production.

The study has seven chapters. This first chapter sketches the theoretical framework, describes some of the problems of measuring mechanization, and summarizes the main conclusions. Chapter 2 describes the pattern and recent trends in the mechanization of Western Europe. Chapter 3 discusses the agricultural policies of the area, and their effect on the use of farm machinery. Chapters 4 and 5 set up theoretical models of derived demand, and apply them to the use of tractors and labour. The first of these two chapters is a cross-sectional study of the use of tractors relative to labour in the western European countries, and the second uses time-series data to analyze the way in which tractors have been substituted for labour in Britain during the post-war period. The relationships among mechanization, farm size, and the type of farming in England and Wales is described in Chapter 6. It is hoped that the study of the most advanced agricultural sector in Western Europe will give insight into likely developments for the rest of that region. This chapter also attempts to identify the reasons why there are low returns on small farms.

The final chapter develops a forecasting model of mechanization, and considers the role of technical change in the model. The model is then applied in retrospect to mechanization in Western

Europe, and is used to study some of the implications of the *Mansholt Plan* for the reform of agriculture in the European Economic Community (EEC).

Variations of a single theoretical model are used throughout the analytical parts of this study. The basis of this model is that the conditions of production can be represented by forms of constant elasticity of substitution production functions.[1/] These production functions, which relate output to the input of the factors of production, are not themselves specified, but derived from them are side relations that relate the productivity of the factors of production to the proportion in which they are used. The assumption is made that farmers maximize their profits (value of output net of their variable costs) subject to the production functions and to the other constraints that face them. The main constraints are the prices of output and inputs, the amount and quality of land available to the farmer, and the immobility of his own or his family's labour, which deprives him of the ability to charge the market wage for this labour. Optimal factor and output proportions are derived for different versions of the production functions and of the constraints, and these are tested against the available data.

The study focuses attention on the proportion in which machinery is used relative to labour. However, there is no reason why the same theoretical model should not be formulated in terms of other pairs of factors of production, or of factors relative to output. Indeed, the use of machinery relative to output and to land is discussed in Chapters 6 and 7. The main emphasis is on the use of machinery relative to labour, because that formulation of the model makes explicit the role of the price of labour in determining the level of mechanization.

One of the main problems in this study has been a shortage of data, making it difficult to measure the level of mechanization, the use of other factors of production, and the level of output.

Tractors have been taken as indicators of mechanization in most of this study. This involves some problems. The first is that tractor sizes differ between countries and over time. These

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1/ This type of production function and the model with which it is used are described in Chapter 4.

differences can be substantial, so that comparisons based on unmodified tractor numbers can be misleading. Tractor horsepower provides a better measure of the capitalization in tractors, but there are fewer statistics for tractor horsepower than for tractor numbers. A more fundamental difficulty is that the use of tractors may not properly represent the general level of mechanization. Mechanization does not proceed at the same rate with all types of equipment. It appears that the tractor is the basic piece of equipment, typically obtained at an early stage of mechanization; other types of machinery are acquired later. Thus the use of tractors as indicators of mechanization understates the difference between advanced countries with a high level of all types of mechanization, and those that might have a lot of tractors but relatively little other equipment. Further difficulties arise from the wide variation in the intensity with which tractors are used in different countries.

Much of the data used in this study is of limited reliability. In particular, it is difficult to get data that are comparable between countries, because of variations in definitions and classifications. In come cases crude approximations have been used to reconcile such differences or to supplement incomplete data. In such cases, the table or figure concerned is described as an "estimate". The data ascribed to official sources are also of varying accuracy. Here again the international comparisons, particularly of wages and prices, are probably the least reliable.

SUMMARY OF CONCLUSIONS

The conclusions of this study are as follows:

(1) The main determinants of the use of machinery relative to labour in agriculture are the level of agricultural wages relative to the price of machinery, and the size (in land) of farms.

(2) There is a high degree of substitutability between machinery and labour in agriculture, so that a change in their relative prices will be associated with a proportionately greater change in their relative use. This elasticity of substitution seems to be of the order of one-and-one half. Since this is a greater degree

of substitutability between machinery and labour than has been observed in most studies of manufacturing industries, two implications can be drawn. First, agriculture will eventually be a capital-intensive industry relative to manufacturing. Second, a given fall in the price of machinery will be a greater depressant on the demand for labour in agriculture than in manufacturing. This could contribute to the lag in agricultural earnings.

These results are supported both by cross-sectional and time-series analysis for both Western Europe and England. Other results, obtained mainly from the study of farming in England and Wales, follow.

(3) The low rate of return on inputs for small farms is primarily due to the immobility of farmers' labour, and only secondarily due to the indivisibility of machinery. In the case of predominantly cropping farms, the indivisibility of machinery appears to be as important a constraint as the immobility of labour. This also explains why the use of machinery relative to labour is lower on small farms than on large ones, again with the exception of cropping farms where it is about the same.

(4) There is no evidence that there are increasing returns to scale over all the factors of production in agriculture, or that the large farms enjoy a technology that is superior to that on the small farms. This was tested, but not supported. The higher returns of the large farms can be explained by their ability to use their factors of production in different proportions than the small farms, for the reasons described in (3).

An implication of these last two results is that there is no point in trying to solve the problem of low incomes on small farms by subsidizing the use of machinery on these farms. This would be an inefficient way of subsidizing the farmer. More to the point are policies to improve the mobility of agricultural labour and increase the size of small holdings.

(5) Dairy and livestock production by traditional extensive-farming methods appear to use less machinery relative to

labour than crop production. However, the intensive production of pig and poultry products, and presumably of other livestock products, by factory-farming methods requires relatively large amounts of machinery. Since these intensive methods are a way of mitigating the small-farm problem, and of increasing the output of the type of products for which there is a rising demand, it seems likely that this could be a major growth point for the use of machinery.

(6) Technical progress over time seems to be somewhat biased towards the use of machinery, in the sense that the use of machinery relative to labour, that would be optimal for given relative prices and size of farm, seems to be rising.

(7) A final, common sense sort of conclusion is that since the increase in the use of machinery can be considered as a substitution for labour, potential markets exist in countries where there are large agricultural labour forces. This potential starts to be realized when the process of industrialization increases the demand for labour and so increases wages throughout an economy. In Italy during the past 10 years, and more recently in Spain, the use of tractors has been rising very rapidly. The rapid growth in the use of tractors in these countries is likely to be maintained. Growth in the use of tractors can be anticipated in other countries that are industrializing and are approaching the level of agricultural wages that exist in Spain -- for example, Portugal, Greece, Yugoslavia, and perhaps some Latin American countries. The use of most other types of machinery appears to develop later than the use of tractors.

2. FARM MECHANIZATION IN WESTERN EUROPE

In this chapter the level of mechanization in Western Europe is compared with that in other parts of the world, and comparisons are made between the different regions and countries of Western Europe. An attempt is made to describe how mechanization has occurred in the regions and countries since the early 1950s, but because of the limited availability of data it is not possible to make all the comparisons at the same date or over the same period of time.

Comparisons of the number of tractors or the amount of tractor horsepower used in different countries are made on the basis of both the quantity of labour employed in agriculture, and the quantity of arable land. The justification for using all agricultural labour as a basis of comparison is that tractors are of such general use in agriculture as to be directly comparable with labour. This is an oversimplification, since different types of agricultural activities might require different labour-tractor combinations. Thus different countries might reflect different levels of mechanization even with similar cost structures due to different patterns of output. For example, livestock products constitute a higher proportion of total agricultural output in the northwestern countries of Europe than in the southwestern countries. The use of combine harvesters is compared relative to land used in cereal cultivation and relative to cereal output. Investment in machines is compared on the basis of agricultural labour and of output.

Two different measures of current gross investment in agricultural machinery have been used. First, current gross investment is taken to be a country's production, plus imports, less exports. This "absorption" measure has the advantage of evaluating the size of the demand at approximately production costs, since distribution costs and tariffs, etc., are not included. As a result, the measure provides a better basis for comparing the quantity of machinery being absorbed or the value of machinery being produced than does a measure of expenditure.

There are advantages connected with the availability of data, since figures for delivery and for international trade are available specifically for agricultural machinery. The main disadvantage of the absorption measure is that it does not always accurately reflect the timing of use of new machinery due to changes in inventory, etc., so measures of this sort are unsuited for analyzing year-to-year changes. Furthermore, since the distribution costs and tariffs are excluded, the absorption measure does not reflect the investment by the farmer.

The other measure of investment used is the national-accounting concept of gross capital formation in machinery and equipment in agriculture. This measure has the advantage of giving the value of expenditure by the farmer, but one disadvantage is that the class "machinery and equipment" is somewhat more broadly defined than is "agricultural machinery". Moreover, since this measure includes the tariffs and distribution costs, it overstates the amount being received by the manufacturers. The results of these two types of measures are generally, but not always, consistent.

WESTERN EUROPE COMPARED WITH OTHER REGIONS

Western Europe is one of the major users of agricultural machinery. It has about a third of the world's total tractors, and almost as many as North America (Table 2.1).

Western Europe has accounted for half the world increase in tractor numbers between 1952/56 and 1966. The rate of increase in the use of tractors has not been appreciably greater in Western Europe than in Eastern Europe and the U.S.S.R., or Latin America, and has been slightly less than in Asia. However, these regions started with fewer tractors than Western Europe so that the growth has been less significant in absolute terms. On the other hand, North America, which at the beginning of the period was by far the major user of tractors, had a much smaller increase, contributing little to the growth of the world tractor population. This comparison of numbers understates the tractor power of North America relative to Western Europe, because North American tractors tend to be larger than European ones. In 1960 the average tractor size in North America was 31 HP compared with 25 HP in Western Europe.[2/] The average tractor size has been increasing considerably in both regions since 1960.

TABLE 2.1

TRACTORS USED IN AGRICULTURE

	Average 1952/56	1966	Increase 1952/56 Average to 1966	
	(Thousands)		(Thousands)	(Per cent)
Western Europe	1,580	4,536	2,956	187
Eastern Europe and U.S.S.R.	957	2,368	1,411	147
North America	4,793	5,425	632	13
Latin America	199	512	313	157
Asia(a)(b)	85	251	166	195
Africa(c)	58	103	45	77
Oceania	249	406	157	63
World Total(d)	8,006	13,812	5,806	73

(a) Excluding China.
(b) Excluding Israel.
(c) Excluding South Africa.
(d) Excluding China but including Israel and South Africa.

Source: Food and Agricultural Organization (FAO), The State of Food and Agriculture 1968, p. 46.

The tables below compare the use of tractors in Western Europe with other regions on the basis of land and labour.

TABLE 2.2

TRACTORS PER 1,000 HECTARES OF ARABLE LAND

	1954	1966
Western Europe	16	43.7
Eastern Europe and U.S.S.R.	3	8.2
North America	21	24.3
Latin America	2	4.7
Oceania	7	10.4

Source: FAO, The State of Food and Agriculture 1968, p. 46; and for 1954, FAO, Production Yearbook, various years.

2/ Organization for Economic Co-operation and Development (OECD), Development of Farm Motorisation and Consumption and Prices of Motor Fuels in Member Countries, Paris, June, 1963, p. 12.

The intensive agriculture of Western Europe has now achieved a very high concentration of tractors on the land compared with North America and other regions. But when the comparison is made on the basis of labour, the level of western European mechanization is seen to be much lower than in North America or Australia and New Zealand. By the mid-1960s Eastern Europe and the U.S.S.R. had reached the level of use of tractors in relation to labour (but not land) achieved in Western Europe a decade earlier.

TABLE 2.3

TRACTORS PER 100 PERSONS ACTIVELY ENGAGED IN AGRICULTURE (ESTIMATES)

	1954	1964	Percentage Increase
Western Europe	5	17	240
Eastern Europe and the U.S.S.R.	2	7	250
North America	67	90	34
Australia and New Zealand	41	66	60

These estimates of mechanization conceal substantial differences within the regions, particularly in the case of Western Europe, considered later.

Data on the world distribution of combined harvester-threshers are less complete than for tractors.

TABLE 2.4

COMBINED HARVESTER-THRESHERS USED

	1954	1964	Increase 1954-64	
	(Thousands)			(Per cent)
Western Europe	90	420	330	367
Eastern Europe and the U.S.S.R.	(350)	600	250	71
North America	1,100	1,160	60	5
Australia and New Zealand		70		

Source: FAO, Production Yearbook, various years.

It is apparent that Western Europe has a smaller share of the world total than it does for tractors, with less than either North America or Eastern Europe and the U.S.S.R. This lag in western European use of combined harvesters relative to tractors, compared with North America, cannot be explained on the basis of differences in the relative importance of grain cultivation in the two regions. Table 2.5 shows that the proportion of arable land being used for the cultivation of cereals is slightly larger in Western Europe than in North America.

TABLE 2.5

ARABLE LAND AND CEREAL CULTIVATION (1963)

	Arable Land	Cereal Cultivation	Cereal/Arable
	(Millions of hectares)		(Per cent)
Western Europe	95	40	42
North America	227	82	36

Source: OECD, Agricultural Statistics, 1953-63, p. 10.

Presumably the intensive cultivation and small size of farms in Western Europe is less conducive to the use of combine harvesters than is the extensive agriculture of North America or the U.S.S.R. The wetter weather and shorter harvesting season might also inhibit the use of harvesters in Western Europe.

The use of combines, standardized on the basis of cereal cultivation and production, is presented in Table 2.6.

TABLE 2.6

USE OF COMBINES RELATIVE TO CEREAL CULTIVATION AND PRODUCTION (1964)

	Combines per 1,000 Hectares of Cereal Cultivation	Combines per 1,000 Tons of Product
Western Europe	11	4.5
U.S.S.R.	4	3
North America	14.5	5.5
Australia and New Zealand	8	6

Source: FAO, Production Yearbook, various years.

Compared with the table showing tractors relative to arable land, Table 2.6 suggests that the intensity of use of combine harvesters on land in Western Europe compared with other regions is appreciably less than the intensity in use of tractors.

The 1954-64 increase in use of combines in Western Europe has been greater than the increase in their use in either North America or Eastern Europe and the U.S.S.R. both in absolute numbers and as a percentage of the initial number. Despite the low numbers at the beginning of the period, Western Europe has been an important source of demand for combines as well as for tractors.

The demand for equipment covers, of course, both new stock and replacements. While Western Europe appears to have been the most important region of demand for augmenting the amount of agricultural machinery, the larger amounts of machinery existing in North America has made that region more important for replacement demand. Rough data on the level of absorption (production net of international trade) indicate that North America has a greater total demand for farm machinery than does Western Europe (Table 2.7). As the size of the stock of machinery in Western Europe approaches that of North America, the replacement demand in the former is likely to approach that in the latter, although with some time lag.[3/]

TABLE 2.7

ABSORPTION OF AGRICULTURAL MACHINERY
IN 1964/65 (ESTIMATES)

	Tractors	Other Machinery	Total
Total Absorption	(Billions of U.S. dollars)		
Western Europe	1.1	1.5	2.6
North America	1.5	2.1	3.6
Absorption per Person Engaged in Agriculture	(U.S. dollars)		
Western Europe	49	66	115
North America	270	380	650

3/ Replacement demand will depend not only on the size of the capital stock, but also on such factors as its age structure, its intensity of use, and the cost of repairs and maintenance relative to cost of replacement.

The present level of absorption per person engaged in agriculture is much higher in North America than in Western Europe. On the other hand, if the level of absorption is compared on the basis of land area instead of labour, it is lower in North America than in Western Europe, reflecting the greater intensity of cultivation in the latter region.

MECHANIZATION WITHIN WESTERN EUROPE

The level of farm mechanization varies widely within Western Europe. In this section a contrast is drawn between Northwestern and Southwestern Europe, and the pattern of mechanization in individual countries is considered. Western Europe is taken to consist of the European zone of the OECD, excluding Turkey but including Finland. Southwestern Europe consists of Greece, Italy, Portugal, and Spain. Particular attention is paid to the four countries that now use most of the agricultural machinery in Western Europe: Britain, West Germany, France, and Italy.

Comparisons between Northwestern and Southwestern Europe

Table 2.8 summarizes the distinction between the two regions.

TABLE 2.8

DISTRIBUTION OF INPUTS AND OUTPUT BETWEEN NORTHWESTERN AND SOUTHWESTERN EUROPE

	Percentage of Total Western Europe	
	Northwestern Europe	Southwestern Europe
Population engaged in agriculture (1966)	48	52
Arable land (1966)	53	47
Tractors in use (1966)	84	16
Combined harvester-threshers in use (1966)	92	8
Absorption of agricultural machinery (1965)	84	16
Gross agricultural product (1966)	63	37

Source: Estimates derived from data in the Appendix.

Briefly, the countries of Northwestern Europe have high national incomes and industrialized economies, with a relatively small proportion of the labour force engaged in agriculture compared to the countries of Southwestern Europe which are poorer and have relatively large agricultural labour forces. Italy has some of the characteristics of both regions, but has been included as part of Southwestern Europe. Northwestern Europe has a little more than half the total arable land, and a little less than half the agricultural labour force of Western Europe, yet it dominates the use of, and demand for, agricultural machinery.

The use and level of absorption of agricultural machinery in 1965 is illustrated in Table 2.9.

TABLE 2.9

AGRICULTURAL MACHINERY USED (1966) AND ABSORBED (1965)

	Used in Agriculture (1966)		Absorption (1965)	
	Tractors	Combines	Tractors	Other Machinery
	(Thousands)		(Millions of U.S. dollars)	
Western Europe	4,453	498	1,100	1,500
Northwestern Europe	3,760	460	900	1,300
Southwestern Europe	693	38	200	200
Britain	455	65	134	139
France	1,051	109	250	313
Germany, Federal Republic	1,215	142	344	492
Italy	461	14	126	147

Source: Estimates derived from data in the Appendix.

The data on capital expenditure on machinery and equipment in agriculture are less recent than that on "absorption" but are consistent with it, and corroborate the importance of Northwestern Europe relative to Southwestern Europe in the demand for machinery. The 1960/62 annual average capital expenditure on new machinery and equipment in Western Europe was about $2.5 billion, and all except $371 million was in Northwestern Europe.[4/] Four countries, France, West Germany, Britain, and Italy, accounted for about 70 per cent of the total use and absorption of agricultural machinery in Western Europe in 1965.

The importance of Northwestern Europe compared with Southwestern Europe in the use of, and demand for, machinery is also reflected in comparisons of the degree of mechanization when standardized on the basis of agricultural labour and land (Table 2.10).

TABLE 2.10

TRACTOR HORSEPOWER IN RELATION TO AGRICULTURAL LABOUR AND LAND, 1966

	Tractor Horsepower	
	Per Person Employed	Per 100 Hectares of Arable Land
Western Europe	6.3	148
Northwestern Europe	10.6	226
Southwestern Europe	2.2	57
Britain	21.2	250
France	9.5	161
Germany, Federal Republic	9.7	340
Italy	3.6	110

Source: Estimates calculated from data in Appendix.

Approximately five times as much tractor horsepower per person is engaged in agriculture in Northwestern Europe as in Southwestern Europe, with the same ratio holding in a comparison between Britain and Italy, two of the most highly mechanized countries of their respective regions. Machinery is also used more intensively on the land in Northwestern than in Southwestern Europe.

It appears that Southwestern Europe is relatively more mechanized in tractors than in combine harvesters. In Northwestern Europe there are ten times as many combine harvesters

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4/ FAO, <u>5th Report on Output, Expenses and Income of Agriculture in European Countries</u>, Geneva, 1965, Vol. II, Table LVII, p. 267.

relative to land as there are in the Southwestern European region, but only four times as many tractors (see Appendix Table A.9).

It is interesting to note the difference in mechanization between the three largest countries of Northwestern Europe although the national income is about the same level in all three. Labour is more mechanized in Britain than in Germany or France, but in Germany both machinery and labour are applied to land much more intensively than in the other two countries.

Mechanization 1950-66

Mechanization in Western Europe has increased greatly since 1950. This increase has not been at a uniform rate in all the countries or constant over time in individual countries. Some countries, especially Britain and Sweden, were using considerable amounts of machinery before the beginning of the period and their consequent rates of mechanization were slow. West Germany, Belgium, and Denmark underwent very rapid mechanization during the early 1950s, slowing down later. Others, such as Spain, started with virtually negligible levels of mechanization, but during the past few years have had rapid growth. The process of mechanization is illustrated by the increase in use of tractor horsepower over the period (Table 2.11).

TABLE 2.11

GROWTH OF TRACTOR HORSEPOWER IN AGRICULTURE

Total	1950	1956	1960	1966
	(Millions of horsepower)			
Western Europe	22.1	52.5	75.8	139.5
Northwestern Europe	19.8	46.0	66.0	114.3
Southwestern Europe	2.3	6.5	9.3	25.1
Per Person Engaged in Agriculture	(Horsepower)			
Western Europe	0.6	1.3	2.7	6.3
Northwestern Europe	1.1	3.1	5.0	10.7
Southwestern Europe	0.1	0.4	0.7	2.2

At the beginning of the period, Southwestern Europe was virtually unmechanized, but by 1966 it reached the level of mechanization attained in Northwestern Europe in the early 1950s. During the period as a whole about four-fifths of the total increase in tractor horsepower was in Northwestern Europe, but in the most recent part of the period Southwestern Europe accounted for about a third of the increase. The rate of increase in tractor horsepower has been faster in Southwestern Europe than in Northwestern Europe throughout the period (about 20 per cent per year compared with 11 per cent per year) but the initial level of mechanization in Southwestern Europe was so low that the fast growth rate has only recently started to have an impact on the relative importance of Southwestern Europe in the total utilization of tractor power. A similar pattern can be seen in the increase in use of combine harvesters.

TABLE 2.12

GROWTH IN USE OF COMBINED HARVESTER-THRESHERS IN EUROPE

Total	1950	1956	1960	1966
		(Thousands)		
Western Europe	29	110	239	498
Northwestern Europe	28	107	228	460
Southwestern Europe	1	4	11	38
Per 1,000 Hectares of Cereal Cultivation				
Western Europe	0.3	2.6	5.9	12.0
Northwestern Europe	1.2	4.6	9.4	19.0
Southwestern Europe	-	0.3	0.7	2.0

Source: Estimated from data in Appendix.

At the beginning of the period there were about 29 thousand combines in Western Europe, most of them being in Britain, Sweden, and France. There were virtually none in Southwestern Europe. By 1966 there were nearly half a million combines in Western Europe, almost all in the richer countries of the Northwest. The use of a considerable number of combines in Northwestern Europe is a development since 1955, and their use in Southwestern Europe has hardly commenced.

Structure of Capital Formation in Agriculture

There is considerable variation in the distribution of capital expenditure in agriculture between new buildings, construction, and general improvements on the one hand, and between new machinery and equipment on the other. This variation is illustrated for the four major countries (Table 2.13).

TABLE 2.13

COMPOSITION OF CAPITAL EXPENDITURE IN AGRICULTURE, 1960-62

	Percentage of Capital Expenditures	
	New Buildings, Construction, and Improvements	New Machinery and Equipment
Britain	33.4	66.6
France	17.1	82.9
Germany, Federal Republic	58.9	41.1
Italy	72.1	27.9

Source: ECE/FAO, 5th Report on Output, Expenses and Income of Agriculture in European Countries, Geneva, 1965, Vol. II, Table LVIII, p. 268.

Data are given in the Appendix for most of the western European countries. There seems to be some tendency for the more industrialized countries to have a relatively high proportion of capital formation in machinery and equipment compared with the countries of Southwestern Europe. Germany, Norway, and The Netherlands are exceptions to that pattern, but the first two of those countries had exceptionally high levels of capital expenditure relative to gross agricultural product.

The data on absorption of agricultural machinery indicate that there is a tendency for tractors to form a relatively high proportion of total absorption of machinery and equipment in the less mechanized countries.

TABLE 2.14

INVESTMENT IN TRACTORS RELATIVE TO AGRICULTURAL MACHINERY, AND TRACTOR HORSEPOWER IN USE -- SELECTED COUNTRIES

	Tractors as Percentage of Total Absorption of Agricultural Machinery (1965)	Tractor Horsepower per Employed Person (1966)
Britain	33	21.2
France	44	9.5
Germany, Federal Republic	41	9.7
Sweden	39	20.0
Greece	58	1.0
Italy	46	3.6
Portugal	74	0.6
Spain	56	1.5

This would appear to support the contention made earlier that investment in tractors occurs at an early stage of the mechanization process.

LAND, LABOUR AND DRAFT ANIMALS IN WESTERN EUROPEAN AGRICULTURE

In this section, trends in the use of three broadly defined factors of production are considered. It should be noted that the data on draft animals, and labour in particular, are only rough indicators of the availability of animal draft power or of the use of manpower.

Agricultural Land

In contrast to the substantial changes that have occurred in the amount of labour and capital used in western European agriculture, the quantity of land has remained almost constant (Table 2.15).

TABLE 2.15

DISTRIBUTION OF AGRICULTURAL LAND

	1952/56 Average	1963	1967
	(Millions of hectares)		
Agricultural Land			
Western Europe	169	170	167
Northwestern Europe	94	94	95
Southwestern Europe	75	76	72
Arable Land			
Western Europe	94	95	94
Northwestern Europe	50	50	50
Southwestern Europe	44	45	44
Cereal Cultivation			
Western Europe	41	40	41
Northwestern Europe	22	23	25
Southwestern Europe	18	17	16

In no country has there been a substantial change in the quantity of agricultural land, although there have been slight increases (about 3 per cent over the period) in the least developed of the southwestern countries, perhaps associated with improved irrigation, offset by a decline of about 1 per cent in the rest of Western Europe, perhaps associated with urbanization and road development. It is possible that these small changes disguise a fall in the quality of the land as urbanization, and to a lesser extent, road development, tend to encroach on high-quality agricultural land near the urban areas. There have been somewhat larger changes in the quantity of land used for cereal production: in particular a fall of about 10 per cent in the southwestern countries.

Although the quantity of agricultural land has remained approximately constant, its fertility has been augmented by the increasing use of artificial fertilizers. In fact, the development of fertilizer use in Western Europe has closely followed the pattern of mechanization. At present, Western Europe consumes about a third of the world total of commercial fertilizer. In 1964/65 nearly 13 million tons were used in Western Europe, compared with 6.3 million tons in 1954/55.[5/] About 83 per cent of the 13 million tons consumed in 1964/65 were used in North-western Europe.[6/]

Labour in Agriculture

It is difficult to make estimates of labour inputs in agriculture that are consistent between countries and over time. These difficulties arise for three reasons. First, there are problems in measuring the population engaged in agriculture, as accurate figures are available only for census years. Second, problems of definition of agriculture arise, relating in particular to the distinction between forestry and agriculture. Third, there is the problem of relating agricultural population to labour input, e.g. weighting different types of unpaid family labour and evaluating part-time labour. Nevertheless, it is important to get at least some idea of the agricultural labour forces, since their present size provides a rough indication of the location of potential future demand for farm machinery, and changes in the labour forces give an idea of how machinery has been substituted for labour in the past.

5/ FAO, The State of Food and Agriculture 1966, p. 124.

6/ Estimated from FAO, Production Yearbook, 1965, Tables 109, 110, and 111.

In 1966 there was a total agricultural labour force of about 22 million in Western Europe, of which over half was in the four southwestern countries (Table 2.16). The western European agricultural population had declined by about a third of its 1950 level. The structure of this decline is of interest. In the early 1950s the southwestern agricultural labour force declined only moderately and at a much slower rate than in Northwestern Europe. Since then the southwestern rate of decline has greatly increased and now is faster than in Northwestern Europe.

TABLE 2.16

EMPLOYMENT IN AGRICULTURE

	Total Employment (Millions)				Annual Rate of Decline (Per cent)		
	1950	1956	1960	1966	1950-56	1956-60	1960-66
Western Europe	34.9	30.6	27.7	22.2	2.0	2.4	3.8
Northwestern Europe	17.7	14.9	13.1	10.7	2.6	3.3	3.4
Southwestern Europe	17.2	15.7	14.6	11.5	1.5	1.8	4.0

Since the rate of decline in Northwestern Europe has also increased slightly, the combined effect is that the decline has gained speed appreciably. From the more detailed table in the Appendix showing individual countries, it can be seen that the southern European agricultural labour-force decline started in Italy where it is still strong, but more recently it has been supplemented by the decline in Spain. So far, the decrease in Portugal remains modest, whereas in Greece the agricultural labour force has only recently ceased to rise. Within Northwestern Europe the decline has been fastest in the EEC countries.

Over 80 per cent of Western Europe's agricultural population is in six countries. In addition, there are large agricultural labour forces in Turkey and Yugoslavia which have not been included as part of "Western Europe".

On the basis of the crude index of tractors relative to labour, it is apparent that only France and West Germany, of the countries with large agricultural labour forces, have achieved a considerable degree of mechanization. Italy has proceeded on the path to mechanization, but the other countries remain virtually unmechanized. A major source of future demand for farm machinery must surely be to replace these pools of unmechanized labour.

TABLE 2.17

AGRICULTURAL LABOUR FORCES AND USE OF TRACTORS: ESTIMATES FOR MAJOR COUNTRIES IN 1966

	Agricultural Employment (Thousands)	Tractors per 100 Persons
France	3,420	31.0
Germany, Federal Republic	2,877	42.0
Greece	1,813	2.5
Italy	4,660	9.9
Portugal	1,069	1.8
Spain	3,981	4.2
Total Western Europe	22,238	
Turkey	10,000	0.5
Yugoslavia	4,000	1.0

Animal Traction in Agriculture

A substantial proportion of the growth in tractor power in western European agriculture has been for the replacement of draft animals. Appendix Table A.7 gives estimates of the number of draft animals (in horse equivalents) used in agriculture in the various countries. Although there are limitations to the data, it is clear that there have been substantial declines in the number of draft animals being used. By applying the conversion factor of one horse unit equals seven tractor horsepower (used by the OECD and the EEC), it is possible to summarize the relationship between the growth of tractor horsepower and decline of animal power between 1950 and 1960 (Table 2.18).

It can be seen that in Northwestern Europe, where nearly all the motorization occurred during the period, about half of the increase in the tractor horsepower was a replacement of animal power, leaving about half as a net gain to total power. In the southwestern countries nearly three-quarters of the modest growth in tractor power replaced animals, leaving only a small net gain to total power. Table 2.19 gives data for certain major countries between 1960 and 1965.

TABLE 2.18

TRACTOR AND ANIMAL HORSEPOWER 1950-60

	Tractor	Animal	Total
	(Millions of horsepower)		
1950			
Western Europe	22.1	92.5	114.6
Northwestern Europe	19.8	52.1	71.9
Southwestern Europe	2.3	40.4	42.7
1960			
Western Europe	75.8	65.1	140.9
Northwestern Europe	66.0	30.0	96.0
Southwestern Europe	9.8	35.1	44.9
Change 1950-60			
Western Europe	53.7	-27.4	26.3
Northwestern Europe	46.2	-22.1	24.1
Southwestern Europe	7.5	- 5.3	2.2

TABLE 2.19

TRACTOR AND ANIMAL HORSEPOWER 1960-65

	Tractor	Animal	Total
	(Millions of horsepower)		
1960			
France	18.4	13.5	31.9
Germany, Federal Republic	15.7	5.7	21.4
Italy	7.4	8.1	15.5
Spain	1.3	12.6	..
1965			
France	30.2	8.7	38.9
Germany, Federal Republic	26.4	1.8	28.2
Italy	14.9	6.4	21.3
Spain	5.3	9.2	..
Change 1960-65			
France	11.8	-4.8	7.0
Germany, Federal Republic	10.7	-3.9	6.8
Italy	7.5	-1.7	5.8
Spain	4.0	-3.4	..

Source: Animal horsepower calculated from EEC, Agricultural Statistics, 1966, No. 5, pp. 78 and 79; and for Spain, from FAO data on horses, asses and mules. Since the Spanish animals include non-agricultural uses, totals are not given.

It appears that in the recent period animal replacement still accounted for a substantial proportion of the motorization in France and Germany (about 40 per cent), but for less in Italy. The data for Spain are less reliable, but it seems that there was substantial replacement in that country. It is possible that the conversion factor of one horse unit being equal to seven tractor-horsepower is too low; in particular, it fails to take account of the longer working day made possible by the use of tractors. If a higher conversion factor is used, then there is a greater net gain of power on farms than has been estimated here. However, it is apparent that animal replacement has been one of the major facets of the motorization of western European agriculture.

WAGES AND PRICES

The price of agricultural machinery, and the relation between its price and the price of a directly competing factor of production, labour, may be expected to be important in determining the level and rate of mechanization. In Chapter 4 these relationships are analyzed in more detail but at this stage a summary of the data is presented.

It has not proved possible to obtain statistics on farm machinery prices that would permit international comparisons, and only for a few countries does there appear to be information on the change in agricultural machinery prices over time. In the Appendix there is a table giving indexes of changes in the prices of outputs, machinery, and wages. These indexes are compared with the ones giving changes in farm wages.

There is somewhat more information available on labour costs and farm wages than on agricultural machinery prices, but this is also subject to some limitations. Table 2.20 compares labour costs of an agricultural worker in certain countries.

Differences in labour costs are not completely associated with variations in per capita national incomes. For example, Switzerland has one of the highest national incomes in Europe, yet the cost of agricultural labour is well below those of other advanced countries such as Sweden, Britain, or The Netherlands.

TABLE 2.20

LABOUR COSTS PER HOUR OF AN AGRICULTURAL WORKER, IN U.S. DOLLARS

	1965/66	1966/67		1965/66	1966/67
Austria	0.51	0.54	Ireland	0.47	0.52
Belgium	0.93	0.97	Italy	0.62	0.62
Britain	0.89	0.92	The Netherlands	0.94	1.03
Denmark	0.81	0.89	Norway	0.89	0.97
Finland	0.67	0.71	Spain	(0.30)[a]	(0.33)[a]
France	0.53	..	Sweden	1.54	1.66
Germany, Fed. Rep.	0.80	0.85	Switzerland	0.69	0.73
Greece	0.38	0.44			

(a) Authors' estimates.

Source: ECE/FAO, Prices of Agricultural Products and Fertilizers in Europe 1966/67, Geneva, 1968, Annex, pp. 72 and 73. Costs include food, lodgings, and paid holidays.

The price of agricultural labour relative to that of tractors has been rising in all the countries, but at varying rates (Table 2.21).

TABLE 2.21

AVERAGE ANNUAL PERCENTAGE CHANGE IN PRICES OF AGRICULTURAL LABOUR AND AGRICULTURAL MACHINERY 1960-66

	Agricultural Wages (a)	Tractor and Machinery Prices (a)	Wages/Tractor Prices
Austria	10.1	3.5	6.4
Belgium	8.0	5.2	2.8
Britain	5.5	2.4	3.1
Denmark	13.5	3.2*	10.3
Finland	7.5	3.1*	4.4
France	7.0	1.6	5.4
Germany, Fed. Rep.	10.0	2.8	7.2
Ireland	8.5	0.3*	8.2
The Netherlands	9.1	6.0*	3.1
Norway	8.4	2.5	5.9
Sweden	9.8	3.9*	5.9
Switzerland	7.2	4.2	3.0
Greece	10.8	3.0*	7.8
Italy	9.5	0.7	8.8
Portugal	11.0	3.0*	8.0
Spain	13.0	3.9*	9.1

(a) Domestic currencies.

Source: Estimated from data in FAO, Production Yearbook, various years, except items marked * developed from authors' estimates.

Agricultural wages tend to change rather erratically: sometimes they remain virtually unchanged for several years, then there might be a period of rapid rise lasting for a few years. As a result the indexes are particularly sensitive to the period chosen. However, the table does give some idea of the rise in wages relative to the price of tractors. This has been particularly strong in Southwestern Europe and probably has contributed to the rapid growth of mechanization in that region.

FARM SIZE

The size of farms is one of the most important determinants of the level of mechanization. This section describes briefly the pattern of farm structure in Western Europe. The next chapter discusses policies designed to increase the size of farms, and subsequent chapters attempt to measure and explain the relationship between farm size and mechanization.

In most of the western European countries the agricultural sector is dominated by farms that are too small to provide full-time occupations for one man at reasonable levels of efficiency. The Commission to the Council of the EEC estimates that this is the case for at least three-quarters of the Community's farms, and that the average size of the farms is less than 11 hectares (26 acres). This seems to represent the situation in most of the European countries, although there is considerable variation in the average size and in the size distribution of farms. Only in Britain does the average size of farms appear to be appreciably greater than that of the Community countries.

The decline in the agricultural population in recent years has brought about a decline in the number of farms and an increase in their average size; however, these changes have occurred slowly. The decline in the number of farms in most of the countries has been at less than 2.5 per cent per year, and the average area per farm has been growing at less than 2 per cent.

These averages are not strictly comparable because of variations in the minimum size of farms included in the averages, because of differences in the definition of land area, and because of differences in the year to which the averages refer. Appendix Table A.6 tabulates these differences and includes data on the distribution by size of the farms. Despite these difficulties, this table is sufficient to illustrate the extent to the small-farm problem in Western Europe. It is also clear that this problem is much less severe in Britain than in the other countries.

TABLE 2.22

AVERAGE SIZE OF FARMS

Country	Average Size (Hectares)	Annual Change (Per cent)	Country	Average Size (Hectares)	Annual Change (Per cent)
Austria	9.6	0.4	Norway	5.5	1.6
Belgium	8.3	2.3	Sweden	14.2	1.8
Britain	43.8	1.3	Switzerland	7.4	1.7
Denmark	17.4	1.9			
Finland	8.9	..			
France	17.8	2.1			
Germany, Federal Republic	8.9	1.9	Greece	3.2	0.5
Ireland	16.1	0.4	Italy	4.8	..
The Netherlands	10.7	1.5	Portugal	5.2	-0.9
			Spain	7.8	..

TRENDS IN THE USE OF TRACTORS AND LABOUR

The accompanying charts illustrate the trends in the use of tractors and labour in Northwestern and Southwestern Europe during recent years. From the first of these it can be seen that in Northwestern Europe the rate of increase in the number of tractors has been declining. It is possible that there is some maximum optimum number of tractors and that once this has been achieved all further increases in mechanization occur through increases in the size of tractors. Modified exponential growth curves were fitted to the number of tractors to see whether such curves could describe the trends and what future levels of tractor use they "predicted". For example, the curve

$$T = \frac{1}{.000233 + (.002784)(.800517)^{t}},$$

where T is the number of tractors in thousands and t is time (in years), provides quite a good fit of the growth of tractors between 1947 and 1964 in Northwestern Europe. Such a curve has a maximum value of 4,293 thousand, and would be at 4,284 thousand by 1985. However, other forms of growth curves can also provide quite good fits to the data but generate very different predictions about the maximum number of tractors and the time path to that maximum. Fitting such curves to the southwestern European data is even more dubious, since that region has not progressed very far along the path to full mechanization. Since there is no reason for preferring one form of growth curve to another, or even for supposing that tractor use should follow some natural law of growth, there is no justification for making predictions from these fitted growth curves. Instead, this study concentrates on how tractors are substituted for labour in the process of agricultural development.

Chart 2.1 shows how the rise in the use of tractors has been associated with a substantial, although slower, decline in the use of labour in western European agriculture. Chart 2.2 shows the great increases in the productivity of labour that has accompanied the process of mechanization. Chart 2.3 shows the relationship between the level of agricultural wages and the use of tractor horsepower relative to labour in the western European agriculture. It is this relationship which provides the basis of the analysis of Chapter 4.

CHART 2.1-TRACTORS AND LABOUR IN WESTERN-EUROPEAN AGRICULTURE 1950-67

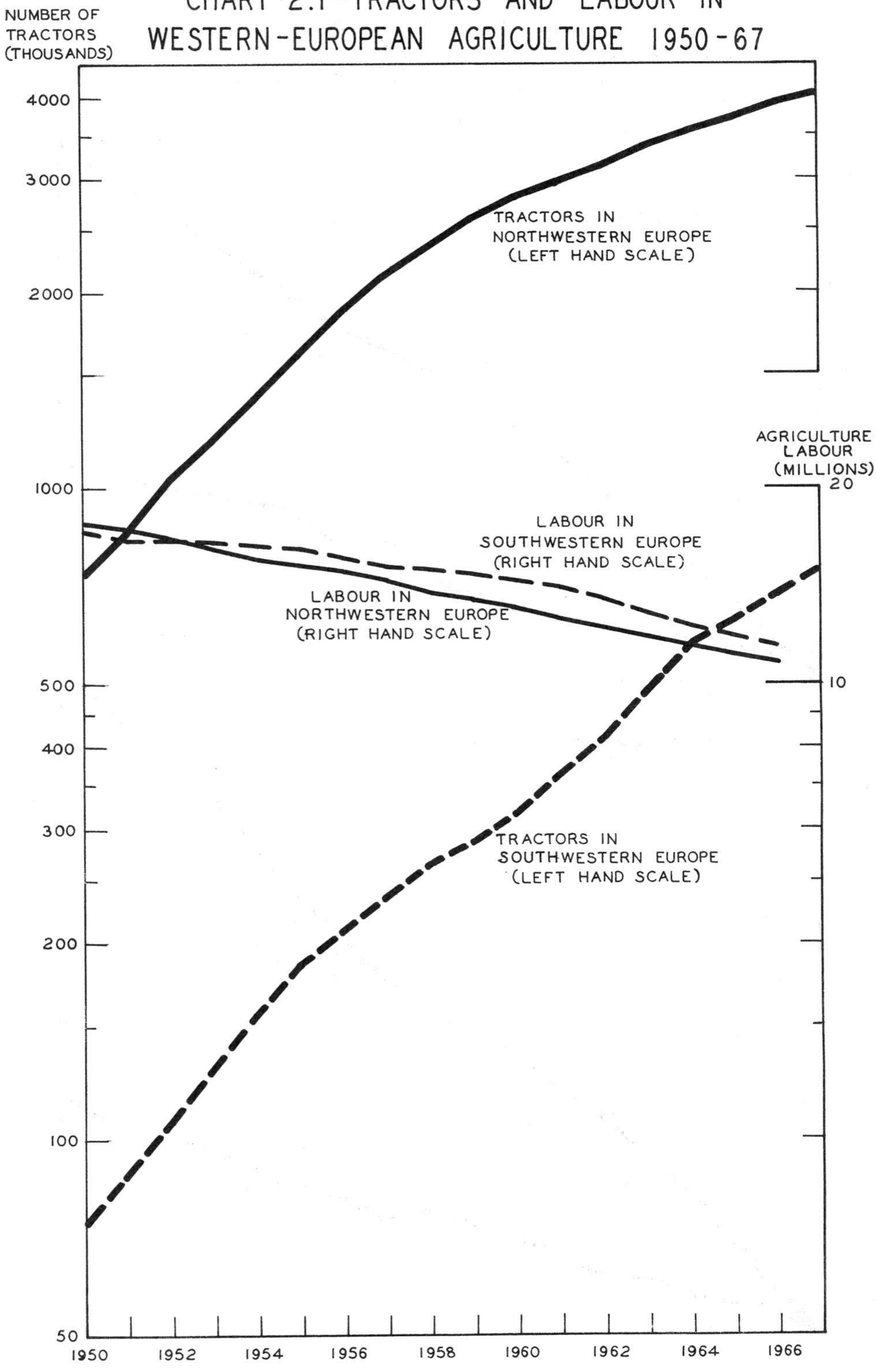


CHART 2.2 - TRACTOR HORSEPOWER AND OUTPUT PER HEAD OF AGRICULTURAL LABOUR FORCE

(1952=100)

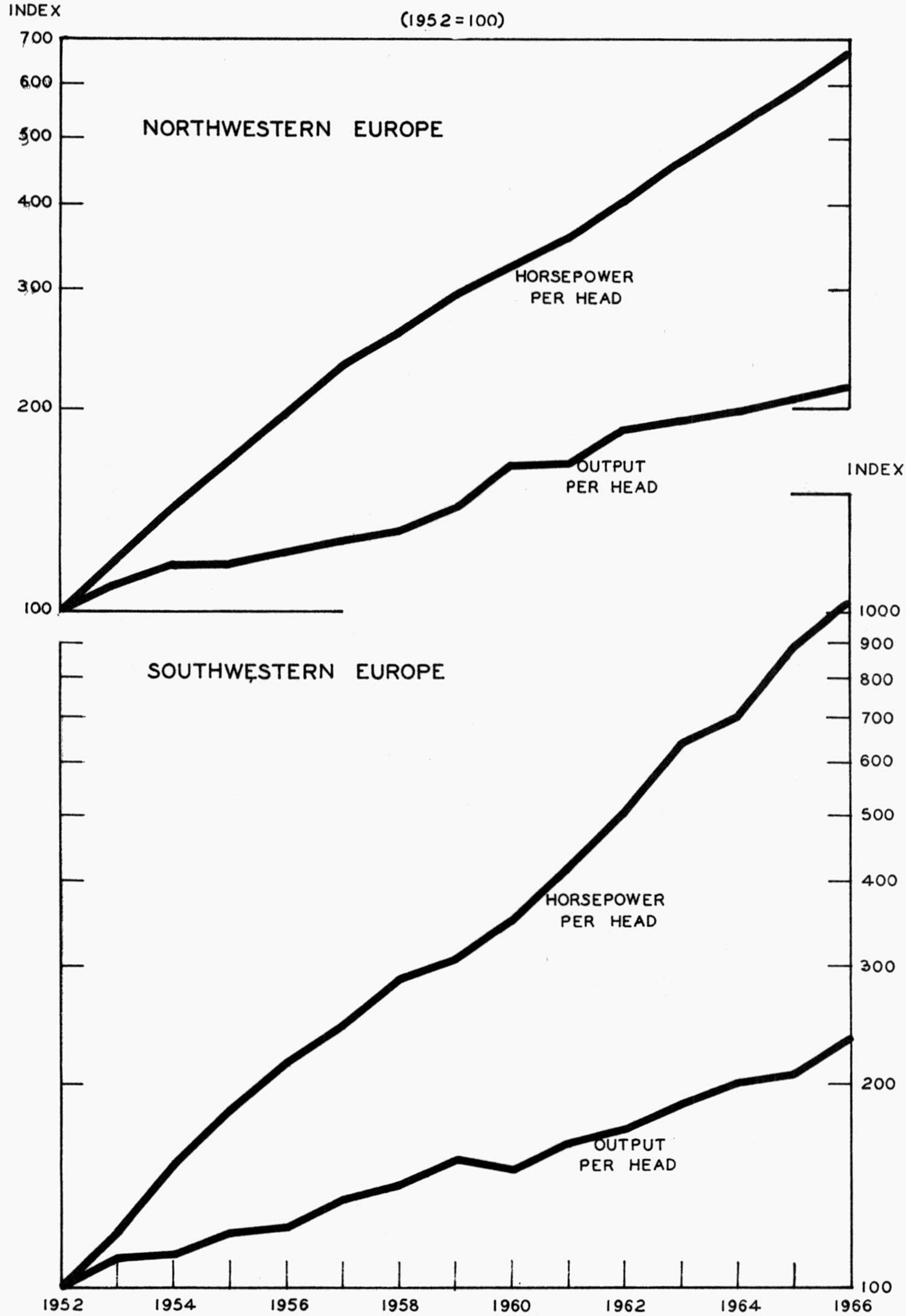
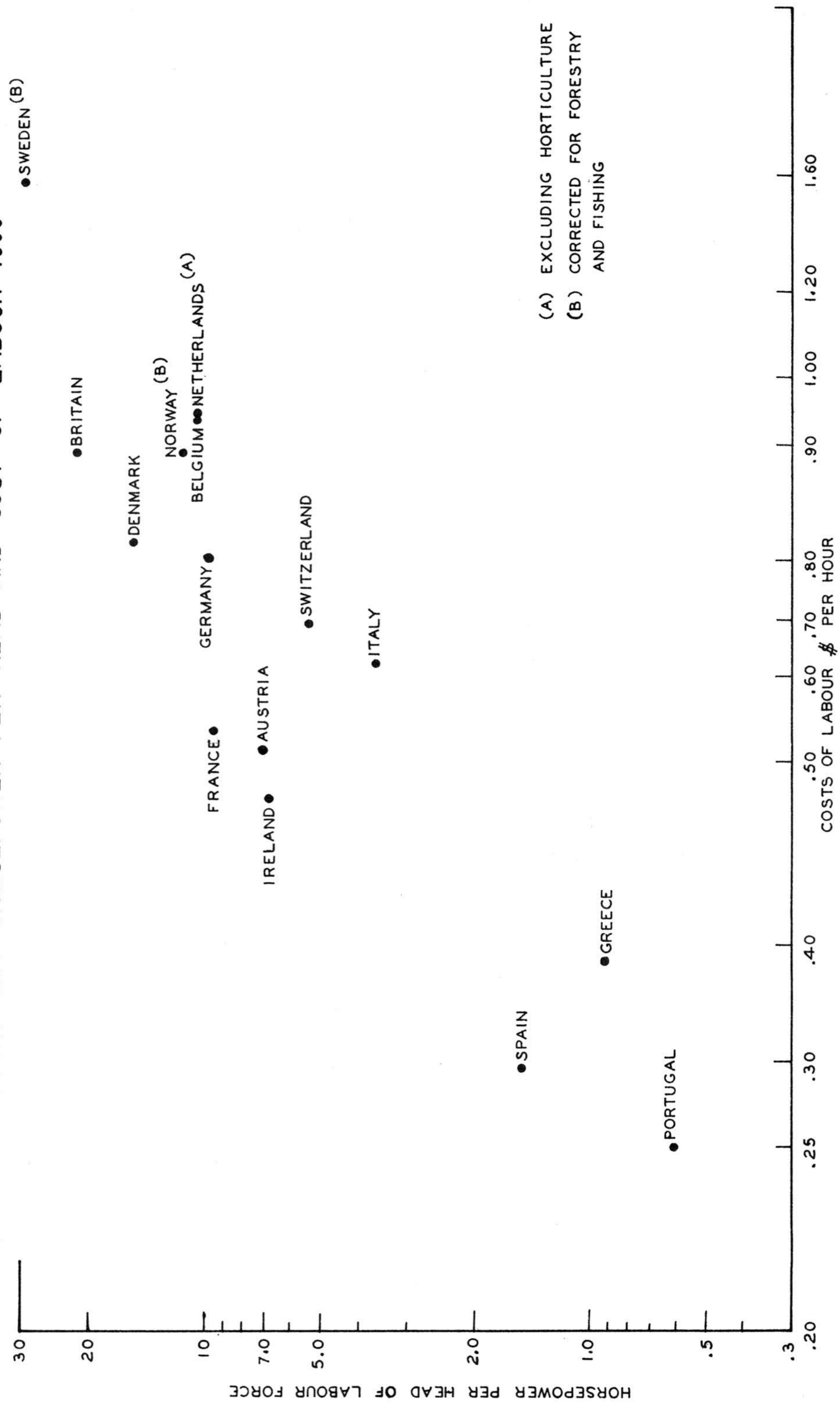


CHART 2.3 - HORSEPOWER PER HEAD AND COST OF LABOUR 1966



3. POLICIES AFFECTING FARM MECHANIZATION

This chapter considers the type of problems facing agriculture in the western European countries, and the types of policies that are being used to deal with these problems. The impact of the problems and policies on farm mechanization is then discussed. A final section describes the *Mansholt Plan* for the reform of agriculture within the European Economic Community (EEC).

THE AIMS OF AGRICULTURAL POLICY

During the past decade and a half, the agricultural sectors of Western Europe have been characterized by rapid increases in labour productivity, resulting in rising output in spite of falling agricultural labour forces. These trends[7/] are summarized as follows:

Annual Rates of Change in Western Europe 1956-1967

Agricultural output	3.3%
Agricultural labour force	-3.2%
Output per head of labour force	6.5%
Output per head of population	2.1%

The growth of output has outpaced population growth in the region, so that agricultural production per head of population has risen.

Because of the low income-elasticity of demand for agricultural products, the expansion of supply during the period resulted in a fall in the relative price of these products, particularly during the late 1950s, thereby partially offsetting the effect of increased productivity on farm incomes. The over-all effect has been that the gap between farm and non-farm incomes has generally remained wide and in some cases has widened although farm incomes have risen.

7/ Calculated from indexes in FAO, Production Yearbook, 1968.

Perhaps the major goal of agricultural policy in the western European countries is to lessen or eliminate this income gap and, in particular, to raise incomes in the depressed agricultural subsectors which exist in all the OECD countries. There is, however, a desire to lessen the dependence of the agricultural sectors on price supports and subsidies and other forms of protection from external competition. These broad aims of policy were summarized in a January 18, 1965, press statement of the Fourth Meeting of the Ministers of Agriculture of the OECD:

> The main object of discussion was the adaption of agriculture made necessary by current economic trends. This adaption, involving the development of a sounder agricultural sector based on viable farms with a sufficient size of business, is an essential means of gaining a rising standard of living for the farm population. Moreover, this objective, together with the improvement of conditions on world agricultural markets, should progressively reduce the dependence on support and protection against outside competition. It should also enable the agriculture of the highly developed countries to obtain, on an efficient basis, a level of output consistent with the demand for food in these countries, and which would take account also of the situation and trends in the rest of the world.

One of the main problems facing western European governments is to determine what size of agricultural sectors and what structures of inputs are consistent with this broad policy. It may well be that high-income, reasonably competitive agricultural sectors would need to be appreciably smaller than those existing in most of the western European countries, not only in size of labour force, but perhaps in quantity of output and land under cultivation as well. It is unlikely that many of the governments would be prepared to permit an expansion in the share of imported agricultural products in their domestic markets;[8/] but they may be forced by the growing costs of their support programs to check the rate of expansion of output. This is the problem now facing the EEC.

8/ Sweden is an exception.

POLICY MEASURES

In the past the main methods of protecting European agriculture and supporting its income have been tariffs and quotas coupled with subsidies to farmers. The combinations in which these are used vary between countries. Most of the western European countries use mainly constraints on trade to maintain prices. The major exception is Britain where tariffs on agricultural products are generally low, with farmers' incomes being supplemented by deficiency price payments. Subsidies are usually a more efficient method of protection than tariffs since they do not directly distort prices facing consumers. However, there is no reason for supposing that the choice between them directly affects the degree of mechanization and the input structure in agricultural production. British entry into the EEC could involve a conversion to the use of tariffs and maintained market prices as the main method of agricultural protection for that country. However, there is growing recognition, particularly in Germany, of the advantages of the deficiency payments system, so it is possible that the Community could adopt the British system, or some compromise between the two systems could come into general use.

In recent years there has been a switch in the methods used by European governments away from reliance on general price and income supports towards policies aimed at increasing productivity. This shift has resulted from the recognition that productivity measures can augment farm income while also assisting the general development of the economy by increasing output and facilitating the release of labour to other sectors. Furthermore, the moves towards integration of European agriculture have meant that individual governments can no longer rely permanently upon subsidies and tariffs as a means of protection from their neighbours. This change of emphasis has been encouraged by various studies and reports put out by official organizations.[9/]

Measures aimed at improving agricultural productivity can be expected to affect the degree of farm mechanization, so this

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9/ See, for example, OECD, Low Incomes in Agriculture, Paris, 1964.

section of the study considers the types of measures being used and the kind of impact they could be expected to have on mechanization.

Policies to improve agricultural productivity can be classified into:

(a) subsidies, rebates and allowances on farm machinery,
(b) credit facilities and interest rate policies,
(c) tax rebates or subsidies on fuels used in agriculture,
(d) subsidies, etc., to competing inputs,
(e) policies affecting the agricultural infrastructure,
(f) policies aimed at farm size,
(g) agricultural co-operatives, etc.,
(h) advisory, education, and research measures,
(i) measures affecting the transfer of labour, and
(j) policies affecting structure of output.

(a) *Subsidies* -- Subsidies on farm machinery used in agriculture can be expected to increase the degree of mechanization and also to increase the rate of replacement of agricultural machinery. Depreciation or capital allowances have the same sort of effect as subsidies. Some of the western European countries have subsidies or rebates on the purchase of farm machinery, but often these subsidies are restricted to farms of certain size or in certain areas. Subsidies on inputs in Northwestern Europe are not particularly high. The ECE/FAO *5th Report* estimates that input subsidies reduced current operating expenses by about 3 per cent (1960-62). They were considerably more important in Spain.[10/]

(b) *Credit policies* -- Practically all the western European countries have measures for providing credit facilities to farmers. The form of these facilities varies considerably between countries. A report of the OECD[11/] distinguishes between three techniques,

-- the support is given through one or several state banks or public funds in which case conditions are established according to the purpose (it may be either non-repayable outright grants or loans at low interest rates);

10/ United Nations, ECE/FAO, 5th Report on Output, Expenses and Incomes of Agriculture in European Countries, Geneva, 1965, Vol. I, p. 68.

11/ OECD, agricultural policies in 1966, Paris, 1967, p. 98.

-- the money is taken as a loan from the private capital market but interest rates are lowered through public subsidies;

-- the money is obtained from the private capital market at the normal rate of interest, but a direct support payment from public means depending in most cases on the amount of the loan is made to the debtor.

In addition, the state often establishes public funds to guarantee certain loans to farmers. The effect of such measures is, of course, to facilitate the availability of credit to farmers. In some cases the schemes are comprehensive enough to isolate the farmer from fluctuations in interest rates and from credit shortages. In other cases it has the effect of converting farmers into the category of prime borrowers.

The OECD report points out that if credit facilities are too easily available, farmers may over-extend their purchase of machinery and equipment, resulting in increased production costs. The problem is to control the availability of credit so that it is made available to farms which may otherwise be under-capitalized.[12/] Some of the countries require that farms applying for cheap credit be examined and supervised by the advisory services; other countries have established criteria such as minimum farm size.

(c) *Cost of fuel* -- Several countries have tax rebates on fuel used in agriculture. These include Austria, France, Germany, Ireland, Italy, Norway, and Switzerland. In some of these countries such as France, fuel taxes are very high, so these rebates are important. However, the impact of these rebates on the demand for farm machinery is not clear-cut. While measures reducing the cost of operation of machinery can be expected to encourage the utilisation of machinery and the degree of mechanization, they might have the opposite effect on the rate of replacement of existing equipment. If new equipment tends to be more economical in the use of fuel, then fuel tax will, to some extent, encourage the rate of replacement of equipment.

(d) *Subsidies, credit assistance, etc., on the purchase of other inputs* -- Most of the western European countries have

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12/ Ibid., p. 99.

measures to assist farmers to acquire other inputs besides farm machinery -- inputs such as buildings, fertilizers, and seeds. Often, credit arrangements or subsidies on such purchases are more comprehensive and substantial than those provided for farm machinery. In a situation where many factors of production are being combined to produce a variety of products, as is the case in agriculture, a fall in the price of one factor will generally result in an expansion in the supply of products, but the demand for other factors of production may rise or fall depending upon the relationship of technical complementarity and substitution between these other factors and the factor whose price has fallen. In the case of farm machinery, inputs such as fertilizers, seeds, etc., are complementary so that there is a strong presumption that subsidies on them will increase the demand for machinery. This presumption is less strong for subsidies on buildings, since improved layout may be a direct substitute for machinery. Subsidies, etc., on the use or purchase of direct substitutes for machinery, such as unskilled labour or draught animals, are likely to reduce the demand for machinery.

Within the OECD countries, subsidies on direct substitutes for farm machinery are rare, but subsidies on fertilizers and seeds are particularly common. There has been a considerable increase in the use of such subsidies by the less-developed member countries, and this should provide an important stimulus towards mechanization.

(e) *The agricultural infrastructure* -- Several of the western European countries have schemes in progress, or planned, to improve the infrastructure of their less-developed areas. Such measures as drainage and irrigation schemes, which improve the productivity of an area, can be expected to directly augment the demand for farm machinery by increasing the profitability of investment. Programs that encourage industrialization in a region or country will also have an impact on mechanization by offering alternative employment for unskilled labour, and also, perhaps, by providing markets for agricultural output.

Countries undertaking heavy investment programs affecting large regions are France, Italy, Greece, Portugal, and Spain. Other countries have programs directed at particularly difficult or remote areas, e.g. Austria and Germany in mountainous areas, Britain in the hill areas of Scotland and Wales, Norway in the northern districts. Often these structural improvement schemes are combined with projects for farm consolidation or enlargement, the effect of which is discussed in the next section.

Probably the most important institution for assisting structural improvement is the European Agricultural Guidance and Guarantee Fund, set up by the members of the EEC to provide funds particularly for over-all improvement projects designed to promote the development of a whole region. This Fund has been particularly active in promoting development of Southern Italy, the most backward region of the EEC.

(f) *Farm size* -- Policies affecting farm size are of great importance in determining the demand for farm machinery. Very small farms inhibit mechanization. However, extremely large ones might achieve a greater degree of economy in machine use.

Most policies concerning farm size are aimed at creating "viable" farms out of smaller or fragmented units. Almost by definition a "viable" farm is one that can be mechanized. Thus the impact of farm-size policies is towards mechanization rather than towards the creation of extremely large farms that might result in the use of less machinery.

The existence of farms of less than viable size is one of the basic problems of western European agriculture. In most of the countries the whole of the agricultural sector is dominated by non-viable holdings. For example, the average size of farms in the EEC is no more than about 11 hectares (27 acres). In other countries, such as Britain, small farms form a depressed sub-sector holding down the average agricultural income.

In many countries the concept of a "viable" farm is closely linked in policy to that of a "family" farm. The aim is to create units large enough to provide a reasonable income to the families that farm them, but to prevent the development of large businesses. As a result, while many of the western European countries have measures to encourage amalgamation and consolidation, some countries, such as France, Germany, and Austria, also have measures which discriminate against large operations, and Greece and Yugoslavia have prohibitions on farms above a certain size.

Measures designed to create and maintain farms of a viable size include state funds for the acquisition, consolidation, and redistribution of land; funds and credit arrangements to enable small farmers to acquire more land; legislation prohibiting the splitting up of existing holdings, and, in the case of Italy, the compulsory regrouping of land plots in certain development areas.

There has been a tendency in recent years for the criterion of what constitutes a viable minimum size to be raised, and there has also been some relaxation of the measures discouraging amalgamation beyond a certain maximum size.

The emphasis on improving farm structure is being maintained in current legislation and plans. For example, in Sweden the preliminary report of the Royal Agricultural Committee stresses the importance of eliminating or enlarging small farms, and in Britain the 1966 *White Paper on Agriculture* reinforces measures encouraging farm amalgamation and enlargement. The main emphasis of the *Manshold Plan* for EEC agriculture (described below) is on structural reform.

However, the OECD report *agricultural policies in 1966*[13/] points out that:

> Very often it is in countries where the needs for this kind of improvement [farm consolidation and enlargement] are high that progress is slow and needs to be accelerated.

(g) *Co-operatives* -- The development of co-operative arrangements are to some extent a substitute for farm amalgamation, so the direction of their impact on mechanization should be similar. In cases where farms are too small to be mechanized, co-operatives would increase the demand for machinery, but in cases where farms are mechanized but are not large enough to fully utilize their machinery, the development of co-operative arrangements might decrease the demand for farm machinery by increasing the degree of utilization.

Co-operatives for marketing farm produce are more common and extensive than co-operatives for production: however, there has been an increase in co-operation at the production stage during the past few years. In France, for example, legislation in 1962 encouraged joint action in production. In Spain, the government supports farmers who combine their land for the production of cereals. Some attempts have been made to establish machinery

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13/ Ibid., p. 94.

syndicates, but so far such arrangements are not widespread. They are, of course, much more common in Eastern Europe.

(h) *Advice, education and research* -- In recent years, advisory, educational, and research programs in agriculture have been greatly increased. It is difficult to make intercountry comparisons of the extent of these programs, since they vary greatly in forms of organization. However, it appears to be the most highly industrialized countries that spend relatively most on research, training, and information for farmers.

Griliches estimates from his U.S. study that such programs have a very high impact on output.[14/] They would, therefore, have an effect on mechanization by generally increasing productivity. These programs could also be expected to result in a better use of machinery, which might mean an increase or decrease, depending upon whether too little or too much machinery was previously being used. Recently, there has been a trend in the highly developed countries from advice on purely technical matters to management advice.

(i) *The transfer of labour* -- Any policies affecting the remuneration of labour or the availability of employment will affect the supply of farm labour, and, therefore, the demand for machinery. Clearly, almost any government policy will have this kind of impact.

In particular, the migration of hired farm workers out of agriculture will depend chiefly on the rate of expansion of employment opportunities in the industrial sectors. However, it is worth considering specific measures designed to encourage the withdrawal of labour, particularly farmers and farm families from agriculture, since this group is particularly immobile and since its reduction is necessary for effective improvements in farm structure. Retraining programs are common in many countries; for example, in Sweden, persons formerly engaged in agriculture and participating in a retraining program for other occupations receive as compensation during the period of training up to 80 per cent of the wage rate paid in industry. Within the EEC, retraining programs are to be financed out of common funds. Some countries, such as Belgium, France, Germany, Netherlands, and Norway, have

14/ Zvi Griliches, "Research Expenditures, Education, and the Aggregate Agricultural Production Function", The American Economic Review, Vol. LIV, December 1964, No. 6.

special retraining schemes for farmers that give financial support or supplementary pensions to elderly farmers who retire and offer their land for general structural improvements. Some countries give travel and removal grants to people taking up new jobs.

(j) *Structure of output* -- In addition to the policies discussed above, any attempts by governments to alter the structure of output by means either of subsidies or protection will, to the extent that they are successful, alter the structure of the demand for machinery. Obviously, changes in the type of product being produced will be accompanied by similar changes in the demand for particular types of machinery.

There appears to be some tendency, particularly in Southwestern Europe, to encourage the production of meat and dairy products relative to cereals. Such developments might be expected anyway, as a result of generally rising levels of income.

Britain and the EEC

British entry to the EEC would be likely to encourage mechanization by making the major importer of agricultural products more dependent upon European production (both domestic and continental). The resulting expansion of output and the transfer of income to the agricultural sectors should increase the demand for machinery. Some of this income transfer would be channeled to the most backward agricultural sectors of Western Europe through the European Agricultural Guidance and Guarantee Fund, and so used directly to promote mechanization. The occasion of Britain's entry could be accompanied by major changes in the agricultural policies of the Community.

Although it is not likely in practice to be possible to distinguish the effects of specific government policies on agricultural mechanization from the effects of industrialization and economic growth, it seems probable that the attempts to increase agricultural productivity by increasing farm size, by improving the skill and knowledge of farmers, and by generally improving the agricultural infrastructures will increase the demand for agricultural machinery.

THE MANSHOLT PLAN

The existing common agricultural policy of the EEC appears to be on the point of collapse. The system of maintained prices is proving extremely expensive, not only to the consumers who bear the brunt of the cost of subsidizing the agricultural sector, but increasingly to the Community Farm Fund which is obliged to buy up surpluses at the intervention price and then attempt to export them. Some of these surpluses are exported at a loss -- much to the annoyance of the major exporting countries -- but increasing amounts have to be stored or disposed of internally at even greater losses.

The productivity of the Community's farmers has been rising much more rapidly than the demand for agricultural products. This is likely to continue, exacerbating the surplus problem, unless radical steps are taken to check the rise in output. Increased farm incomes require increased productivity, but this can only be achieved without over-production if the number of producers is reduced. It is the recognition of this point that is the basis of the 10-year program for agricultural reform presented by the European Commission and associated with the name of S. Mansholt, who is the Vice-President of the Commission.[15/]

The *Plan* emphasizes the need for structural reform. It stresses that it is now impracticable to support farm incomes by further increases in prices; instead, costs should be reduced by rationalizing agricultural production. Since the average size of farms is less than 11 hectares and 80 per cent of the farms are less than 20 hectares (50 acres), there should be scope for a very considerable reduction in costs through rationalization.

The *Plan* suggests that it should be possible to halve agricultural employment from about 10 million in 1970 to 5 million by 1980. Half of this reduction would be achieved by pensioning-off farmers and farm workers, and the rest would be encouraged to find employment outside of agriculture. The area of agricultural land would be reduced by about 5 million hectares (about 7 per cent). Most of this would be converted into woodland, and the rest used for recreational purposes.

15/ EEC, Memorandum on the Reform of Agriculture in the European Economic Community, Supplement to Bulletin No. 1, 1969.

It is intended that this reduction in agricultural employment would involve a large number of farmers giving up their farms, thereby making possible a substantial increase in farm size. The *Plan* stresses the need for social and working conditions in agriculture to be similar to those in industry, so that farmers and farm workers can work regular and normal hours for most of the year, and enjoy annual holidays. This means that the reforms need to do more than create larger one-man farms. The farms would have to employ sufficient labour to permit these normal working conditions.

The *Plan* emphasizes that some of the advantages of size can be obtained by specialization, through setting up economically viable production units. These production units should comprise of at least 80 to 120 hectares for cropping, 40 to 60 cows in dairy farming, 150 to 200 head of cattle in meat production, 100,000 birds a year in poultry farming, and 450 to 600 animals in pig farming.

The kind of measures proposed by the *Plan* to encourage farmers and farm workers to give up farming are allowances, grants and pensions to farmers, members of their family, and farm workers who give up farming; retraining grants; scholarships for the children of farmers and farm workers; unemployment benefits, etc.

The formation of "production units" would be encouraged by investment grants, loan guarantees, tax concessions, etc. It is proposed that after 1975, the payment of some subsidies be limited to farms that are attempting to set up and have a chance of attaining the specified production unit size.

This *Plan* has received considerable criticism from the agricultural sectors of the member countries, and there will probably be reluctance on the part of the member governments to ratify and implement such a radical program. Yet the need for reform is obviously pressing.

4. SUBSTITUTION OF TRACTOR POWER FOR LABOUR IN WESTERN EUROPEAN AGRICULTURE

INTRODUCTION

This chapter examines the proportion in which tractors are used, relative to agricultural labour, in the various western European countries. In particular, the relationship between the tractor-labour ratio and the relative tractor-labour price is measured. This is an attempt to derive the demand for tractors relative to an alternative factor of production, as a function of these relative factor prices. Such a procedure is in contrast to the more general method of relating the demand for a factor of production to the demand for the final output, and to the supply of all other inputs.

The principal advantage in attempting to derive the demand for tractors by measuring their substitutability for labour is that the procedure involved is simpler, and the data required are more readily available than in most alternative methods. In particular, the approach avoids the problem of measuring agricultural output, and it avoids the problem of unidentified or unspecified factors of production. The main limitation is that conditional rather than unconditional forecasts are generated.

The substitutability of tractors for labour is estimated by means of cross-sectional analysis over 16 western European countries. Cross-sectional rather than time-series analysis is used, because the ultimate purpose of this study is to explain the level of farm machinery utilization for the whole of Western Europe. In the absence of time-series data for the whole area, it seems desirable to measure the degree of substitutability across as many of the countries as possible. Furthermore, cross-sectional analysis avoids the problem of identifying the short-run adjustment process so as to distinguish between the long-run and the short-run elasticities. This is a difficult procedure and probably results in a downward bias in the estimates of the elasticity of substitution.[16/] Since this study is intended to facilitate long-term forecasting, estimates of the short-run elasticity are not needed. In the next chapter, time-series data are used, so the adjustment process has to be considered.

Analysis at the national level disguises important regional variations within the individual countries. The justification for ignoring these variations is the one traditionally used in international economic studies -- that each country provides a sufficiently unified factor market to make the variations within countries small relative to the variations between them.

In order to measure the degree to which machinery can be substituted for labour, a theoretical model is used that implies that there will be a relationship between, on the one hand, the proportion in which capital is used relative to labour, and on the other hand, the price of labour relative to the price of capital. The subsequent section then attempts to measure this relationship by observing how the ratio of tractors to labour in the western European countries varies with the relative price of labour to tractors.

The justification for applying a theoretical model of this sort to a situation where some of its assumptions obviously do not hold is that the model works. A substantial proportion of the observed variation in the ratio in which tractors are used relative to labour in western European agriculture can be explained in terms of the model. Furthermore, the deviation of the observed results from those predicted by the model can give insight into the way in which the actual conditions of agricultural production differ from the assumptions of the model.

THE MODEL

The model used here has two aspects. First, it is assumed that the conditions of agricultural production in all the countries can be represented by a particular type of production function,

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16/ For a discussion of this point see G. Harcourt, "Biases in Empirical Estimates of the Elasticities of Substitution of C.E.S. Production Functions", The Review of Economic Studies, Vol. XXXIII (3) No. 95, July, 1966.

relating output to the inputs of all the factors of production. From the production function can be derived a technical relation between the proportion in which any pair of the factors of production is used, and the ratio of the marginal products of those factors. (The marginal product of a factor is the increment of output that can be obtained by means of a marginal increase in the use of one factor when all the other factors are held constant. The ratio of the marginal products of a pair of factors is the marginal rate of substitution between the factors, i.e. the marginal amount of one factor needed to replace a marginal amount of the other factor when output remains constant.) The second aspect of the model is a behavioural relationship between the marginal products of the factors and their market prices. This relation will hold if the farmers are purchasing or hiring the factors of production in competitive markets and if they are maximizing the value of their output net of their variable costs. The combination of these two aspects of the model give the relationship between the ratio of the marginal products of a pair of factors (the marginal rate of substitution) and their relative prices.

The basic model used is a neo-classical theory of production, in which output is a continuous function of inputs $Y = F(X_1, X_2, .., X_n)$, the marginal product of any factor being positive but diminishing, i.e. $\frac{\partial Y}{\partial X_i} > 0$, $\frac{\partial^2 Y}{\partial X_i^2} < 0$ for all factors X_i. In the two factor cases this gives a constant output curve that is downward-sloping and convex to the origin. It is also initially assumed that the factors of production are employed in such a way that the ratio of the marginal products of any pair of factors is equal to the ratio of their costs (prices), e.g. $\frac{\partial Y}{\partial X_i} / \frac{\partial Y}{\partial X_j} = \frac{P_i}{P_j}$. This condition will be satisfied if there is competition in factor markets and if producers are profit-maximizing. If the above conditions obtain, there will be a relationship between the level of utilization of the factors and their prices. The form of this relationship will depend upon the form of the production function.

A Cobb Douglas production function is of the form

(1) $$Y = A\left[X_1^{\alpha_1} X_2^{\alpha_2} \ldots . X_n^{\alpha_n}\right]$$

so $$\frac{\frac{\partial Y}{\partial X_i}}{\frac{\partial Y}{\partial X_j}} = \frac{\alpha_i}{\alpha_j}\left[\frac{X_j}{X_i}\right]$$

and if $$\frac{P_i}{P_j} = \frac{\frac{\partial Y}{\partial X_i}}{\frac{\partial Y}{\partial X_j}} \text{ then } \frac{X_i}{X_j} = \frac{\alpha_i}{\alpha_j}\left[\frac{P_j}{P_i}\right]$$ or

(2) $$\log\left(\frac{X_i}{X_j}\right) = \log\left(\frac{\alpha_i}{\alpha_j}\right) + \log\left(\frac{P_j}{P_i}\right).$$

This derived relationship between factor proportions and relative factor prices is likely to be easier to measure than the original production function since only data pertaining to the relevant pair of factors are required instead of data on all the factors. Furthermore, the relationship will hold even if the production function is not identical across all sectors, provided the variations are neutral, i.e. that there are no variations in the marginal rate of substitution between pairs of factors for given factor proportions. In the case of the Cobb Douglas production function given in (1) above, variations in A or proportional variations in α_i and α_j would not affect equation (2).

The elasticity of substitution can be defined as the proportional change in factor proportions relative to a proportional change in the marginal rate of substitution between the factors. If relative factor prices are equal to their marginal rate of substitution, then

$$\sigma = \frac{d(X_i/X_j)}{d(P_j/P_i)} \Big/ \frac{(X_i/X_j)}{(P_j/P_i)} \text{ or } \sigma = \frac{d \log (X_i/X_j)}{d \log (P_j/P_i)}.$$ 17/

17/ The elasticity of substitution is defined here so as to be normally positive.

This is a measure of the degree of substitution between a pair of factors, and is a measure of how a change in factor proportions is associated with a change in relative prices. If the elasticity of substitution is low, then the factors are poor substitutes and change in their relative prices will not induce much change in the proportion in which the factors are used. On the other hand, if the elasticity of substitution is high, then the factors are good substitutes and there will be a considerable substitution of one factor for the other if there is a change in their relative prices. In the case of a Cobb Douglas production function the elasticity of substitution is unity, thus a one per cent change in the price of one factor relative to another would be associated with a one per cent change in the use of the second factor relative to the first. Since one of the purposes of this chapter is to measure the substitutability between factors, it would be inappropriate to constrain the form of the production function to a Cobb Douglas one. Therefore a more general "constant elasticity of substitution" (CES) production function is used.

(3) $$Y = A(\alpha_1 X_1^{-\beta} + \alpha_2 X_2^{-\beta} + \ldots + \alpha_n X_n^{-\beta})^{-\frac{v}{\beta}}$$. 18/

In this production function A is a neutral efficiency or scale parameter that does not affect the marginal rate of substitution between the factors, and so does not affect the relationship between factor prices and factor proportions. The degree of homogeneity, or the returns to scale, is given by the parameter v. Since the production function is being measured at the country level of aggregation, and there is no reason to associate economies of scale in agriculture with the absolute size of the country concerned, it seems sensible to let $v = 1$. However, this does not affect the analysis that follows. The parameter β is associated with the elasticity of substitution $\sigma = \frac{1}{\beta+1}$.

18/ The CES production function is derived by K. J. Arrow, H. B. Chenery, B. S. Minhas, and R. M. Solow, "Capital-Labor Substitution and Economic Efficiency", The Review of Economics and Statistics, Vol. XLIII, No. 3, August 1961. For a discussion of the properties and uses of the CES function see Murray Brown, On the Theory and Measurement of Technological Change (Cambridge: University Press, 1966).

The distribution parameters α are a measure of the factor intensity of the technology. Changes in α_i will affect the marginal productivity of X_i relative to the other factors and so affect the relationship between factor prices and factor proportions.

The relationship between the factor proportions and the relative factor prices can be derived from the CES production function:

$$\frac{X_i}{X_j} = \left[\frac{\alpha_i}{\alpha_j}\,\frac{P_j}{P_i}\right]^{\frac{1}{\beta + 1}}$$

giving a relationship that is linear in the logs

$$\text{(4)} \qquad \log \left(\frac{X_i}{X_j}\right) = C + \sigma \log \left(\frac{P_j}{P_i}\right)$$

where $c = \sigma \log (\alpha_i/\alpha_j)$ and $\sigma = \frac{1}{\beta+1}$ is the elasticity of substitution. This form is used to measure the substitutability between tractors and labour. It should be noted that only data about the factors and the prices of the factors directly involved are required, so it is not necessary to have information about the quantity and price of output or of other factors that might enter into the production process. Also this relationship will hold even if the production functions differ between the countries, provided these differences are neutral.

THE RESULTS

Data for 1965-66 on the use of tractors relative to labour and on the price of labour relative to that of tractors in western European countries are fitted to the theoretical model by means of least-squares regressions. The influences of farm size, of output structure, and of aggregate land area are also tested.

Tractor stock is measured by both the number of tractors and the estimated total horsepower. In each case an allowance is made for the use of garden tractors by weighting a garden tractor at one-third of a tractor, or by counting it as five horsepower. The data on tractor numbers are more reliable than those on horsepower, but horsepower might be a superior measure of the tractor stock. The quantity of labour is measured by the total number of persons engaged in agriculture. Farm size is measured by the average size of farms, and by the percentage of total farms greater than 10 hectares and 20 hectares. For most countries there were no data on the size distribution of farms greater than 20 hectares. This limitation is serious since 20 hectares (approximately 50 acres) is a small farm by North American or even British standards, so the available categories do not give the size distribution of medium and large farms. These data are subject to the further limitation that they pertain to varying dates and definitions of type of land and minimum size farm.[19/]

Land area is taken as arable land since this seems the relevant type of land with which to compare the tractor stock. Output structure is measured by an index giving livestock products as a percentage of total agricultural production. FAO data on agricultural wages and labour costs are used to measure the cost of labour, although there are some problems of comparability. The most serious data limitation is in tractor costs. Ideally, the cost of a factor of production should take account of its price, the relevant rates of interest and depreciation, and the costs of maintenance and operation. This information is not available, so a rough index was constructed based on tariffs and freight from Britain on the grounds that British tractors are competitive in all of the western European countries. The problems that arise from using indexes instead of absolute prices are discussed below.

The countries providing the observations are Austria, Belgium, Denmark, Finland, France, West Germany, Greece, Ireland, Italy, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and Britain.

Symbols employed to represent the data are:

$T_{(N)}$	Number of tractors (thousands)
$T_{(H)}$	Tractor horsepower (thousands)
L	Labour engaged in agriculture (thousands)
P_T	Price of tractors (Index Britain = 100)
P_L	Cost of agricultural labour (U.S. dollars per hour)
R	Average size of farms (hectares)

19/ These data are shown in Table A.6.

The model implies that there is a relationship between the factor proportions and the relative factor prices that is linear in the logs so the logarithms of the tractor-labour ratios are regressed on the logarithms of the relative labour-tractor prices. This gives the results:

$$(5) \qquad \log \frac{T}{L}^{(N)} = \underset{(.50)}{-2.12} + \underset{(.29)}{2.00} \log \left(\frac{P_L}{P_T}\right) \qquad \bar{r}^2 = .75 \ \underline{20/}$$

and

$$(6) \qquad \log \frac{T}{L}^{(H)} = -\ .64 + 2.00 \log \left(\frac{P_L}{P_T}\right) \qquad \bar{r}^2 = .82.$$

The relationship is surprisingly strong considering the crudeness of the data. The computed relative price coefficients are significantly greater than unity. These are estimates of the elasticity of substitution, so it appears that there is greater substitutability between the factors than would be implied by a Cobb Douglas production function. Since the ratio of the factor prices is based on an index rather than on the actual prices, the constant term cannot be used to calculate the relative factor shares or relative output elasticities. However, the estimate of the elasticity of substitution is not affected, provided the price index is a linear function of the true relative prices.

It is interesting to note that the estimated elasticity of substitution is the same for tractor horsepower as it is for tractor numbers.

The theoretical model takes the form

$$\log \left(\frac{X_i}{X_j}\right) = C + \sigma \log \left(\frac{P_j}{P_i}\right).$$

This can be expressed

$$\log \left(\frac{X_i}{X_j}\right) = C + \sigma \log P_j - \sigma \log P_i.$$

Thus, when the factor price terms are separated in the regression, their coefficients should be equal but of opposite sign. This provides a test of the appropriateness of the CES model. The

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20/ Logs are calculated to the base 10. The standard errors are given in brackets below the coefficients, and $\bar{r}$ is the coefficient of correlation corrected for degrees of freedom.

result of the regressions, using separate labour- and tractor-price terms, are:

$$(7) \quad \log \frac{T}{L}(N) = \underset{(.59)}{-2.21} + \underset{(.31)}{2.03} \log P_L - \underset{(1.93)}{1.40} \log P_T \qquad \bar{r}^2 = .74$$

and

$$(8) \quad \log \frac{T}{L}(H) = \underset{(.49)}{.58} + \underset{(.26)}{1.99} \log P_L - \underset{(1.62)}{2.46} \log P_T \qquad \bar{r}^2 = .80.$$

The price coefficients have the expected signs and are of similar magnitude. However, although the labour-price coefficient is highly significant, the tractor-price coefficient is not significantly different from zero at the 5 per cent level of confidence. Similarly, the two coefficients are not significantly different. Thus there is no indication that the CES model is inappropriate, but the test is a weak one because of the high standard error of the tractor-price coefficient.

An alternative method of checking the appropriateness of the CES model is to test the influence of a third factor of production upon the relationship between the proportion in which a pair of factors is used and the relative price of that pair of factors. One of the properties of this model is that the ratio in which a pair of factors is used is a function of the price of those factors only. The other factors of production do not directly enter this relationship. This was checked by testing whether the residuals of the fitted regressions are correlated with the labour-land ratios. No such correlations were found so the use of the CES model was supported.

It might be expected that the use of tractors relative to labour would depend upon the type of agricultural activity. This was tested at the country level by introducing, as an explanatory variable, the proportion of livestock products in total agricultural output. This proportion depends upon income, and so is correlated with the price of labour. As a result, it was a significant explanatory variable of tractor-labour ratios in formulations that omitted the price-of-labour variable. However, it was not significant in formulations that included the price of labour. The relationship between the use of machinery and labour, and type of farming in England and Wales, is examined in Chapter 6.

The effect of farm size on the tractor-labour proportions was tested by introducing into the model alternative measures of the size of farms in the various countries. The percentage of farms greater than 10 hectares and greater than 20 hectares improved the fit of the regressions and were usually significant. However, the best and most easily interpreted results were obtained by using the average size of farms as a variable. These results are

$$(9) \quad \log \frac{T}{L}(N) = \underset{(.45)}{-2.08} + \underset{(.30)}{1.71} \log \left(\frac{P_L}{P_T}\right) + \underset{(.23)}{.48} \log R \qquad \bar{r}^2 = .80$$

and

$$(10) \quad \log \frac{T}{L}(H) = \underset{(.31)}{-.59} + \underset{(.18)}{1.66} \log \left(\frac{P_L}{P_T}\right) + \underset{(.16)}{.56} \log R \qquad \bar{r}^2 = .90.$$

The coefficient of log R is the elasticity of the tractor-labour ratio with respect to the average size of farms. It suggests that an increase of 10 per cent in the average size of farms at unchanged prices would be accompanied by rise of about 4 to 6 per cent in the tractor-labour ratio. Two alternative explanations of this result are now suggested.

First, there could be increasing returns to scale for the farm, and these increasing returns could be biased in favour of machinery so that an increase in the size of farms would have a greater effect on the productivity of tractors than of labour, and so encourage the use of tractors relative to labour.

Second, there could be a divergence between the relative marginal products of the factors and their relative prices. This divergence could occur if the labour input on a small farm is in fixed supply and therefore is used to an extent where the value of its marginal product is less than the market price of labour. The point is, that if the farmer and his family are unable to hire out their own labour, then the market wage does not represent the opportunity cost of the farmer's labour on his farm. Therefore he has no economic incentive to stop applying his own labour to his farm when its marginal product falls below the wage. If this is the case, then the tractor-labour proportion on a small farm, or in countries with many small farms, would be less than that implied by the relative tractor-labour price.

Both of these explanations are consistent with the results given here. However, in Chapter 6, it will be argued that the latter explanation is more consistent with the results of the study of farming in England and Wales.

When these results are compared with those omitting the farm-size variable, e.g. regressions (5) and (6) above, it is observed that the relative factor price coefficient is lower in both cases. The fall in the relative price coefficient reduces the estimate of the elasticity of substitution. Correlation between farm size and the price of labour would explain this reduction, since the labour-price variable would act as a proxy for farm size and so have a higher coefficient in formulations in which the farm-size variable is omitted. The appropriate estimate of the elasticity of substitution depends upon whether it is taken to subsume the effects of induced changes in farm size.

A similar point occurs when considering differences in technologies between countries. This analysis has been carried out on the assumption that differences in technologies are neutral. However, if technical progress is biased towards a particular factor of production, in the sense that the productivity of that factor relative to others increases with technical progress, then the factor proportions will be a function of the state of technology as well as of the relative prices and of the size of farms. Since it is likely that the differences in technologies between countries will be closely related to the differences in relative factor prices, the estimates of the elasticity of substitution will be biased. For example, if technical progress is biased towards tractors, then part of the relatively large use of tractors in the richer countries should be ascribed to their more advanced technologies, rather than to their higher labour prices. Thus the estimates of the elasticity of substitution will be too high. An attempt is made to check for this by reformulating the model in terms of changes over time. Thus if

$$\log \left(\frac{T}{L}\right) = C + a \log \left(\frac{P_L}{P_T}\right) + b \log R,$$

then differentiate with respect to time:

$$\left(\frac{T}{L}\right)^{\bullet} = a \left(\frac{P_L}{P_T}\right)^{\bullet} + b(R)^{\bullet}$$

where the expression

$$(\frac{T}{L})^{\cdot} = \frac{d \log (\frac{T}{L})}{dt}$$

is the rate of change of the (T/L) ratio over time, and similarly the dots indicate the rates of change in the other variables. The point to note is that the coefficients of the change in the variables is the same as those for the variables themselves, but the constant term disappears. However, if in the static formulation the relative price variable is acting as a proxy for a technology variable, then when the model is converted into its rate-of-change form, there will be a constant term representing the influence of the technical change on the factor proportions, and the coefficient of the change in relative price term will be free of this particular source of bias.

The ratio of change in tractor horsepower per head, from 1960 to 1966 in the northwestern European countries, and from 1962 to 1966 in the southwestern European countries, were regressed against the estimated rates of change in the relative labour-tractor prices during the same period. The regression should have included an independent variable for the rate of change in farm sizes, but there were no adequate data. This omission is probably not too serious since the change in farm sizes has been very slow in most countries. The increase in size that has occurred increases the constant term of the regression. The result of the regression is

$$(\frac{T}{L})^{\cdot} = \underset{(2.15)}{5.01} + \underset{(0.30)}{1.43} (\frac{P_L}{P_T})^{\cdot} \qquad \bar{r}^2 = .62.$$

This gives a lower estimate of the elasticity of substitution than the cross-sectional study, although this elasticity still appears to be greater than unity. The constant term suggests that the rate of change in the tractor-labour ratio has been about 5 per cent per year greater than can be accounted for by the change in relative prices and the estimated elasticity of substitution. The effect of the increase in farm size will account for part of this constant term, but probably for less than half of it, so it would appear that there has been some capital-biased technical progress.[21/] Since the cross-sectional regressions gave higher estimates of the elasticity of substitution, there is probably also a capital-intensive difference in technologies between the countries.

It has been observed that the tractor-labour ratio is a function of the price of agricultural labour and farm size:

$$T/L = [P_L, R].$$

Since neither of these explanatory variables is likely to be completely exogenous, the relationship is unidentified. Farm size might be mainly determined by the system of land tenure and by legal and social custom, but it will also depend upon tractor and labour prices, since a fall in the cost of machinery relative to labour will provide an incentive for farm rationalization. The cost of agricultural labour will be related to the general level of wages and incomes within the economy, but it will also depend upon its own productivity which in turn depends upon the proportion in which the factors are used. If it were possible to find some exogenous determinants (X) of the price of agricultural labour, i.e. $P_L = [T/L, X]$ then the two key endogenous variables, T/L and P_L, could be identified as functions of the exogenous variable X, and the mainly exogenous variable R, i.e. the system $T/L = [P_L, R]$ and $P_L = [T/L, X]$ would reduce to $T/L = [R, X]$ and $P_L = [R, X]$. Attempts were made to introduce exogenous variables into the system by relating the price of agricultural labour to some index reflecting the influence of the non-agricultural sectors on the supply of agricultural labour. Two measures used were the rate of growth of industrial production (as an index of job opportunities) and the divergence between non-agricultural and agricultural earnings. Neither of these was significant so the system is unidentified, except on the assumption that both the price of agricultural labour and farm size are exogenously determined. Because of this lack of identification, the model is not able to determine factor prices and the factor proportions

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21/ An increase in the quality of the tractor-horsepower which is not reflected in its price indexes will have the same sort of effect.

independently. It does, however, determine the relationship that exists between them, and so can be used to develop conditional forecasts of the use of one factor relative to the other.

The main conclusions of this chapter are that farm size significantly affects the proportion in which tractors are used relative to labour at given factor prices; and that the elasticity of substitution between tractors and labour is significantly greater than unity, and is substantially greater than that observed in most studies of manufacturing industries.[22/]

An implication of this second conclusion is that a given fall in the price of tractors relative to the price of agricultural labour will tend to be associated with a proportionately greater fall in the use of labour relative to tractors. Thus a fall in the price of tractors will be a greater depressant on the price of labour than if the elasticity of substitution had been lower. A high elasticity of substitution between all machinery and labour in agriculture could be one of the reasons why agricultural earnings lag behind those in manufacturing industries.

22/ For example, Minhas estimates the elasticity of substitution to be slightly less than unity in most of the industries included in his cross sectional study: B. S. Minhas, An International Comparison of Factor Costs and Factor Use, Amsterdam: North-Holland Publishing Co., 1963.

5. A STOCK ADJUSTMENT MODEL OF DERIVED DEMAND TRACTORS IN BRITAIN 1948-65

In this chapter a stock adjustment model of tractor utilization is applied to time-series data for Britain. In particular, an equilibrium stock model derived from a constant elasticity of substitution production function is combined with a Gompertz adjustment model. Since this approach is somewhat similar to other studies of tractor demand by Griliches (Ref. 1), Cromarty (Ref. 2), Rayner and Cowling (Ref. 3), and by Austin Fox (Ref. 4) and to a study of the utilization of computers by Chow (Ref. 5), a brief discussion of these studies is included.[23/]

The model used here is basically the same as that of the preceding chapter, except that the tractor-labour proportions and their relative prices are observed in one country over a number of years, instead of between several countries at a point of time. Since there is likely to be a lag of some years before full adjustment in the factor proportions is made to a change in the relative prices, it is necessary to introduce an adjustment mechanism into the model. This makes it possible to distinguish between the short-run and the long-run elasticities of substitution.

Optimal Factor Use

As in the preceding cross-sectional study, the optimum stock of a factor is derived from a CES production function

$$(1) \qquad Y = A(\alpha_1 X_1^{-\beta} + \alpha_2 X_2^{-\beta} + \ldots.)^{-\frac{v}{\beta}}$$

where Y is output and $X_1 \ldots X_n$ are factors of production. Given profit-maximizing behaviour under competition by the producers, the optimum use of a factor X_i can be related to either an alternate factor X_j and relative factor prices

23/ These references are listed at the end of this chapter.

$$(2) \qquad \log X_i = C(2) + \sigma \log \left(\frac{P_j}{P_i}\right) + \log X_j$$

or to output Y and the relative price of output to the factor

$$(3) \qquad \log X_i = C(3) + \sigma \log \left(\frac{P_Y}{P_i}\right) + \sigma \left(\frac{\beta}{v} + 1\right) \log Y.$$

In each case the relationship is linear in the logs C(2) and C(3) being constants and $\sigma = \frac{1}{\beta + 1}$ is the elasticity of substitution.

Given constant returns to scale so that v=1, (3) reduces to

$$(4) \qquad \log X_i = C(4) + \sigma \log \left(\frac{P_Y}{P_i}\right) + \log Y.$$

Equations of the form of (2) and (4) are used to express the optimum stock of tractors T*, relative to agricultural labour L or to agricultural output Y

$$(5) \qquad \log T^* = C(5) + \sigma \log \left(\frac{P_L}{P_T}\right) + \log L,$$

and

$$(6) \qquad \log T^* = C(6) + \sigma \log \left(\frac{P_Y}{P_T}\right) + \log Y.$$

The Gompertz Adjustment Model

The actual stock of tractors T is related to the desired or optimum stock T* by means of the Gompertz curve

$$(7) \qquad T = T^* A^{B^t}$$

where t is time. If log A < 0 and B < 1, T moves asymptotically towards T*; and the rate of change of T depends upon the divergence between T and T*.[24/] Equation (7) can be written

24/ This is similar to the way in which the temperature of a cooling object approaches that of its environment.

$$\log T = \log T^* + B^t \log A$$

so

$$\frac{d \log T}{dt} = B^t \log A \log B$$

but

$$B^t \log A = -(\log T^* - \log T)$$

so

(8)
$$\frac{d \log T}{dt} = a(\log T^* - \log T)$$

where $a = - \log B$.

The rate of change of stock can be approximated by the change in the log of the stock during the current period: i.e.

$$\frac{d \log T}{dt} = \log T_t - \log T_{t-1};$$

and the actual stock can be approximated by the stock at the beginning of the period, so equation (8) is replaced by

(9)
$$\log T_t - \log T_{t-1} = a(\log T^* - \log T_{t-1})$$

or

$$\log \left(\frac{T_t}{T_{t-1}}\right) = a \log \left(\frac{T^*}{T_{t-1}}\right).$$

For moderate changes in T, the adjustment coefficient "a" approximates the proportion of the disequilibrium corrected in the period. Chow in the article referred to above describes how he uses this Gompertz adjustment model to explain the growth in the number of computers in the United States; and Griliches uses the same adjustment equation in his study of the demand for tractors in the United States. This present study differs from both Chow and Griliches in the way in which the optimum stock model is combined with the adjustment model.

The Stock Adjustment Model

The optimum stock equation (5) or (6) can be substituted into equation (9) to give an expression for the change in stock (net investment) in terms of the explanatory variables. Thus combining (5) with (9) gives

$$(10) \quad \log \left(\frac{T_t}{T_{t-1}}\right) = C(10) + a\sigma \log \left(\frac{P_L}{P_T}\right) + a \log L - a \log T_{t-1}$$

or using output instead of labour as an independent variable, i.e. combining (6) with (9) gives

$$(11) \quad \log \left(\frac{T_t}{T_{t-1}}\right) = C(11) + a\sigma \log \left(\frac{P_Y}{P_T}\right) + a \log Y - a \log T_{t-1}.$$

In either formulation "a" is the tractor adjustment coefficients and "a" and "σ" are respectively the short- and long-run elasticities of substitution. If the assumption of constant returns to scale is relaxed, (11) is modified into

$$(12) \quad \log \left(\frac{T_t}{T_{t-1}}\right) = C(12) + a\sigma \log \left(\frac{P_Y}{P_T}\right) + a\left[\sigma - \frac{(1 - \sigma)}{v}\right] \log Y - a \log T_{t-1}$$

where v is the degree of homogeneity of the CES production function.

Chow's model of the demand for computers is the same form as (12): the rate of change of computer utilization is related to output (GNP at constant prices), to the price of computers relative to the general price level, and to lagged computer utilization. Chow uses the coefficients of this regression as estimates of the adjustment coefficient and the price elasticities.25/

25/ Chow does not assume a CES production function, so his elasticities do not have quite the same interpretation as those in this paper.

The difficulty with these formulations is that the factor utilization relationship derived from the production function is only optimal for a given relative price if the level of output and the utilization of other factors is also optimal at that price. Chow does not deal with this problem. However, since the level of GNP is probably only remotely related to the price of computers, it can be considered as exogenous. The present study relates the stock of tractors to relative factor prices and to the quantity of agricultural labour. The amount of labour cannot be considered independent of the relative price of labour to tractors, nor is it appropriate to assume that the adjustment in the labour force occurs in one period. It is clear that the scale variable in the optimum stock equation should also refer to an optimum level. Thus the appropriate form of equation (5) above is

$$(13) \qquad \log T^* = C(13) + \sigma \log \left(\frac{P_L}{P_T}\right) + \log L^*$$

where L* is the optimal level of labour. If the adjustment of the quantity of labour used can also be represented by a Gompertz equation,

$$(14) \qquad \log \left(\frac{L_t}{L_{t-1}}\right) = b(\log L^* - \log L_{t-1}),$$

then equation (14) and the tractor adjustment equation (9)

$$(9) \qquad \log \left(\frac{T_t}{T_{t-1}}\right) = a \log \left(\frac{T^*}{T_{t-1}}\right)$$

can both be combined with the optimal stock equation (13) to give an expression relating actual quantities and the relative prices:

$$(15) \quad \log\left(\frac{T_t}{T_{t-1}}\right) = C(15) + a\sigma \log\left(\frac{P_L}{P_T}\right) + \frac{a}{b} \log\left(\frac{L_t}{L_{t-1}}\right) - a \log\left(\frac{T}{L}\right)_{t-1} .$$

In expression (15) it is of course arbitrary whether the rate of change in the tractor stock or in the quantity of labour is considered the dependent variable: in either case, the coefficients of the explanatory variables provide estimates of both adjustment coefficients and of the elasticity of substitution between the factors, although these estimates are not independent of each other.

The formulation using output as a scale variable can be adapted in a similar way if it is considered that the actual output Y diverges from the output Y* which would be optimal for the desired level of factor utilization at given relative prices. Thus the optimal relationship (with constant returns to scale) becomes

$$(16) \qquad \log T^* = C(16) + \sigma \log\left(\frac{P_Y}{P_T}\right) + \log Y^*$$

and if the output adjustment relation is also represented by a Gompertz equation,

$$(17) \qquad \log\left(\frac{Y_t}{Y_{t-1}}\right) = c \log\left(\frac{Y^*}{Y_{t-1}}\right),$$

these two equations can be combined with the tractor adjustment equation (9) to give an expression relating the rate of change in tractor stock, to relative prices, changes in output, and lagged output relative to the factor use:

$$(18) \quad \log\left(\frac{T_t}{T_{t-1}}\right) = C(18) + a\sigma \log\left(\frac{P_Y}{P_T}\right) + \frac{a}{b} \log\left(\frac{Y_t}{Y_{t-1}}\right) + a \log\left(\frac{Y}{T}\right)_{t-1} .$$

This formulation is derived from the same theoretical model as (15) which uses labour utilization as a scale variable. In both formulations the coefficients generate estimates of the elasticity of substitution and of the relevant adjustment coefficients. However, the output model is not so satisfactory empirically as the "relative factor use" model, because agricultural output is subject to considerable variation from year to year due to weather conditions, etc., and aggregate agricultural output in real terms is difficult to measure. Furthermore, the "relative factor use" formulation is independent of the assumption of constant returns to scale. For these reasons formulation (15) rather than (18) is used to fit the data on tractor utilization in Britain between 1948-1965. Use is made of some of Rayner's data (Ref. 6), particularly his "constant quality" tractor price index, and his index of the average price of tractor horsepower.[26/] Tractor numbers and estimated total horsepower are used as alternative measures of tractor stock.

The Results

The best result (as indicated by the coefficient of correlation) was obtained from the use of tractor numbers and Rayner's constant quality price index.

$$(19)\quad \log\left(\frac{N_t}{N_{t-1}}\right) = \underset{(.770)}{.054} + \underset{(.062)}{.429}\log\left(\frac{P_L}{P_T}\right) + \underset{(.38)}{1.01}\log\left(\frac{L_t}{L_{t-1}}\right) - \underset{(.071)}{.579}\log\left(\frac{N}{L}\right)_{t-1}$$

$$\bar{r}^2 = .92,\ D.W. = 2.69$$

where N is tractor numbers; L is total agricultural labour; P_L is the price of agricultural labour, and P_T is the "constant

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26/ Rayner's "constant quality" price index does not differ substantially from a confidential index provided by the U.K. Board of Trade. This latter index makes no claim to take account of quality changes other than that of changes in tractor size.

quality" price of tractors; D.W. is the Durban-Watson statistic. The prices refer to the current period. In this regression the coefficients of the variables have the expected signs and are significant at the 5 per cent level. They provide the following estimates:

$a = .58$ (tractor adjustment coefficient)

$b = .58$ (labour adjustment coefficient)

$a\sigma = .43$ (short-run elasticity of substitution)

$\sigma = .74$ (long-run elasticity of substitution)

This suggests that over half of the adjustment in the quantity of both factors takes place during the period of a year. Intuitively this seems rather high, although it is of the same order as estimated by Rayner and Cowling (Ref. 3) in a somewhat different model. The coefficient of the relative price term is an estimate of the short-run elasticity of substitution, and the value obtained, .43, seems quite feasible. However, when it is combined with the tractor adjustment coefficient to estimate the long-run elasticity of substitution the resulting estimate of .74 seems low. One of the shortcomings of this model is that the estimate of the long-run elasticity of substitution is inversely dependent upon the estimate of the adjustment coefficient, and a bias in the latter will bias the former.

The alternative measure of tractor price gives

$$(20)\quad \log\left(\frac{N_t}{N_{t-1}}\right) = -.195 + .164 \log\left(\frac{P_L}{P_T}\right) + 1.11 \log\left(\frac{L_t}{L_{t-1}}\right) - .210 \log\left(\frac{N}{L}\right)_{t-1}$$

$$(1.30)\quad (.060)\qquad\qquad (.646)\qquad\qquad (.047)$$

$\bar{r}^2 = .77$, D.W. $= 1.73$

where P_T is an index of the average price per tractor horsepower. The estimates calculated from this regression are $a = .21$, $b = .19$, $a\sigma = .16$, and $\sigma = .78$. Thus the adjustment coefficients are both much lower, but since the estimate of the short-run elasticity is also lower than in the previous regression, the estimate of the long-run elasticity is virtually unchanged.

The same procedure is carried out using total horsepower as a measure of tractor stock rather than tractor numbers, yielding

$$(21)\quad \log\left(\frac{T_t}{T_{t-1}}\right) = -1.41 + .247 \log\left(\frac{P_L}{P_T}\right) + 1.60 \log\left(\frac{L_t}{L_{t-1}}\right) - .223 \log\left(\frac{T}{L}\right)_{t-1}$$

$$\qquad (1.48)\ (.125) \qquad\qquad (.721) \qquad\qquad (.094)$$

$\bar{r}^2 = .60$, D.W. $= 1.68$

where T is total horsepower. This provides $a = .22$, $b = .14$, $a\sigma = .25$, and $\sigma = 1.1$. Again, the adjustment coefficients are low, but in this case the estimates of both the long- and short-run elasticities of substitution are higher.

The alternative tractor price index gives

$$(22)\quad \log\left(\frac{T_t}{T_{t-1}}\right) = -.820 + .243 \log\left(\frac{P_L}{P_T}\right) + 1.27 \log\left(\frac{L_t}{L_{t-1}}\right) - 1.58 \log\left(\frac{T}{L}\right)_{t-1}$$

$$\qquad (1.32)\ (.087) \qquad\qquad (.661) \qquad\qquad (.045)$$

$\bar{r}^2 = .67$, D.W. $= 1.61$

so $a = .16$, $b = .13$, $a\sigma = .24$, and $\sigma = 1.54$, which gives a still lower tractor adjustment coefficient and a higher estimate of the elasticity of substitution. The alternative tractor price indexes and measures of tractor stock give a wide range of estimates of the adjustment coefficients and of the elasticity of substitution. To some extent the variation in these estimates can be rationalized by the index or measure used. First, the elasticity of substitution appears to be higher for tractor horsepower than for tractor numbers. This, of course, is to be expected, since some of the change in tractor power available will be made by a change in the size of tractors. Second, the "constant quality" price index of tractors gives a lower estimate of the elasticity of substitution than does the other price index. This again is to be expected, since during a period in which the price of labour has been rising relative to the price of tractors, an index that does not take account of the improvement in the quality of tractors will indicate a smaller change in relative prices, and so provide a higher estimate of the elasticity of substitution than does an estimate that does take quality changes into account. However, the "constant quality" tractor price index does not necessarily provide a superior estimate of the elasticity of substitution, since it is probable that the quality of labour has also been improving over the period because of increased education and greater familiarity with the operation of machinery.[27/] If this is the case then the labour price index overestimates the rise in the cost of labour, and so biases downward the estimate of the elasticity of substitution. The index of relative prices, in which only the tractor price component is standardized for quality changes, might well be inferior to an index in which neither component is so standardized, since in the latter index the biases will be operating in opposite directions and will partially or totally offset each other.

Other Studies

The models of both Griliches (Ref. 1) and Rayner and Cowling (Ref. 3) differ from the model used here, in not having a scale variable relating tractor stock to an alternative factor or to output. Griliches justifies this by pointing out that in the conventional theory of the firm, the production function is the only constraint, so no scale variable is required. This, of course, is correct; but the conventional theory of the firm assumes that the firm is operating under conditions of increasing costs, for otherwise its optimum size is indeterminate. It is quite clear that models like Griliches', which relate optimum tractor stock to relative prices only, would be inappropriate for cross-sectional studies between countries, since they would leave unexplained why a large country such as the United States might have absolutely more tractors than a smaller country such as Canada,

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27/ The proportion of children staying on at school beyond the age of 15 has increased substantially in Britain during the post-war period. In addition there has been a considerable expansion of agricultural advisory and educational programs. The growing complexity and sophistication of some machines have increased the need for education. It is perhaps arbitrary whether the higher productivity made possible by these machines should be attributed to improvements in the quality of the machines or of the labour force.

even though relative prices might be similar. The point is that the increasing costs that act as a constraint on size in the theory of the firm are not operable at the national level of aggregation. What is not so clear is the effect of the omission of a scale variable in time-series analysis. At the industry level of aggregation, demand will not be perfectly elastic, so commodity prices will be related to output, and so will impose a constraint on the size of the industry, even if there are constant returns to scale. The result is that optimum stock is not homogeneous with respect to any pair of prices, but only to all relative prices. Thus in the type of model used by Griliches, and also by Rayner and Cowling, it is necessary to have the price of tractors relative to output and relative to the price of other factors of production as explanatory variables. Both Griliches and Rayner and Cowling do in fact include the price of tractors relative to output prices, as well as the price of tractors relative to labour in their models. Ideally, the relative prices of all other factors to tractors should be included as well, but, of course, data limitations and imperfect knowledge as to what factors are used make this impossible. In the CES scale model theoretically only one relative price is required, since the influence of other factor or commodity prices is subsumed in the scale variable. From the point of view of data requirements, the scale variable model seems more satisfactory, but it has the disadvantage that the factor demand is only determined relative to output or the use of an alternative factor, and that the elasticity of substitution rather than the total price elasticity is measured. The relation between the different elasticities is discussed below.

The stock adjustment model of Rayner and Cowling gives estimates for Britain similar to regression (19) above: a high adjustment coefficient, .68, and a low long-run relative price elasticity, .97.[28/] In their model the adjustment in a period is proportional to the disequilibrium between the desired and actual stock, instead of the percentage adjustment being some proportion of the percentage disequilibrium, as in the Gompertz model.

28/ Only the numerical values of the elasticities are given. They all have the expected sign.

However, this difference in formulation will not make much difference to the estimates of the adjustment coefficient. Their relative prices refer to the prices of tractors relative to the price of crops or labour lagged by one period.

On the other hand, Griliches' model of the stock demand for tractors in the United States provides estimates similar to those in regression (22) above. His estimated adjustment coefficient is .17 and his estimated long-run price elasticity is 1.5. Both these models include financial variables such as interest rates and investment allowances.

The study by Cromarty (Ref. 2) is several years older than the others and does not include an adjustment mechanism. His estimates of the price elasticity of shipments of tractors range from .5 to 1.0. This is appreciably lower than the estimate of Griliches or of Fox (Ref. 4) and somewhat lower than that of Cowling and Rayner. However, Cromarty's estimates are of short-run elasticities because of the absence of an adjustment mechanism, and so would underestimate the long-run elasticities.

The more recent study by Austin Fox for the U.S. Department of Agriculture (Ref. 4) uses crop production as a scale variable, and is specified so as to include an adjustment mechanism for tractors. But this model does not include an adjustment term for the crop production itself. This study estimates the long-run elasticity of demand for tractors to be 1.8. This result is not appreciably different from Griliches, but the U.S. Department of Agriculture estimate of the short-term elasticity is much higher than Griliches' estimate.

The Elasticities of Demand and Substitution

In order to compare the estimates of the elasticities of substitution arrived at in this study, with the estimates of demand elasticity of the other studies, it is necessary to consider the relationship between the elasticity of substitution, the elasticity of derived demand, and the elasticity of the demand for output. If the long-run (optimum) relation is as in equation (6) above,

$$\log T = C - \sigma \log P_T + \sigma \log P_Y + \log Y,$$

with σ being the elasticity of substitution of the CES production function, then

$$(23)\quad \frac{\partial \log T}{\partial \log P_T} = -\sigma + \sigma\left(\frac{\partial \log P_Y}{\partial \log P_T}\right) + \left(\frac{\partial \log T}{\partial \log y}\right)\left(\frac{\partial \log y}{\partial \log P_Y}\right)\left(\frac{\partial \log P_Y}{\partial \log P_T}\right).$$

In this expression the left-hand side is the elasticity of demand for the stock of tractors with respect to their price, "εT". The term $\frac{\partial \log P_Y}{\partial \log P_T}$ equals "θ", the share of the value of tractors in the value of output. The term $\frac{\partial \log T}{\partial \log y}$ equals unity, assuming constant returns to scale. The term $\frac{\partial \log y}{\partial \log P_Y}$ is the elasticity of demand for output with respect to its price, "εY".
Thus $\varepsilon T = -\sigma + \sigma\theta + (\varepsilon y)\theta$, or defining all the elasticities so as to be normally positive,

$$|\varepsilon T| = (1 - \theta)\sigma + \theta|\varepsilon y|.$$

Thus the derived demand elasticity is a weighted average of the elasticity of substitution and the elasticity of demand for the output. The weighting is determined by the share of the tractors in output. Since tractors probably account for a fairly small proportion of the value of agricultural output, the derived demand elasticity will not differ greatly from the elasticity of substitution. The common-sense interpretation of this argument is that a change in the price of tractors will only induce a moderate change in the price of agricultural output, so the main effect on the demand for tractors will be a substitution for other factors, rather than a substantial induced change in the scale of production.

The relationship between the three elasticities suggests how information concerning the two demand elasticities can be used to estimate the approximate size of the elasticity of substitution. Since the derived elasticity is a weighted average of the other two, it must be bounded by them. Thus, if the derived elasticity of demand for tractors appears to be greater than the elasticity of demand for agricultural output, the elasticity of substitution must be greater still. The evidence of the other studies suggests that the long-run demand elasticity for tractors is quite high. Rayner and Cowling's estimate is around unity, but this is probably rather low because their relative price index takes account of quality changes in tractors but not in labour. The estimates of Griliches and of Fox are appreciably higher. Since it is generally agreed that the elasticity of demand for agricultural output is probably well below unity, it seems likely that the elasticity of substitution between tractors and alternative factors of production (labour) is somewhat higher than the observed price elasticities of demand for tractors. Thus the result given in regression (21) above, which uses Rayner's "constant quality" tractor price index, and which estimates the elasticity of substitution between tractor horsepower and labour at 1.1, seems to be consistent with Rayner and Cowling's estimate of about unity for the price elasticity of demand for tractors. The estimate given in regression (22) uses a price index which does not so fully reflect changes in the quality of tractors, and so gives an appreciably higher estimate of the elasticity of substitution of about 1.5. This would be consistent with an elasticity of demand of rather less than 1.5 and so is slightly low when compared with the estimates of Griliches and of Fox.

Conclusions

This study has suggested a method of measuring the adjustment coefficients. The other studies discussed have such a wide variation in their estimates of the adjustment coefficients and of the short-run elasticities that none of these estimates alone inspire much confidence. The demand elasticity estimates of Rayner and Cowling, Griliches, and the U.S. Department of Agriculture study by Fox, can be reconciled by the estimates of the long-run elasticity of substitution between tractor horsepower and labour made in this study. These results are sensitive to the index of relative prices used, and the estimates vary accordingly. It seems probable that the estimated elasticity of substitution of 1.1 arrived at by using Rayner's "constant quality" tractor price index is too low, since it fails to take account of improvements in the quality of labour. On the other hand, the alternative estimate of 1.5 and the higher related estimates of Griliches and of Fox might be too high if improvements in the quality of tractor horsepower have been greater than the improvements in labour. However, there is no evidence as to whether this is the case. Tentatively it is suggested that the elasticity of substitution is well above unity, but probably not much greater than 1.5. This latter figure is consistent with the cross-sectional study carried out in the previous chapter.

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6. MECHANIZATION IN ENGLAND AND WALES

INTRODUCTION

This section of the study discusses farm mechanization in England and Wales. England has one of the highest levels of agricultural mechanization (relative to labour) of the European countries. It has the best farm structure in that the percentage of farms of less than 20 hectares (50 acres) is lowest, and there is little fragmentation of farms. It is hoped that an examination of the use of agricultural machinery and equipment in England will give some idea of likely trends in countries whose agricultural sectors are less advanced.

The principal source of data for this analysis is the U.K. Ministry of Agriculture, Fisheries and Food's *Farm Incomes in England and Wales* series, which gives considerable information derived from the Farm Management Survey, on the inputs and incomes by types and sizes of farms. Use is made of these classifications to measure the dependence of mechanization upon the structure of output and upon farm size. The elasticity of substitution of machinery for labour with respect to output and with respect to size will be used as measures of this dependence. These are concepts analogous to that of the elasticity of substitution between the factors with respect to factor prices, which was used in Chapters 4 and 5. An advantage of the "Farm Incomes" series is that the size of farm is classified on the basis of the labour requirements for that type of farm calculated on average levels of labour efficiency. This means that comparisons of size can be made between different types of farms. For example, a "cropping, mostly cereal" farm of 120 acres is small, requiring little more than one person's full-time labour at average efficiency, whereas a "specialist dairy" farm of the same acreage would have about four times the labour requirement. This classification of size on the basis of labour requirement has only been used since 1965, so it is difficult to make comparisons over a number of years. However, 1964 is compared with 1954 on the basis of the previous classification, and this is used to provide further evidence as to the elasticity of substitution between factors with respect to price.

Most of the data in the "Farm Incomes" series is based on a sample of about 2,200 farms, so for some of the sub-classes the number of farms in the sample is quite small and might not be representative. Where possible, attention is focused on sub-classes that contain a substantial number of sample farms. These sub-classes will tend to be important ones, because the Farm Management Survey is structured so as to reflect the national distribution of farms. No data are given for sub-classes in which the number of sample farms is less than 10.

Measures of Mechanization

As in other sections of this study, there is the problem of how to measure mechanization. *Farm Incomes in England and Wales* (FIEW) provides data on the value of machinery and on the cost of machinery and power inputs. The latter is further broken down into types of costs. The value of machinery being used might seem to be the most relevant measure of the demand for machinery, but this will take no account of the intensity with which machinery is used, and will also understate its use by classes of farms that hire machinery services. Furthermore, the valuation of machinery is probably more arbitrary than the estimation of aggregate machinery costs, and is perhaps more liable to fluctuation. For these reasons machinery and power costs (described as "machinery costs") will be used as the principal measure of machinery input. Data on machinery valuations are given in the Appendix.

To maintain consistency with the earlier sections of this study machinery inputs are expressed relative to total labour input. However, unlike the earlier sections, there are reasonable data on total costs and on the value of output, so mechanization is also measured relative to these.

Unfortunately there is no information concerning the types of machinery being used in different sizes and types of farms. Included in the Appendix is a table giving the total use of different types of machinery in England and Wales.

Most of the data in this section refer to the value of inputs and outputs, and not to their quantities. This differs from the previous chapters where quantities were generally used. The use of values instead of quantities causes no difficulties in most of the study since it concerns prices of inputs and outputs at one period of time in a unified market. Thus the prices of inputs and outputs can be assumed to be invariant for size and type of farm, and relationships between values can equally well represent relationships between quantities. In the section comparing 1954 with 1964, the distinction between quantities and values becomes important.

Definitions

(a) *Size of farm* -- The size of farms is measured in "Standard Man-Days" (SMDs), that is, the total labour requirement of cropping and stocking on the farm at average levels of labour efficiency, plus an allowance of 15 per cent for overhead labour use, measured in terms of an eight-hour day of adult labour. The main classification is of farms greater than 275 SMDs -- i.e. of farms large enough to provide full-time engagement for at least one person. However, there is some information on farms smaller than this, described as "very small farms", which are full-time occupations. Averages for "all sizes" as calculated by FIEW are the size-group-sample averages weighted by the total number of holdings of that type and size in England and Wales.

(b) *Costs and output* -- Labour costs include wages and employers' contributions, payments in kind, unpaid family labour including that of the farmer and his wife, and salaried management.[29/]

Machinery and power costs include expenditure on vehicle taxes, fuel, depreciation and repairs, twine and wire, and contract operations and electricity, less allowances for appreciation and for private use. They include the costs of cars and vans on the farm but exclude transport and haulage costs.

"Total costs" include the labour of farmer and wife, and the estimated rent of owner-occupied land. They exclude feeds, seeds, and livestock.

"Net agricultural output" is the value of production including deficiency payments and production grants, less the inputs of feeds, seeds, and livestock.

29/ Most of the tables in FIEW give the value of labour of the farmer and his wife separately from "labour costs", but in this study they are combined.

(c) *Type of farm* -- The type of farm is classified on the basis of the standard labour requirement of the various activities of the farm -- e.g. "specialist dairy" has more than 75 per cent of the labour spent in dairying activities, whereas a "mainly dairy" farm has between 50 and 75 per cent of the labour spent in dairying. The distinction between "dairy" type and "livestock" type farms is that the latter are mainly involved in rearing and fattening livestock.

The precise definition of the various types of farming is given in FIEW. "All types" of farms exclude "horticulture". The averages for "all types" is calculated by FIEW in the same way as the averages for "all sizes" described above.

MECHANIZATION BY TYPE OF FARMING

The distribution of agricultural output among types of farms is given in Table 6.1. This shows the relative importance of different types of farming in England and Wales. It is intended as a reference table to the following discussion on mechanization by type of farm. The distribution of agriculture output is not the same as the distribution of types of farms, as there is a substantial livestock output from the dairy-type and cropping-type farms, as well as from the livestock and mixed farms.

Machinery costs, labour costs, and total costs by type of farming for "all sizes" farms are shown in Table 6.2.

As might be expected, there is great variation in the intensity of inputs per acre. The intensity of farming in horticulture is about 30 times as great as in sheep farming. The former activity is mainly located on valuable and probably fertile land near urban areas, whereas much of the sheep farming is on rough grazing-land in remote and hilly regions.

It is more interesting to note the proportion in which machinery and power is used relative to labour and to total inputs. Here the variation is much less. In most types of farming, machinery and power costs are between 60 and 70 per cent of the size of labour costs, and constitute about a quarter of total costs. The exceptions are horticulture which uses relatively less machinery and power, and cereal farming, and pigs and poultry, which use relatively more.

TABLE 6.1

PERCENTAGE DISTRIBUTION OF HOLDINGS AND NET AGRICULTURAL OUTPUT, BY TYPE OF FARM, ENGLAND AND WALES, 1966 (ESTIMATES)

		Net Agricultural Output			
Type of Farm	Agricultural Holdings	Crops	Milk and Milk Products	Other Livestock Products	Total
Specialist dairy	21	2	47	9	13
Mainly dairy	19	7	39	16	17
Livestock, mostly sheep	4	-	1	3	2
Livestock, cattle and sheep	13	4	1	22	8
Cropping, mostly cereal	6	16	1	5	10
General cropping	11	34	1	11	20
Mixed	10	10	10	17	12
Pigs and poultry	6	2	-	15	6
Horticulture	10	24	-	2	12
All holdings over 275 SMDs	100	100	100	100	100

Source: From or calculated from Ministry of Agriculture, Farm Income in England and Wales, 1966. The table refers to holdings greater than 275 SMDs. Holdings smaller than 275 SMDs take up about 5 per cent of the total agricultural land.

In order to distinguish between the influence of farm type and farm size on mechanization, machinery costs relative to labour and total costs are also given for farms within one size class, 1,200 to 1,799 SMDs. Nearly two-thirds of the farms are smaller than 1,200 SMDs, but farms of this size appear to be getting most of the benefits of scale, as indicated by the margin of net agricultural output over total costs.

It can be seen that the machinery and power costs are somewhat higher, relative to either labour costs or total costs, in cropping activities than in livestock and dairy activities, although this relationship does not hold for the highly intensive types of farming of "pigs and poultry" and "horticulture". Therefore shifts in the structure of output in the non-intensive (non-factory) farming sectors would be associated with changes in factor proportions. The tables above understate this relationship, because cropping farms have some output of livestock products and *vice versa*.

TABLE 6.2

MACHINERY, LABOUR, AND TOTAL COSTS BY TYPE OF FARMING, 1966

(All sizes over 275 SMDs)

Type of Farm	Machinery	Labour	Total Costs	Machinery Relative to Labour Costs	Machinery Relative to Total Costs
	(£'s per acre)			(Per cent)	
Specialist dairy	8.3	14.2	35.3	58	24
Mainly dairy	7.5	11.5	30.2	65	25
Livestock, mostly sheep	1.4	2.6	5.9	54	23
Livestock, cattle and sheep	3.6	5.6	14.4	64	25
Cropping, mostly cereal	7.6	7.6	26.5	100	29
General cropping	10.9	16.1	42.4	68	26
Mixed	7.8	11.7	30.8	67	25
Pigs and poultry	19.3	23.2	62.1	83	31
Horticulture	25.2	87.2	185.7	29	14

TABLE 6.3

MACHINERY, LABOUR, AND TOTAL COSTS BY TYPE OF FARMING, 1966

(Farms of 1,200 to 1,799 SMDs)

Type of Farm	Machinery	Labour	Total Costs	Machinery Relative to Labour Costs	Machinery Relative to Total Costs
	(£'s per acre)			(Per cent)	
Specialist dairy	8.6	12.8	35.6	67	24
Mainly dairy	8.8	11.9	33.7	74	26
Livestock, mostly sheep	1.1	2.1	5.0	56	23
Livestock, cattle and sheep	4.0	5.6	16.5	71	25
Cropping, mostly cereal	7.0	7.6	25.6	92	27
General cropping	10.4	13.3	37.3	78	28
Mixed	8.2	11.4	32.3	72	25
Pigs and poultry	19.9	21.5	58.6	92	34
Horticulture	22.6	53.4	127.7	42	18

This is taken into account by relating output structure (livestock including dairy products as a percentage of total output) to relative factor inputs for each type of farming, except "horticulture" and "pigs and poultry", within a size group.

This relationship is shown in Table 6.4 for two measures of factor proportions, and for two size groups. Machinery costs are expressed relative to labour costs, and relative to all costs excluding machinery. This latter basis is used rather than "total costs" so as to maintain the concept of substitution between factors. In each case these are shown for small farms and fairly large farms.

If log-linear regressions are fitted to these data, the regression coefficient is an estimate of the elasticity of substitution of the factor proportion variable with respect to output structure. These regressions are as follows:

For small farms:

$$(1)\quad \log(M/L) = \underset{(1.01)}{2.26} - \underset{(.06)}{.29}\log S \qquad \bar{r}^2 = .79$$

$$(2)\quad \log(M/AOC) = \underset{(.05)}{1.85} - \underset{(.03)}{.19}\log S \qquad \bar{r}^2 = .85.$$

For large farms:

$$(3)\quad \log(M/L) = \underset{(.09)}{2.17} - \underset{(.05)}{.18}\log S \qquad \bar{r}^2 = .63$$

$$(4)\quad \log(M/AOC) = \underset{(.04)}{1.73} - \underset{(.03)}{.12}\log S \qquad \bar{r}^2 = .76$$

where M is machinery costs,
AOC is all other costs (excluding machinery)
L is labour costs
S is the percentages of livestock produce in total output.

From these regressions it can be seen that the output structure elasticity of substitution between machinery and labour is greater than between machinery and all other costs. This suggests that the livestock farms use large amounts of labour relative to all other inputs, and not just relative to machinery. The elasticities are higher for small farms than for large ones. A 10 per cent change in the structure of output from crops to livestock products would be associated with about a 3 per cent decrease in the use of machinery relative to labour on small farms, and about a 2 per cent decrease on large farms.

TABLE 6.4

OUTPUT STRUCTURE* AND RELATIVE COSTS

Type	Small Farms (275 to 499 SMDs)			Large Farms (1,200 to 1,799 SMDs)		
	Output Structure	Machinery / Labour	Machinery / All other Costs	Output Structure	Machinery / Labour	Machinery / All other Costs
	(Percentages)					
Specialist dairy	92	53	32	93	67	32
Mainly dairy	91	48	30	71	74	35
Livestock, mostly sheep	71	48	32	100	56	30
Livestock, cattle and sheep	89	54	33	60	71	33
Cropping, mostly cereal	16	97	45	20	92	37
General cropping	13	77	43	19	78	39
Mixed	60	50	30	48	72	33

* See definition in text.

The preceding analysis excludes the highly intensive activities of horticulture, and pigs and poultry. Pig and poultry farming uses a great deal of machinery relative to labour and other inputs, while horticulture uses relatively little. The heavy machinery input into pig and poultry production reflects the application of so-called "factory methods" of rearing. It is apparent that these methods are now starting to be applied in other forms of livestock and dairy farming. When these techniques become more widespread, livestock products will require relatively more machinery than at present, and might well become more machinery-intensive than crop production.

On the other hand, shifts away from the production of cereals and other extensive crops and towards perishable vegetables will be associated with a reduction in the use of machinery relative to labour.

To conclude this section, it can be said that the effects of probable changes in output structure on the demand for farm machinery will be complex and multi-directional. Increases in livestock production relative to crops, if carried out by traditional, extensive methods of farming will be associated with a decline in the use of machinery relative to other inputs. However, an increase in livestock production by intensive farming methods will have the opposite effect. Such shifts would, of course, be associated with changes in the type of machinery required. One of the main growth points for machinery demand might well be in the kind of equipment used in battery rearing of poultry and livestock. Some of this type of equipment has perhaps hardly been developed.

MECHANIZATION BY SIZE

In most of the preceding section of this chapter attempts were made to abstract from the effects of farm size on mechanization by confining comparisons to within particular size groups. In this section, the effects of farm size are considered. It may be recalled that the cross-sectional study between countries carried out in Chapter 4 identified the size of farms as being an important determinant of the level of mechanization. However, the data on farm size were too fragmentary to give much idea about the nature of this relationship; in particular, there was a lack of information on the size distribution of farms in the several countries. Advantage is taken of the FIEW data on farms by type and size to examine the relationship between size and efficiency, and size and mechanization, and to consider how these relationships vary between types of farm.

The relationship between total costs (including all imputed labour and rents) and net agricultural output is taken as an indicator of efficiency, since it shows the output being obtained per input at current prices, subsidies, and grants. This is shown by type and size of farm in Table 6.5, which includes data on the "very small farms" of less than 275 SMDs.

TABLE 6.5

NET AGRICULTURAL OUTPUT AS A PERCENTAGE OF TOTAL COSTS

	Size in Standard Man-Days (SMDs)					
Type	-275	275-449	450-599	600-1,199	1,200-1,799	1,800+
Specialist dairy)	) 87	104	121	122	128	140
Mainly dairy)		108	114	123	124	127
Livestock, mostly sheep)	) 77	85	94	105	128	128
Livestock, cattle and sheep)		94	104	119	125	126
Cropping, mostly cereal	..	105	114	124	128	134
General cropping	97	117	123	135	136	132
Mixed	..	89	112	122	129	125
Pigs and poultry	65	..	..	139	130	138
Horticulture	..	..	..	126	131	123

It is not intended that this table should be used to compare the "levels of efficiency" between different types of farms, since this measure depends upon the prices and subsidies received which vary between types. However, the table can be used to compare the relationship between size and efficiency within each type.

It can be seen that for every type of farm, those of less than 600 SMDs get appreciably lower returns on their inputs than larger farms, and this is most pronounced for the smallest farms.[30/] The relationship between size and efficiency for farms larger than 600 SMDs is less clear. In some types such as mainly dairy, general cropping, mixed farming, pigs and poultry, and horticulture, farms of between 600 and 1,200 SMDs get as high a rate of return as larger farms. In other types, such as specialist dairy, livestock, and cereal farming, farms of 600 to 1,200 SMDs are still not large enough to get the full benefits of large-scale production. It appears that some types such as horticulture, general cropping, and mixed farming, might be running into diminishing returns, while in dairy and cereal farming the rate of return on inputs appears to be still rising even for the largest farms.

This study is not going to consider the problems of diminshing returns for large farms, partly because the rate of diminution does not seem very high, but mainly because the problem of small farms is much more important. Most of western European agriculture is dominated by very small farms, whereas the number of farms large enough to encounter serious diminishing returns is probably negligible.

The rest of this section attempts to identify the cause of these decreasing costs. Two alternative models explaining why small farms might have low returns are described, and their alternative predictions concerning the relationship between factor and output proportions and farm size are considered for farming in England and Wales. Decreasing costs might occur between the firms (or farms) of an industry, even though the individual firm is operating under conditions of increasing costs. This might arise

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30/ It might appear that the farms of less than 275 SMDs are inefficient by definition since they are full-time occupations, yet do not have sufficient output to justify full-time work for one person at average levels of labour output. However, it is possible that these small farms use sufficiently less of other inputs to compensate for their high labour-output ratios.

either because there are increasing returns to scale over all the factors of production and at least one factor is in fixed supply for the individual producer, or because there are constant returns to scale over all the factors, but two or more of them are in fixed supply for the individual producer. Clearly, if only one factor is in fixed supply and there are constant returns to scale, all the producers could use the same factor proportions irrespective of the quantity of the fixed factors that they possess, and would therefore have the same relative costs of output. On the other hand, if there are increasing returns to scale, then the existence of one fixed factor, held in differing quantities by producers, is sufficient to cause varying relative costs.

The first model assumes that there are constant returns to scale over all the factors, but the problem of small farms arises because of the outward immobility of a farmer's labour and the fixed supply of land available to him. The second model assumes that there are increasing returns to scale over all the factors, for at least some range of farm sizes. These returns to scale might be neutral in the sense that the marginal rate of substitution between factors is independent of size, or they may be biased towards particular factors such as capital. These models can to some extent be combined. However, the properties of their pure forms are discussed in order to derive alternative predictions concerning factor and output proportions.

Model 1. Constant Returns to Scale and Fixed Labour Supply

The proprietor of a small farm operates under two major constraints: his limited supply of land, and the low outward immobility of his own labour. This latter constraint has the effect of determining the minimum supply of labour to the farm. The labour requirements of a large farm will be greater than that provided by the farmer alone, so he will probably be hiring labour, and as a result he will have considerably more choice in the quantity of labour used.

This model considers the variability of factor proportions with respect to size between small farms with fixed labour supply. The results are compared with those derived for larger farms with variable labour supply.

A farmer with a fixed supply of land and labour will, if he is attempting to maximize the return to the fixed factors, employ the variable factors until the value of their marginal products is equal to their marginal costs (prices); and he will use his fixed factors (land and labour) until either their marginal products are zero or until the factors are being fully utilized.[31/] Given normal conditions of production, the marginal products of the factors will not be zero, so the factors will be fully utilized. These conditions will determine the proportion in which factors are used, and how these proportions will vary with the quantity of land (farm size). The solution depends upon the nature of the production function. If the conditions of production are homogeneous with constant returns to scale over *all* the factors of production,

$$Y = Y(K, L, R)$$

where Y is output, K is capital representing all the variable factors, L is labour, and R is land; then the relationship between K, Y, and the marginal product of capital (Y_K) is fully determined:

$$\frac{K}{Y} = f(Y_K).$$

But for the maximizing farmer (large or small) the value of the marginal product of K will equal its price, i.e.

$$(P_Y Y_K) = P_K$$

where P_Y is the price of output and P_K is the price of capital, so

$$\frac{K}{Y} = f\left(\frac{P_K}{P_Y}\right).$$

But P_Y and P_K are market prices, which will probably be invariant with respect to the size of a particular farm:[32/] thus the model predicts that the capital-output ratio will also be invariant with respect to farm size.

31/ Full utilization of labour means up to some normal working day. It is being assumed that the opportunity cost (in terms of leisure) is zero up to some length of a working day, then it becomes very high.

32/ This analysis compares farms of different sizes within a particular agricultural sector at a particular time so prices can be considered constant. If the structure of farm sizes in an agricultural sector changed, there would probably be associated changes in prices.

The relationship between the capital-output ratio and relative prices can also be expressed

$$\log K = \log f\left(\frac{P_K}{P_Y}\right) + \log Y, \text{ where } Y = Y(K, L, R).$$

Differentiate with respect to farm size, and since $\frac{P_K}{P_Y}$ is invariant with farm size

$$\frac{d \log K}{d \log R} = \frac{d \log K}{d \log Y}\frac{d \log Y}{d \log R}$$

$$= \frac{d \log K}{d \log Y}\left[\frac{\partial \log Y}{\partial \log K}\frac{d \log K}{d \log R} + \frac{\partial \log Y}{\partial \log L}\frac{d \log L}{d \log R} + \frac{\partial \log Y}{\partial \log R}\frac{d \log R}{d \log R}\right].$$

But for the small farms the labour supply is fixed to that of one person so

$$\frac{d \log L}{d \log R} = 0.$$

Also if there are constant returns to scale, then

$$\frac{d \log K}{d \log Y} = 1.$$

Thus

$$\frac{d \log K}{d \log R} = \left[\frac{\frac{\partial \log Y}{\partial \log R}}{1 - \frac{\partial \log Y}{\partial \log K}}\right],$$

$$\frac{d \log K}{d \log R} = \varepsilon KR$$

is the elasticity of the use of K with respect to farm size for the small farm (e.g. with labour constant)

$$\frac{\partial \log Y}{\partial \log K} = \varepsilon YK$$

is the elasticity of output with respect to K (other factors constant)

$$\frac{\partial \log Y}{\partial \log R} = \varepsilon YR$$

is the elasticity of output with respect to R (other factors constant) so

$$\varepsilon KR = \left[\frac{\varepsilon YR}{1 - \varepsilon YK}\right].$$

Thus in the range where labour is fixed, the elasticity of K with respect to R (farm size) depends positively upon the elasticities of output with respect to land and capital; also εKR depends negatively upon the output elasticity of labour εYL, since εYK and εYR will be low when εYL is high ($\varepsilon YK + \varepsilon YL + \varepsilon YR = 1$).

Since εYK and εYR are both positive but less than unity, εKR is also positive. Thus, as might be expected, the quantity of capital used (and the capital-labour ratio) will be lowest for the smallest farms. However, by using the property that the output elasticities sum to unity so that

$$\varepsilon KR = \frac{\varepsilon YR}{\varepsilon YR + \varepsilon YL},$$

it can be seen that εKR is less than unity. Thus as the size (in area) of the farm increases, the quantity of capital increases at a slower rate, so that the K/R ratio falls. These are the second and third predictions of this model. The factor proportion elasticity εKR lies between zero and unity, but it is not necessarily constant. εKR will rise or fall as R increases, depending upon whether the elasticity of substitution between the factors is greater or less than unity.

Model 2. Increasing Returns to Scale and Variable Labour Supply

The second model differs from the first in two respects. First, although the farmer has a fixed supply of land, the quantity of labour that he applies to it can be varied. Second, there are increasing returns to scale over all the factors of production. Clearly, if there were constant returns to scale over all the factors, and all the factors except one were variable, then the farmer could achieve optimum factor proportions, and so the cost of inputs relative to output would be independent of size. Thus, if it is assumed that all the factors except land are variable, it is also necessary to assume that there are increasing returns to scale in order to explain the high output relative to inputs of large farms.

In this model the farmer will use both capital and labour until the value of their marginal products equal their prices. Provided that the production functions are homogeneous and separable so that the returns to scale are neutral between factors, the relative marginal products of capital and labour will depend only upon the proportions in which capital and labour are used. Thus the K/L ratio will be determined by the relative factor prices. Since these prices are assumed to be invariant with respect to farm size, the K/L ratio will be the same for all size farms. This is the first way in which the predictions of this model differ from the preceding one.

The relationship between capital and output will depend upon relative capital and output prices and upon the returns to scale and the substitutability between the factors. Given a CES production function of the form

$$Y = \left[\alpha_1 K^{-\beta} + \alpha_2 L^{-\beta} + \alpha_3 R^{-\beta}\right]^{-\frac{v}{\beta}}$$

where v is the degree of returns to scale and

$$\frac{1}{\beta + 1}$$

is the elasticity of substitution between factors. Then

$$\log K = C + \frac{\beta + v}{\beta v + v} \log Y + \frac{1}{\beta + 1} \log \left(\frac{P_Y}{P_K}\right)$$

where C is a constant involving the parameters of the production function. Since $^{P_Y}/_{P_K}$ is assumed to be constant with respect to farm size,

$$\frac{d \log K}{d \log Y} = \frac{\beta + v}{\beta v + v}$$

is the proportional change in capital associated with a proportional change in output for given factor and output prices. v is positive and will be greater than one if there are increasing returns to scale. β is negative if the elasticity of substitution is greater than one, but has a minimum value of -1. Thus increasing returns to scale implies

$$\frac{d \log K}{d \log Y} > 0$$

but the expression will be greater than unity if $\beta < 0$, and less than unity if $\beta > 0$. Therefore the implications of this model are that for increasing returns to scale and elasticities of substitution greater than unity, the capital-output ratio will increase with size, and that this ratio will fall if the elasticity of substitution is less than unity. Since the empirical evidence of this study suggests that the elasticities of substitution are greater than unity, this particular model implies that the capital-output ratio will be higher for large farms than for small ones.

The relationship between the use of the variable factors (capital and labour) and the fixed factor (land) can be derived in the same way as in the first model.

$$\frac{d \log K}{d \log R} = \frac{d \log K}{d \log Y} \frac{d \log Y}{d \log R}$$

or

$$\frac{d \log K}{d \log R} = \frac{d \log K}{d \log Y} \left[\frac{\partial \log Y}{\partial \log K} \frac{d \log K}{d \log R} + \frac{\partial \log Y}{\partial \log L} \frac{d \log L}{d \log R} + \frac{\partial \log Y}{\partial \log R} \frac{d \log R}{d \log R} \right] .$$

This is the same expression used to derive the elasticity of capital use with respect to size in the preceding model. But there are differences in the solution: first, in the preceding model

$$\frac{d \log K}{d \log Y} = 1$$

because of the assumption of constant returns to scale, whereas in this model

$$\frac{d \log K}{d \log Y} = \frac{\beta + v}{\beta v + v} ;$$

and second, in the preceding model

$$\frac{d \log L}{d \log R} = 0$$

because labour was assumed to be fixed, whereas in this model it is variable. However, since it has been assumed that returns to scale are neutral between factors so that the K/L ratio is independent of size, then

$$\frac{d \log L}{d \log R} = \frac{d \log K}{d \log R} .$$

Thus

$$\varepsilon KR = \frac{\left(\frac{\beta + v}{\beta v + v}\right) \varepsilon YR}{1 - \left(\frac{\beta + v}{\beta v + v}\right) (\varepsilon YK + \varepsilon YL)}$$

where εKR is the elasticity of capital use with respect to farm size, and εYR, etc., are the elasticities of output with respect to the factors of the production function. Since these elasticities of output sum to v, the expression can be written

$$\varepsilon KR = \frac{\left(\frac{\beta + v}{\beta + 1}\right)\frac{\varepsilon YR}{v}}{1 - \left(\frac{\beta + v}{\beta + 1}\right) + \left(\frac{\beta + v}{\beta + 1}\right)\frac{\varepsilon YR}{v}} .$$

This expression is quite complex, but it is possible to determine whether it is positive and greater than unity for the relevant range of the parameters. Since it is assumed that $v > 1$, the numerator of the expression is positive, thus the sign of the whole expression will be the same as the sign of the denominator. It can easily be seen that provided the denominator is positive, the total expression will be greater than unity, since

$$\frac{\beta + v}{\beta + 1} > 1.$$

However, it might appear that the denominator could become negative for high elasticities of substitution $\beta \to -1$, and for high value of v relative to εYR, so that the expression could change sign as it became infinitely large. This will not happen because for high elasticities of substitution the output elasticities are not constant, so as the proportion of the variable factors relative to land increased, the elasticity of output of the variable factors would decrease and εYR would approach v. Thus the total expression would approach a value of

$$\frac{\beta + v}{\beta + 1} .$$

For the special case of a Cobb Douglas production function $\beta = 0$; $\varepsilon KR = \varepsilon YR/(\varepsilon YR + 1 - v)$. This will be positive and greater than unity provided $v - \varepsilon YR < 1$. Since $v = \varepsilon YK + \varepsilon YL + \varepsilon YR$ this condition can be written $\varepsilon YK + \varepsilon YL < 1$. This is a reasonable constraint, requiring that there are diminishing returns to the variable factors when the fixed factor is held constant. If this is not satisfied, an infinite quantity of capital and labour would be applied to a fixed quantity of land.

The foregoing analysis has been carried out to determine the elasticity of capital use with respect to farm size (land) under the restrictions of this model. Since the capital-labour ratio remains constant, the labour-land elasticity will be equal to the capital-land elasticity; so the results of this analysis are that

$\varepsilon KR = \varepsilon LR > 1$. Thus as farm size increases, the quantity of capital and labour will increase at a faster rate. The predictions of this model are that the capital-land ratio and the labour-land ratio will be higher for large farms than for small ones. These predictions differ from those of the previous model.

The predictions of the alternative models are contrasted with each other, and then are compared with the observed relationships.

Factor Proportions for Large Farms Relative to Small Farms

Change in	Model 1 Constant Returns to Scale Fixed Labour Supply	Model 2 Increasing Returns to Scale Variable Labour Supply
K/Y	0	+ (if $\sigma > 1$) or - (if $\sigma < 1$)
K/R	-	+
L/R	-	+
K/L	+	0

(+....increase, 0....constant, -....decrease)

The following four tables show each of these ratios for the different types and sizes of farms.

TABLE 6.6

MACHINERY AND POWER COSTS AS A PERCENTAGE OF NET AGRICULTURAL OUTPUT

	Size in Standard Man-Days				
Type	275-449	450-599	600-1,199	1,200-1,799	1,800+
Specialist dairy	23	19	19	19	17
Mainly dairy	22	22	20	21	20
Livestock, mostly sheep	28	25	22	18	18
Livestock, cattle and sheep	26	25	21	20	18
Cropping, mostly cereal	30	26	24	21	20
General cropping	25	23	19	21	19
Mixed	26	25	22	20	20
Pigs and poultry	..	..	25	26	23
Horticulture	..	..	12	14	10

TABLE 6.7

MACHINERY AND POWER COSTS AS A PERCENTAGE OF RENTS

	Size in Standard Man-Days				
Type	275-449	450-599	600-1,199	1,200-1,799	1,800+
Specialist dairy	242	201	190	175	179
Mainly dairy	227	237	184	180	164
Livestock, mostly sheep	239	200	187	139	180
Livestock, cattle and sheep	200	186	169	131	129
Cropping, mostly cereal	212	159	158	151	150
General cropping	293	282	202	218	187
Mixed	255	223	205	167	181
Pigs and poultry	..	..	349	333	247
Horticulture	..	..	327	257	233

TABLE 6.8

LABOUR COSTS AS A PERCENTAGE OF RENTS

	Size in Standard Man-Days				
Type	275-449	450-599	600-1,199	1,200-1,799	1,800+
Specialist dairy	453	372	326	260	271
Mainly dairy	468	396	296	243	228
Livestock, mostly sheep	497	392	335	250	326
Livestock, cattle and sheep	367	272	258	184	200
Cropping, mostly cereal	220	148	144	164	166
General cropping	383	425	293	279	292
Mixed	511	323	296	232	270
Pigs and poultry	..	..	372	360	301
Horticulture	..	..	1,070	608	881

TABLE 6.9

MACHINERY AND POWER COSTS AS A PERCENTAGE OF LABOUR COSTS

	Size in Standard Man-Days				
Type	275-449	450-599	600-1,199	1,200-1,799	1,800+
Specialist dairy	53	54	58	67	66
Mainly dairy	48	59	62	74	72
Livestock, mostly sheep	48	51	56	56	55
Livestock, cattle and sheep	54	60	65	71	64
Cropping, mostly cereal	97	107	110	92	91
General cropping	77	66	69	78	64
Mixed	50	69	69	72	67
Pigs and poultry	..	..	94	92	82
Horticulture	..	..	29	42	26

From these tables it can be seen that in most cases there is a clear relationship between the factor proportions and farm size, although in some cases this relationship reverses for the largest farms. Since it has been observed that the tendency for large farms to have increasing output relative to inputs is also reversed for the largest class, attention is focused on farms up to a size to 1,200 to 1,799 SMDs. The table below gives the direction of change of the factor proportions between small (275-449 SMDs) and large (1,200-1,799 SMDs) farms. A significant change is arbitrarily taken to be one of 10 per cent in the small farm's ratio. Changes of less than this are indicated by a zero.

If machinery and power costs are taken to represent the use of capital, while rents, which include imputed rents for owner-occupied land, represent the use of land,[33/] these results can be compared with those predicted by the alternative models.

It is apparent that Model 2, i.e. increasing returns to scale and variable labour supply, is unsatisfactory. It fails in all its predictions for almost every type of farm. Furthermore, simple modifications of this model will not reverse these failures. For

33/ The use of rents to represent land involves the difficulty that some of the rents include payments on buildings -- a variable factor which should be included in capital. On the other hand, using acreage as the measure of land would fail to take account of its quality.

TABLE 6.10

CHANGE IN FACTOR PROPORTIONS BETWEEN SMALL AND LARGE FARMS

Type	Machinery and Power Costs to Net Agricultural Output	Machinery and Power Costs to Rents	Labour Costs to Rents	Machinery and Power Costs to Labour Costs
Specialist dairy	-	-	-	+
Mainly dairy	0	-	-	+
Livestock, mostly sheep	-	-	-	+
Livestock, cattle and sheep	-	-	-	+
Cropping, mostly cereal	-	-	-	0
General cropping	-	-	-	0
Mixed	-	-	-	+
Predicted by Model 1:	0	-	-	+
Predicted by Model 2:	+	+	+	0

example, it might be assumed that the increasing returns to scale are biased towards the use of capital so that as farms get larger, the productivity of capital would rise relative to the productivity of other factors. This would explain why the capital-labour ratio rises with size, but it would worsen the failure to explain why the capital-land ratio falls.

On the other hand, Model 1 (fixed labour supply, constant returns to scale) is much more satisfactory. It successfully explains the declines in the capital-land ratios, and in the labour-land ratios, with size; and it predicts the rise in the capital-labour ratio which is observed in all except the cropping farms. The principal shortcoming of this model is that it predicts that the capital-output ratio is constant, whereas for most types of farms this ratio falls. The model also fails to explain why the capital-labour ratio for cropping farms should remain approximately constant.

An explanation of these failings is that capital is not perfectly variable since some types of machinery are indivisible. If small farms opt to have too much machinery rather than too little, in the sense that the value of the marginal product of capital is below its market cost, then the capital-output ratio might be expected to fall with farm size.[34] Provided that the distortions due to the indivisibility of labour are greater than those due to the indivisibility of capital, the other predictions of the model will hold, although the tendency for the capital-labour ratio to rise with size will be weakened. The indivisibility of machinery is perhaps most severe in the case of cropping-type farms, and it is only for these farms that the capital-labour ratio fails to rise.

It then appears that the model with the properties of constant returns to scale (over all the factors), fixed labour supply, and partial variability of capital, is capable of explaining (a) the tendency for the value of output relative to inputs of large farms to be high compared with that of small farms; and (b) the observed variations in the capital-output ratio, the capital-land ratio, the labour-land ratio, and the capital-labour ratio, between small and large farms. There is, however, one final difficulty. The model has been constructed in terms of a supply of labour that is fixed up to a certain size of farm, and then becomes variable because additional labour can be hired. The model predicts that the relative output and factor proportions will vary with size only in the range in which labour is fixed. For larger farms, the factor proportions will be optimal, so the proportions and relative output will remain constant with further increases in size. However, in British agriculture the labour used per farm is not constant throughout the range of farm sizes in which the observed variations in factor and output proportions occur, but even quite small farms use some hired labour. The point is, of course, that farming has certain periods of peak-labour requirements, and some activities have minimum-labour requirements irrespective of the size of the farm. Since labour is to a considerable extent indivisible, the small farm will have too much labour most of the time. On the other hand there will be a steadier utilization of labour on the large farm. The predictions derived from the fixed-labour-supply model, concerning the relationship between farm size

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34/ This does not suggest that the farmers are not making the optimal decision subject to the constraints that face them. Government investment grants, and the schemes to help small farmers, etc., are likely to encourage the farmers to opt for a relatively large amount of machinery rather than a relatively small amount.

and the factor and output proportions, will hold if labour supply is partially variable, provided that the distortions due to the indivisibility of labour are greater than those arising from the indivisibility of capital. It is the conclusion of this section that the low rate of return on inputs of small farms in British farming is, for most types of farms, primarily due to the indivisibility and immobility of labour, and only secondarily due to the indivisibility of capital. However, for cropping farms, the indivisibility of capital appears to be as severe a constraint as the indivisibility of labour.

There is no support for the contention that there are increasing returns to scale over all the factors of production, or that the large farms are technologically superior to the small ones.

The implications of this model for mechanization in countries whose agricultural structures are dominated by small farms is discussed in the final chapter.

Measures of the Elasticity of Substitution with Respect to Size

It has been observed that the use of machinery and power relative to labour tends to rise with the size of farm (Table 6.9). There is, however, some difficulty in measuring this relationship, because the degree of change between different size groups varies erratically. The theoretical model used does not predict that this elasticity should remain constant throughout the range of sizes, but the amount of variation is probably exacerbated by the indivisibility of machinery and labour. In spite of these problems, an attempt is made to measure the elasticity of the machinery-labour ratio with respect to farm size between small farms of 275-449 SMDs, and large farms of 1,200-1,799 SMDs. Define $\varepsilon M/L.R$ as

$$\log \frac{(M/L)_2}{(M/L)_1} \Big/ \log \left(\frac{R_2}{R_1}\right)$$

which is the proportional change in the machinery-labour ratio with respect to a proportional change in rents, where the subscripts 1 and 2 refer to the variables for farms of 275-449 SMDs and of 1,200-1,799 SMDs, respectively. Then $\varepsilon M/L.R$ is a measure of the arc elasticity between these sizes. The same calculations are made using acres (A) instead of rents as the measure of land use, and are described as εM/L.A. These computed elasticities are shown in the accompanying table.

TABLE 6.11

FARM SIZE ELASTICITY OF SUBSTITUTION BETWEEN MACHINERY AND LABOUR, BETWEEN SMALL AND LARGE FARMS

Type	εM/L.R (rents)	εM/L.A (acres)
Specialist dairy	.13	.17
Mainly dairy	.25	.35
Livestock, mostly sheep	.13	.09
Livestock, cattle and sheep	.15	.19
Cropping, mostly cereal	-.04	-.04
General cropping	.01	.01
Mixed	.20	.27

There is considerable variation in this elasticity among the different types of farming. It is particularly low for the cropping farms, and in one case is slightly below zero. The use of acres instead of rents as the measure of land use does not radically alter the estimates of the elasticities.

Since estimates of this elasticity are needed to predict the effects of an increase in farm size on the level of mechanization in Western Europe -- most of which is characterized by very small farms -- an attempt is made to measure the elasticity between the "very small farms" (less than 275 SMDs) and the "small farms" (275-449 SMDs) in England and Wales. The FIEW only provides limited data on these very small farms, but these data are applied in the same way as described above to compute the elasticities. These are shown in the table.

TABLE 6.12

FARM SIZE ELASTICITY OF SUBSTITUTION BETWEEN MACHINERY AND LABOUR, BETWEEN "VERY SMALL" AND "SMALL" FARMS

Type	εM/L.R	εM/L.A
Dairy	.52	.39
Livestock	1.06	.99
Cropping, mostly cereal	.52	.63

These are appreciably higher, suggesting that it is in the lowest range of farm sizes that changes in the size of farms will have the most substantial impact on the level of mechanization. This is consistent with the theoretical model used, since these very small farms are the ones that conform most closely to the model of one-man farms.

The Size of a Viable Farm

It is of interest to note the size of farm that seems to be necessary to obtain a reasonably high rate of return on inputs, in different types of farming. Table 6.13 shows the acreage associated with a rate of return in net agricultural output relative to the cost of inputs of 120 per cent. This latter figure is chosen arbitrarily as a criterion of a satisfactory rate of return, and the acreages of size of activity that generate this rate of return are estimated from data given in the statistical appendix.

TABLE 6.13

AVERAGE SIZE ASSOCIATED WITH A RATE OF RETURN ON INPUTS OF 120 PER CENT
(Approximations)

Type	Size in Labour Requirements (Standard Man-Days)	Size in Acres
Specialist dairy	530	70
Mainly dairy	650	132
Livestock, mostly sheep	1,250	660
Livestock, cattle and sheep	851	288
Cropping, mostly cereal	710	260
General cropping	455	70
Mixed	880	180
Pigs and poultry	..	50
Horticulture	..	20

It appears that quite a small acreage is sufficient to allow a reasonable rate of return in specialist dairy farming, general cropping, horticulture, or in intensive livestock rearing as shown by pigs and poultry. Of course, for some of these activities the land would have to be of a particular type and fertility, or be close to markets. Much larger acreages are necessary for cereal production and for the production of livestock and dairy products by the more extensive methods. Trends towards the former types of activities will help to reduce the association of low incomes with small farms.

COMPOSITION OF MACHINERY AND POWER COSTS

The FIEW data give the composition of machinery and power costs by size and type of farm. This is not provided for the very small farms, but it is possible to compare small farms (275-449 SMDs) with larger ones (1,200-1,799 SMDs), and this is done in the table.

Table 6.14 shows, first, that contract services generally constitute a higher proportion of machinery and power costs for small farms than for large ones. This, of course, is to be expected, but there is some variation between types of farms. Small farms in the categories of mainly dairying, livestock (mainly sheep), general cropping, and mixed, use relatively more contract services than the other types of farms.

Second, for some types of farms, fuel and electricity expenses relative to depreciation are much higher for small farms than for larger ones. This holds for dairying and livestock and mixed farms, but not for the cropping farms. Thus for the former types there is no evidence that small farms are over-mechanized and are under-utilizing their machinery; in fact the opposite may be the case. Only for cereal farming do these data suggest that machinery on small farms might be under-utilized.

Third, for the non-intensive large farms, depreciation constitutes a fairly constant proportion of between 40 and 45 per cent of total machinery and power costs. However, for pigs and poultry depreciation is an appreciably higher proportion, and for horticulture a somewhat lower proportion, of these costs. It was noted earlier that pigs and poultry are the most mechanized type of farming, and horticulture the least mechanized. This relationship is strengthened if mechanization is measured by machinery depreciation, instead of machinery and power costs, relative to labour costs.

MECHANIZATION IN HIGH- AND LOW-PERFORMANCE FARMS

It has been observed that small farms have low rates of return on their inputs, and are characterized by low inputs of machinery and power relative to labour. In this section, evidence on the level of mechanization of high- and low-performance farms

TABLE 6.14

COMPOSITION OF MACHINERY AND POWER COSTS FOR SMALL AND LARGE FARMS

Type	Small Farms (275-449 SMDs)			Large Farms (1,200-1,799 SMDs)		
	Fuel and Electricity	Depreciation	Contract Services	Fuel and Electricity	Depreciation	Contract Services
	(Percentage of total machinery and power costs)					
Specialist dairy	42	31	13	26	41	10
Mainly dairy	32	36	20	24	41	8
Livestock, mostly sheep	43	34	23	32	40	7
Livestock, cattle and sheep	28	40	14	23	40	11
Cropping, mostly cereal	20	44	14	23	45	7
General cropping	20	43	18	20	42	10
Mixed	28	32	22	24	44	6
Pigs and poultry	..	..	..	26	56	5
Horticulture	..	..	..	26	38	13

within particular size categories is used to determine whether the low efficiency of the small farms can be attributed directly to inadequate use of machinery. This is a question of some importance since Britain in common with other western European countries has arrangements to facilitate the use of machinery on small farms. If the small farms are using machinery and labour in optimum proportions, given the constraint of their size, then policies specifically encouraging further mechanization might lower efficiency rather than improve it.

The FIEW provides data on output and inputs for "high-performance" and "low-performance" farms within some type and size classes. The high-performance farms are those for which gross output relative to total inputs is among the top 25 per cent in that class, and the low-performance farms are in the bottom 25 per cent. There are data for all sizes of farms greater than 275 SMDs in three broad categories of farm, and from these data can be calculated the machinery and power costs relative to labour costs for high- and low-performance farms. This, and average size, is shown in Table 6.15.

It can be seen that within the two smallest classes of each type the high-performance farms have a higher input of machinery relative to labour than do the low-performance farms. This difference is quite substantial for dairy and livestock farms, but is only marginal for cropping. In the preceding section it was noted that the small dairy and livestock farms used their machinery intensively, as indicated by the proportion between fuel and power inputs relative to depreciation costs. This was taken to indicate that these small farms were not using too much machinery. The fact that high-performance small dairy farms and livestock farms are using relatively more machinery than similar low-performance farms reinforces this conclusion, and suggests that these farms have too little machinery, and the high rate of utilization is not sufficient to offset the deficiency.[35/] These conclusions do not hold for cropping farms, for which there is some evidence that machinery is under-utilized, and that high-performance small cropping farms do not have appreciably more machinery than similar low-performance farms.

35/ The high-performance small farms of each type tend to be slightly larger (in SMDs) than the low-performance farms. However, this difference in average size is not sufficient to account for the differences in mechanization.

TABLE 6.15

AVERAGE SIZE AND RELATIVE COSTS IN HIGH- AND LOW-PERFORMANCE FARMS

Type	Size Class	Average Size		Machinery Costs as a Percentage of Labour Costs	
		High-Performance Farms	Low-Performance Farms	High-Performance Farms	Low-Performance Farms
		(Standard Man-Days)		(Per cent)	
All dairy	275- 449	382	361	53	47
	450- 599	521	530	63	52
	600-1,199	904	862	64	59
	1,200-1,799	1,489	1,488	76	68
	1,800+	2,736	2,500	65	74
All livestock	275- 449	370	346	66	50
	450- 599	535	592	77	67
	600-1,199	911	813	58	63
	1,200-1,799	1,502	1,403	65	70
	1,800+	2,239	2,220	59	57
All cropping	275- 449	384	380	88	87
	450- 599	515	532	87	84
	600-1,199	875	843	82	93
	1,200-1,799	1,497	1,512	80	77
	1,800+	2,810	3,792	73	67

There is no clear-cut relationship between mechanization and performance for farms greater than 600 SMDs. In some cases the high-performance farms of a given size use more machinery relative to labour than do the low-performance farms, but in other cases this is reversed.

MECHANIZATION 1954 AND 1964

To get an idea of how the level of mechanization has changed over recent years, 1954 is compared with 1964 for four broadly defined types and two sizes of farms. The year 1964 is chosen instead of 1966 because farm type and size classification was changed in the FIEW series after 1964.

Very small farms are compared with quite large farms. The former are dairy, mixed, and arable farms of less than 50 acres, or livestock farms of between 50 and 100 acres. The latter are dairy, mixed, and arable farms of between 150 and 300 acres, or livestock farms of between 300 and 500 acres. These sizes of farms are taken to represent large farms because they correspond approximately to farms of between 1,200 and 1,799 SMDs. Farms of this size appear to be large enough to obtain most of the benefits of large-scale production.

In this section, because of data limitations, machinery costs comprise the repair and depreciation of machinery, and not the total cost of power and machinery. Since repair and depreciation constitutes a smaller proportion of total machinery and power costs for small farms than for larger ones, these comparisons understate the relative use of machinery and power by the small farms.

Table 6.16 shows the repair and depreciation costs relative to labour inputs for the four types and two sizes of farms, and it can be seen that the relative share of machinery costs has risen for all types of farms and for both size groups.

Machinery has not been substituted for labour at the same rate in all the types of farms. The share of machinery in costs has increased rapidly in mixed farming for both the small and the large farms, so that by 1964 the mixed farms were more mechanized than the dairy or livestock type. The large arable farms had a fast rate of mechanization whereas the small arable farms mechanized slowly. As a result, by 1964 the large arable farms had the highest level of mechanization, while the small arable farms were among the least mechanized.

TABLE 6.16

MACHINERY REPAIR AND DEPRECIATION COSTS
AS A PERCENTAGE OF LABOUR INPUTS

	Small Farms		Large Farms	
Type	1954	1964	1954	1964
Dairy	24	29	32	38
Livestock	27	29	33	37
Mixed	23	37	32	46
Arable	24	28	36	52

These changes in the relative share of machinery expenses to labour costs occurred during a period in which the price of labour relative to machinery rose. They appear to be consistent with an elasticity of substitution greater than unity and with a moderate rate of capital-biased technical progress.

7. MECHANIZATION AND TECHNICAL CHANGE: A FORECASTING MODEL

In this chapter the results derived in the earlier sections of the study are used to develop a conditional forecasting model that relates the use of machinery in agriculture to output, to labour inputs, to output and input prices, and to technical progress.

This model is applied in retrospect to trends in mechanization in Western Europe to check its formulation and its parameters, and to show how these trends can be explained in terms of the model.

The model is applied to an approximation of the *Mansholt Plan* for the reform of EEC agriculture to demonstrate how the theoretical model and the associated estimates of its parameters can be used to work out some of the implications of a development program. The purpose is to demonstrate the method, rather than to make actual forecasts, since a very crude interpretation of the *Plan* is used, and the *Plan* itself may not be implemented.

A final section suggests briefly how the methods and results of this study can be reconciled to, or combined with, methods of analyzing mechanization at the farm level of aggregation.

THE CONDITIONAL FORECASTING MODEL

In the earlier sections of this study attempts have been made to identify the relationships determining the proportions in which machinery and labour are used in agriculture. Successful identification of these relationships would generate conditional forecasts of the growth in the use of machinery.

The Change in Factor Proportions

The study has suggested that the main determinants of the use of machinery relative to labour (K/L) are: the relative price of labour and capital, the size of farms, and the type of farms, i.e.

$$\frac{K}{L} = f(P, R, Q)$$

where P, R and Q represent these three variables. Changes in these variables will be associated with changes in the machinery-labour ratio. Differentiate this function with respect to time (t):

$$\frac{dK/L}{dt} = \left(\frac{\partial K/L}{\partial P}\right)\left(\frac{dP}{dt}\right) + \left(\frac{\partial K/L}{\partial R}\right)\left(\frac{dR}{dt}\right) + \left(\frac{\partial K/L}{\partial Q}\right)\left(\frac{dQ}{dt}\right)$$

or

$$\left(\frac{1}{K/L}\right)\left(\frac{dK/L}{dt}\right) = \left(\frac{1}{P}\,\frac{dP}{dt}\right)\left(\frac{\partial K/L}{\partial P}\,\frac{P}{K/L}\right) + \left(\frac{1}{R}\,\frac{dR}{dt}\right)\left(\frac{\partial K/L}{\partial R}\,\frac{R}{K/L}\right) + \left(\frac{1}{Q}\,\frac{dQ}{dt}\right)\left(\frac{\partial K/L}{\partial Q}\,\frac{Q}{K/L}\right) .$$

This "prediction function" can be written

$$\left(\frac{K}{L}\right)^{\bullet} = \dot{P}E_P + \dot{R}E_R + \dot{Q}E_Q$$

where the dots indicate the proportional rate of change of the variable over time, e.g.

$$\left(\frac{K}{L}\right)^{\bullet} = \left(\frac{1}{K/L}\right)\left(\frac{dK/L}{dt}\right) = \frac{d\ \log\ (K/L)}{dt}$$

and similarly $\dot{P}$, $\dot{R}$ and $\dot{Q}$ are the proportional rates of change in P, R and Q. Also the E's are the elasticities of the prediction function with respect to the variables, e.g.

$$E_p = \frac{\partial K/L}{\partial P}\,\frac{P}{K/L} = \frac{\partial\ \log\ (K/L)}{\partial\ \log\ P}$$

is the proportional change in the K/L ratio associated with a proportional change in P. Similarly E_R and E_Q are the elasticities of substitution between capital and labour with respect to farm size and farm type.

The prediction function expresses the rate of change in the capital-labour ratio as the average of the rate of change of the variables, weighted in each case by the relevant elasticity. Since $(K/L)^{\bullet} = \dot{K} - \dot{L}$ 36/ the rate of change in the use of capital can be expressed:

$$\dot{K} = \dot{P}E_P + \dot{R}E_R + \dot{Q}E_Q + \dot{L} .$$

It is of course arbitrary whether K or L is treated as the dependent variable; indeed, all the variables are to some extent interdependent, e.g. the change in farm size is likely to be related to

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36/ The rates of change are logarithmic functions and so are operated in the same way as logarithms.

the change in the agricultural labour force. This interdependence raises problems of identification[37/] and causes interdependence in the estimates of the elasticities. However, the model can be used to check the consistency of forecasts of the individual variables.

Earlier sections of this study have attempted to measure the elasticities of this prediction function. The most important of these is the elasticity of substitution with respect to price: E_P. This is important because it seems to be quite large and because changes in the variable to which it relates, relative factor prices, have also been large. This elasticity has been estimated by fitting forms of the CES production function to the various sets of data. The elasticity of substitution of the production function (σ) becomes the elasticity of the prediction function with respect to relative factor prices. This seems to have been an appropriate procedure, and has generated estimates of the elasticity of substitution which are consistently greater than unity and which generally lie in the range one-and-one-half to two. The elasticity appears to be of this order even though the production function might change over time, or vary between countries.

The relationship between farm size and factor proportions is more difficult to estimate. One difficulty is that this relationship (elasticity) probably varies with farm size. It is also difficult to determine an appropriate measure of farm size. However, there does seem to be a strong positive relationship between the K/L proportion and farm size, at least over the range of small- and medium-size farms that characterize western European agriculture. Two hypotheses explaining this relationship have been suggested. First, it may be that the technical conditions of production, as indicated by the production function, are such that the productivity of capital relative to labour rises with farm size. Second, the relationship between the marginal product of the factors and their market prices may vary with farm size due to the immobility or indivisibility of the factors of production. Both of these hypotheses can explain the tendency of the K/L ratio to rise with farm size. But they have different implications for

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37/ The problem of identification is discussed in Chapter 4 below.

the relationship between the factor-output ratios and farm size. The hypothesis, that the dominant constraint on the small farmer is the immobility of his own labour so that the marginal product of labour relative to that of capital is less than the ratio of their prices, is consistent with the relationship between factor and output proportions and farm size that has been observed in the study of agriculture in England and Wales. However, such a hypothesis implies that the influence of farm size on factor proportions diminishes as farms become larger, because the problem of the immobility of labour becomes less important, i.e. the elasticity of substitution with respect to farm size is diminishing. Thus the over-all effect in an agricultural sector of a rise in farm sizes will depend upon whether the change in size occurs mainly among the smaller farms, and upon the importance of the small farms in the total sector. The study carried out in Chapter 6 suggests that, for very small farms, the farm size elasticity is high -- perhaps greater than unity -- so that a rise in the average size of these farms could induce a proportionately greater rise in the machinery-labour ratio. In Western Europe, the agricultural sectors of most of the countries, although not England, are characterized by very small farms indeed, and it is at these farms that "rationalization" policies are directed, so the over-all farm size elasticity in these countries is probably quite high.

The effect of change in the type of farming on the capital-labour ratio is difficult to estimate, because it appears to operate in two directions. Shifts from the production of crops to livestock products is associated with a decrease in the use of machinery relative to labour, whereas a shift in production from traditional, extensive rearing of livestock to intensive "factory farming" methods involves an increase in the relative use of machinery. Since both these shifts seem to be occurring, they will partially offset each other. This probably explains why no significant relationship between output structure and factor proportions was found in the cross-sectional study of Chapter 4.

Factor-Output Proportions and Technical Change

In the preceding section, nothing was said about the effect of technical progress on the use of capital relative to labour.

This is because the relationship between the factors of production and factor prices which is postulated by the simple CES model is unaffected by changes in the production function over time, provided that these changes are neutral in the sense that the marginal rate of substitution between the factors is unchanged. This can be seen by considering a CES production function of the form

$$Y = Ae^{\lambda t}\left[\alpha_1 K^{-\beta} + \alpha_2 L^{-\beta} + \ldots\right]^{-\frac{1}{\beta}}$$

where t is time, and e is the base of the natural logarithms. In this function, output Y will grow at the steady proportional rate of λ per cent if the quantities of the factors of production remain unchanged. The relationship between the factor proportions and factor prices derivable from this production function, initially assuming that the value of the marginal products is equal to their prices, is

$$\log\left(\frac{K}{L}\right) = \sigma \log\left(\frac{\alpha_1}{\alpha_2}\right) + \sigma \log\left(\frac{P_L}{P_K}\right) ;$$

so the capital-labour ratio is not affected by the rate of neutral technical progress. This same point arose in Chapter 4, where it was pointed out that neutral changes in technologies between countries would not affect the relationship between factor proportions and factor prices. On the other hand, the relationship between capital and output is affected by neutral technical progress. This is one of the reasons why, in Chapter 5, the formulation of the stock adjustment model, which used labour as a scale variable, was preferred to the formulation that used output.

The relationship between the capital-output ratio and neutral technical progress can be derived from the preceding production function:

$$\log\left(\frac{K}{Y}\right) = (\sigma - 1) \log A + (\sigma - 1) \log e^{\lambda t} + \sigma \log \alpha_1 + \sigma \log\left(\frac{P_Y}{P_K}\right) .$$

This is differentiated with respect to time, to give a prediction function:

$$\dot{\left(\frac{K}{Y}\right)} = \sigma\dot{\left(\frac{P_Y}{P_K}\right)} + (\sigma - 1)\lambda .$$

These variables will not be independent of each other; in particular, technical progress (λ) will tend to reduce the price of output relative to capital (P_Y/P_K). To clarify this relationship, two special cases are considered. First, suppose that there has been neutral technical progress at the rate λ, but no change in any factor prices; then there will be no change in factor proportions, so that output should increase relative to the use of any of the factors at the same rate as the technical progress, i.e. $(K/Y)^{\cdot} = -\lambda$, and the price (cost) of output should fall relative to the factors at the same rate, i.e. $(P_Y/P_K)^{\cdot} = -\lambda$. This checks with the above equation. Second, suppose that the cost of output relative to capital has remained constant so $(P_Y/P_K)^{\cdot} = 0$, in spite of the technical progress which would tend to reduce this relative price. This could happen if there had been sufficient rise in the price of other factors of production to offset the technical progress. The relationship in this special case is $(K/Y)^{\cdot} = (\sigma - 1)\lambda$ since $(P_Y/P_K)^{\cdot} = 0$. Thus K/Y would rise if the elasticity of substitution is greater than unity, and fall if it is less than unity. This is because there are two countervailing effects: a technical progress effect, which tends to reduce the use of capital relative to output, and a substitution effect, which will increase the use of capital relative to the other factors of production and relative to output. The substitution effect will outweigh the technical progress effect, if the elasticity of substitution is greater than unity.

The effect of farm size upon the factor-output ratio depends upon whether the production function itself is affected by farm size, or, alternatively, whether farm size influences the relationship between factor prices and marginal products.

If the production function involves a farm-size variable with a capital-intensive bias, the capital-output ratio will increase with farm size, at given relative output-capital prices. This is because the marginal product of capital, at a given capital-output ratio, would be higher on a large farm than on a small farm; but the cost-minimizing farmers will vary their capital-output ratios until the value of the marginal product of capital is equal to its price on all the farms.

The preferred hypothesis is that the production function is unaffected by farm size, but the cause of the observed relationship between the capital-labour ratio and farm size is the divergence between the value of the marginal product of labour and its market price on the small farms. The capital-output ratio will not be affected by farm size, provided that the value of the marginal product of capital is equal to its price. In this case the prediction model remains

$$\dot{\left(\frac{K}{Y}\right)} = \sigma\dot{\left(\frac{P_Y}{P_K}\right)} + (\sigma - 1)\lambda \ .$$

However, if on the small farms the value of the marginal product of capital also diverges from its market price, because of the indivisibility of some types of machinery, then the K/Y ratio will vary with farm size. In England and Wales, it appears that machinery is used on the small farms to the extent that its marginal product is less than its price, so that the machinery-output ratio is greater on small farms than on large ones. However, as there is no reason for supposing that this should necessarily be the case, the effect of farm size on the K/Y ratio is ignored.

So far, in this discussion, the assumption has been made that technical progress is neutral, so that the factor proportions are independent of the technical change. If, however, technical progress is biased in favour of a particular factor, in the sense that the productivity of that factor increases relative to the other factors at constant factor proportions, then the relationship between factor proportions and factor prices will change with technical progress, and so will the relationship between factor-output proportions and relative factor-output prices. Thus, if there is capital-intensive technical progress, the use of capital will increase relative to both labour and output at given factor prices. If technical progress is biased towards both capital and labour relative to other factors of production, then the use of capital will increase relative to output, but not necessarily relative to labour at given prices.

Changes in the quality of the factors which are not accounted for in their price indexes will have the same sort of effect as non-neutral technical progress on the observed relationship between the change in the factor and output proportions, and the change in the prices.

MECHANIZATION IN RETROSPECT

Variations of this model can be applied in retrospect to the mechanization that has occurred in Western Europe. No attempt is made to statistically test these variations. The purpose is to suggest how the changes in output and in the use of tractors and labour that have occurred in the regions, in aggregate, can be described within the framework of this model.

Two relationships have been developed involving, respectively, the capital-labour ratio and the capital-output ratio.[38/] In their simplest form these are:

(1) $$\left(\frac{K}{L}\right)^{\cdot} = \sigma\left(\frac{P_L}{P_K}\right)^{\cdot} + R^{\cdot}E_R$$

and

(2) $$\left(\frac{K}{Y}\right)^{\cdot} = \sigma\left(\frac{P_Y}{P_K}\right)^{\cdot} + (\sigma - 1)\lambda .$$

These are both derived from the same model and involve the assumptions that production is subject to a CES production function in which technical progress is neutral; that shifts in the structure of output do not affect the factor and output proportions; and that the value of the marginal product of capital is equal to its price, but the value of the marginal product of labour on small farms is less than its market price.

If tractor horsepower is taken to represent the use of machinery, and is described as capital, then the changes that have occurred in Northwestern and Southwestern Europe between 1956 and 1966 can be summarized:

	Annual Rates of Change					
	$\dot{L}$	$\dot{K}$	$\dot{Y}$	$(P_L/P_K)^{\cdot}$	$(P_Y/P_K)^{\cdot}$	$R^{\cdot}E_R$
Northwestern Europe	-3.3%	9.6%	2.7%	6%	1%	2%
Southwestern Europe	-3.2%	15.0%	2.7%	9%	2%	2%

These are approximations, particularly of the relative prices, and there have been considerable variations between the countries, but they represent the kind of changes that have occurred. The farm size effect is estimated at 2 per cent for both regions.

38/ Relationships involving the labour-output ratio, and the relative shares of capital and labour can be derived directly from the relationships given here.

When these rates of change are applied to the relationship (1):

$$\left(\frac{K}{L}\right)^{\bullet} = \sigma\left(\frac{P_L}{P_K}\right)^{\bullet} + R^{\bullet}E_R ,$$

a computed elasticity of substitution $\sigma = 1.8$ is obtained for both regions. This is almost the same as was estimated from the cross-sectional analysis of Chapter 4. However, when the rates of change and the estimate $\sigma = 1.8$ are applied to relationship (2)

$$\left(\frac{K}{Y}\right)^{\bullet} = \sigma\left(\frac{P_Y}{P_K}\right)^{\bullet} + (\sigma - 1)\lambda$$

the computed rates of neutral technical progress are $\lambda = 5\%$ and $\lambda = 11\%$. These are obviously much too high. Capital has risen relative to output too much to be explained by the apparent change in the output-capital price and by neutral technical progress. It therefore seems probable that technical progress has been biased towards capital, or that the fall in the price of capital relative to the price of output has been underestimated due to quality improvements in the capital. If this should be the case, then the estimate of the elasticity of substitution computed from (1) will be too high, since either some of the change in factor proportions ascribed to the change in factor price should properly be attributed to the capital-biased technical progress, or alternatively the estimate of that change in relative factor prices is too low. In Chapter 4 an attempt was made to separate the influence of capital-biased technical progress from the estimate of the elasticity of substitution, by regressing the change in tractor horsepower relative to labour upon the change in relative prices over time, for the western European countries, with the result

$$\left(\frac{T}{L}\right)^{\bullet} = 5.0\% + 1.4\left(\frac{P_L}{P_T}\right)^{\bullet} .$$

This gives a lower estimate of the elasticity of substitution than the cross-sectional regressions, and gives a constant term greater than can be attributed to the change in farm sizes. If this estimate ($\sigma = 1.4$) is applied to the aggregate changes, then an annual change is the K/L ratio of 2.5 per cent in Northwestern Europe and 3.6 per cent in Southwestern Europe is left to be explained by the increase in the productivity of capital relative to labour. Since technical progress may have been biased in favour of both capital and labour relative to other factors, the change in capital relative to output caused by the biased technical progress could be considerably higher than the change caused in capital relative to labour.

AN APPLICATION TO THE PLAN FOR THE REFORM OF EEC AGRICULTURE

The conditional forecasting model and the estimates of its parameters can be applied to a particular set of proposals for agricultural development or to predictions of change, in order to work out the implications and to check the consistency of those proposals or predictions.

The simple neutral technical-change model is now applied to a crude approximation of the *Mansholt Plan* for the reform of agriculture within the EEC.[39/] The central feature of the *Plan* is to increase the efficiency of farming, and the returns to farmers within the Community by structural reforms. These involve halving the agricultural labour force over the next decade, increasing the average size of farms, withdrawing land from production, and encouraging specialization. The intention is to increase farm incomes by these means rather than by increasing prices received by farmers.

Two interpretations of this *Plan* are considered. The first version takes as a target that the returns to labour are to be increased by 9 per cent per year ($\dot{P}_L = 9\%$), if necessary allowing output prices to rise. The second version takes as a constraint that the price of output should remain constant. In both these versions of the *Plan* it is assumed that the postulated fall in the labour force will occur, so $\dot{L} = -7\%$, and that the change in the farm size will be such that $R^{\cdot}E_R = 3\%$. The lower estimate of the elasticity of substitution, $\sigma = 1.4$, is used. The effects of changes in the type of output are ignored. The price of capital is treated as a parameter and the price of all other inputs is assumed to be constant.

39/ EEC, Memorandum on the Reform of Agriculture in the European Economic Community, Supplement to EEC Bulletin No. 1, 1969.

Thus:

		Version (1)	Version (2)
$\dot{L}$	=	-7%	-7%
$R^{\bullet}E_R$	=	3%	3%
$\dot{P_L}$	=	9% (target)	unknown
$\dot{Y}$	=	unknown	unknown
$\dot{K}$	=	unknown	unknown
$\dot{P_Y}$	=	unknown	0 (constraint)
$\dot{P_K}$	=	parameter	parameter
λ	=	parameter	parameter
σ	=	1.4	1.4
		Other factor prices assumed constant	

The relationships assuming neutral technical progress at the rate λ are

$$\dot{\left(\frac{K}{L}\right)} = \sigma \dot{\left(\frac{P_L}{P_K}\right)} + R^{\bullet}E_R$$

and

$$\dot{\left(\frac{K}{Y}\right)} = \sigma \dot{\left(\frac{P_Y}{P_K}\right)} + (\sigma - 1)\lambda \ .$$

These can be expressed:

(1) $$\dot{K} = \dot{L} + \sigma \dot{P_L} - \sigma \dot{P_K} + R^{\bullet}E_R$$

(2) $$\dot{Y} = \dot{L} + \sigma \dot{P_L} - \sigma \dot{P_Y} + R^{\bullet}E_R - (\sigma - 1)\lambda$$

The change in price (cost) of output can be approximated by a weighted average of the change in the price of the inputs, less the rate of neutral technical progress, so

(3) $$\dot{P_Y} = \dot{P_L}\left[\frac{(LP_L)}{(YP_Y)}\right] + \dot{P_K}\left[\frac{(KP_K)}{(YP_Y)}\right] - \lambda \ ,$$

and substituting this into (2) gives

(4) $$\dot{Y} = \dot{L} + \sigma \dot{P_L}\left[\frac{(1 - LP_L)}{(YP_Y)}\right] - \sigma \dot{P_K}\left[\frac{(KP_K)}{(YP_Y)}\right] + R^{\bullet}E_R + \lambda \ .$$

In the EEC the share of labour in output (LP_L/YP_Y) is probably about one-half and the share of machinery (KP_K/YP_Y) is about one-seventh.

The first equation gives the rate of growth in the use of capital consistent with the target increase in the price of labour:

$$\dot{K} = -7\% + 1.4(9)\% - \sigma \dot{P}_K + 3\% ,$$

so $\dot{K}$ = 8.6% less 1.4% for each percentage point rise in the cost of capital. Since it appears that technical progress in Western Europe has been biased towards capital, this computed increase in capital should probably be augmented by 3 to 4 percentage points so $\dot{K}$ = 12% with capital-biased technical progress, and no change in the price of capital.

The change in output can be computed from (4)

$$\dot{Y} = -7\% + 1.4(9)(\tfrac{1}{2})\% - 1.4(\dot{P}_K)(\tfrac{1}{7}) + 3\% + \lambda ,$$

so at constant costs of capital, output would rise at about 2.3 per cent plus the rate of technical progress; this would only be reduced slightly by rises in the cost of capital. If the technical progress is biased towards capital, then the rate of increase in output would be slightly greater, because of the greater increase in the use of capital. The associated increase in the cost of output can be calculated from (3),

$$\dot{P}_Y = 9(\tfrac{1}{2})\% + \dot{P}_K(\tfrac{1}{7}) - \lambda ,$$

so at constant capital costs the price of output would rise at 4.5 per cent less the rate of technical progress. Such a result might not be compatible with the conditions of demand for agricultural produce, in which case the program would fail in some way.

The second version of the program inverts the targets by taking the stability of the price of output as a constraint so $\dot{P}_Y = 0$. Then the rate of increase in the price of labour that is consistent with this constraint can be calculated from the price relationship (3). So if the price of output, and the price of capital and other inputs, except labour, are constant, and the share of labour in output is one half, ($LP_L/YP_Y = \frac{1}{2}$), then the rise in the price of labour is twice the rate of technical progress, $\dot{P}_L = 2\lambda$. This could of course be greater without increasing the cost of output if technical improvements in the production of capital or of other factors reduced their prices. The associated increase in the use of capital is obtained from (1),

$$\dot{K} = -4\% + 2.8\ \lambda\ ,$$

and in the level of output from (2) or (4),

$$\dot{Y} = -4\% + 2.4\ \lambda\ .$$

Here again the change in the use of capital would probably be 3 to 4 per cent greater, and the associated increase in output about 0.5 per cent greater than computed here, because of the tendency for technical progress to be capital-intensive.

The rates of change of output, factor inputs, and of prices computed here will not generally remain constant, since the factor shares upon which the calculations are based will be changing.

Some points should be made about this application of the forecasting model to the *Mansholt Plan*. First, a very crude interpretation and quantification of the *Plan* has been used. The purpose here has not been to generate forecasts, but to demonstrate how a model of this sort could be used for forecasting, or to check the consistency of a program. Even a crude application of this type of model can focus attention on some of the implications of a program. But if the model is to be used for forecasting, the parameters of the model would need to be estimated independently for individual agricultural sectors, and would need to be applied at much lower levels of aggregation. In addition, the program itself would need to be specified much more precisely, and more account taken of its details. For example, the *Mansholt Plan* emphasizes that farms should form minimum-size "production units". For livestock production these production units are specified in terms of numbers of animals or poultry. Since the *Plan* would include financial incentives to develop these units, it would encourage farmers with small amounts of land to use intensive-farming methods. These intensive methods tend to require relatively large amounts of machinery, so this aspect of the *Plan* could have a considerable effect on the level of mechanization, and would need to be taken into account. Similarly, the effect of the program on the size distribution of farms would need to be determined, and the appropriate estimates of the farm-size elasticities applied to the changes in size.

Second, it is not theoretically necessary to explicitly introduce changes in the use of factors other than capital and labour, since the effects of their changing quantities is subsumed in the changes in the factor and output prices. However, it should be recognized that changes in other factors will affect these prices. If there is a substantial change in the use of an important third factor, it would probably be desirable to introduce it explicitly into the forecasting model.

Third, the concept of biased technical progress has not been fully specified, but has been applied in an intuitive sort of way to the observed changes in Western Europe, and to the interpretation of the *Mansholt Plan*.

ALTERNATIVE SPECIFICATIONS OF THE MODEL

In this study, attention has been focused primarily upon the relationship between the use of machinery relative to labour and secondarily upon that between machinery and output.

One of the reasons for concentrating on the use of machinery relative to labour is that it is difficult to measure output and the use of land, at the high levels of aggregation used in this study. If analysis is carried out at the farm level of aggregation, i.e. by comparing individual farms, it becomes easier to describe the use of machinery relative to output and land.

The basic model developed in this study can readily be applied at the micro-level, and the parameters estimated by means of the micro-study can be compared with those derived here. For example, the relationship between the capital-labour ratio and the relative factor prices derived from a CES production function under the assumption that the value of the marginal product of capital is equal to its price, but that the value of the marginal product of labour is less than its price on small farms due to the immobility of labour, and assuming that there are no technological differences between farms, is

$$(1) \qquad \log \left(\frac{K}{L}\right) = \log C_1 + \sigma \log \left(\frac{P_L}{P_K}\right) + a \log R$$

where C_1 is a constant and R is some measure of the size of farms. The capital-output ratio, derived from the same model, is

(2) $$\log\left(\frac{K}{Y}\right) = \log C_2 + \sigma \log\left(\frac{P_Y}{P_K}\right) .$$

If it were desired to study the relationship between yields and the use of machinery relative to land, i.e. Y/R and K/R where R is the area of the farm or the area used for a type of output, then relation (2) can be adapted by adding log Y/R to both sides of the equation so that

(3) $$\log\left(\frac{K}{R}\right) = \log C_2 + \sigma \log\left(\frac{P_Y}{P_K}\right) + \log\left(\frac{Y}{R}\right) .$$

If there is variation in the relative prices between farms, the elasticity of substitution could be estimated. But if, as is more likely in a cross-sectional study, all the farms have the same relative price, then the model would predict that yields are directly proportional to the use of machinery relative to land. If large farms enjoyed a higher level of technology than the small ones, the model would predict that the use of capital relative to output would be higher on the large farms.

The "prediction models" that have been used in this chapter to analyze the changes over time in the aggregate use of machinery relative to labour and to output can also be adapted to analyze the changes in yields and relative factor use that occur at the farm level of aggregation. Since the relative factor prices will usually change over time, it becomes possible to estimate the elasticity of substitution and also the nature of the technical progress.

The results of such micro-studies could be compared to those obtained in this study, providing further evidence on the values of the parameters, and on the appropriateness of various formulations of the model.

APPENDIX A

LIST OF TABLES

Note: These tables are of limited reliability and have not been fully annotated.

Symbols:
- \- negligible
- n.a. not available

(E) Estimate. In some cases these estimates will have been taken or derived from sources different from the principal source of the table.

TABLE A.1

NUMBER OF TRACTORS USED IN AGRICULTURE

	1950	1956	1960	1966	1967
			(Thousands)		
Austria	15	73	112	206	218
Belgium	8	28	43	71	78
Britain	278	377	431	455	459(E)
Denmark	17	67	111	166	171
Finland	12	52	78	131	136
France	142	425	765	1,110	1,155
Germany, Federal Republic	139	544	857	1,215	1,257
Iceland	1	4	6	9	9
Ireland	13	31	44	64	66
Luxembourg	1	5	6	8	8
The Netherlands	18	44	66	106	108
Norway	11	35	48	75	79
Sweden	64	125	160	244	251
Switzerland	13	28	43	65(E)	66(E)
Total Northwestern Europe	732	1,838	2,770	3,925	4,061
Greece	5	11	21	45	52
Italy	57	168	249	461	509
Portugal	2	5	10	18	18
Spain	10	27	39	169	181
Total Southwestern Europe	74	211	319	693	760
Total Western Europe	806	2,049	3,089	4,618	4,821

Note: The EEC and FAO are usually consistent, but for The Netherlands, the FAO figures on tractor numbers include garden tractors and so are about 25 per cent higher than the EEC figures which are given in this table. FAO estimates for Britain exclude Scotland and Northern Ireland, so data from the Motor Manufacturing Yearbook are used here.

Source: OECD, Development of Farm Motorisation; FAO, Production Yearbook, various years; EEC, Agricultural Statistics, 1966 No. 5, and 1968 No. 8; Motor Industry of Great Britain, Yearbook, various years.

TABLE A.2

TRACTOR HORSEPOWER IN AGRICULTURE

(Estimates)

	1950	1956	1960	1966
	(Thousands of horsepower)			
Austria	284	1,436	2,193	4,700(E)
Belgium	225	776	1,204	2,260
Britain	9,067	12,276	12,722	18,500(E)
Denmark	497	1,949	3,223	5,800
Finland	340(E)	1,400(E)	2,400(E)	4,500(E)
France	3,418	10,624	18,406	32,634
Germany, Federal Republic	2,723	10,189	15,723	27,776
Iceland	45	130	182	300(E)
Ireland	370	878	1,238	2,250(E)
Luxembourg	37	137	179	235(E)
The Netherlands	437	1,098	1,766	3,354
Norway	345	1,082	1,505	2,700(E)
Sweden	1,853	3,645	4,651	8,000(E)
Switzerland	198	416	649	1,300(E)
Total Northwestern Europe	19,839	46,036	66,041	114,310(E)
Greece	167	407	783	1,700(E)
Italy	1,695	5,009	7,410	16,700
Portugal	71	154	294	650(E)
Spain	324	880	1,264	6,100(E)
Total Southwestern Europe	2,257	6,450	9,751	25,150(E)
Total Western Europe	22,096	52,486	75,792	139,460(E)

Note: The 1966 figures for the non-EEC countries are rough estimates arrived at by projections and by comparisons with EEC countries. All of the data in this table, including that from the official sources, are of limited reliability.

Source: OECD, Development of Farm Motorisation; EEC, Agricultural Statistics, 1966 No. 5, and 1968 No. 8.

TABLE A.3

COMBINED HARVESTER-THRESHERS USED IN AGRICULTURE

	1950	1956	1960	1966	1967
			(Thousands)		
Austria	0.1	4.0	8.9	22.9	24.5
Belgium	0.6	1.1	3.4	6.7	7.2
Britain	10.5	32.9	52.7	64.9[c]	
Denmark[a]	0.4	2.7	8.9	34.0	37.3
Finland	0.2	3.1	7.0	17.8	19.9
France	4.9	24.1	50.1	108.9	n.a.
Germany, Federal Republic	1.0(E)	12.9	58.0	142.0	147.0
Iceland	-	-	-	-	-
Ireland	0.4	2.3	4.3	6.0	5.9
Luxembourg	-	-	-	1.5	1.7
The Netherlands	1.2	2.0(E)	3.0	5.5(E)	n.a.
Norway	0.2	3.0	5.5	9.6	9.8
Sweden	8.3[b]	18.4	25.1	37.5	38.0
Switzerland	-	0.2	0.6	2.7[c]	n.a.
Total Northwestern Europe	27.8	106.7	227.5	460.0	n.a.
Greece	0.4	0.9	1.9	3.8	4.1
Italy	n.a.	1.8	4.4	14.2	15.1
Portugal	-	n.a.	0.4	1.3	1.3
Spain	0.5	1.0	4.6	18.4	20.6
Total Southwestern Europe	0.9	3.7	11.3	37.7	41.1
Total Western Europe	28.7	110.4	238.8	497.7	n.a.

(a) Excluding machine stations.

(b) 1951.

(c) 1965.

Source: FAO, Production Yearbook, various years.

TABLE A.4

EMPLOYMENT IN AGRICULTURE

	1950	1956	1960	1966
	(Thousands)			
Austria	1,108(E)	920	796	660
Belgium	368(E)	295	257	216
Britain	1,262(E)	1,091	1,031	863
Denmark	550(E)	500	455	378
Finland	900(E)	800(E)	721	660(E)
France	5,940(E)	4,852	4,185	3,420
Germany, Federal Republic	5,020(E)	4,182	3,623	2,877
Iceland	23(E)	20	18	16
Ireland	510(E)	430	390	330
Luxembourg	32(E)	26	22	18
The Netherlands	556(E)	521	465	375
Norway	450(E)	380	337	285
Sweden	660(E)	574	535	385
Switzerland	355(E)	309	280	242
Total Northwestern Europe	17,734(E)	14,900	13,115	10,715
Greece	1,850(E)	1,885	1,913	1,813
Italy	8,560(E)	7,453	6,567	4,660
Portugal	1,564(E)	1,424	1,338	1,069
Spain	5,217(E)	4,986	4,757	3,981
Total Southwestern Europe	17,191(E)	15,748	14,575	11,523
Total Western Europe	34,925(E)	30,648	27,690	22,238

Note: This table includes employment in forestry, hunting and fishing. For Norway, Sweden, and Finland these activities are important, so in the regression analysis of Chapter 4, Finland is excluded and the labour force estimates for Norway and Sweden are reduced to exclude forestry, hunting and fishing.

Source: For 1950: Estimates derived from data in FAO, Production Yearbook, various years; and OECD, Manpower Statistics 1950-1962, Paris, 1963; for 1956 to 1966, OECD, Labour Force Statistics 1956-1966, Paris, 1968, p. 22; Finland: FAO, Production Yearbook, various years.

TABLE A.5

DISTRIBUTION OF LAND

	Agricultural Land (a)		Arable Land (b)		Cereal (c)	
	1952/56	1967	1952/56	1967	1952/56	1967
	(Thousands of hectacres)					
Austria	4,080	3,927	1,762	1,670	870	903
Belgium	1,884(E)	1,634	1,092(E)	895	562(E)	483
Luxembourg		133		66		47
Britain	19,417	19,543	7,222	7,416	3,154	3,821
Denmark	3,122	3,023	2,737	2,700	1,343	1,638
Finland	2,879	2,851	2,596	2,760	895	1,180
France (d)	34,663	33,846	21,405	20,214	8,797	9,158
Germany, Fed. Rep.	14,370	13,982	8,743	8,185	4,805	4,971
Iceland	2,349	2,280	2	1	-	-
Ireland	4,699	4,783	1,411	1,194	454	357
The Netherlands	2,317	2,239	1,055	922	523	436
Norway	1,035	1,000	825	845	184	229
Sweden (d)	4,282	3,683	3,598	3,158	1,499	1,395
Switzerland (d)	2,175	2,178	447	404	172	169
Total North-western Europe	97,272	95,102	52,895	50,430	23,258	24,787
Greece (d)	8,783	9,090	3,515	3,851	1,751	1,615
Italy	20,826	20,379	15,695	15,213	7,011	5,771
Portugal (d)	4,910	4,900	4,010	4,370	1,993	1,626
Spain	40,642	37,189	20,411	20,482	7,544	7,210
Total South-western Europe	75,161	71,558	43,631	43,916	18,299	16,222
Total Western Europe	172,423	166,660	96,526	94,346	41,557	41,009

(a) Arable land plus meadows and pasture.
(b) Tillage plus temporary grass land.
(c) All land used for the cultivation of cereals.
(d) The figures in the 1967 columns refer to 1966 for France, Sweden, and Greece; to 1964 for Switzerland; and to 1963 for Portugal.

Source: OECD, Agricultural and Food Statistics 1952-1963; FAO, Production Yearbook, 1968.

TABLE A.6

SIZE OF FARMS

				Average Size		Percentage Distribution by Size of Farm (At end of period)		
	Farms -Included	Period	Type of Area[a]	At End of Period (Hectares)	Average Annual Percentage Change	< 10 ha	10-20 ha	> 20 ha
Austria	All farms	1951-60	A	9.6	+ 0.4	11.6	14.7	73.7
Belgium	> 1 ha	1950-59	A	8.3	+ 2.3	38.5	29.9	31.6
Britain	>.1 ha	1960-65	A	43.8	+ 1.3	4.6	6.2	89.2[c]
Denmark	>.55 ha	1960-65	A	17.4	+ 1.9	13.2	29.4	57.4
Finland	> 2 ha	1950-60	B	8.9	-	44.6	31.9	23.5
France	> 1 ha	1955-63	A	17.8	+ 2.1	12.2	21.7	66.1
Germany, Fed. Rep.	>.5 ha	1960-65	A	8.9	+ 1.9	25.5	32.8	41.7
Ireland	All farms	1950-60	C	16.1	+ 0.4	21.6	11.9	66.5
The Netherlands	>.1 ha	1962-65	A	10.7	+ 1.5	25.6	34.5	39.9
Norway	>.5 ha	1959-64	A	5.5	+ 1.6	62.5	20.6	16.9
Sweden	> 2 ha	1956-61	B	14.2	+ 1.8	25.0	24.0	51.0
Switzerland	All farms	1955-65	A	7.4	+ 1.7	46.6	36.0	17.4[b]
Greece	>.1 ha	1950-61	B	3.2	+ 0.5	71.9	10.1	18.0[b]
Italy	All farms	1961	A	4.8	n.a.	35.3	15.1	49.5
Portugal	All farms	1952-60	A	5.2	- 0.9	32.2	6.0	61.8
Spain	All farms	1962	B	7.8	n.a.	12.2	10.8	77.0

(a) A: Agricultural area, B: Arable land, C: Total area.

(b) Size distribution at beginning of period.

(c) U.K. size distribution estimated from Ministry of Agriculture, Fisheries and Food, Agricultural Statistics, 1966/1967, London: Her Majesty's Stationery Office 1968.

Source: ECE/FAO Agricultural Division, Farm Rationalization III, New York, 1967.

TABLE A.7

DRAFT ANIMALS IN AGRICULTURE, IN "HORSE UNITS"[a]

	1950	1955	1960	1965[b]
		(Thousands)		
Austria	285	237	150	97
Belgium and Luxembourg	262	207	166	92
Britain	662	365[c] (E)	170[c] (E)	n.a.
Denmark	502	309	271	53
Finland	389	n.a.	235	184
France	2,592	2,335	1,872	1,246
Germany, Federal Republic	1,574	1,102[c]	713[c] (E)	253
Iceland	42	37	30	30
Ireland	510	401[c]	306[c]	172
The Netherlands	252	222	187	102(E)
Norway	191	150	109	67
Sweden	440	312	209	110
Switzerland	137	122	101	73
Greece	901	1,041	1,056	826(E)
Italy	1,967	1,652	1,290	925
Portugal	435[c] (E)	427[c] (E)	425[c] (E)	n.a.
Spain	2,464	2,352	2,238	1,312(E)

(a) The following weights have been used in calculating "horse units": 1 horse = 1.0 horse units; 1 ass or mule = 0.7 horse units; 1 ox = 0.3 horse units.

(b) The 1965 figures for countries other than the EEC refer to horses only, except for Greece and Spain which include weighted estimates of asses and mules.

(c) Excluding oxen.

Source: OECD, Development of Farm Motorisation; FAO, Production Yearbook, various years; EEC, Agricultural Statistics, 1966 No. 5.

TABLE A.8 (PART 1)

TRACTOR HORSEPOWER PER PERSON EMPLOYED
(Estimates)

	1950	1956	1960	1966
Austria	0.26	1.6	2.8	7.1
Belgium	0.61	2.6	4.7	10.5
Britain	7.2	11.3	12.3	21.4
Denmark	0.90	3.9	7.1	15.3
Finland	0.38	1.8	3.3	6.8
France	0.58	2.2	4.4	9.5
Germany, Federal Republic	0.54	2.4	4.3	9.7
Iceland	2.0	6.5	10.0	18.7
Ireland	0.73	2.0	3.2	6.8
Luxembourg	1.2	5.3	8.1	13.0
The Netherlands	0.79	2.1	3.8	8.9
Norway	0.77	2.8	4.5	9.5
Sweden	2.8	6.4	8.7	20.8
Switzerland	0.56	1.3	2.3	5.4
Average Northwestern Europe[(a)]	1.1	3.1	5.0	10.7
Greece	0.1	0.2	0.4	0.9
Italy	0.2	0.7	1.1	3.6
Portugal	-	0.1	0.2	0.6
Spain	0.1	0.2	0.3	1.5
Average Southwestern Europe[(a)]	0.1	0.4	0.7	2.2
Average Western Europe[(a)]	0.6	1.7	2.7	6.3

Source: Calculated from Tables A.2, A.4, and A.5. See note to Table A.1, concerning the reliability of these data.

TABLE A.8 (PART 2)

TRACTOR HORSEPOWER PER HECTARE OF ARABLE LAND

	1950	1956	1960	1966
Austria	0.2	0.8	1.3	2.8
Belgium				2.5
and	0.3	0.8	1.4	
Luxembourg				3.6
Britain	1.2	1.7	1.7	2.5
Denmark	0.2	0.7	1.2	2.1
Finland	0.1	0.5	0.9	1.6
France	0.2	0.5	0.9	1.6
Germany, Federal Republic	0.3	1.2	1.9	3.4
Ireland	0.3	0.6	0.9	1.9
The Netherlands	0.4	1.0	1.8	3.6
Norway	0.4	1.3	1.8	3.2
Sweden	0.5	1.0	1.3	2.5
Switzerland	0.5	0.9	1.5	3.2
Average Northwestern Europe[a]	0.4	0.9	1.2	2.3
Greece	-	0.1	0.2	0.4
Italy	0.1	0.3	0.5	1.1
Portugal	-	-	-	0.1
Spain	-	-	-	0.3
Average Southwestern Europe[a]	-	0.1	0.2	0.6
Average Western Europe[a]	0.2	0.5	0.8	1.5

(a) Averages are total horsepower divided by that of arable land.

TABLE A.9

COMBINED HARVESTER-THRESHERS PER 1,000 HECTARES OF CEREAL CULTIVATION

	1950	1956	1960	1966	1967
Austria	0.1	4.5	10.0	25.0	27.0
Belgium	1.2	2.0	6.2	14.0	15.0
Britain	3.3	10.0	16.0	17.0	n.a.
Denmark	0.3	1.9	5.7	21.0	23.0
Finland	0.2	3.1	7.0	15.0	17.0
France	0.6	2.7	5.6	12.0	n.a.
Germany, Federal Republic	0.2	2.6	12.0	29.0	30.0
Ireland	1.0	5.1	11.0	17.0	16.0
Luxembourg	n.a.	n.a.	n.a.	32.0	36.0
The Netherlands	2.3	3.8	6.0	13.0 (E)	n.a.
Norway	1.1	16.0	27.0	42.0	43.0
Sweden	5.5	12.0	17.0	27.0	27.0
Switzerland	n.a.	1.1	3.3	16.0	n.a.
Average Northwestern Europe	1.2	4.6	9.4	18.5	n.a.
Greece	0.2	0.5	1.3	2.3	2.5
Italy	n.a.	0.3	0.7	2.5	2.6
Portugal	n.a.	n.a.	0.2	0.8	0.8
Spain	0.1	0.2	0.7	2.6	2.8
Average Southwestern Europe	-	0.3 (E)	0.7	2.3	2.5
Average Western Europe	0.3	2.6	5.9	12.2	n.a.

Source: Derived from Tables A.3 and A.5.

TABLE A.10

NUMBER OF WORKING HOURS PER FARM TRACTOR PER YEAR, 1960[a]

Country	Hours	Country	Hours
Austria	750	Norway	290
Belgium	964	Sweden	414
Britain	714	Switzerland	867
Denmark	724		
France	583	Greece	500
Germany, Fed. Rep.	500	Italy	733
Ireland	642	Spain	1,500
Luxembourg	679	Portugal	1,871
The Netherlands	593		
Average OECD Area[b]	640		

(a) Estimated by OECD on the basis of fuel consumption.

(b) Including Ireland and Turkey.

Source: OECD, Development of Farm Motorisation, p. 26.

TABLE A.11

DELIVERIES AND TRADE IN AGRICULTURAL MACHINERY

		Total Agricultural Machinery (SITC 712)		Tractors (SITC 712.5)		Other Agricultural Machinery (SITC 712 ex 712.5)	
		1964	1965	1964	1965	1964	1965
		(Millions of U.S. dollars)					
Austria	Deliveries	71.7	86.0	32.7	32.3	39.0(E)	53.7
	Imports	26.6	38.2	7.9	8.6	18.7	29.6
	Exports	7.1	8.4	2.6	3.9	4.5	4.5
	Absorption	91.2	115.8	38.0	37.0	53.2(E)	78.8
Belgium and Luxembourg	Deliveries	n.a.	95.9(E)	n.a.	40.6(E)	51.9	55.3(E)
	Imports	29.9	33.7	13.6	13.6	16.3	20.1
	Exports	38.7	77.9	0.3	36.5	38.4	41.4
	Absorption	n.a.	51.7(E)	n.a.	17.7(E)	29.8	34.0(E)
Britain	Deliveries	515.9	531.4	331.2	343.9	184.7	187.5
	Imports	39.4	38.1	8.5	5.9	30.9	32.2
	Exports	377.7	363.4	295.8	282.5	81.9	80.9
	Absorption	177.6	206.1	43.9	67.3	133.7	138.8
Denmark	Deliveries	n.a.	n.a.	n.a.	n.a.	60.8	n.a.
	Imports	45.6	37.1	26.4	21.6	19.2	15.5
	Exports	24.4	29.7	0.5	0.4	23.9	29.3
	Absorption	n.a.	n.a.	n.a.	n.a.	56.1	n.a.
Finland	Deliveries	n.a.	15.2(E)	n.a.	6.6(E)	n.a.	8.6(E)
	Imports	36.7	46.6	27.0	34.9	9.7	11.7
	Exports	2.1	2.9	0.1	0.1	2.0	2.8
	Absorption	n.a.	58.9(E)	n.a.	41.4(E)	n.a.	17.5(E)

TABLE A.11 *(Continued)*

		Total Agricultural Machinery (SITC 712)		Tractors (SITC 712.5)		Other Agricultural Machinery (SITC 712 ex 712.5)	
		1964	1965	1964	1965	1964	1965
		(Millions of U.S. dollars)					
France	Deliveries	471.2	493.0	206.9	225.6	264.3	267.4
	Imports	151.9	159.0	70.4	72.3	81.5	86.7
	Exports	71.5	89.0	33.9	48.2	37.6	40.8
	Absorption	551.6	563.0	243.4	249.7	308.2	313.3
Germany, Federal Republic	Deliveries	877.5	980.2	356.3	384.8	521.2	595.4
	Imports	55.9	75.6	24.1	35.7	31.8	39.9
	Exports	209.3	219.5	67.0	76.3	142.3	143.2
	Absorption	724.1	836.3	313.4	344.2	410.7	492.1
Greece	Deliveries	0.0 (E)	0.0 (E)	0.0 (E)	0.0 (E)	0.0 (E)	0.0 (E)
	Imports	21.7	28.8	13.9	16.6	7.8	12.2
	Exports	0.0	0.0	0.0	0.0	0.0	0.0
	Absorption	21.7 (E)	28.8 (E)	13.9 (E)	16.6 (E)	7.8 (E)	12.2 (E)
Iceland	Deliveries	0.0	0.0	0.0	0.0	0.0	0.0
	Imports	2.0	2.1	1.3	1.3	0.7	0.8
	Exports	0.0	0.0	0.0	0.0	0.0	0.0
	Absorption	2.0	2.1	1.3	1.3	0.7	0.8
Ireland	Deliveries	3.0 (E)	3.0 (E)	1.0 (E)	1.0 (E)	2.0 (E)	2.0 (E)
	Imports	19.0	20.2	7.6	8.3	11.4	11.9
	Exports	0.7	0.6	0.0	0.1	0.7	0.5
	Absorption	21.3 (E)	22.6 (E)	8.6 (E)	9.2 (E)	12.7 (E)	13.4 (E)

TABLE A.11 *(Continued)*

		Total Agricultural Machinery (SITC 712)		Tractors (SITC 712.5)		Other Agricultural Machinery (SITC 712 ex 712.5)	
		1964	1965	1964	1965	1964	1965
		(Millions of U.S. dollars)					
Italy	Deliveries	277.4	290.9	146.2	153.7	131.2	137.2
	Imports	43.0	41.7	14.7	17.5	28.3	24.2
	Exports	45.4	59.4	35.3	44.8	10.1	14.6
	Absorption	276.0	273.2	125.6	126.4	149.4	146.8
The Netherlands	Deliveries	n.a.	n.a.	0.0(E)	0.0(E)	n.a.	n.a.
	Imports	40.9	46.9	20.1	22.9	20.8	24.0
	Exports	19.6	22.7	1.0	2.6	18.6	20.1
	Absorption	n.a.	n.a.	19.1(E)	20.3(E)	n.a.	n.a.
Norway	Deliveries	10.9	n.a.	0.0(E)	0.0(E)	10.9	12.8(E)
	Imports	27.6	26.9	21.8	20.6	5.8	6.3
	Exports	6.5	7.7	1.0	1.0	5.5	6.7
	Absorption	32.0	n.a.	20.8(E)	19.6(E)	11.2	12.4(E)
Portugal	Deliveries	0.0(E)	0.0(E)	0.0(E)	0.0(E)	0.0(E)	0.0(E)
	Imports	7.5	9.8	5.4	7.0	2.1	2.8
	Exports	0.4	0.5	0.1	0.1	0.3	0.4
	Absorption	7.1(E)	9.3(E)	5.3(E)	6.9(E)	1.8(E)	2.4(E)
Spain	Deliveries	65.0(E)	n.a.	40.0(E)	n.a.	25.0(E)	n.a.
	Imports	34.7	33.8	12.7	11.3	22.0	22.5
	Exports	5.2	5.0	0.2	0.3	5.0	4.7
	Absorption	94.5(E)	n.a.	52.5(E)	n.a.	42.0(E)	n.a.

TABLE A.11 *(Concluded)*

		Total Agricultural Machinery (SITC 712)		Tractors (SITC 712.5)		Other Agricultural Machinery (SITC 712 ex 712.5)	
		1964	1965	1964	1965	1964	1965
		(Millions of U.S. dollars)					
Sweden	Deliveries	101.5	106.7(E)	39.3	34.6(E)	62.2	72.1(E)
	Imports	35.2	34.9	20.5	17.5	14.7	17.4
	Exports	44.9	43.3	15.7	13.8	29.2	29.5
	Absorption	91.8	98.3(E)	44.1	38.3(E)	47.7	60.0(E)
Switzerland	Deliveries	n.a.	22.6(E)	n.a.	4.6(E)	n.a.	18.0(E)
	Imports	15.2	12.8	0.2	0.2	15.0	12.6
	Exports	4.2	4.0	1.0	1.0	3.2	3.0
	Absorption	n.a.	31.4(E)	n.a.	3.8(E)	n.a.	27.6(E)

Source: OECD, The Engineering Industries 1965, Paris, 1966, Tables IV.2, IV.4, IV.5; FAO, Trade Yearbook, 1965, Tables 119 and 124.

TABLE A.12

ABSORPTION AND GROSS CAPITAL FORMATION BY MAJOR USERS OF AGRICULTURAL MACHINERY

	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
Absorption of Agricultural Machinery(1) (Millions of U.S. dollars at current prices and exchange rates)												
Britain	138	136	78	111	137	154	114	146	182	173	178	206
France	206	305	395	506	502	395	384	471	436	491	552	563
Germany, Fed. Rep.	246	370	369	375	425	485	563	686	652	595	724	836
Italy	234	246	214	222	222	243	197	206	251	288	276	273
Gross Capital Formation in Machinery and Equipment in Agriculture(2) (Millions of U.S. dollars at current prices and exchange rates)												
Britain	157	168	140	174	213	227	213	221	204	244	241	(240)
France	294	397	554	502	397	553	555	653	641	725	833	(860)
Germany, Fed. Rep.	314	351	361	412	459	523	631	623	585	640	716	(740)
Italy	231	234	219	205	200	206	230	237	270	325	346	(340)

Source: (1) OECD, The Engineering Industries 1965, Tables IV.2, IV.4, IV.5, and FAO Trade Yearbook 1965, Tables 119 and 124; (2) EEC, Agricultural Statistics 1966/5 and 1968/4; and United Kingdom, National Income and Expenditure, 1967, Central Statistical Office, London: Her Majesty's Stationery Office, 1967.

TABLE A.13

COMPOSITION OF CAPITAL EXPENDITURES, 1960/62 AVERAGE

	New Buildings, Construction and Improvements (Per cent)	New Machinery and Equipment (Per cent)
Austria	37.0	63.0
Belgium	40.5	59.5
Britain	33.4	66.6
Denmark	34.9	65.1
Finland	17.2	82.8
France	17.1	82.9
Germany, Fed. Rep.	58.9	41.1
Ireland	48.2	51.8
Italy	72.1	27.9
The Netherlands	57.8	42.2
Norway	64.3	35.7
Portugal	68.6	27.9
Sweden	39.5	60.5
Switzerland	39.7	60.3

Source: ECE/FAO, 5th Report on Output, Expenses and Income of Agriculture in European Countries, Geneva, 1965, Vol. II, Table LVIII, p. 268.

TABLE A.14

LABOUR COSTS IN AGRICULTURE[a]

	1953/54	1956/57	1960/61	1965/66	1966/67
		(U.S. dollars per hour)			
Austria	0.17	0.21	0.27	0.51	0.54
Belgium	0.43	0.48	0.51	0.93	0.97
Britain	0.42	0.51	0.63	0.89	n.a.
Denmark	0.38	0.43	0.41	0.81	0.89
Finland	0.41	0.54	0.45	0.67	0.71
France	n.a.	n.a.	n.a.	0.53(E)	n.a.
Germany, Fed. Rep.	0.25	0.34	0.45	0.80	0.85
Ireland	n.a.	0.26	0.32	0.47	0.52
The Netherlands	0.29	0.38	0.56	0.94	1.03
Norway	0.34	0.41	0.53	0.89	0.97
Sweden	0.53	0.64	0.87	1.54	1.66
Switzerland	0.38	0.42	0.48	0.69	0.73
Greece	0.11	0.20	0.23	0.38	0.44
Italy	0.23	0.27	0.29	0.62	0.62
Portugal	n.a.	n.a.	n.a.	0.25(E)	n.a.
Spain[b]	n.a.	0.14(E)	0.17(E)	0.29(E)	0.33(E)

(a) Labour costs per hour of a permanent non-specialized agricultural worker, including lodgings, food, and paid holidays.

(b) Estimated from data on weekly labour costs.

Source: FAO, Prices of Agricultural Products and Fertilizers in Europe, various years.

TABLE A.15

PRICE OF OUTPUT, PRICE OF TRACTORS, AND WAGES, 1966 INDEXES (1960 = 100)

	Price of Agricultural Output	Price of Tractors and Farm Machinery	Agricultural Wages
Austria	119	124	178
Belgium	125	137	159
Britain	109	115 (E)	138
Denmark	n.a.	118[a] (E)	224
Finland	133	n.a.	155
France	124	110	150
Germany, Federal Republic	105	114	177
Ireland	119	102	163
The Netherlands	135	142[a] (E)	169
Norway	125	115	162
Sweden	114	126[a] (E)	175
Switzerland	124	128	153
Greece	120	n.a.	185
Italy	126	100	173
Portugal	118	n.a.	188
Spain	143	n.a.	213

(a) All production requisites.

Source: FAO, Production Yearbook, 1968.

TABLE A.16

COSTS AND OUTPUT ON FARMS IN ENGLAND AND WALES, 1966

Type of Farm and Size Class, Expressed in SMDs	Average SMDs per Farm	Average Acres per Farm	Average Costs in £ per Farm: Labour Costs[(a)]	Machinery and Power Costs	Rents and Rates[(b)]	Total Costs	Average Value of Agricultural Output in £ per Farm	Average Value of Machinery in £ per Farm
Specialist Dairy								
275 - 449	367	51	815	436	180	1,807	1,870	1,734
450 - 599	531	71	1,038	561	279	2,439	2,947	1,137
600 - 1,199	892	122	1,717	1,002	527	4,286	5,252	2,077
1,200 - 1,799	1,474	206	2,638	1,776	1,013	7,334	9,417	4,074
1,800 +	2,459	349	4,488	2,974	1,658	12,598	17,617	6,980
Weighted average of all sizes over 275	729	100	1,420	833	427	3,532	4,298	1,719
Mainly Dairy								
275 - 449	387	74	982	477	210	2,048	2,211	872
450 - 599	512	100	1,050	628	265	2,484	2,844	1,250
600 - 1,199	874	147	1,633	1,016	552	4,187	5,152	2,226
1,200 - 1,799	1,479	250	2,971	2,194	1,222	8,420	10,474	5,133
1,800 +	2,687	482	5,559	4,002	2,440	16,004	20,308	9,158
Weighted average of all sizes over 275	917	161	1,856	1,208	656	4,856	5,931	2,500
Livestock, Mostly Sheep								
275 - 449	389	142	904	435	182	1,816	1,544	659
450 - 599	526	262	881	449	225	1,938	1,817	820
600 - 1,199	857	524	1,302	726	389	3,150	3,299	1,336
1,200 - 1,799	1,421	749	1,538	857	616	3,727	4,768	1,687
1,800 +	2,234	1,890	2,096	1,161	643	4,998	6,389	1,882
Weighted average of all sizes over 275	788	461	1,178	631	336	2,714	2,840	1,119

TABLE A.16 *(Continued)*

Livestock, Cattle and Sheep								
275 - 449	350	127	966	526	263	2,121	1,992	1,043
450 - 599	529	188	1,147	783	421	2,951	3,078	1,559
600 - 1,199	851	288	1,772	1,159	686	4,587	5,450	2,614
1,200 - 1,799	1,434	540	3,052	2,181	1,660	8,896	11,081	4,480
1,800 +	2,172	1,268	3,207	2,061	1,601	8,965	11,285	4,061
Weighted average of all sizes over 275	704	268	1,507	963	586	3,858	4,373	2,037
Cropping, Mostly Cereal								
275 - 449	368	135	1,302	1,256	593	4,026	4,211	2,702
450 - 599	525	199	1,446	1,554	978	5,177	5,906	3,348
600 - 1,199	860	310	2,216	2,426	1,537	8,162	10,112	5,558
1,200 - 1,799	1,472	479	3,619	3,343	2,213	12,266	15,694	7,375
1,800 +	2,791	859	6,742	6,100	4,058	22,882	30,721	12,841
Weighted average of all sizes over 275	976	332	2,534	2,518	1,590	8,811	10,985	5,548
General Cropping								
275 - 449	379	63	1,092	836	285	2,818	3,293	1,594
450 - 599	530	81	1,488	987	350	3,541	4,340	1,624
600 - 1,199	885	150	2,361	1,629	805	6,234	8,422	3,605
1,200 - 1,799	1,505	274	3,641	2,852	1,306	10,215	13,890	5,624
1,800 +	3,383	481	8,101	5,197	2,772	21,237	27,971	9,919
Weighted average of all sizes over 275	1,460	226	3,632	2,467	1,214	9,582	12,624	4,850
Mixed								
275 - 449	369	69	1,058	528	207	2,243	2,003	908
450 - 599	531	118	1,160	801	359	2,924	3,264	1,719
600 - 1,199	899	187	1,897	1,315	640	4,909	5,969	2,981
1,200 - 1,799	1,460	260	2,960	2,123	1,275	8,402	10,865	5,414
1,800 +	3,133	537	6,996	4,676	2,587	18,991	23,749	10,338
Weighted average of all sizes over 275	1,165	219	2,555	1,717	903	6,749	8,222	3,871

TABLE A.16 *(Concluded)*

Type of Farm and Size Class, Expressed in SMDs	Average SMDs per Farm	Average Acres per Farm	Average Costs in £ per Farm: Labour Costs (a)	Machinery and Power Costs	Rents and Rates (b)	Total Costs	Average Value of Agricultural Output in £ per Farm	Average Value of Machinery in £ per Farm
Pigs and Poultry								
600 - 1,199	942	69	1,680	1,580	452	4,491	6,242	5,274
1,200 - 1,799	1,534	122	2,626	2,428	729	7,154	9,292	7,549
1,800 +	3,911	194	4,102	3,368	1,362	10,806	14,920	8,106
Weighted average of all sizes over 275	1,174	78	1,810	1,503	486	4,843	6,150	4,325
Horticulture								
600 - 1,199	883	20	2,095	604	196	4,160	5,234	1,200
1,200 - 1,799	1,454	48	2,564	1,085	422	6,131	8,031	2,140
1,800 +	3,815	73	6,740	1,780	765	14,919	18,380	3,637
Weighted average of all sizes over 275	1,551	36	3,138	906	360	6,686	8,366	1,839
Very Small Farms								
Dairy	209	41	707	266	135	1,290	1,122	
Livestock	178	68	720	302	146	1,513	1,168	
Pigs and poultry	170	24	685	372	114	1,445	935	
Cropping	200	59	851	494	215	1,978	1,913	

(a) Including the value of the labour of the farmer and his wife.

(b) Including the rental value of owner occupied farms.

Source: U.K. Ministry of Agriculture, Fisheries and Food, Farm Incomes in England and Wales 1966, London: Her Majesty's Stationery Office, 1968.

TABLE A.17

AGRICULTURAL MACHINERY IN ENGLAND AND WALES, 1966

Type of Machine	Number
Tractors	
10 HP and over:	
Wheeled (including half-track)	355,220
Tracklaying (excluding half-track)	16,620
Under 10 HP:	
Wheeled and tracklaying (including 1- and 2-wheeled and self-propelled implements and motor hoes)	46,170
Dairying Machinery	
Milking equipment; number of teat-cup clusters (not installations):	
In cowshed	193,570
In milking shed (for relay milking)	21,540
In parlour	56,300
In mobile bail	11,330
Tillage and Cultivating Machinery	
Disk harrows	88,720
Other harrows, sets	294,290
Sowing Machinery	
Potato planters	26,680
Hay and Silage Harvesting Machinery	
Mowers over 3 ft wide:	
Cutter bar	161,250
Flail	3,990
Forage harvesters:	
Flail types	17,310
Metered chop and combined flail and chopping types	2,370
Hay crushers and crimpers	4,480
Siderakes, swath-turners, tedders, and combined hay-making machines	214,240
Buckrakes	56,260
Root Harvesting Machinery	
Potato spinners	41,570
Potato elevator diggers and shaker diggers	13,910
Potato harvesters, complete	6,090
Sugar beet harvesters, complete (combined topper, lifter and cleaner)	14,870
Potato sorters, power operated	18,640

TABLE A.17 (*Concluded*)

Type of Machine	Number
Drying Machinery	
Barn hay driers and multi-purpose crop driers	1,590
Grain driers:	
Continuous grain flow	11,110
Tray, platform (in sack) or other batch type	6,650
Floor drying installations	5,650
Transportable multi-purpose drying units (includes mobile units used in fixed installations):	
Wheeled engine-driven fans	2,560
Mobile tractor fans	2,300
Grain moisture meters	21,080
Sprayers	
Power fruit sprayers (50 gallon tank capacity and over)	8,420
Other wheeled and tractor-mounted sprayers	57,540
Knapsack sprayers, power operated	3,250
Transport	
Tractor trailers	339,790
Motor lorries and motor vans (including pick-up trucks):	
Under 1 ton	65,740
1 ton and over	35,380
Landrovers and similar four-wheel drive vehicles	34,010

Source: U.K. Ministry of Agriculture, Fisheries and Food, Agricultural Statistics 1966/1967, London: Her Majesty's Stationery Office 1968, Table 84, Agricultural Machinery Estimated Number of Machines and Implements.

PUBLICATIONS OF THE ROYAL COMMISSION ON FARM MACHINERY

Reports

Special Report on Prices of Tractors and Combines in Canada and Other Countries
(Z1-1966/4-1-1, $2.50)

Available in French:

Rapport Spécial sur les Prix des Tracteurs et des Moissonneuses-Batteuses au Canada et dans d'Autres Pays
(Z1-1966/4-1-1F, $2.50)

Studies

1. Farm Machinery Safety: Physical Welfare Effects of the Man-Machine Interaction on Farms
   - Graham F. Donaldson
   (Z1-1966/4, $1.00)

   Available in French:

   La Sécurité Agricole: Répercussions sur la Santé de l'Interaction de l'Homme et de la Machine dans les Exploitations Agricoles
   - Graham F. Donaldson
   (Z1-1966/4F, $1.00)

2. Farm Tractor Production Costs: A Study in Economies of Scale
   - N.B. MacDonald, W.F. Barnicke, F.W. Judge, K.E. Hansen
   (Z1-1966/4-2, $3.00)

3. Productivity in the Farm Machinery Industry: A Comparative Analysis between Canada and the United States
   - Christopher J. Maule
   (Z1-1966/4-3, $1.00)

4. Farmers' Attitudes to Farm Machinery Purchases: A Survey Conducted in the Prairie Provinces, in Mid-1967
   - Alexander Segall
   (Z1-1966/4-4, $1.25)

5. The Prairie Farm Machinery Co-operative: "The Canadian Co-operative Implements Limited"
   - Rubin Simkin
   (Z1-1966/4-5, $1.50)

6. Locational Advantages in the Farm Machinery Industry
   - Neil B. MacDonald
   (Z1-1966/4-6, $2.25)

7. Research and Development in the Farm Machinery Industry
   - Alex G. Vicas
   (Z1-1966/4-7, $1.50)

8. Farm Machinery Testing: Scope and Purpose in the Measurement and Evaluation of Farm Machinery
   - Graham F. Donaldson
   (Z1-1966/4-8, $1.25)

Note: Copies of the above publications may be obtained from the Canadian Government Book Shops listed on the reverse side of the title page. Payment should accompany orders to avoid possible delay in shipment.

Mimeographed Studies Prepared for the Canadian Agriculture Congress - Ottawa, 1969

Farm Tractor Prices in Canada Compared with Those in England and Other Countries

Les Prix des Tracteurs Agricoles au Canada en Comparaison avec Ceux d'Angleterre et des Autres Pays

Farm Machinery Costs and Productivity

Coût et Productivité des Machines Agricoles

Technological Changes in Farm Machinery and Canadian Agriculture

Les Transformations Techniques dans le Domaine de L'Outillage Agricole et Leur Portée sur l'Agriculture Canadienne

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Note: These studies may be obtained from the Royal Commission on Farm Machinery, Ottawa.