A MARGINAL PRODUCTIVITY STUDY OF FARMS IN SELECTED WESTERN PILOT AREAS IN IRELAND 1966 - 1968

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ABSTRACT

A MARGINAL PRODUCTIVITY STUDY OF FARMS IN SELECTED WESTERN PILOT AREAS IN IRELAND 1966-1968

By

Patrick Joseph Higgins

The purpose of this study was to examine resource productivity on farms within selected pilot areas in Western Ireland counties over the two year period 1966-68. Estimates of the marginal value productivities for groups of inputs used in the farms were calculated. It was anticipated that these estimates would be of value to extension agents, farm managers, policy, credit and other workers in providing a more objective basis for evaluating the efficiency of farm business organizations and in planning reorganizations, within the studied areas.

To achieve these objectives, marginal value productivities were calculated for the various input categories of the farm businesses studied. The marginal value productivities were derived by fitting Cobb-Douglas functions to a random sample of farms from each of six pilot areas in the west of Ireland. The analysis was carried out both on individual pilot areas, on combinations of pilot areas and on all farms together.

Two separate regressions were made on the data for each of the six pilot areas and on various combinations of pilot areas. The second function fitted to the data, combined livestock investment and variable non-labor costs into one input category, these were treated as separate independent categories in the first function.

The regression coefficients for each input category in both functions were tested against the b_i's required to equate marginal value products with the minimum expected return or reservation prices for the inputs used.

Tentative conclusions regarding the usual organization of farms in the pilot areas studied 1966-68 were that too much labor was being used relative to other input categories. Variable non labor costs were earning high returns in all areas and could be expanded. Investments in machinery costs earned high returns in some areas. Livestock investments seemed to be in about the proper proportion relative to other inputs. The land input was earning very low returns, but it is felt that the regression coefficient for land was downward biased. Conclusions, recommendations and implications were made with a view to achieving the objectives stated in the introductory chapter. It is felt that the increased use of input categories with regression coefficients higher than those necessary to equate MVP with MFC, may help to increase the marginal value products of inputs

with low MVP's such as land. The overall result would be a better combination of resources and a higher gross output on pilot area farms under 1966-68 farming conditions.

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Patrick Joseph Higgins

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CHAPTER 1

INTRODUCTION

The present study originated as a detailed farm account study of a random sample of farmers chosen from six of the twelve pilot area counties located in the western region of Ireland.[1] The counties included in the study were Galway, Mayo, Roscommon, Sligo, Clare and Kerry. The study was carried out over a two year period, 1966-1968. It had several objectives, some of which form the basis for the present paper.

Extension agents, farm managers, policy, credit and other workers in the areas of farm planning and efficient resource use need answers to questions on the profitability of various factors used in the production process. They need to know if it pays to increase livestock investment or labor, for instance. Answers to these questions may often shape agricultural policy and give needed directions to farmers if they are considering reorganizations of present input mixes; to government officials in formulating policy proposals; to credit agencies in appraising loan proposals; to extension agents in complementing gross margin and other

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[1]See Figures 1 and 2

farm management study results. The primary objective of this study is to establish guidelines in the form of estimates of the earning power (marginal value product) of categories of inputs used in the farming operation. The inputs studied will include livestock investment, variable non-labor costs, machinery costs, adjusted acres and labor units.

Secondly, the study results may enable interested workers to see what directions possible reorganizations on farms should take.

Thirdly, the difficulties encountered in this study will serve as a guide to future studies of this type in Ireland.

The Cobb-Douglas analysis used in the study is based on static economic principles. This allows the measurement of returns to categories of inputs in marginal terms which allow us to calculate, for example, the return to an additional unit of labor or the marginal value product in production economics terminology. This has advantages over the usual methods of farm management analysis used in Ireland where labor efficiency is commonly measured in terms of total output of all factors per one hundred pounds total labor costs, or the total output of all factors per labor

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[2]The increment to total gross output resulting from the use of an additional unit of input. (A labor unit in this case.)

unit <u>or</u> as an accounting residual in the form of labor and management income after other costs have been subtracted from gross output. This study aims at measuring labor efficiency by isolating the return to labor and likewise for the other categories of inputs used.

In Chapter II, the background to the problem in the west of Ireland and to the establishment of pilot areas and the existence of low income problems is discussed.

Chapter III contains the theoretical background and some of the static theory of production economics which underlies the present study. A review of some of the research studies which used Cobb-Douglas functions, statistical problems in their estimation and rules for grouping inputs are also included.

Chapter IV contains a description of the farm income survey conducted in the west of Ireland and of the input data used in fitting the functions.

Chapter V describes the fitting of the production function and the evaluation of the statistical results for the six county pilot areas involved, both for each pilot area separately and for various combinations of pilot area data. Two functions were fitted.

Chapter VI deals with the usefulness of the statistical results and general conclusions are made about their usefulness for policy and other purposes.

CHAPTER II

AGRICULTURE IN THE WEST OF IRELAND--
THE PILOT AREA PROGRAM

Introductory remarks on agriculture in Ireland

It is generally accepted that a highly developed economy should have only a small proportion of its population engaged in primary production. Increasing agricultural productivity and industrial-urban development are complementary in many respects and both contribute to economic growth. Rising agricultural productivity could contribute to the development of the Irish economy in many ways. Among the most important would be:

1. The creation of foreign exchange through exports.
2. Reasonably low food prices for industrial consumers.
3. The release of labor to meet industrial expansion requirements.

The development planner in Ireland, as in other countries, is faced with the problem of establishing priorities between the allocation of limited resources between the agricultural and industrial sectors. Some economists (Hirschman, Leibenstein, Higgins) conclude that rising agricultural productivity can be accomplished only by giving a "big push" industrialization program top priority.[1] This would presumably lead to an adequate flow of resources out of agriculture. In Ireland, labor does not flow freely out of agriculture at a rate necessary to avoid stagnation or slowly growing incomes in that sector. A cursory look at agricultural labor in Ireland and especially in the western part of the country would bear this out. Some workers are better informed about alternative opportunities than others, some are geographically closer to the alternatives, and some are at an age, family status, economic position that decreases their mobility. Some can better finance the cost of moving out of agriculture. Others find themselves trapped in agriculture, sometimes because the earning power of some of the resources they own are somewhere between acquisition and salvage price. There are those who are immobile because of social factors like age, education and physical and mental conditions. Nevertheless, the government recognizes the necessity for further decline in the population engaged in agriculture. The Third Programme for Economic and Social Development 1969-1972, envisages a decline of 36,000 in the numbers at work in the agricultural sector over the four year period. In 1968, approximately 29 percent of the total labor force was engaged in agriculture.[2]

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[1] Carl K. Eicher, Agriculture in Economic Development. McGraw-Hill Book Co., New York, 1964, p. 16.

[2] Third Programme--Economic and Social Development 1969-72. Government Publications Sale Office, G.P.O. Arcade, Dublin 1. p. 29, derived statistics.

The problem of economic growth and development is even more crucial for the West of Ireland since the area, despite heavy emigration, still has a high proportion of its population engaged in primary agriculture (55 percent).[3] An improvement in agricultural productivity is a key requirement if economic development is to be a reality in this area. Some of the major misallocations in resource use will be mentioned later. The adoption of new technology would help to increase agricultural productivity, and allow for further decreases in the labor force and increases in farm size, as well as the substitution of capital for labor. The migration of farm labor from agriculture has not led to the development of conditions necessary for agricultural progress. There still remain technical and structural defects within agriculture which act as bottlenecks to growth. The maps (Figures 1 and 2) delineate the twelve western counties--the major areas of low income problems. In this study, a sample of farms from the pilot areas within six of these counties will be examined and estimates of marginal value productivities will be calculated and examined for evidence of maladjustment in resource use.

Discrepancies between East and West

In examining structural defects, we find that in 1961, 20 percent of the active labor force was engaged in agriculture in the East of Ireland. A similarly defined

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[3]John J. Scully, "The Pilot Area Development Program," p. 1.

Fig. 1.--Ireland, Western and Eastern Counties

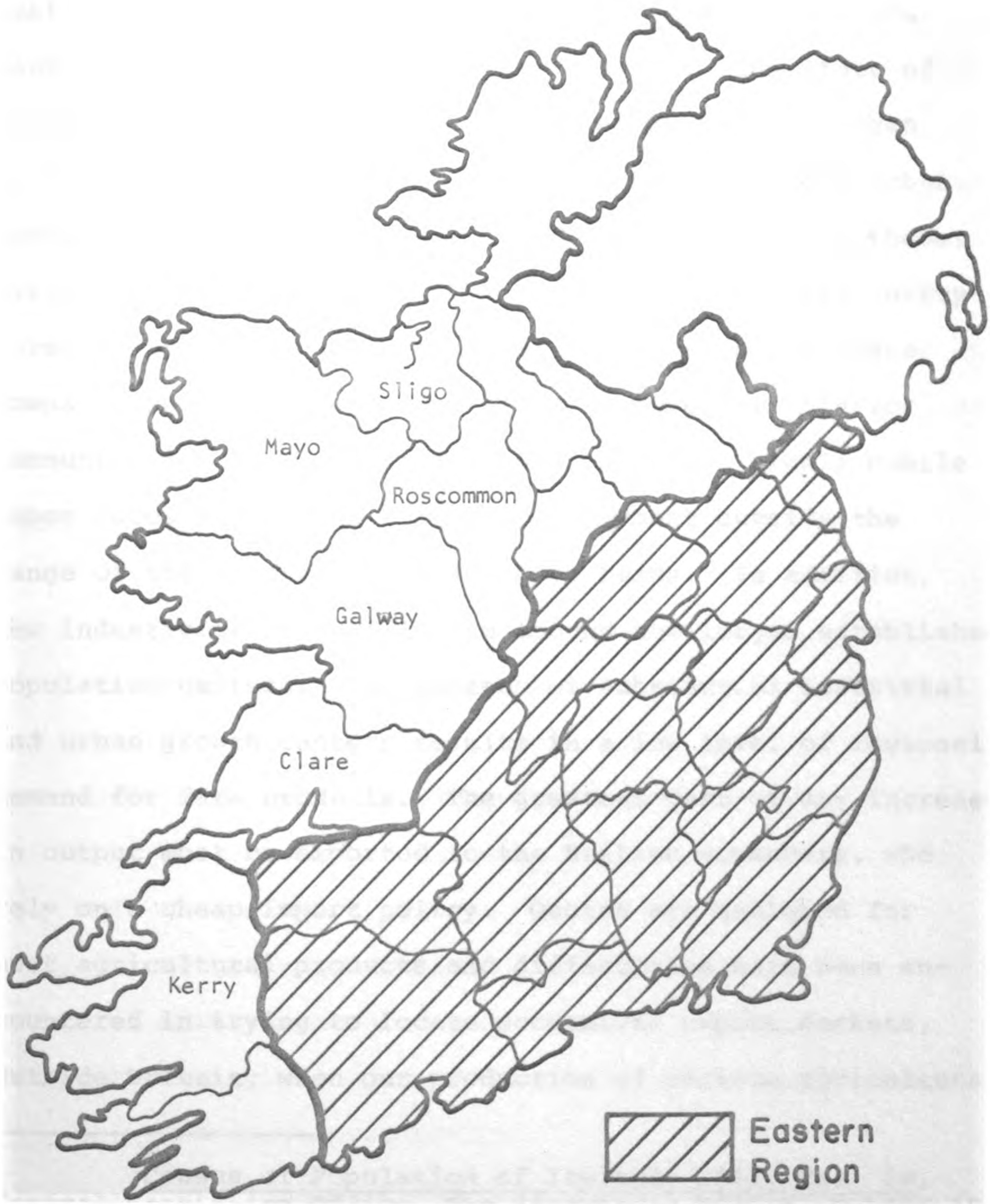

Fig. 2.--Ireland, Twelve Western Counties and pilot area locations.

figure for the western counties shows 55 percent involved in agriculture.[4]

The high percentage engaged in agriculture in the west reflects the presence of a low industrial base and lack of off-farm employment opportunities. The state of industrialization in the West is far more critical than in the East. In the two areas, there were only 100 urban areas with populations exceeding 1,500 in 1961. Of these, sixty-seven are located in the Eastern counties and thirty-three in the West.[5] The poor spatial location of these towns in the latter area coupled with somewhat inferior communication linkages is not conducive to a highly mobile labor force and places off-farm employment outside the range of the majority of low income farms. In addition, new industry prefers to locate around the larger established population centers. The absence of substantial industrial and urban growth centers results in a low level of regional demand for farm products. The greatest part of any increase in output must be exported to the British consumers, who rely on a cheap import policy. Quotas are assigned for most agricultural products and difficulties have been encountered in trying to locate economical export markets, outside Britain, when our production of various agricultural

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[4] Census of Population of Ireland, 1961, Vol. iv, Central Statistics Office, The Stationery Office, Dublin 1964.

[5] John J. Scully, Agricultural Adjustment in Ireland, Paper no. 13. Agricultural Economics Conference, Dublin 1968.

commodities exceeds the British quota. All these dimensions help to keep farm incomes low, especially for the farmers who depend on cash from the output of small, fragmented farms. Many of the Irish exchequer subsidies on agricultural products also help the larger farmers more than the smaller ones, since they are tied to sales and output figures.

In the next section, some of the major bottlenecks in the way of agricultural progress will be examined. These are felt to be among the chief reasons for low labor and land productivity, estimates of which will be calculated in Chapter IV of this paper. The next section of this chapter draws heavily from the work of John Scully.[6]

Causes of low income problems in the Western Region

1. Those relating to land resources
   a. Small farm size
   b. Fragmentation of holdings
   c. Poor soils
   d. Inadequate drainage--field and arterial
   e. Geographical location
   f. Vacated holdings
2. Those relating to labor and management
   a. High age structure of the farm population
   b. Inadequate education
   c. Inadequate production
   d. Low level of managerial capacity

[6]John J. Scully, Western Regional Director, Department of Agriculture and Fisheries, Athenry, Co., Galway, Ireland.

3. Those relating to capital
   a. Scarcity of working capital
   b. Low livestock investment
   c. Inadequate sources of good quality breeding stock
4. Those relating to institutional factors
   a. Delinquent farm titles
   b. Resistance to division of land commonages
   c. Inadequate factor/product markets
5. Miscellaneous
   a. Lack of adequate cooperative facilities
   b. Poor main and side roads
   c. Absence of piped water and electricity on many farms
   d. Inadequate off-farm employment opportunities

Farm size, fragmentation and soils

One of the reasons for the existence of an income gap between farmers and comparable occupational groups arises from farm size. About seventy percent of all the farms in the European Community are less than ten hectares in area (twenty-five acres) in contrast to about forty percent in Ireland. This maladjustment in structure is to a great extent the result of historical protectionist policies, followed by the E.E.C. countries, especially Germany and France.[7]

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[7]Michael Tracy, Agriculture in Western Europe, Jonathan Cape, 1964, Chapter 1, p. 1f.

The lack of exposure to world competition results in the lack of incentive to modernize. The distribution of farms by size varies substantially between regions in Ireland (Table 1). 52.4 percent of all farms are still less than 30 acres in the West. The corresponding figure for the East is 31.8 percent.[8] A fairly substantial decline in the number of holdings under 30 acres has taken place in Ireland in all regions since 1949. The number of holdings between 30 and 200 acres have increased. Similar trends show in other European countries.[9] A survey of the twelve pilot areas in 1964 showed that 35.5 percent of all farms are less than 25 acres in area. In counties Donegal, Sligo, Longford and Roscommon, the proportion of farms falling into this category was 63 percent, 57 percent, 46 percent and 38 percent respectively. Small farm size of itself need not necessarily be a serious limiting factor to increased farm production. In the pilot areas and in the Western Region as a whole, the problem is aggravated by the fragmentation of farm holdings and poor soil resources.

The fragmentation problem especially where the distance separating the two main fragments is large, is a barrier to increased farm production. The soils in the Western Region are less fertile than those in the remainder of the

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[8]John J. Scully, Agricultural Adjustment in Ireland, op. cit., Table 1.

[9]Robert O'Connor, (Professor, Economic and Social Research Institute.) Implications of Agricultural Statistics, Paper 2, Economic Conference, Dublin, 1968. p. 3.

TABLE 1

DISTRIBUTION AND CHANGES IN DISTRIBUTION OF FARMS BY SIZE GROUPS, BY REGION, IRELAND 1953 AND 1965

Size Group (Acres)	1953 No.	1953 Percent of total	1965 No.	1965 Percent of total	Change 1953-1965 No.	Change 1953-1965 Percent of total
IRELAND (26 Counties)						
5 to 10	30,602	10.6	22,871	8.8	- 7,731	-25.3
10 to 30	114,594	39.6	90,802	34.9	-23,792	-20.8
30 to 50	62,654	21.8	61,238	23.5	- 1,416	- 2.3
50 to 100	52,036	18.0	55,197	21.2	+ 3,161	+ 6.1
100 to 200	21,979	7.6	23,325	8.9	+ 1,346	+ 6.1
Over 200	7,163	2.4	6,971	2.7	- 192	- 2.7
Total	289,028	100.0	260,404	100.0	-28,624	-10.9
EASTERN REGION						
5 to 10	10,610	8.9	8,890	8.1	- 1,720	-16,2
10 to 30	32,472	27.3	26,068	23.7	- 6,404	-19.7
30 to 50	24,932	21.0	23,547	21.4	- 1,385	- 5.6
50 to 100	29,972	25.2	30,038	27.3	+ 111	+ 0.4
100 to 200	15,816	13.3	16,522	15.0	+ 706	+ 4.5
Over 200	5,058	4.3	4,924	4.5	- 134	- 2.6
Total	118,860	100.0	110,034	100.0	- 8,826	- 7.4
WESTERN REGION						
5 to 10	19,992	11.7	13,981	9.3	- 6,011	-30.1
10 to 30	82,122	48.2	64,734	43.1	-17,388	-21.2
30 to 50	37,722	22.2	37,691	25.1	- 31	- 0.1
50 to 100	22,064	13.0	25,114	16.7	+ 3,050	+13.8
100 to 200	6,163	3.7	6,803	4.5	+ 640	+10.4
Over 200	2,105	1.2	2,047	1.3	- 58	- 2.4
Total	170,168	100.0	150,370	100.0	-19,798	-11.6

Source: Central Statistics Office, Statistical Abstract of Ireland, 1954, (Dublin: The Stationery Office. 1955) p. 86, and Statistical Abstract of Ireland, 1966. (Dublin: The Stationery Office, 1966). p. 87.

country. In some cases they do not lend themselves to easy mechanization. In addition to this, there are many areas in need of reclamation and field drainage. Efforts to push ahead at area level are often thwarted by lack of action at the macro level. There is a need first for better arterial drainage to provide satisfactory outlets for hinterland drainage schemes. In addition to these problems, many farms are located in remote areas relative to main transport routes, markets and milk collection routes. All of these structural factors lead to underemployment of labor and a reduction in the income earning opportunities available to the small farms in the areas.

Labor management and income

The continuing subsistence level incomes and lack of employment opportunities have led to a continuous drop in farm population through emigration. The resulting population structure shows a decreasing proportion of young adults and an increasing proportion of family dependents. The older farmers are mainly concentrated on the smaller farms in the pilot areas. Over 45 percent of farmers are unmarried and many of the bachelor farmers are beyond normal marrying age. The aging of the farm population appears to be typical of the whole Western Region.[10]

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[10]John J. Scully, Paper, "The Pilot Area Development Program." p. 8.

The numbers leaving agriculture are not absorbed into industry within the region. The residual population are being burdened with higher rates each year in order to support and maintain present infrastructure. Because of age, many farmers continue to use traditional technology and fail to make the relevant changes which would improve their income situations. They are often not willing to borrow capital or consolidate fragmented holdings.

Poor management capacity is reflected in low incomes also. The extension agents cannot easily improve management practices and techniques, since most of the farmers have very low levels of formal education. In many cases traditional conservative attitudes toward farming and life in general are very evident. These regions are often left with the less dynamic of their population. It can be hypothesized that the better educated are usually the ones who emigrate.

The farm income problem between the regions can be partly highlighted by Table 2 which follows.[11] The discrepancy between north and west and the rest of the country is broad. This study, however, classified three of the western counties in the south and east/midland areas. The income gap would then be broader between the West and other areas if this had not occurred. A problem, common to all areas in this study, was that the general level of incomes in

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[11]J. F. Heavey, B. C. Hickey, J. Gaughan, Farm Management Survey 1966-67, Agricultural Institute, 33 Merrion Rd., Dublin 4, Sept. 1969.

1966-1967 was low as a result of depressed cattle prices. Management and investment income below is a residual quantity after the value of family labor has been deducted from family farm income. It shows the return to the farmers capital investment and management.

TABLE 2.

FAMILY FARM INCOME, NUMBER OF LABOR UNITS AND MANAGEMENT AND INVESTMENT INCOME BY REGION, IRELAND, 1966-67

Region	Family Farm Income Per Farm	No. of Family Labor Units Per Farm	Management and Investment Income
	pounds	number	pounds
North and West	222	1.03	-219
East and Midlands	504	1.13	19
South	698	1.18	191
Republic of Ireland	465	1.12	- 5

Capital

Since farm income has a low base in the West, shortages of investment capital for livestock and other purchases ensures the continuation of an extensive type agriculture. The productivity of investment in livestock will be measured in this study. It is generally conceded that additional investment in most categories of livestock would more than cover the marginal factor cost of such investment. If the

traditional reluctance to borrow could be overcome and lower interest loans offered, some headway could be made in increasing the investment base; leading in the long run to much higher farm incomes, assuming present input output price ratios are maintained. The intensification of the advisory service in the pilot areas will no doubt help to overcome this barrier.

Institutional factors

The problem of delinquent titles to holdings is a serious bottleneck to the development of many farms in the Western Region. Without a registered title, it is almost impossible for a farmer to secure long-term credit at market rates through the normal channels. This is a sufficient damper in holding up any large scale developments on many holdings. There is an obvious need for reform of the laws relating to titles since many farmers still die intestate.

Commonages

The commonages occur mainly on hill and mountain land and are largely open areas, the grazing rights to which are shared by a varying number of farmers from county to county. As a result of this sharing, lime and fertilizer are not applied in sufficient amounts, if at all. Farmers sometimes find it difficult to agree on separate responsibilities for the maintenance of these areas. This is largely due to the differential use of commonage as between farmers. Since land is a scarce resource, substantial increases in output could be achieved by rationalizing the use of these areas. The best approach possibly would be to divide them among individual farmers. If present use was used as an index of the size of allotments, these farmers would be worse off than previously and may even have to reduce their present scale of operation. The external observers in government and other power roles cannot really make comparisons of utility among the separate farmers involved in the division of commonages. It is possible, however, to say that the welfare of the group of farmers involved is increased if (1) every individual in the group is made better off or (2) if at least one member in the group is made better off without anyone being made worse off.[12] A formula could be worked out which would enable total output from the commonages involved to be increased. The distribution of the land would involve normative judgments which might be reconciled within the existing democratic framework.

Other factors impeding development

Inadequate market structures for selling and buying products and factors of production help in diminishing farm profits and in discouraging investment. The increased costs

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[12]James M. Buchanan and Gordon Tullock, The Calculus of Consent, logical Foundations of Constitutional Democracy, Ann Arbor Paperbacks, University of Michigan Press, 1969. p. 172. For further insights into the topic of optimality, value and utility theory, refer to J. R. Hicks, Value and Capital, Oxford University Press, London 1939, Introduction and Cl.

of factors of production, e.g., feedingstuffs in some areas remote from manufacturing and market locations, place an added burden on the smaller farmer. The smaller farmers also have a tendency to buy some factor inputs in small lots due to their small scale of operation, inadequate storage facilities and possible short-term operating cash shortages. This greatly increases the direct costs of operation in those areas relative to the more commercialized Eastern farmers. Another factor influencing low incomes is the absence of an adequate cooperative structure. Economies of operation and purchasing economies could be available in the purchasing of inputs or in the utilization of machinery if an organized cooperative structure existed. Forward contracts for livestock and other products could be forthcoming from purchasers and factories if farmers cooperated.

The discussion so far has been an attempt to highlight some of the major factors contributing to low incomes in Western Ireland agriculture. The next section attempts to give the reader some perspective on the establishment of pilot areas in the twelve western counties.

The Establishment of Pilot Areas in the West of Ireland

In April, 1961, the Minister for Agriculture set up a committee which included officials from the Department of Agriculture, Finance, Lands and Gaeltacht, the Central Statistics Office and the Agricultural Research Institute. They were directed to consider and report on sound and practicable measures to deal with the special problems of agriculture in the western part of the country where small farms predominate.[13] This committee outlined the major problems and offered a series of suggestions for possible action.

They attributed the decline in population and the lack of economic progress in the Northwest and West of Ireland to four main causes, having first acknowledged the poverty of the area's natural resources. These causes can be summarized as follows:[14]

1. The movement of young people to Britain where higher incomes and higher living standards prevailed.
2. The inability of the majority of farmers in those areas to benefit from fixed price crops and commodities such as wheat, barley, sugar beets and milk.
3. The loss of "farmyard" income from pigs, poultry and eggs and increased dependence on stock raising which

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[13] Report of the Interdepartmental Committee on the problems of small western farms. Government Publications Office, G.P.O. Arcade, Dublin Pr. 6540, p. 5.

[14] Ibid., pg. 7

under their particular conditions is extensive in the use of land, uncertain financially as a system of farming and not well suited to smallholders.

4. Lack of industrialization.

The continuous emigration from the western area indicates that agricultural activity in the area is not able to sustain the population. Off-farm migration usually results in departure from the area since the industrial base is insufficient to support the numbers leaving the farms. There seems to be no ready single solution to the complex problems involving economic, social, physical and human resources in the area. The committee offered a number of suggestions the most important of which are summarized below.

1. Greater powers for the Land Commission to enable them to handle structural problems.
2. Credit should be made available to suitable applicants for land purchase.
3. Intensive farming systems such as milk production, bull beef production on a commercial scale, pigs, eggs and horticultural production should be investigated and encouraged.
4. A comprehensive cooperative system should be developed in Western areas with the provision of state financial assistance for a period.

5. The Agricultural Advisory Services in western areas should be strengthened and state assistance toward this land provided.
6. County Development teams incorporating officials from the various government departments and local authorities should be established.
7. The weight of future efforts by the state should be directed to the possibilities of non-farm employment through industrialization, forestry, tourist development, etc.

In 1963, the committee was reconvened and asked "to furnish a report on the possibilities, with some assessment of the implications of pilot area development in the West." Its major recommendations were:[15]

1. Certain rural areas in the "small farm" counties of the West and North should be selected as pilot areas. They recommended that a pilot area should be established in each of the counties: Galway, Mayo, Sligo, Roscommon, Leitrim, Longford, Donegal, Cavan, Monaghan, Clare, Kerry and West Cork. For the approximate geographical location of these areas and counties, refer to the map. (Figure 2). The purpose of a pilot area would be to demonstrate what could be accomplished by community effort in making full and proper use

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[15] Inter-Departmental Committee on the Problems of Small Western Farms. Report on Pilot Area Development, The Stationery Office, Dublin (Pr. 7616), pp. 3-17.

of all available resources and facilities. Similar areas could possibly adopt results arising from the program.

2. The chief agricultural officers in each county should be responsible for the selection of the pilot area in each county as he would have technical and local knowledge to guide him. The criteria which he would apply in making his selection would take into consideration population and other resources of the area, the climate of local opinion, and the evidence of cooperation among farmers. The areas selected should be:
   a. Representative as far as possible of the small farm areas in the county.
   b. Holdings should be of such size that they would be capable of yielding an income sufficient to meet reasonable family needs.
   c. The size of the pilot area should be clearly identifiable, reasonably compact and homogenous and would provide a basis for whatever form of cooperation it was desirable to develop as time went on.[16] A community of 200 to 400 farmers was thought to be sufficient to satisfy the size criterion.

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[16] _Ibid._ p. 11.

3. Each pilot area should be assigned a full-time extension agent having access to the part-time assistance of any specialists required.
4. In the short-run, the program in each pilot area should be concerned with the improvement of existing activities and patterns of production. In the long run, other aspects of development outside agriculture would have to be dealth with.
5. Repayment of interest and capital on borrowed credit could be deferred for three years, while individual farmers new revenue-earning potential was being developed.
6. The Agricultural Credit Corporation should be encouraged to deal sympathetically with applications from the pilot areas which were supported by a farm plan drawn up by the extension agent. The latter would be responsible for supervising the programmed developments.
7. The Irish Agricultural Organization Society should participate in the pilot area development program and promote cooperative educational programs in the selected areas.
8. State grants for farm buildings and land reclamation in the pilot areas should be brought up to the level

already available to farmers in Gaeltacht areas.*

9. A local committee, consisting mainly of more enterprising and younger farmers, should be established to work with the extension agent on the selection and implementation of development projects.

The origin of the present study

The government acted on the suggestion for the establishment of pilot areas. In August, 1964, the first pilot areas were established in Sligo and Kerry. The other eight were established between September, 1964, and April, 1965. It is beyond the scope of this paper to deal with the advisory goals and methods, progress and achievements of the pilot areas to date. The present study is a detailed farm account study of a random sample of farmers from six of the pilot areas (Galway, Mayo, Roscommon, Sligo, Clare, Kerry.) It covered a two year period--1966 to 1968. Accounts were analyzed and data abstracted for the purpose of establishing marginal value productivities for various input categories. The derived coefficients and marginal value products were believed to be of value to farmers, extension agents, government and other officials.

The technique to be used and described next in this study should add to the present farm management knowledge in the areas studied and it is hoped derive reliable

*Gaeltacht areas are Gaelic speaking and generally underdeveloped. Grants for farm buildings in the Gaeltacht and pilot areas are generally 50 percent higher than elsewhere. Land reclamation grants are 75 percent of the estimated cost, subject to £50 maximum per acre.

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estimates of marginal value products. The Cobb-Douglas production function is one of the best known methods of deriving these estimates. It is used in this study and the theory underlying its use is described in the next chapter. Other techniques which could be used in estimating returns from farm reorganizations or productivity of added resources, under certain assumptions, include Budgeting and Linear Programming.

CHAPTER III

PRODUCTION FUNCTION ANALYSIS--
THE COBB-DOUGLAS FUNCTION

Production functions and underlying theory

The production function is usually expressed in the following form:

$$Y = f(X_1, X_2, \ldots, X_n)$$

where Y is the value or quantity of output and the X's are the inputs used. If there is no fixed factor (input) and if the inputs can be increased in constant proportions, then Y will increase in constant proportions. This is illustrated in Figure 3.

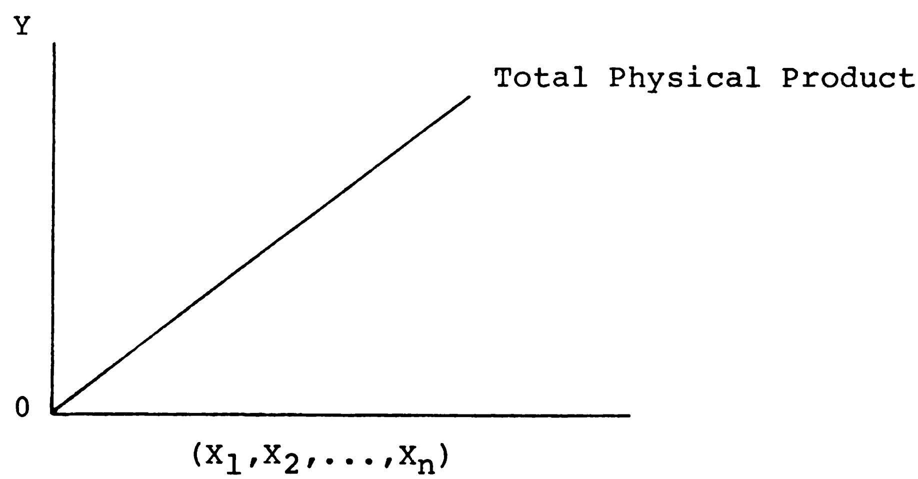

Fig. 3.--Total physical product, when inputs $(X_1, \ldots X_n)$ are all variable and increased in constant proportions.

If some inputs are held constant, e.g., land, labor, the "law of diminishing returns" holds true. This relationship can be written thus:[1] As a variable factor of production is added, in combination with a fixed factor, the total product will first increase at an increasing rate, second increase at a decreasing rate, finally, the total product will decrease.

Diminishing returns are caused by the presence of fixed inputs. The subfunction $Y = f(X_1X_2/X_3.....X_n)$ as shown in Figure 4 demonstrates the effect of fixing inputs $X_3...X_n$, while X_1 and X_2 vary. The three stages of the production function are illustrated in Figure 4. Stage I and III are both irrational areas of production. Stage II is the rational area to produce in. A necessary step in finding the optimum allocation of productive resources which will maximize profits, is the calculation of marginal value products and marginal factor costs. The physical relationships expressing actual total marginal and average products in Figure 4 are multiplied by the price of the product (Y) and converted to value productivity relationships. Marginal value products represent one part of the high profit point ratio. Marginal factor cost, is the other part and represents the costs involved in using the last unit of input and is equivalent to the minimum expected return. These

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[1] Glenn L. Johnson, and Lawrence A. Bradford, Farm Management Analysis (New York: John Wiley and Sons, Inc. 1953), p. 113.

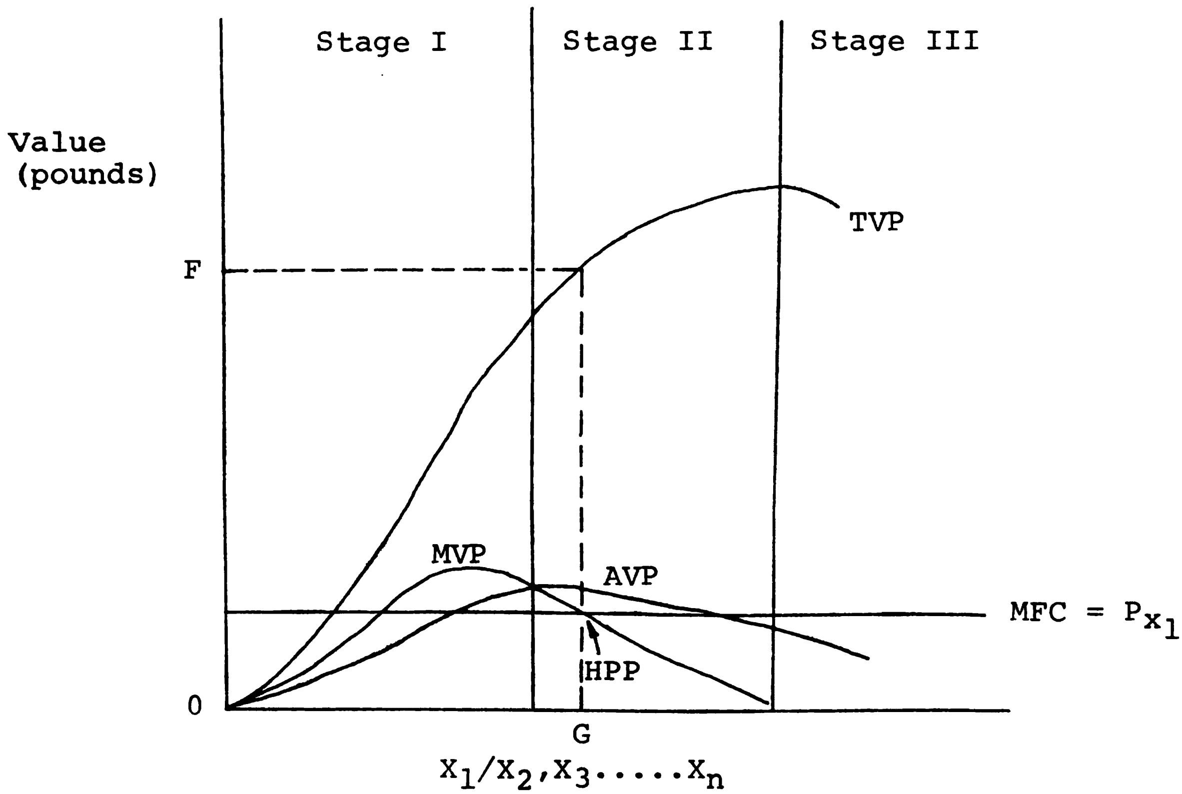

Fig. 4.--Illustration of the production function, showing the three stages of production and the operation of the law of diminishing returns.

relationships are shown by means of Figure 4. The optimum amount of an input (X_1) to use in the production of Y is found from the intersection of the price line Px_1 with the MVP curve. At this point, the value of the marginal product is equal to the cost of the last unit of input. If additional input is used beyond this point, the pounds returned from using another unit of input are less than the cost of the input. Use of X_1 up to the point of intersection is justified, since each additional unit of X_1 would earn a return in excess of its cost. The relationship of marginal factor cost ($MFC_{x_{1(y)}}$) and marginal value product ($MVP_{x_{1(y)}}$) which shows the optimum quantity of resource to use in the production of a product is:[2]

$$1. \quad MVP_{x_{1(y)}} = MFC_{x_{1(y)}} \quad \text{or} \quad \frac{MVP_{x_{1(y)}}}{MFC_{x_{1(y)}}} = 1$$

This expresses optimum resource utilization for one variable input. When there is more than one input involved in the production process, the optimum combination but not the optimum level is reached when the ratios between marginal factor cost (MFC) and marginal value product (MVP) are the same for each variable factor used. This ratio is expressed as:[3]

$$2. \quad \frac{MVP_{x_{1(y)}}}{MFC_{x_{1(y)}}} = \frac{MVP_{x_{2(y)}}}{MFC_{x_{2(y)}}} = \text{--} = \frac{MVP_{x_{n(y)}}}{MFC_{x_{n(y)}}}$$

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[2]Glenn L. Johnson and Lawrence A. Bradford, Farm Management Analysis, op. cit., p. 131.

[3]Ibid., p. 129f.

where x_1, x_2,....x_n are variable factors being combined together in a production process and where y is the product.

Two variable inputs can be represented on a three dimensional diagram and the optimum combination of the two inputs can be shown. Figure 5 represents such a diagram.

The circular lines represent isovalue product lines. Each of these lines connect all points of equal value and are analogous to the geographer's contour map used in delineating elevations. Each isovalue product line shows different combinations of X_1 and X_2 which yield that particular value product. As we move from the origin (0) to the northeast, higher value product is represented by each successive line until the point T is reached which is the top of the production hill. Additional increments of X_1 and X_2, after point T, would serve only to decrease total product and add to total costs under normal circumstances. The dotted lines represent all combinations of X_1 and X_2 which can be purchased for a given outlay. These are usually referred to as isocost lines. The point of tangency between an isocost line and the highest isovalue product line touched by it shows the greatest value of Y which can be produced for a given cost, e.g., isocost line CD is tangent to isovalue line C_3 at P. The point P then defines the optimum proportion of X_1 and X_2 to use in the production of that value of Y. This proportion is shown on this diagram by OB units of X_2 and OA units of X_1. This point, P,

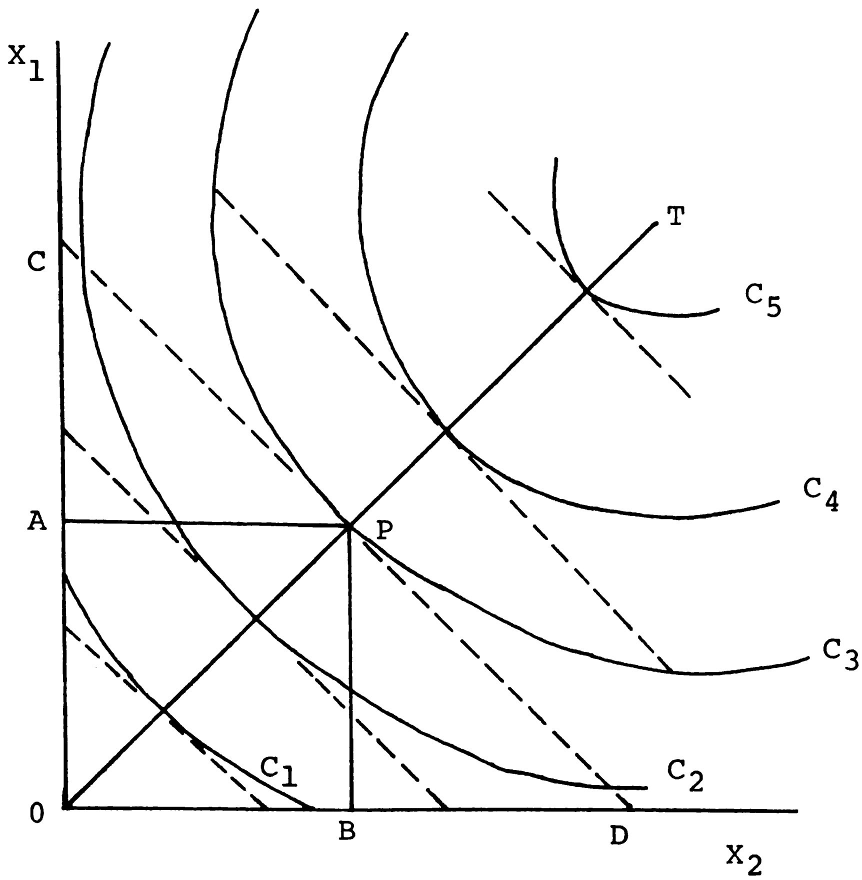

Fig. 5.--Isovalue product lines (C_1 .....C_5), with Isocost lines and scale line OT, using two variable inputs, X_1 and X_2.

satisfies the equation:

$$\frac{MVP_{x_{i(y)}}}{MFC_{x_{1(y)}}} = \frac{MVP_{x_{2(y)}}}{MFC_{x_{2(y)}}}$$

The other isocost lines shown in the diagram are all tangent to some particular isovalue product. If these points of tangency are connected by line OT, this line becomes the line of optimum proportions. The above equation holds along the scale line for the two inputs represented. More than two inputs cannot be shown diagramatically. Equation 2 hold for all inputs which can be used in production. It states that inputs are being used at optimum proportions provided the ratio between the respective marginal value products and marginal factor costs of the different inputs is held constant.

With increasing use of variable inputs in scale line proportions, the law of diminishing returns comes into operation. This results in the marginal value product of the inputs decreasing after a certain point and this continues until they are equal to their respective marginal factor costs. The effect of the law of diminishing returns on the marginal value products of inputs, which are combined in scale line proportions can be illustrated by two dimensional diagram. In the discussion so far, I have assumed no difference between acquisition and salvage price for inputs. So MFC acq. = MFC salvage. In a more thorough presentation, this assumption would have to change and the implications of our inadequately developed investment and disinvestment (asset fixity) theory would be examined.

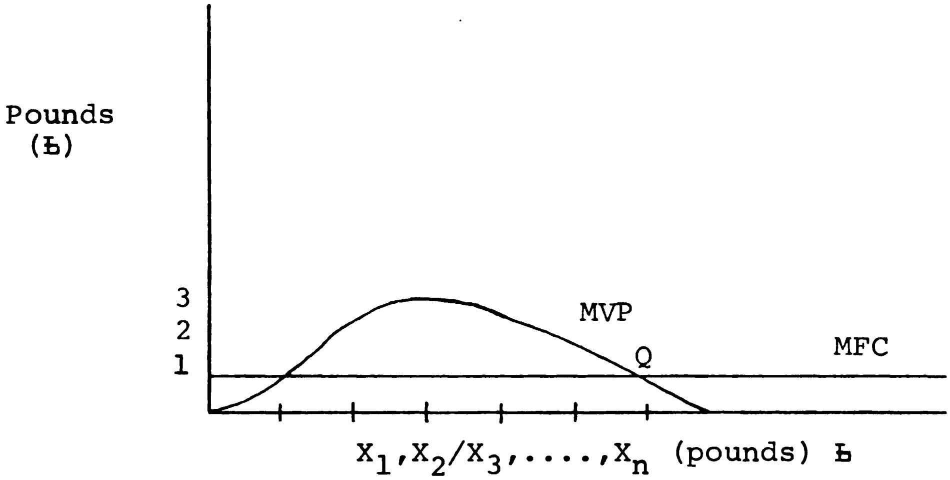

Fig. 6.--Illustration of the high profit point (Q) using two inputs X_1 and X_2 in scale line proportions, and holding the remaining inputs fixed.

In the above diagram, pounds sterling are represented on the vertical and horizontal axes. The law of diminishing returns as previously stated can be seen in the shape of the MVP curve. As more of the joint inputs X_1 and X_2 are used, MVP declines, after first increasing at an increasing rate and then at a decreasing rate. When the marginal value product falls to the point Q, where it becomes equal to the marginal factor cost, the condition for the optimum level of resource use of the joint inputs X_1 and X_2 hold. This can be represented algebraically by:[4]

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[4]*Ibid.*, p. 131.

$$\frac{MVP_{x_{1(y)}}}{MFC_{x_{i(y)}}} = \frac{MVP_{x_{2(y)}}}{MFC_{x_{2(y)}}} = \ldots\ldots = \frac{MVP_{x_{n(y)}}}{MFC_{x_{n(y)}}} = 1$$

The basic principles outlined so far underlie the use of algebraic functions such as the Cobb-Douglas, which provides estimates of returns to various input categories. The derived estimates aid the manager in examining returns to various inputs or categories of inputs. The estimates of productivity coefficients, however, are open to many sources of error. There are theoretical shortcomings in the method of data collection, in the aggregation of inputs into various categories; and errors result from uncontrollable factors like weather, economic fluctuations and management differences.

Marginal analysis and the Cobb-Douglas function

Efficiency can be measured by the principles of marginal analysis. Marginal return is the ratio of change in total product for a change in input. Efficiency and maximum profit are achieved when the marginal product of inputs and investments are at a point where any possible shift in resources to other uses would cause a decrease in total product. The use of Cobb-Douglas analysis is an algebraic method which uses marginal analysis in deriving input-output data. The equation which is now known as the Cobb-Douglas originated with Wicksell. His function appeared as:

$$P = a^{\alpha} b^{\beta} c^{\gamma}$$

where ∝, β, y, summed to 1.[5]

Production functions were used in the analysis of empirical data by Paul H. Douglas[6] and Charles W. Cobb[7] in 1927-1928. They fitted a function to data for American manufacturing industries for the years 1899-1922. The function fitted was linear in logarithmic form constrained to be homogenous in the first degree, and was fitted by least squares regression. The function appeared as:

$$P = bL^{k}C^{1-k}$$

The variables in the equation were P, L, C, where P was the predicted index of manufacturing output over the period, L was the index of employment in manufacturing industries, and C was the index of fixed capital in industry. Cobb and Douglas selected the above function and its restriction that the sums of elasticities or regression coefficients should equal one because they wished to impute total product (P), back to two factors L and C.

This restriction built into the production function, the assumption of constant returns to scale. A proof of

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[5] Earl O. Heady and John L. Dillon, Agricultural Production Functions (Iowa State University Press, 1961) p. 16.

[6] Paul H. Douglas, Theory of Wages (New York: The Macmillan Company, 1934) p. 152.

[7] Charles W. Cobb and Paul H. Douglas, "A Theory of Production," The American Economic Review, Supplement, XVIII, (March, 1928), pp. 139-165.

this is shown in the footnote below.* Durand[8] suggested that this restriction should be relaxed and Douglas and his co-workers revised the formula to allow k and j to take on any value as in Wicksells original formulation. The function was then represented as:[9]

$$P = bL^kC^j \ , \qquad k + J \gtreqless 1$$

This function allows increasing or decreasing returns to scale to be reflected in the total product. The exponents k and j are the coefficients of elasticity of P with respect to L and C. b is a constant term. This power function is linear in logarithms and is the most common form of the Cobb-Douglas function. The function allows for increasing

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*Footnote: Consider the Cobb-Doublas function

$P = f(C,L) = bC^kL^{1-k}$

where b and k are positive constants and $0 < k < 1$. If C and L are increased in the proportion then

$$\begin{aligned} f(\lambda C,\lambda L) &= b(\lambda C)^k \ (\lambda L)^{1-k} \\ &= b\lambda^k.\lambda^{1-k}.C^kL^{1-k} \\ &= b\lambda C^kL^{1-k} \\ &= \lambda (bC^kL^{1-k} \\ &= \lambda f(C,L) \\ &= \lambda p \end{aligned}$$

So, if the inputs C, L, are expanded in the same proportion, output is expanded in that proportion.

[8]David Durand, "Some Thoughts on Marginal Productivity with special reference to Professor Douglas' Analysis," Journal of Political Economy, 45 (Dec., 1937), pp. 745-758.

[9]Paul H. Douglas, "Are There Laws of Production?" The American Economic Review, Vol. 38, No. 1 (March, 1948) pp. 1-41.

constant and decreasing returns to scale and has become popular in fitting production relationships to agricultural firm data.

The use of the Cobb-Douglas Function in agricultural firm analysis

The earlier applications of the function revolved around experimental data and industry functions. The major application in agriculture has been to cross sectional observations of enterprises on farms. Tolley, Black and Ezekiel[10] fitted production functions to farm data in 1924. Gerhard Tintner[11] used production functions to derive productivity estimates of various input categories for 609 Iowa farms for the year 1942. A similar study by Tinter and Brownlee, using farm account records of 468 Iowa farms and deriving estimates of earning power for various inputs and investments, was made for the year 1939.[12]

Heady derived production functions using a random sample of 738 Iowa farms. The data used was collected in 1939 by interview.[13] In this study, functions were derived

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[10]H. R. Tolley, J. D. Black, M. J. B. Ezekiel, "Input as related to Output in Farm Organization and Cost of Production Studies," Tech. Bull. 1277, USDA, Washington D.C. 1924.

[11]Gerhard Tintner, "A note on the derivation of production functions from farm records," Econometrica XII., No. 1, January, 1944, pp. 26-34.

[12]Gerhard Tintner and D. H. Brownlee, "Production Functions Derived from Farm Records," Journal of Farm Economics XXVI, Aug. 1944, pp. 566-571.

[13]Earl O. Heady, "Production Functions from a Random Sample of Farms," Journal of Farm Economics, 28, No. 4, Nov., 1946, pp. 989-1004.

for types of farms and areas of the state. The inputs used throughout the study were land, labor, equipment, livestock and feed, and miscellaneous operating expenses all in dollar terms. The sum of the elasticities for each function fitted was less than one. This indicates decreasing returns to scale. Heady comments on the absence of an objective measure for management in this study and states that the results might well have differed had it been possible to measure the input of this factor.[14] Fienup[15] at Montana State College used a random sample of wheat farmers in a study of resource productivity on Montana dry-land crop farms for the year 1950. Drake[16] at Michigan State College used farm account records for the year 1950 to estimate marginal productivity of various inputs. He outlined some of the problems encountered in the derivation of value productivity estimates from farm records.

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[14]E. O. Heady and John L. Dillon, Agricultural Production Functions, Iowa State University Press, 1961, p. 28.

[15]Darrell F. Fienup, Resource Productivity on Montana Dryland Crop Farms, Mimeograph Circular 66 (Bozeman: Montana State College, Agricultural Experiment Station, 1952.

[16]Louis Schneider Drake, Problems and Results in the use of Farm Account Records to Derive Cobb-Douglas Value Productivity Functions, unpublished Ph.D. thesis, Dept. of Agricultural Economics, Michigan State University, 1952.

Johnson[17] at the University of Kentucky in 1952 used a "purposive sampling" technique to select 234 western Kentucky farms. He fitted a Cobb-Douglas function to these and came up with estimates of the earning power of various input categories. Similar studies using purposive sampling techniques have been done by Toon[18] at Kentucky and Wagley[19] at Michigan State. Wagley states that the purposive sample can be somewhat smaller than random or farm account samples as they are drawn from a limited geographical area (usually a type of farming area within a country) but cover a wide range with respect to the independent variables (inputs.)[20]

In purposive sampling, an attempt is made to select farms so as to include imperfectly adjusted farms, i.e., farms which are not in scale line adjustment. This helps to reduce intercorrelation among the input categories and the

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[17]Glen L. Johnson, Sources of Income on Upland Marshall County Farms, Progress Report No. 1, and Sources of Income on Upland McCracken County Farms, Progress Report No. 2, (Lexington: Kentucky Agricultural Experiment Station, 1952.)

[18]Thomas G. Toon, The Earning Power of Inputs, Investments, and Expenditures on Upland Grayson County Farms during 1951, Progress Report No. 7, (Lexington: Kentucky Agricultural Experiment Station, 1953.)

[19]Robert Vance Wagley, Marginal Productivity of Investments and Expenditures, Selected Ingham County Farms, 1952, (Unpublished M.S. thesis, Dept. of Agricultural Economics, Michigan State University, 1953.

[20]*Ibid.*, p. 19.

data is chosen over a sufficient range to enable the computation of reliable estimates of the regression coefficients and their calculated marginal value productivities. Subsequent to Johnson, Toon and Wagley's work, several modifications and additions to the Cobb-Douglas function have been made at Michigan State by Carter[21] and Trant.[22]

Statistical problems in the estimation of Cobb-Douglas Functions

1. Errors in observation occur, e.g., inventory valuations of livestock; adjusting acreage.
2. Errors occur due to the human element, e.g., data computations.
3. Problems in aggregating inputs.

These occur when the inputs are not homogenous either within or between farms. Variations in quality occur in the measurement of land, labor and capital in cross sectional surveys. In the case of land variations in quality and soil type can occur from field to field and within any particular farm and between farms. The standardization of land into a homogenous input category is a difficult task. In the present study, the extension agent in each pilot area was asked to adjust the acreage on the farms sampled. It is not

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[21]Harold O. Carter, Modifications of the Cobb-Douglas Function to Destroy Constant Elasticity and Symmetry, Unpublished M.S. thesis, Department of Agricultural Economics, Michigan State University, 1955.

[22]Gerald Ion Trant, A Technique of Adjusting Marginal Value Productivity Estimates for Changing Prices, Unpublished M.S. thesis, Department of Agricultural Economics, Michigan State University, 1954.

possible to get very meaningful results unless inputs and investments are grouped into independent categories. Johnson[23] suggests the following conditions as guides to be followed in grouping the inputs into categories having a meaningful relationship with gross income and selecting a suitable unit of measurement.

1. That the inputs within a category be as nearly perfect substitutes or perfect complements as possible.
2. That categories made up of substitutes (a) be measured according to the least common denominator (often physical) causing them to be good substitutes and (b) be priced on the basis of the dollar value of the least common denominator unit.
3. That categories made up of complements (a) be measured in terms of units combined in the proper proportions (which are relatively unaffected by price relationships) and (b) be priced on an index basis with constant weights assigned to each complementary input.
4. That the categories of inputs be neither perfect complements nor substitutes relative to each other.
5. That investments and expenses be kept in separate categories.
6. That maintenance expenditures and depreciation be eliminated from the expense categories because of

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[23]Johnson and Bradford, _op. cit._, p. 144.

the difficulty encountered in preventing duplication. (This means that the earnings of the investment categories must be large enough to cover maintenance and/or depreciation.)

Johnson[24] states that, "The first three of the above conditions are desirable in order to insure that the inputs, within each category, are combined in the proportion dictated by the scale line in the uncategorized production function: $Y = f(X_1, X_2, --- X_n)$." It is not possible to include all factors affecting gross output in the above set of rules. Weather, economic factors, management and other factors are excluded because of problems of definition and measurement. These nonstudied variables, however, are assumed to be (1) normally and randomly distributed, (2) they do not bias the estimated marginal value products of the independent variables studied.

In examining the literature on Cobb-Douglas functions, many different classifications have been used in measuring input and output variables studied. The rules established by Johnson can be seen in application in the Kentucky studies.[25] In these studies, gross income (X_1) included all receipts from sales of crops, livestock and livestock products, plus changes in inventories and the value of products

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[24] Ibid., p. 145.

[25] Glenn L. Johnson, Sources of Income on Upland Marshall County Farms and Sources of Income on Upland Mc Cracken County Farms, op. cit., and Toon, op. cit.

used in home consumption. Input categories included land (X_2) in total acres, labor (X_3) in months, livestock and forage investment (X_4) in dollars, machinery investment (X_5) in dollars and current operating expenses (X_6) in dollars. In grouping inputs, the complementarity between livestock and forage investment resulted in these being aggregated into one category. The purposive sampling technique used in the Kentucky studies[26] allows for the selection of farms with a wide range in the proportions and quantities of inputs. This enables a reduction in the intercorrelation between the input categories and reduces the standard errors of the regression coefficients.

<u>The Cobb-Douglas production function as used in this study</u>

The Cobb-Douglas function in its general form and as used in this study can be represented by:

$$Y = aX_1^{b_1}, X_2^{b_2}, \ldots, X_n^{b_n}$$

The exponents (b_i's) in the equation represent the elasticities of the independent variables $X_1 \ldots X_n$ with respect to the dependent variable Y.

The value of any b_i, shows the percentage change in gross output (Y) resulting from a one percent change in the particular input category associated with the b_i and holding all other inputs constant.

The "a" in the equation is a constant term. The function when converted to logarithms is linear and can be

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[26] *Ibid.*

represented by:

$$\log Y = \log a + b_1 \log X_1 + b_2 \log X_2 \ldots\ldots + b_n \log X_n$$

Modern computer programs provide an easy method of fitting the function, using least squares regression techniques and calculating several statistics including the b_i's and their significance levels determined by "t" tests. Having calculated the elasticities (b_i's), they can be used to estimate marginal value products for each input category and expected gross output for the average farm using the geometric mean inputs in the above equation.

The formula for calculating the marginal value product which is the change in gross output resulting from an increase in the use of an input (X_i) with other inputs held constant is represented as:

$$MVP_{X_i} = \frac{b_i\ E(Y)}{X_i}$$

where E(Y)[27] is the expected gross output from the set of X_i's used.

Having calculated the estimated marginal value products for each input category, a comparison can be carried out between these figures and the estimated marginal factor cost involved in using each category of input.

If the comparisons show that a significant difference exists between the marginal value products and their

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[27]E(Y) is the antilog of the equation:

$\log Y = \log a + \sum_{i=1}^{n} (b_i \log GX_i)$, where $G(X_i)$ is the geometric average quantity of input in each input category.

associated marginal factor costs, then a reorganization of the particular input category showing a significant difference can be recommended. Different quantities of inputs can be used until the equation below holds.

$$\frac{MVP_{x_{1(y)}}}{MFC_{x_{1(y)}}} = \frac{MVP_{x_{2(y)}}}{MFC_{x_{2(y)}}} = \ldots\ldots = \frac{MVP_{x_{n(y)}}}{MFC_{x_{n(y)}}}$$

This will give the optimum combination of inputs to use in the production of Y.

Having determined the optimum combination of inputs to use, the use of these inputs combined in optimum proportions can be changed until the following equation holds true:

$$\frac{MVP_{x_{1(y)}}}{MFC_{x_{1(y)}}} \quad \frac{MVP_{x_{2(y)}}}{MFC_{x_{2(y)}}} = \ldots\ldots = \frac{MVP_{x_{n(y)}}}{MFC_{x_{n(y)}}} = 1$$

When suggesting reorganizations, one should stay within the range of the observed study data and avoid extrapolating. The sum of the b_i's in this study can be equal to, less than, or greater than one. If they are equal to one, constant returns to scale can exist for the function. If the sums of the b_i's are greater than one, increasing returns to scale can exist and decreasing returns to scale is indicated if the sum of the b_i's is less than one.

Advantages of using the Cobb-Douglas Function

Tintner[28] gave the following reasons to justify using the function:

1. It gives immediately elasticities of the product with respect to the factors of production.
2. This form of the production function permits the phenomenon of decreasing marginal returns to come into evidence without using too many degrees of freedom.
3. If the errors in the data are small and normally distributed, a logarithmic transformation of the variables will preserve the normality to a substantial degree.

Johnson[29] gave the following four main advantages of the Cobb-Douglas which together with Tintner's are the major reasons why this analysis is so often used. These were:

1. It permits diminishing returns due to size of operation and lack of balance in a farm business to be reflected in the estimates of earning power.
2. The estimates of earning power refer to the gross income produced by the last unit of the input used;

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[28]Gerhard Tintner, "A Note on the Derivation of Production Functions from Farm Records," Econometrica, XII, No. 1, (January, 1944), pp. 26-27.

[29]Glenn L. Johnson, The Earning Power of Inputs and Investments on Montgomery Community Farms, Trigg County, 1951 Progress Report No. 9, March 1953, Kentucky Agricultural Expt. Station, p. 2.

such estimates are particularly useful because a farmer considers the earning power of what he is going to add or subtract instead of the average earning power so commonly estimated.

3. It permits the earning powers of the separate inputs and investments to be estimated simultaneously without assuming the earning power of the other inputs. In short, data from actual farm businesses determine the earning power estimates rather than having the estimates partially determined by the assumed earning power of the other inputs in in-investment.
4. The method yields estimates reflecting the effect of changes in the earning power of one investment or input on the earning powers of other investments and inputs.

Disadvantages of the Cobb-Douglas

Among the disadvantages are the following listed by Carter:[30]

1. The function is limited to handle relationships for firms in only one stage of production at a time because the coefficients of elasticity are constant over the entire range of the function.

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[30]Harold O. Carter, "Modifications of the Cobb-Douglas function to destroy constant elasticity and symmetry," Unpublished M.S. Thesis, Department of Agricultural Economics, Michigan State University, 1955, pp. 11-14.

2. The function always originates at $Y = X_2 = 0$ and in addition if any $X_1 = 0$, then $Y = 0$.
3. Symmetry of the function implies that there is an unlimited range in which the proportion of any two inputs could be used to produce a given level of output.

Other disadvantages of the Cobb-Douglas which are often found in other farm management analyses techniques include the problem of measuring management. Since no satisfactory measurement for management has appeared, the factor is left out of this study.

CHAPTER IV

FARM INCOME SURVEY OF WESTERN IRELAND PILOT AREA FARMS

The survey for this study was conducted in six pilot area counties over a two year period, 1966-68. The counties selected were Galway, Mayo, Roscommon, Sligo, Clare and Kerry. A ten percent random sample was chosen from each pilot area. Table 3 shows the number of farms in each pilot area at the inauguration of the pilot area program. It also shows the number of farmers who kept account books on their farming operations over a two year period for this survey. This number was somewhat less than the original ten percent sampled. This occurred due to dropouts over the period.

The sample data was collected over a two year period in order to eliminate wide price fluctuations. In the selection of farms for the purpose of constructing marginal value products of the input categories, more reliable marginal value products can be calculated, if the farms used in the analysis are fairly homogenous with respect to the non studied variables. This is difficult to achieve, especially since the present survey includes a wide range of managerial capacity within each area.

TABLE 3

DISTRIBUTION OF SAMPLE FARMS, BY PILOT AREA AND DATE OF THE PROGRAM.

County	Number of Farms	Program Commenced	Number of Farmers Keeping Accounts	Sample as a Percent of the Total
Galway	267	Dec. 1964	22	8.2
Mayo	272	March 1965	23	8.5
Roscommon	372	Nov. 1964	23	6.2
Sligo	413	Aug. 1964	28	6.8
Kerry	212	Aug. 1964	17	8.0
Clare	580	Feb. 1965	52	9.0
Total	2216		165	7.4

The following conditions outlined by Wagley[1] help to achieve a certain degree of homogeneity if met:

1. The farms in the group must have about the same inherent productive capacity. This requirement could be fulfilled to a great extent by choosing farms within a limited geographic area and having about the same soil type association.
2. All farms must be using about the same technology. This condition is easily met if inputs are grouped

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[1]Robert Vance Wagley, "Marginal Productivities of Investments and Expenditures, Selected Ingham County Farms, 1952," M.S. Thesis, Michigan State University, 1953, p. 31.

according to the rules mentioned earlier.

3. The inputs within each input category should be combined in the best possible proportion within each category.

If these conditions can be reasonably approximated, similar quantities of inputs would effect gross output in the same way from farm to farm.

Inputs used in describing the function

The input categories derived from farm accounts in the different areas included the following variables:

X_1, gross output as the dependent variable.

X_2, livestock investment in pounds.

X_3, variable non-labor costs in pounds.

X_4, machinery costs, in pounds.

X_5, adjusted acres.

X_6, labor units, in man equivalents.

(a) Gross Output.--Gross output included the value of cash sales of farm products less purchases plus or minus adjustments for inventory changes in livestock and crops. It also included an allowance for farm produce used by the household. Subsidies accruing from the various government schemes were included in calculating the dependent variable. The figure used in this study is the average gross output over the two year period 1966-68.

(b) Livestock Investment.--This figure is designed to measure the investment in livestock as a whole. The largest part of the livestock investment figure accrued from the cattle and dairy herd. It also includes investments in sheep, pigs, horses and poultry. The figure is the sum of the beginning inventory of stock in 1966 plus the closing inventory 1967, or the opening inventory in 1967, plus the closing inventory in 1968, divided by three.

(c) Variable Non-labor Costs.--This figure includes all current expenses on the farm, with the exception of rates and rent, labor hire, machinery depreciation, operating costs and that portion of car, telephone and electricity not directly attributable to the farm operation.

Inputs included are fertilizer, feed, seeds, livestock maintenance, transportation costs and other miscellaneous items. This resource category combines those items from which the farmer would expect a pound for pound return within the accounting year.

(d) Machinery Costs.--This figure included depreciation, fuel and oil expenditures, tractor and other machinery operating costs. This is not an actual measurement of investment in machinery, but it is hoped that in some way it reflects the investment. (The real input during the production period is units of service from the machinery investment).

If straight line depreciation holds true, the results would be substantially the same as if machinery inputs had been measured in terms of depreciation rather than inventories. However, when the depreciation is other than straight line, the two are not necessarily parallel.[2] In this study ten and twenty percent depreciation was used on non-power and power machinery respectively. It is required in Cobb-Douglas fitting that some quantity of input be used if output is to be non zero. In County Kerry pilot area, two farmers had zero machinery costs. In both cases a figure of one pound was substituted for zero, for computation purposes.

(e) Labor.--The labor input was estimated on the basis of labor units used. A labor unit is a male over eighteen years of age, working full time on the farm. For males under eighteen years and for females the adult male equivalents are:[3]

Males	16-18 years	3/4
Males	14-16 years	1/2
Females	Over 16 years	2/3
Females	14-16 years	1/2

In adjusting labor for estimational purposes, an effort was made to represent the labor input actually used in deriving the particular gross output. Time

[2]Earl O. Heady, "Production Functions from a random sample of farms," Journal of Farm Economics, 28, No. 4, pp. 989-1004, Nov. 1946.

[3]J. F. Heavey, B. C. Hickey, and J. Gaughan, Farm Management Survey 1966-67, An foras taluntars, 33 Merrion Rd. Dublin 4, p. viii.

spent off the farm at non-farming activities has been excluded. The variation in labor quality due to age, hired labor and other factors is partially taken care of in the adjustment equivalents. Family and hired labor were grouped together and represent the labor unit input. This measurement unit does not differentiate between hours worked by different labor units, nor is there any allowance for differences in labor productivity.

The accounts did not give any breakdown between direct and indirect labor. Direct labor can be thought of as labor used for milking, feeding, animal care, while indirect would include time spent in repairing investment items. The labor input used here includes both direct and indirect.

(f) Land.--Land was measured in adjusted acres. The pound value of the land was not used. The latter approach does not always reflect the true income earning capacity of the land. The adjusted acreage figure gives a more accurate picture of actual land input than the total area of the farm. The farm is adjusted using a "best acre for the area" as a common denominator for comparison. Objections to this method may arise because the different extension agents in the different pilot areas may have used different subjective criteria before arriving at an adjusted acre figure. Variations in land quality occur from farm to farm and within farms, so the adjustments can at best be only approximations in the absence of precise knowledge on soil types and other quality differentials. The effect of differences in land quality could be related to differences in the use of other inputs since the best land is probably farmed the most intensively. This will be true whether we use a rent/rate approach or whether we use actual farm size or adjusted acres.

In 1962, a joint British and Irish Farm Accounts Survey was carried out and Cobb-Douglas functions fitted to the data.[4] Land input was represented by rent and rates (which included rent paid for an acre of land.) This approach was taken instead of adjusted acres because the residual variances from the regression using rent and rates with other independent variables were smaller than those using acres with the same independent variables except in the case of subsistence farms, where the differences were very slight. Error in the rent/rate approach may arise also from the weighting attached to farmers who have a relatively high amount of land rented. They pay more per acre rented than owned.

Another shortcoming of this approach is that the amount of rates paid is not a sure guide to the quality

[4]K. Rasmussen and M. M. Sandilands, University of Nottingham, "Production function analyses of British and Irish Farm Accounts," 1962.

of land farmed in Ireland. They have been based on the Griffith Valuation, which was conducted during the 1853-1865 period. Some of the land valued at close to zero then because of heather, scrub and unsuitability for the predominant crops of the time is now among the most productive. Thus, it is felt that standardization of the land input on the basis of adjusted acres may have been the most uniform method in treating land for this analysis.

All the farms in the survey were using the same types of technology. The farmers were using the same input categories. These categories were designed to be as near perfect substitutes or complements of each other as possible.

Maintenance expenses on buildings and the costs of new farm buildings, new fences, gates and roadways, land reclamation, water supply, and tree planting were excluded from input categories as these were classified as capital expenses.

Likewise, grants received for land reclamation, farm buildings and other capital investment items were excluded from gross output.

Farm buildings were not used as an input category in this study. There was no market price for existing farm buildings which could reflect their earning power as an asset.

CHAPTER V

FITTING THE PRODUCTION FUNCTIONS AND ANALYSIS OF THE STATISTICAL RESULTS

Marginal analysis will be employed to determine the marginal return to resources in this chapter.[1] The derived coefficients will be examined for possible adjustments which are necessary in the organization of some farms. Comparison of marginal value products and their marginal factor costs and evaluation of the results will be discussed here together with statistical measures used to test the reliability of the results. The equation used for the Cobb-Douglas function is:

$$Y = aX_1^{b_1} X_2^{b_2} \ldots X_n^{b_n}$$

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[1]The marginal value product of a factor (X_i) is obtained by taking the partial derivative of the production function with respect to that factor.

1) $Y = AX_1^{b_1}X_2^{b_2} \ldots X_i^{b_i} \ldots X_n^{b_n}$

2) $\frac{\partial Y}{\partial X_i} = AX_1^{b_1}X_2^{b_2} \ldots b_i X_i^{b_i - 1} \ldots X_n^{b_n}$

3) $\frac{\partial Y}{\partial X_i} = \frac{b_i (AX_1^{b_1}X_2^{b_2} \ldots X_i^{b_i} \ldots X_n^{b_n})}{X_i}$

4) $\frac{\partial Y}{\partial X_i} = \frac{b_i Y}{X_i} = MVPx_i$

All inputs (X_i's) are at the geometric mean. The marginal value product can be calculated for any level of Y or X_i which lies within the range of the data used to estimate the function.

The data from the accounts are converted to logarithms and fitted to the function by the least squares technique. The data were used as the basis for two regressions. The first regression was fitted to all the inputs described in the previous chapter. This regression was done on a county by county basis for each of the six county pilot areas and for all pilot areas combined. It was also fitted to Clare and Kerry pilot areas combined and to Galway, Mayo, Roscommon and Sligo together.

First function results.--The results from fitting the Cobb-Douglas for the sample of all farms (165) was:

$$Y = 1.71X_1^{.62}\ X_2^{.35}\ X_3^{.09}\ X_4^{-.06}\ X_5^{.13}$$

where

Y = gross output

X_1 = livestock investment

X_2 = variable non-labor costs

X_3 = machinery costs

X_4 = adjusted acres

X_5 = labor units

The regression coefficients, their standard errors and levels of significance and calculated marginal value products are shown in Table 4. The "t" test of the regression coefficients showed the b_i values of all the independent variables were found to be highly significant when tested against the null hypothesis that the regression coefficients taken individually were equal to zero. There was one exception, however. The coefficient for acres was

TABLE 4

REGRESSION COEFFICIENTS (b_i's) THEIR STANDARD ERRORS (σb_i's), AND LEVEL OF SIGNIFICANCE AND ASSOCIATED MVP'S AT THE GEOMETRIC MEAN ORGANIZATION. ONE HUNDRED AND SIXTY-FIVE PILOT AREA FARMS 1966-68

Input category	b_i	σb_i (2)	Significance level	MVP's pounds
Livestock Investment (X_1)	.617941	.080221	.0005	0.491
Variable non-labor costs (X_2)	.351217	.046438	.0005	1.794
Machinery Costs (X_3)	.087843	.026632	.001	1.898
Adjusted Acres (X_4)	-.062450	.064451	.334	-1.187
Labor Units (X_5)	.132741	.054226	.015	61.585

(2) The formula from which the standard error b_i is calculated from and which determines the precisions of the regression coefficient estimates can be represented as[2]

$$\sigma_{b_{x_i}} = \sqrt{\frac{\Sigma \bar{u}^2}{n\sigma_{x_i}^2 \,(1-R^2_{x_i,(X_1 \ldots X_h,\ X_j \ldots X_n)})}}$$

where ΣU^2, is the sum of the squared unexplained residuals. (These should be minimized in order to reduce $\sigma_{b_{x_i}}$.)

n, is the number in the sample. (This should be maximized in order to reduce $\sigma_{b_{x_i}}$.)

$\sigma^2_{x_i}$, is the variance of X_i. (Try to maximize the variance to reduce $\sigma_{b_{x_i}}$.)

$R^2_{x_i}(x_1 \ldots x_h,\ x_j \ldots x_n)$, is the percentage variance in X_i explained by the other studied variables. (Try to minimize to reduce $\sigma_{b_{x_i}}$.)

[2] Mordecai Ezekiel, Methods of Correlation Analysis (2nd Ed.), New York, John Wiley and Sons, Inc., 1949, p. 502.

not significantly different from zero at any acceptable level. The sum of the b_i's was 1.13. The constant log (a) was computed as .231945. The Cobb-Douglas function in logarithmic form for the total survey can be written as:

$$\log Y = 0.231945 + (.617941) \log X_1 + (.351217) \log X_2 + (.087843) \log X_3 - (.062499) \log X_4 + (.132741) \log X_5$$

The multiple correlation coefficient (R) was .94. The coefficient of determination (R^2) was .88, which indicates that eighty-eight percent of the variance in the logarithms of the dependent variable (gross output) was associated with the independent variables. The unexplained variance, 12 percent, was probably due to unmeasured independent variables such as management, weather conditions, economic influences and institutional influences. It is assumed that the effect of these variables (which were external to the study) on gross output, were randomly and normally distributed.

The logarithm of gross output at the geometric mean was 2.7232, the antilog of which is 528.6 pounds (Table 5.) The Standard Error of estimate ($\overline{S}$) of the dependent variable was .111327. Therefore, under random sampling conditions and given the prices, weather and other unstudied independent variables in the 1966-68 period, 67 percent of the time the logarithms of actual gross output would fall within the range 2.7232 ± .111327 or between the fiducial limits of 409 pounds and 683 pounds. So one out of every three farmers on average would be expected to have output greater than 683 or less than 409 pounds. The regression coefficients with their standard errors and the marginal value product at the geometric mean quantities are shown in Table 5.

TABLE 5

USUAL ORGANIZATION AND ESTIMATED MARGINAL AND GROSS VALUE PRODUCTS ONE HUNDRED AND SIXTY-FIVE PILOT AREA FARMS, 1966-68

Input Category	Quantity of Inputs*	log GX_i*	b_i's	log $GX_i \cdot b_i$	MVP** pounds
Livestock Investment (X_1) ₤	665.8	2.82333	.6179	1.74454	.491
Variable non-labor costs (X_2) ₤	103.5	2.01485	.3512	.70762	1.794
Machinery Costs (X_3) ₤	24.45	1.38843	.0878	.12190	1.898
Adjusted Acres (X_4)	27.83	1.44451	-.0625	-.09028	-1.187
Labor Units (X_5)	1.139	.05620	.1327	.00746	61.585

log constant (a) = .231945

$$\log Y \text{ (gross output)} = \log a + \sum_{i=1}^{5} (b_i \log GX_i)$$

$$= .23195 + 2.49124$$

$$= 2.7232$$

Antilog E (Y) = 528.6 pounds

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*[3]Fredrick E. Croxton and Dudley J. Cowden, Applied General Statistics, (New York: Prentice Hall Inc., 1939) p. 721.

The quantity of inputs shown above represents the geometric mean quantity or the usual farm organization and differs from the arithmetic mean quantity. The geometric mean is defined as the Nth root of the product of N items which is written symbolically as:

$$\sqrt[N]{X_{i_1} \cdot X_{i_2} \cdot X_{i_3} \ldots . X_{i_n}}$$

The computation is usually carried out by means of logarithms thus

$$\log GX_i = \frac{\log X_{i_1} + \log X_{i_2} + \ldots + \log X_{i_n}}{N}$$

$$^{**}MVP_{x_i} = \frac{b_i \text{ (EY)}}{X_i}$$

where b_i is the regression coefficient, E(Y) is the antilog of log Y or the geometric average gross output and X_i is the geometric average quantity for any particular input category for which an MVP can be calculated.

Estimated marginal value products

The marginal value product estimates are shown in Table 5, and their individual calculation in Appendix A. The marginal value product is the return to the last unit of each input category. In this case, the last pound invested in livestock was estimated to be earning .491 pounds, the last pound of variable non-labor costs was earning 1.794 pounds, the last pounds of machinery costs earned 1.898 pounds, the last acre of land earned 1.187 pounds and the return on the last labor unit is 61.585 pounds. The marginal value products are derived from the regression coefficients (b_i's). The significance of the marginal value products is related to the significance of the regression coefficient estimates.

The usual method of establishing the significance of regression coefficients is to test them against zero as the null hypothesis. In Table 4, it can be seen that the regression coefficients for livestock investment (b_1) and variable non-labor costs (b_2) are highly significant, differing from zero at less than the .05 percent level. Machinery costs (b_3) differed from zero at the 0.1 percent level and is also highly significant, while the regression coefficient for labor (b_5) differed from zero at the 1.5 percent level. The regression coefficient for land or adjusted acres (b_4) was not significantly different from zero at any acceptable significance level. The standard error of b_4 (land) was larger than the b_4 coefficient.

The reliability of the regression coefficients and the derived marginal value products is indicated by their standard errors. The inter-correlations among the independent variables is a factor in determining the size of the standard errors. The simple correlations between independent variables are shown in Table 6.

TABLE 6

SIMPLE CORRELATIONS BETWEEN INPUT CATEGORIES, ONE HUNDRED AND SIXTY-FIVE FARMS

Input Category	X_1	X_2	X_3	X_4	X_5
X_1	1	.82	.64	.80	.37
X_2		1	.56	.55	.38
X_3			1	.57	.36
X_4				1	.40
X_5					1

It can be seen from examining the simple correlation coefficients that X_1 and X_2 were highly correlated as were X_1 and X_4. These high correlations may cause errors in the estimated b_i's for those pairs of inputs. In any of these two pairs of variables X_1, X_2 or X_4, the regression coefficients could be higher or lower than the true regression coefficients and the marginal value products could be effected in the same way.

Land was measured by adjusted acres in this study. It may be argued that no valid common denominator acre exists between pilot areas for adjustment purposes. It is thought that each extension agent adjusted the farms in his own area on the basis of what he considered a best acre for each farm. Care must be exercised in drawing inferences then as livestock investment and land may be expected to be in error in opposite directions. Since both livestock investment and variable non-labor costs are highly correlated, their regression coefficients may reasonably be expected to be in error in opposite directions, also.[4] Highly correlated input categories can be combined together in attempting to derive better estimates of value productivity and in overcoming the multi-collinearity problem. This technique is said to result in standard errors of regression coefficients which are smaller than formerly. This technique is attempted in the second fit on the data to be discussed later. However, there is a drawback in that the more aggregated the input data becomes, the less specific one can be in the interpretation of the implications from the derived coefficients for policy decisions. In our case here, the information concerning the productivity of the inputs which can be aggregated is not lost, since it is available from the first fit on the data. Livestock investment and variable non-labor costs can be easily combined here since they are measured in the same units.

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[4]Gerald T. Trant, Institutional Credit and the Efficiency of selected dairy farms, Unpublished Ph.D. thesis, Department of Agricultural Economics, Michigan State University, 1959, p. 36.

It would be a more difficult task to combine livestock investment and land, unless a capital value for the land could be worked out. Using land valuation as an index of land quality may lead into the same problems as Rasmussen encountered.[5] Among these is the problem that rates payable were based on the Griffith valuation made during the period 1853-1865. Some of the land valued at close to zero then is now among the most productive. So, valuation does not take into account the capital improvements made on the land input. (See Chapter 4, page 55).

The correlation between livestock investment and land in this first fit is .80 which is high. The standard error for acres is large. The regression coefficient was negative, but not significant at any acceptable level. It seems unreasonable to infer that increasing the quantity of land could decrease output. Tintner and Brownlee[6] commented that "negative elasticities, within the range of inputs on most farms are meaningless." The high correlation between livestock investment and land is partly responsible for the high standard error and low reliability of the land regression coefficient. Some of the underestimation in the

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[5]K. Rasmussen and M.M. Sandilands, Production Function Analyses of British and Irish Farm Accounts, University of Nottingham, 1962.

[6]Gerhard Tintner and D. H. Brownlee, "Production Functions Derived from Farm Records," Journal of Farm Economics XXVI, August, 1944, pp. 566-571.

land coefficient may be due to an overestimation in the livestock investment coefficient.

Testing the regression coefficients against the b_i necessary to equate MVP and MFC

We have seen that the regression coefficients can be tested for significance against the null hypothesis. Another method for testing the regression coefficients for significance is to compare them with the regression coefficients, which would be necessary to yield marginal value products equal to a set of minimum expected returns or reservation prices for the different input categories. The minimum expected return, however, can vary from farm to farm as different cost structures exist on individual farms and internal cost structures are often influenced by family position, management capacity, price uncertainty, weather and other influences. The set of minimum expected returns in Table 7 for the input categories are used to test the actual regression coefficients against the minimum regression coefficients necessary to give marginal value productivities equal to marginal factor costs of the resources. The following are a set of minimum expected returns which are considered as reasonable minima to be expected:

TABLE 7

MINIMUM EXPECTED RETURNS OR RESERVATION PRICES FOR FACTOR INPUTS

Input Category	Unit of Measurement	Value
Livestock Investment (X_1)	pound/per 100 pound	40 1/
Variable non-labor Costs (X_2)	pound/per pound	1.06 2/
Machinery Costs (X_3)	percent on investment	24 3/
Adjusted Acres (X_4)	percent on investment	9.0 4/
Labor Units (X_5)	pounds/labor unit	455.0 5/

1/ For each 100 pounds invested a return of 40 necessary to cover 6 percent interest charge, 12 percent for depreciation, 2 percent for insurance and 20 percent for variable costs.

2/ A return of one pound plus 6 percent interest on every pound spent was expected.

3/ This is based on the following charges: 12 percent for depreciation; 5 percent for maintenance and repairs, 1 percent for taxes and insurance, 6 percent for interest.

4/ The minimum expected return to land was based on a 6 percent interest charge with land valued at 150 pounds per acre.

5/ Based on an average minimum wage of 8.75 pound per week for 1966-68 period.

The regression coefficient or standard b_i^* which will yield a minimum or reservation marginal value product is obtained by solving the equation $MVP = \frac{b_i^* E(Y)}{X_1}$ for b_i^* after the required minimum MVP has been decided on and substituted in the equation. The calculations involved are shown in Appendix B. The estimated b_i is subtracted from the standard b_i^* and the difference is divided by the standard error of the estimated b_i. Table 8 compares the estimated regression coefficients and the regression coefficients necessary to yield the minimum expected returns.

TABLE 8

COMPARISON OF ESTIMATED b_i's AND THE b_i's REQUIRED TO YIELD MINIMUM MARGINAL VALUE PRODUCTS

b_i	Estimated b_i's	b_i's to yield minimum return	Difference b_i-b_i*	Standard Error	t value	Significance level
b_1	.6179	.5038	.1141	.0802	1.4227	N.S.
b_2	.3512	.2075	.1437	.0464	3.0970	.01
b_3	.0878	.0111	.0767	.0266	2.8835	.01
b_4	-.0625	.0047	-.0672	.0645	1.0419	N.S.
b_5	.1327	.9804	-.8477	.0542	15.6402	.001

The above table compares the estimated b_i's with the b_i's necessary to yield the minimum expected returns, which are equivalent to the marginal factor cost. The comparison shows the divergence of the MVP's of the different input categories from their respective MFC's. The difference between the estimated b_i's and their respective optimal b_i gives the following statistic which has a "t" distribution, with N-k-1 degrees of freedom:

$$t= \frac{b_i - b_i^*}{\sigma b_i}$$

where b_i = estimated regression coefficient

b_i^* = is the b_i necessary to yield the minimum return (or MFC)

σb_i = standard error of the b_i

N = sample size

K = the number of independent variables

The foregoing examination shows that all the regression coefficients (with the exception of land and livestock investment) are significantly different from the standard b_i necessary to equate marginal factor cost and marginal value product. On the basis of these results, it appears that there are maladjustments in the use of resources under the usual organization (at their geometric means) on the farms examined. Inputs are not being used to satisfy the MVP equal to MFC criterion of efficiency. Additional use of variable non-labor costs and machinery costs are suggested to the point where estimated MVP's approximate the b_i's which yield the minimum return. Less labor is suggested since the MVP's earned by the usual labor organization on the farms examined fell significantly lower than the marginal factor cost. The marginal return of an additional unit of labor was calculated to be 61.585 pounds, whereas the marginal factor cost of employing an additional unit at market minimum wages would be 455 pounds. The reliability of the regression coefficients for livestock investment (X_1) adjusted acres (X_4) and variable non-labor costs (X_2) is reduced because of the high correlations mentioned earlier, but these effects are accounted for in the calculated standard errors of b_1, b_2, b_4. However, if "outside" information is available to indicate that any particular one of the regression coefficients is high or low, then a system of errors is possible in the b_i estimates which effects marginal value products also. The method of adjusting land may very well have influenced the results and a more efficient way of measuring land could produce a higher marginal value product.

The nature of the aggregate comprising livestock investment (X_1) varies from pilot area to pilot area. This could effect the accuracy of the livestock investment coefficient. Since some "outside" evidence is available regarding the land and livestock investment inputs, care must be exercised in proposing any reorganization and the equating of marginal value product and marginal factor cost may not be very meaningful. It is, nevertheless, felt that the recommendations made would coincide broadly with those that would be made by most Irish farm management experts if asked to recommend a reorganization of the geometric average farm in the study. Wold[7] has commented interestingly on tests of significance saying,

> The conclusion is that in regression analysis of non-experimental data, the formal tests of significance, however refined, carry little weight as compared with the non-formal and non-quantitative significance that is embodied in results derived from independent sources, provided these results support one another and form an organic whole.

There are many possible ways individual farm organizations could be improved using Cobb-Douglas results. The usual methods would examine the effect on gross output of increasing one input category having a high rate of return on

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[7]Herman Wold, Demand Analysis, (New York: John Wiley and Sons, Inc., 1953.) pp. 56-59.

investment in it. Other changes when two or more input categories are increased holding the others constant could be examined and reorganizations suggested. The implications of asset fixity, investment and disinvestment theory would have to be dealt with before proposing any reorganizations for individual farmers. The present study does not address itself to specific possible reorganizations. Any suggested reorganizations which are made in this type of study usually assume that the decision maker (farmer) wants to achieve more efficient use of resources for profit maximization or that non-monetary concerns such as additional insurance are the motivating forces. There are, however, many obstacles which hinder the type of reorganization suggested by this study and which lie outside its scope. Among these can be numbered institutional factors such as internal or external capital rationing, scarcity of production factors (land may not be readily available on the market), and human factors like age, infirmity and the absence of management capacity. Another obstacle in this type of data is that an individual farmer can use the data only to the degree to which he approximates the geometric average farmer. Since the marginal value products are computed at the geometric mean, an individual farmer cannot be certain that his production function approximates the average of farms surveyed. There are other problems also in making recommendations which revolve around the degree of aggregation of the inputs. The more aggregated they are, the less meaningful any recommendation will be from an extension viewpoint.

Heady[8] wrote that,

> If a high degree of aggregation is used, the implications of the resultant function may be of little relevance in decision making. For the farm operator, knowledge that the marginal return to the broad category "capital" exceeds its marginal cost is insufficient. Returns may not exceed costs for some capital items within the aggregate; for others, the opposite will be true. On the other hand, the information derived from a production function based on aggregative input and output categories may be useful to a government policy maker.

The results examined were from the first function fitted to the random sample of 165 farms combined. A summary of the results for individual counties will be presented next in Table 9. This table shows regression coefficients for individual counties together with their levels of signifance as determined by the t test of the null hypothesis equal to zero. It also included $\sum_{i=1}^{5} b_i$.

Six separate fits were made on counties Clare, Kerry, Galway, Mayo, Roscommon, and Sligo. An additional regression was fitted on Clare and Kerry combined and on the remaining four counties combined.

Table 10 shows the estimated marginal value products for the different counties and for combinations of counties.

Appendix B shows the computations of b_i's to yield minimum returns and comparisons with the estimated marginal value products for all counties combined and individually

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[8]Earl O. Heady and John L. Dillon, Agricultural Production Functions, Iowa State University Press, 1961, p. 219.

TABLE 9

ELASTICITIES (REGRESSION COEFFICIENTS) AND LEVELS OF SIGNIFICANCE FOR 1966-68 RANDOM SAMPLE OF PILOT AREA FARMS IN IRELAND

Pilot Area	Livestock Investment	Variable non Labor Costs	Machinery Costs	Adjusted Acres	Labor Units	Sum of the Elasticities
	Input category					
Clare	.566***	.527***	.027	.014	-.028	1.08
Kerry	.652*	-.111	.333***	.286	-.113	1.05
Galway	.640***	.460***	.018	-.221	.052	.95
Mayo	.542***	.401***	.151*	-.162	.216**	1.15
Roscommon	.746**	.185	.101	-.181	-.081	.77
Sligo	.564***	.352**	.135	.181	.408**	1.64
Clare & Kerry	.545***	.342***	.103***	.015	.059	1.06
The Others	.625***	.378***	.061	-.082	.165***	1.15
All Counties	.618***	.351***	.088***	-.063	.133**	1.13

*** Significant at the .01 level

** Significant at the .05 level

* Significant at the .10 level

and for combinations of counties.

Appendix A, Table 1 shows regression coefficients, their standard errors and levels of significance. Table 2 shows the simple correlation between input categories. Table 3 shows the calculation of gross output from the fitted regression equation. Table 4 shows the computation of the marginal value products. Appendix A includes all counties, each county individually and combinations of counties. The detailed results of the computations for individual counties and combinations of counties have been assigned to Appendix A and B to avoid explanations which would be essentially repetitive. The results, however, have particular relevance for the separate pilot areas from which the samples were taken.

TABLE 10

MARGINAL VALUE PRODUCTS FOR 1966-68, RANDOM SAMPLE OF PILOT AREA FARMS, MEASURED IN POUNDS (£)

Pilot Area	Input category			
	Livestock Investment	Variable non Labor Costs	Machinery Costs	Labor Units
Clare	.482	3.045	.397	-16.443
Kerry	.522	-.455	12.343	-59.866
Galway	.502	2.077	.368	23.068
Mayo	.425	2.128	3.719	94.788
Roscommon	.502	1.067	2.210	-26.042
Sligo	.457	1.585	4.080	163.28
Clare & Kerry	.457	1.816	1.891	33.866
The Others	.477	1.879	1.467	65.84
All Counties	.491	1.794	1.898	61.585

Table 11 summarizes elasticities, standard errors, MVP's and other statistics related to the sample.

Table 12 shows the usual organization of inputs in pounds, acres or labor units together with the gross output resulting from fitting the estimating equation.

Table 13 summarizes the significance levels of the b_i's when tested against zero as the null hypothesis, and the significance levels of the concluding test on the comparison between the regression coefficients (b_i's) and the b_i's required to yield minimum marginal value products. (See Appendix B). Where both tests are shown to be significant it is possible to make recommendations on resource adjustments.

Summary of Results for the Different Pilot Areas

We have already looked at the problems involved in interpreting the results for the one hundred and sixty-five farms combined. In treating the different county pilot areas the results for Clare will be examined first.

County Clare pilot area results

Livestock investment (X_1) and variable non-labor costs (X_2) both have regression coefficients differing significantly from zero at the .01 percent level (Table 9). The simple correlation between X_1 and X_2 was .77. X_1 was also highly correlated .87 with adjusted acres (X_4). (Appendix A). The "t" test to establish whether the b_i's were significantly different from the b_i's required to yield minimum marginal

Table 11

Elasticities, Standard Errors, Marginal Value Productivities and Related Statistics for the 1966-68 Random Sample of Pilot Area Farms in Ireland

Input Category		Pilot Areas: All	Clare	Kerry	Galway	Sligo	Mayo	Roscommon	Clare and Kerry	Galway Mayo Sligo Roscommon
Livestock Investment (X_1)	b_1	.618	.566	.652	.640	.564	.542	.746	.545	.625
	(σ_b)	(.080)	(.150)	(.362)	(.177)	(.186)	(.133)	(.291)	(.151)	(.095)
	MVP	.491	.482	.522	.502	.457	.425	.502	.457	.477
Variable non labor costs (X_2)	b_2	.351	.527	-.111	.460	.352	.401	.185	.342	.378
	(σ_b)	(.046)	(.070)	(.201)	(.089)	(.166)	(.092)	(.209)	(.075)	(.065)
	MVP	1.794	3.045	-.455	2.077	1.585	2.128	1.067	1.816	1.879
Machinery costs (X_3)	b_3	.088	.027	.333	.018	.135	.151	.101	.103	.061
	(σ_b)	(.027)	(.041)	(.101)	(.075)	(.101)	(.080)	(.130)	(.038)	(.050)
	MVP	1.898	.397	12.343	.368	4.080	3.719	2.210	.189	1.467
Adjusted acres (X_4)	b_4	-.063	-.014	.286	-.221	.181	-.162	-.181	.015	-.082
	(σ_b)	(.064)	(.117)	(.347)	(.132)	(.187)	(.122)	(.241)	(.120)	(.081)
	MVP	-1.187	-.313	5.082	-3.878	3.931	-2.713	-2.635	.326	-1.443
Labor units (X_5)	b_5	.133	-.028	-.113	.052	.408	.216	-.081	.059	.165
	(σ_b)	(.054)	(.105)	(.274)	(.094)	(.178)	(.077)	(.177)	(.108)	(.063)
	MVP	61.585	-16.443	-59.866	23.068	163.28	94.778	-26.042	33.866	65.84
	R	.94	.96	.94	.98	.95	.95	.90	.92	.94
	R^2	.88	.92	.87	.97	.91	.91	.81	.85	.89
	S	.111	.090	.147	.077	.111	.072	.120	.123	.104
	Σb_i's	1.13	1.08	1.05	.95	1.64	1.15	.77	1.06	1.15
	n	165	52	17	22	28	23	23	69	96

*MVP's are measured in pounds.

Table 12

The Usual Organization of Inputs on Pilot Area Farms and the Resultant Gross Output from Fitting the Regression Equation

Input Category	Pilot Area								
	All Counties	Clare	Kerry	Galway	Sligo	Mayo	Roscommon	Clare and Kerry	Galway Mayo Sligo Roscommon
Livestock Investment(£)	665.8	857.4	798.0	659.1	510.7	627.3	486.1	842.6	562.0
Var. Non Labor Costs(£)	103.5	126.3	155.7	114.7	91.98	92.87	56.79	133.0	86.4
Machinery Costs(£)	24.45	49.83	17.25	25.71	13.70	20.04	14.93	38.37	17.8
Adjusted Acres	27.83	32.93	35.91	29.52	19.06	29.32	22.43	33.63	24.29
Labor Units	1.139	1.248	1.204	1.169	1.035	1.123	1.013	1.235	1.074
E (Y) Gross Output (£)	528.6	730.3	639.0	517.6	414.0	492.3	327.3	706.5	429.6

TABLE 13

SIGNIFICANCE LEVELS OF REGRESSION COEFFICIENTS, (b_i's) WHEN TESTED AGAINST THE NULL HYPOTHESIS AND AGAINST THE b_i's NECESSARY TO EQUATE MVP AND MFC

Kind of test	Regression coefficient	Pilot areas and levels of significance								
		All counties	Clare	Kerry	Galway	Sligo	Mayo	Roscommon	Clare and Kerry	Galway Mayo Sligo Roscommon
"t" test of regression coefficients against the null hypothesis that b_i's are equal to zero	b_1	***	***	*	***	***	***	**	***	***
	b_2	***	***		***	**	***		***	***
	b_3	***		***			*		***	
	b_4									
	b_5	**				**	**			***
"t" test of regression coefficients against the b_i's necessary to equate MVP and MFC	b_1									
	b_2	***	***		**		**			***
	b_3	***		***					**	
	b_4									
	b_5	***	***	***	***	***	***	***	***	***

*** significant at the .01 level

** significant at the .05 level

* significant at the .10 level

Blank spaces were not significant, for the above tests.

value products (Appendix B) showed that there was not significant difference for the livestock investment input. The coefficient for variable non-labor costs was, however, significantly different from that necessary to yield the minimum MVP. Additional use of variable non-labor costs (X_2) seems justifiable.

County Kerry pilot area

The regression coefficients for livestock investment (X_1) and machinery costs (X_3) were both significantly different from zero at the .09 and .007 percent levels, respectively. The simple correlations between X_1 and X_2 was .86 which may explain part of the reason why the regression coefficient for X_2 was negative. The simple correlation between X_2 and X_3 was .75, which may add further evidence to the occurrence of a negative b_i for X_2. The comparison test between estimated b_i's and the b_i's required to yield minimum marginal value products for livestock investment showed no significant difference. (Appendix B). There was a significant difference in the machinery cost (X_3) test (at a .01 level) but in this case it is felt that the machinery coefficient is explaining part of what should be attributed to variable non-labor costs. A closer examination of the machinery cost input in Kerry shows three of the seventeen farmers had over 70 percent of total machinery costs and over 45 percent of the total variable non-labor costs. This may have been a further distorting factor in the Kerry results. More accurate results may be possible if a purposive sample was drawn or a larger random sample.

County Galway pilot area

Livestock investment (X_1) and variable non-labor costs (X_2) both had regression coefficients differing significantly from zero at the .001 percent level. The simple correlation between X_1 and X_2, however, was .89 and X_1 and X_4 (adjusted acres) had a simple correlation of .83. (Appendix A). The comparison test between estimated b_i's and the b_i's required to yield minimum marginal value products showed no significant difference for X_1. There was a significant difference at .05 level for X_2. (Appendix B). Additional use of X_2 is probably justifiable.

County Mayo pilot area

The regression coefficients for livestock investment (X_1), variable non-labor costs (X_2), labor units (X_5) were all significantly different from zero at levels less than two percent. Machinery costs (X_3) were significantly different from zero at less than the ten percent level. (Appendix A). The simple correlations between inputs for Mayo were among the lowest observed in the study, none of them being over .70. X_1 and X_2 had simple correlation coefficients of .65 suggesting a certain degree of positive correlation; while X_1 and X_4 (adjusted acres) had a simple correlation of .69 which may have partially caused the negative coefficient to the land input. The comparison test of estimated b_i's and the b_i's required to yield minimum marginal value product showed significant differences in the case of X_2 and X_5. The additional use of variable non-labor costs and a decrease in the use of the labor input are the recommendations which emerge from this analysis.

<u>County Roscommon pilot area</u>

The regression coefficient for livestock investment (X_1) was the only input category which differed significantly from zero in their particular fit. (Appendix A). The simple correlation between X_1 and X_2 was .84 and .88 between X_1 and X_4. Table 11 shows a R^2 of .81 for Roscommon which was the poorest fit computed. No significant difference occurred when the comparison test between estimated b_i's and minimum b_i's was carried out. No recommendations can be made on the basis of the calculations done on the Roscommon data. An examination of Table 12 shows that Roscommon had the lowest geometric average of all counties in its livestock investment and variable non-labor costs and in the gross output resulting from fitting the Cobb-Douglas equation.

<u>County Sligo pilot area.</u>

The regression coefficients for livestock investment (X_1), variable non-labor costs (X_2) and labor units (X_5) were significantly different from zero at less than the five percent level. (Appendix A). There was a high correlation, however, (.87) between X_1 and X_2. The test for a significant difference between the estimated regression coefficients and the b_i's required to yield minimum marginal value products did not prove significant. The test on the labor input (X_5)

was significant at a .001 level which suggests a decrease in the use of the labor input on Sligo pilot area farms. The MVP of labor in Sligo at 163.28 pounds is the highest return to the labor input which was significant in this study. County Mayo had the second highest significant MVP for labor at 94.778 pounds.

Clare and Kerry pilot areas

These two counties were combined and the regression coefficients for livestock investment (X_1), variable non-labor costs (X_2) and machinery costs (X_3) were all significantly different from zero at less than the one percent level. (Appendix A).

The recurring problem of multi-collinearity between X_1 and X_2 can be suspected as the simple correlation coefficients between X_1 and X_2 were .78. X_1 and X_4 (adjusted acres) had a .78 correlation coefficient.

The comparison test between estimated b_i's and the b_i's required to yield minimum marginal value products showed a significant difference for machinery costs (X_3), but not for the other inputs, X_1 and X_2. However, this must be looked on with some degree of suspicion since the Kerry component of machinery costs have already been found to be highly correlated with variable non-labor costs (X_2).

Galway, Mayo, Roscommon, Sligo pilot areas

These four counties combined showed significant regression coefficients for livestock investment (X_1), variable non-labor costs (X_2) and labor units (X_5). The simple correlation between X_1 and X_2 was .82. (Appendix A) The comparison test for the b_i's required to yield minimum MVP's was significant for X_2, but not for X_1. Additional use of X_2 can be recommended on the basis of farm management observations in those four counties where fertilizer expenses lime and feed could all be increased profitably on the average farm.

The comparison of the estimated b_i's and the b_i's required to yield minimum marginal value products was significant at a .001 level for labor units (X_5). The resulting recommendation would be a decrease in the labor force engaged under the average circumstances in the study. The labor force has been declining for many years in the western counties. There may be a considerable amount of underemployment on some farms at certain periods of the year. Nevertheless, despite the nature of the labor contribution being for the most part family farms, the (geometric) average labor content in the four pilot areas observed was only 1.07 labor units. This labor force should be able to manage increased livestock numbers which would result from improvements in grassland management from the additional variable non-labor cost input. The inclusion of pigs as a profitable farm yard enterprise could absorb any underemployed labor if the farmers acquired the necessary skill and management capacity for the successful operation of the enterprise.

Second Function Fitted

An observation of the simple correlation coefficients across all pilot areas shows high correlations between livestock investment (X_1) and variable non-labor costs (X_2). These two inputs, therefore, were grouped together to form a single input category and a second function was fitted.

Since both inputs are measured in units of a homogenous nature, namely, value in pounds, they were added together to form a new input X_{12}. Relative to each other, X_1 and X_2 in the first fitted function seemed to be good if not perfect complements. It is to be noted though, that the arithmetic sum of inputs X_1 and X_2 can introduce bias in the resultant estimates unless the inputs summed are always used in fixed proportions.[9] This bias can be reduced if the geometric sum or product rather than the arithmetic sum is used for the aggregated input.[10]

Since the arithmetic sum of inputs was used in this study, the resultant regression coefficients may have elements of bias incorporated in them. The second function fitted was of the form

$$Y = .16\, X_{12}^{1.05}\, X_3^{.09}\, X_4^{-.18}\, X_5^{.18}$$

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[9] R. W. Shephard, Cost and Production Functions, Princeton University Press, Princeton, 1953. pp. 61-71. (for a discussion on this topic).

[10] E. O. Heady and J. L. Dillon, Agricultural Production Functions, Iowa State University Press, 1961, p. 229.

where X_{12} is the new input variable combining livestock investment and variable non-labor costs. The regression coefficients, standard errors, significance levels and calculated marginal value products are shown in Table 14 for all farms combined.

TABLE 14

REGRESSION COEFFICIENTS, STANDARD ERRORS, LEVEL OF SIGNIFICANCE, AND ASSOCIATED MVP'S AT THE GEOMETRIC MEAN ORGANIZATION, ONE HUNDRED AND SIXTY-FIVE PILOT AREA FARMS, 1966-68. SECOND FUNCTION

Input Category	b_i	σb_i	Significance level	MVP pounds
Livestock Invest. and Costs (X_{12})	1.053209	.056850	.0005	.715
Machinery Costs (X_3)	.093714	.028138	.001	2.026
Adjusted Acres (X_4)	-.184881	.061766	.003	-3.512
Labor Units (X_5)	.182005	.056392	.002	84.465

The regression coefficients were all found to be significantly different from zero. The sum of the b_i's was 1.14. The constant log (a) was computed as -.195229. The multiple correlation coefficient (R) was .93. The coefficient of determination (R^2) of .87 shows that 87 percent of the variance in gross output (Y) was associated with variations in the independent variables. The unexplained variance is 13 percent. The unexplained variance in the first function was 12 percent, which would indicate that the first function may be a slightly better fit than the second. The standard error of estimate (S) was .117768. The logarithm of gross output at the geometric mean was 2.7232, the anti-log of which is 528.6, as calculated in the first function. Table 15 shows the usual organization of inputs, regression coefficients and marginal and gross value products. This table is similar to Table 5, and the first function fit, with the exception of the calculations for the aggregated input (X_{12}), and the resulting changes in all the regression coefficients and their associated MVP's.

TABLE 15

USUAL ORGANIZATION AND ESTIMATED MARGINAL AND GROSS VALUE PRODUCTS, ONE HUNDRED AND SIXTY-FIVE PILOT AREA FARMS, 1966-68 SECOND FUNCTION

Input Category	Quantity of Inputs	log GX_i	b_i's	$b_i \log GX_i$	MVP pounds
Livestock Invest. & Costs (X_{12})	778.5 (£)	2.89148	1.0532	3.0453	.715
Machinery Costs (X_3)	24.45(£)	1.38843	.0937	.1301	2.026
Adjusted Acres (X_4)	27.83	1.44451	-.1849	-.2671	-3.512
Labor Units (X_5)	1.139	.05620	.1820	.0102	84.465

log constant (a) = -.195229

$$\log Y = \log (a) + \sum_{i=12}^{5} b_i \log GX_i$$

$$= -.1953 + 2.9185$$

$$= 2.7232$$

Antilog E (Y) = 528.6

The estimated marginal value products second function

The marginal value product estimates are shown in Table 15 on the preceding page. The MVP's for machinery costs and labor units have increased. The MVP for land has decreased negatively. The simple correlations between independent variables are shown in Table 16.

TABLE 16

SIMPLE CORRELATIONS BETWEEN INPUT CATEGORIES (ALL FARMS)

Input Category	X_{12}	X_3	X_4	X_5
X_{12}	1	.64	.77	.38
X_3		1	.57	.36
X_4			1	.40
X_5				1

It can be seen from an examination of the correlation coefficients that the livestock investment/costs input category is still highly correlated with acres (X_4). A test of comparisons of the estimated b_i's and the b_i's required to yield minimum returns is shown in Table 17. The minimum expected return for the combined livestock investment variable non-labor cost input category (X_{12}) was increased to forty-six percent in this test. Other reservation prices are the same as those used in the first function tests.

TABLE 17

COMPARISON OF THE ESTIMATED b_i's AND THE b_i's REQUIRED TO YIELD MINIMUM MARGINAL VALUE PRODUCTS SECOND FUNCTION

	Estimated bi's	b_i's to yield minimum return	Difference $b_i - b_i^*$	Standard Error	t value	Significance Level
b_{12}	1.0532	.6774	.3758	.0569	6.610	.001
b_3	.0937	.0110	.0827	.0281	2.939	.01
b_4	-.1849	.0047	-.1896	.0618	3.06	
b_5	.1820	.9804	-.7984	.0564	14.159	.001

The estimated b_i for X_{12} and X_4 may be in error in opposite directions because of the high degree of correlation existing between them. On the basis of these results, one could not conclude then that increasing land use would result in a reduction in gross output, despite the significance of the acreage regression coefficient. A comment has been made earlier in this chapter on the Tintner, Brownlee statement regarding negative elasticities. A comment was made on pp. 67 on possible sources of bias in the adjusted acre variable. For these reasons, no significance is attached to the result for land.

The second function is similar to the first in that increased use of machinery costs and a reduction in the labor input emerge as recommendations from the comparison test on the b_i's. The marginal value product of an additional unit of labor in the second function was 84.465 pounds with a corresponding marginal factor cost of 455 pounds. Increased use of machinery costs is recommended to the point where marginal value product equals marginal factor cost.

The MVP of an additional pound expended on machinery costs at the geometric average was 2.026 pounds. The usual care must be exercised in making recommendations here as there is a very positive correlation between X_{12} and X_3 (machinery costs), the coefficient being .64. The second function does not add to the knowledge we gained from the first function. We noted a lower coefficient of determination (R^2) of .87 versus .88 for the first function. A comparison of Table 11 and Table 20 also shows that the second function has a higher standard error of estimate ($\bar{S}$) and the individual standard errors for the regression coefficients for X_3 and X_5 are somewhat larger. In addition to these effects, the coefficient for X_{12} does not enable us to make any genuine recommendation on livestock investment or variable non labor costs due to the degree of aggregation involved.

Table 18 summarizes the regression coefficients for all pilot areas for the second function.

Table 19 shows the resulting marginal value products calculated in Appendix C. The regression coefficients which were significant using the second function are basically the same as in the first function with the exception of the appearance of significant coefficients for the land input for the pilot areas in counties Clare, Galway, Mayo, the others (Galway, Mayo, Roscommon, Sligo) and all counties. (Table 18)

TABLE 18

ELASTICITIES (REGRESSION COEFFICIENTS) FOR 1966-68 RANDOM SAMPLE OF PILOT AREA FARMS IN IRELAND (SECOND FUNCTION)

Pilot Area	Input Category				
	Livestock Investment and Costs	Machinery Costs	Adjusted Acres	Labor Units	Sum of the Elasticities
Clare	1.380***	.031	-.333***	-.006	1.072
Kerry	.451*	.316***	.424	-.201	.99
Galway	1.310***	.035	-.426***	.046	.873
Mayo	.974***	.144	-.310**	.232**	1.040
Roscommon	.937***	.110	-.211	-.051	.785
Sligo	.910***	.172*	.116	.430**	1.627
Clare & Kerry	1.015***	.094**	-.136	.137	1.110
The Others	1.071***	.093*	-.214***	.200***	1.150
All Counties	1.053***	.094***	-.185***	.182***	1.144

*** Significant at the .01 level

** Significant at the .05 level

* Significant at the .10 level

TABLE 19

MARGINAL VALUE PRODUCTS FOR 1966-68 RANDOM SAMPLE OF PILOT AREA FARMS, (SECOND FUNCTION)

Pilot Area	Input Category			
	Livestock Investment and variable non labor costs (pounds)	Machinery Costs (pounds)	Adjusted Acres (pounds)	Labor Units (pounds)
Clare	1.012	.450	-7.390	-3.376
Kerry	.296	11.708	7.546	-106.698
Galway	.863	.711	-7.474	20.585
Mayo	.659	3.534	-5.213	101.879
Roscommon	.354	2.421	-3.080	-16.666
Sligo	.621	5.185	2.509	172.074
Clare & Kerry	.724	1.739	-2.858	78.351
The Others	.702	2.249	-3.786	80.077
All Counties	.715	2.026	-3.512	84.465

Table 20 summarizes elasticities, standard errors, MVP's and other statistics for the second function. A comparison of the R^2 and the standard error of estimate ($\bar{S}$) in Tables 11 and 20 shows larger R^2 values in nearly all cases for the first function and smaller values for ($\bar{S}$).

Table 20

Elasticities, Standard Errors, Marginal Value Productivities* and Related Statistics for the 1966-68 Random Sample of Pilot Area Farms (Second Function)

Input Category		All Farms	Clare	Kerry	Galway	Sligo	Mayo	Roscommon	Clare and Kerry	Galway Mayo Sligo Roscommon
		Pilot Areas								
Livestock Investment and Costs (X_{12})	b_{12}	1.053	1.380	.451	1.310	.910	.974	.937	1.015	1.071
	(σ_b)	.057	.134	.210	.111	.114	.118	.203	.107	.064
	MVP	.715	1.012	.296	.863	.621	.659	.354	.724	.702
Machinery Costs (X_3)	b_3	.094	.031	.316	.035	.172	.144	.110	.094	.093
	(σ_b)	.028	.051	.100	.095	.098	.091	.124	.039	.053
	MVP	2.026	.450	11.708	.711	5.185	3.534	2.421	1.739	2.249
Adjusted Acres (X_4)	b_4	-.185	-.333	.424	-.426	.116	-.310	-.211	-.136	-.214
	(σ_b)	.062	.123	.301	.146	.180	.129	.227	.109	.080
	MVP	-3.512	-7.390	7.546	-7.474	2.509	-5.213	-3.08	-2.858	-3.786
Labor Units (X_5)	b_5	.182	-.006	-.201	.046	.430	.232	-.051	.137	.200
	(σ_b)	.056	.130	.244	.119	.178	.088	.165	.110	.066
	MVP	84.465	-3.376	-106.698	20.585	172.074	101.879	-16.667	78.35	80.077
	R	.93	.93	.93	.97	.95	.94	.90	.91	.93
	R^2	.87	.87	.87	.95	.90	.88	.81	.83	.87
	S	.118	.111	.144	.097	.112	.082	.117	.130	.111
	Σb_i's	1.144	1.072	.990	.873	1.627	1.040	.785	1.110	1.150
	n	165	52	17	22	28	23	23	69	96

*MVP's are measured in pounds.

Table 21 summarizes the significance levels of the b_i's when tested against zero as the null hypothesis, and the significance levels of the concluding test on the comparison between the regression coefficients (b_i's) and the b_i's required to yield minimum marginal value product for the second function fitted.

TABLE 21

SIGNIFICANCE LEVELS OF REGRESSION COEFFICIENTS, (b_i's) WHEN TESTED AGAINST THE NULL HYPOTHESIS AND AGAINST THE b_i's NECESSARY TO EQUATE MVP AND MFC, FOR THE SECOND FUNCTION FITTED

Kind of test	Pilot areas and levels of significance									
	Regression coefficient	All counties	Clare	Kerry	Galway	Sligo	Mayo	Roscommon	Clare and Kerry	Galway Mayo Sligo Roscommon
"t" test of regression coefficients against the null hypothesis that b_i's are equal to zero	b_{12}	***	***	*	***	***	***	***	***	***
	b_3	***		***		*			**	*
	b_4	***	***		***		**			***
	b_5	***				**	**			***
"t" test of regression coefficients against the b_i's necessary to equate MVP and MFC	b_{12}	***	***		***	*	**		***	***
	b_3	***		***					**	
	b_4	***	***		***		**			***
	b_5	***	***	***	***	***	***	***	***	***

*** significant at the .01 level
** significant at the .05 level
* significant at the .10 level

Summary of the Results for the Different Pilot Areas Second Function

Clare

Livestock investment and costs (X_{12}) and adjusted acres (X_4) had regression coefficients significantly different from zero. They were, however, highly correlated (.85). An increase in the use of livestock investment and costs would probably help to reduce the negative MVP for acres.

Kerry

The regression coefficients for investment and costs (X_{12}) and machinery costs (X_3) were significantly different from zero. The correlation coefficient between these input categories was .70.

Galway

Investment and costs (X_{12}) and adjusted acres (X_4) had regression coefficients significantly different from zero at the one percent level. The comparison test on the b_i's was also significant. The simple correlation coefficient was .80 indicating a high correlation between the two inputs. Increased use of livestock investment and costs on the present farm sizes would probably increase the MVP of land in this area.

Mayo

The regression coefficients for X_{12}, X_4 and labor units (X_5) were all significantly different from zero. The comparison test on the b_i's necessary to yield minimum marginal product were significantly different from the estimated b_i's. The correlation coefficient between X_{12} and

X_4 was .66. The decreased use of labor (X_5) to the point where MVP would be equated with MFC can be recommended here. As in the Galway case, increased use of various components in the investment/costs aggregate would probably result in a positive MVP for land.

Roscommon

The regression coefficient for X_{12} was significantly different from zero which is similar to the first function result where both X_1 and X_2 were significant. The comparison test on the b_i's necessary to yield minimum marginal product were not significantly different from the estimated b_i's. A high degree of correlation (.87) between X_{12} and X_4 existed. No recommendations on reorganization are made on the basis of the fitted function.

Sligo

The regression coefficients for X_{12} and X_5 were significant and that for X_3 marginally so (10 percent level). An examination of the simple correlation coefficients showed a correlation of .67 between X_{12} and X_4. A comparison of the estimated b_i's and the b_i's necessary to yield minimum marginal products was significant for X_{12} at the 10 percent level and for labor units (X_5) at the 1 percent level. An additional unit of labor would earn 172.074 pounds in Sligo. Less labor is recommended to the point where the estimated b_i's and b_i's to yield minimum returns are equal. The labor content in Sligo pilot area farms is the second lowest in this study at 1.035 labor units. The geometric average farm size is the smallest, being only 19.06 adjusted acres.

Clare and Kerry

A combination of these two pilot areas showed the regression coefficients for livestock investment and costs (X_{12}) and machinery costs (X_3) were significantly different from zero. X_{12} and X_3 had a simple correlation coefficient of .63 and X_{12} and X_4 (acres) had a correlation coefficient of .75. No clear-cut recommendation can be made on the basis of these results alone due to the previously observed lack of range in the Kerry machinery cost input and the possibility of errors in measuring the land input.

Galway, Mayo, Roscommon, Sligo

The regression coefficients for all the independent variables were significant in the second function fitted. (See Table 18). The regression coefficient for X_4 (adjusted acres) was negative but as in former cases it was highly correlated (.76) with X_{12}. The regression coefficient for machinery costs (X_3) was significant at a 10 percent level. Its correlation with X_{12} was .61. It was also positively correlated with acres (X_4), the coefficient being (.63).

Labor units (X_5) had a significant regression coefficient and its estimated b_i and the b_i's necessary to yield minimum marginal product were significantly different from each other. The reduction of the labor input on the geometric average farm can be recommended on the basis of these results. It is felt that an increase in the most profitable components of livestock investment and variable non labor costs would probably have a positive effect on the MVP for adjusted acres.

CHAPTER VI

CONCLUSIONS, RECOMMENDATIONS AND IMPLICATIONS

The primary objective of this study was to establish estimates of the marginal value productivities of various inputs used in the production process on Western Ireland pilot area farms in the period 1966-68 and make recommendations on the possible reorganization of these inputs. Some difficulties were encountered which reduced the reliability of a number of the derived estimates. It is thought that a possible better estimate of the underlying relationships and production functions may have been obtained by using a purposive rather than the random sample technique used in this study. A purposive sample could help to ensure lower inter-correlations and the coverage of a larger area of the production surface than that covered by random sampling. This would aid in reducing the inter-correlations between the input categories and increase the reliability of the regression coefficients and estimated marginal value products. Under the conditions prevailing in the 1966-68 period covered by the survey, it is possible to suggest the following adjustments and changes, on the basis of the survey results analyzed here and complemented by general farm management experience and knowledge. The results in general

indicated that excess labor was being used in the "usual" or geometric mean farm organization. The regression coefficient for labor was significantly less than required to equate MVP with the minimum expected return or reservation price for hired labor in both functions. This occurred in counties Mayo, and Sligo pilot areas and in the four county pilot areas of Galway, Mayo, Sligo and Roscommon combined and for all counties combined.

Scully[1] describes the labor situation in these areas, writing that "normally excess labor in agriculture is associated with intensive land use. In Ireland, however, land use is extensive on the aggregate. This problem is most acute in large areas of the western region where store cattle production has been a traditional enterprise on small farms."

The efficiency of labor on pilot area farms could be increased in several ways.

1. Less labor could be used relative to the present input mix.
2. The use of increased quantities of livestock investment and elements of variable non labor costs in association with the present labor position.
3. The existing labor force could adopt more efficient farm practices, adjusting to technological changes which would allow for more efficient use of labor.

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[1]John J. Scully, Agricultural Adjustment in Ireland, Paper No. 13, Economic Conference, Dublin, 1968, p. 15.

Options one and three would lead to an unemployed residual which could in theory be removed from the agricultural sector assuming mobility. This may be an alternative; but when one examines Scully's work,[2] from a survey of the western region, he states that "approximately sixty percent of full-time farmers are over fifty years of age; twenty-eight percent of these have no successors, while the potential successors of a further twenty-two percent have already emigrated." The average age of the decision maker in this survey was 50.3 years. These figures along with others which have been published, show evidence of a strong aging of the farm operator population. The figures in themselves, are a sufficient guide to why labor is not efficiently organized. It often lacks the economic and psychological drive and this together with age, marital status, size of farm, delinquent titles to property, low level of education and other reasons help to highlight the problem.

The aging of the farm population resulting from the outmigration of a considerable percentage of the younger members, will hardly be reversed unless the ratio of farm to non farm wages becomes more favorable towards farming. Options one and three may enhance farm income if the under-employed labor is mobile enough to take off-farm employment,

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[2]John J. Scully, "Western Development--The Problem in Perspective," The Agricultural Record, Journal of the Agricultural Science Association, Dublin, Ireland, Vol. XXVI, Spring 1968.

assuming its availability. This arises from the possible provision of cash from non-farm employment to finance the purchase of livestock and make other investments which would have the further effect of making any remaining family labor more efficient since productive investment could be intensified. A recent study by Lucey and Kaldor[3] showed among other things that, in the case studies of rural industrialization examined by them, farm operators who were employed in industry generally showed no reduction in their farm output. The part-time farmers worked harder and longer than they had done when farming was their sole occupation. There were also strong farm investment effects as part of the additional income was reinvested in farming.

The second option of increasing investments in the particular livestock and variable non labor costs categories which present the most profitable alternative opportunities would be instrumental in increasing output and incomes providing the present prices continue to prevail.

The conclusion here is that the labor input as reresented by the usual farm organization in this study could be reduced for the specified pilot areas. This recommendation cannot be made for Kerry or Clare, which are the two pilot

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[3]Denis T. F. Lucey, and Donald K. Kaldor, Rural Industrialization: The impact of Industrialization on Two Rural Communities in Western Ireland, Geoffrey Chapman (Ireland) Ltd., Dublin, 1969.

areas in the survey with relatively large dairy herds, 1966-68 (Appendix C), which may be a significant factor in the efficient organization of labor.

The alternative to reducing the labor input could be to increase other categories of investment so that labor could be used more efficiently.

The regression coefficient for land in the study was not significantly negative in the first function and the b_i's were not significantly below the b_i's necessary to equate MVP with MFC. In the second function the b_i's were significantly less than those required to equate MVP with MFC for three of the counties, (Galway, Mayo, Clare,) and for all counties combined. It is felt that the regression coefficient for land is downward biased because of unaccounted for lower quality differentials associated with larger acreages. The high inter-correlations between the aggregated livestock investment and variable non-labor cost input category and land in the second function and between livestock investment and land in the first function provided evidence on the presence of multi-collinearity which, together with the possible bias introduced measuring acres, made interpretation difficult. Still it is suspected that land was a low earner in the study as stocking rates and fertilizer and lime inputs were low in these areas in the survey period. This means then, that a reorganization in the quality and quantity of the productive investments have regression coefficients higher than those necessary to equate MVP with

MFC, could be made and would lead to higher returns on the land input. Johnson in his Kentucky studies[4] has this to say, which has in the writer's opinion considerable relevance for the situation in the western pilot areas, "Acreage or size of farm is unimportant until the farmer concerned has developed all the land capable of development on his farm." There was at the time of the pilot area study, considerable land reclamation, drainage, fertilizer and lime applications both requiring to be carried out and in the process of being carried out. Johnson continues, that in time small acreages will place a limit on the ability of many farmers to make further profitable investments in livestock and forage production, and says that as more and more farms reach this condition, the problems of combining farms and of adding more land to commercial farms will become much more important. It is felt that this limit has not yet been reached by many pilot area farmers. There are others who have reached it and who have the alternatives of renting additional land or buying it assuming its availability.

Evidence has been accumulated from this study that increased use of machinery costs may be profitable on some farms. Both functions showed that the regression coefficients for machinery costs, when compared with that required

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[4] Glenn L. Johnson, Sources of Incomes on Upland Marshall County Farms, Progress Report No. 1, Kentucky Agricultural Experiment Station, University of Kentucky, Lexington, 1952, p. 10.

to equate MVP with MFC, showed a significant difference for some counties. Care has to be exercised in recommending increases in machinery costs as this may allow for substitution of capital for labor. Capital may have a high opportunity cost relative to labor, which may be close to zero on some farms. A general conclusion on power machinery use (the level of investment of which is reflected in the depreciation component of machinery costs) is that the average pilot area farm is not large enough or crop oriented enough to justify heavy individual investments. An alternative would be to do hired work off the farm or the formation of machinery pools by groups of farmers organized along cooperative lines.

Livestock investment and variable non labor costs gave considerable trouble in the estimation of their marginal value productivities because of inter-correlation and their complementary nature. In the first function fitted, where the two variables formed separate input categories, the estimated b_i of variable non labor costs was significantly different from the b_i necessary to yield minimum marginal product for all areas except Roscommon, Kerry and Kerry/Clare combined. Despite the observed high correlation between the two variables, it would not be unreasonable to make the general extension agent recommendation for the average farm. That is, increase the use of the variable non labor cost category which consists chiefly of fertilizer and feed and livestock maintenance inputs. The regression coefficient for livestock investment when compared with that required to equate MVP with MFC, showed no significant difference for the first function fitted. This indicates that the livestock investment figure on the "usual" farm seems to be in about the proper proportion relative to other inputs. This will not be true for many individual farms.

When the above two categories of inputs were amalgamated, a test for a difference among the b_i's showed all pilot areas and combinations of pilot areas except Kerry and Roscommon were significantly different from the optimum organization. Increased use of investments in livestock, fertilizer, grassland improvements are likely to lead to improvements in the farm income and gross output situation despite the limitations set on such a recommendation, if one were to rely on this study alone. An examination of the original input data in Appendix E, where farmers are ranked by gross output, shows an obvious relationship between high gross output, livestock investment and variable non labor costs.

As can be seen then, the usefulness of the productivity coefficients as management and decision guides on individual farms has many limitations unless the input coefficients are disaggregated to a considerable extent. The function is also limited in that it is an average indicator and farmers who are at extreme ends of a sample may derive little benefit from average recommendations.

From a policy point of view, recommendations, if implemented at the farm level, would advocate increased production in the pilot areas. This type of increase, when aggregated, could cause quite considerable price decreases for some products at the macro level, which in turn could cancel the gains from the increased productivity at the micro level.

In general, Cobb-Douglas function analysis can be used as an aid in the measurement of the productivity and returns to the various resources involved in the production process. Other complementary techniques, include gross margin planning, budgeting, linear programming, critical path analysis, program evaluation and review technique (P.E.R.T.) and simulation. Some of these techniques aid in handling problems not dealt with in Cobb-Douglas analysis and involve additional data which may be required in the solution of problems concerned with:

(i) Finding the best order in the execution of alternative actions.

(ii) Finding normative common denominators for maximizing differences between good and bad courses of action.

(iii) Decision-making rules under the assumptions of perfect and imperfect knowledge.

(iv) Specifying alternative courses of action through time.

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APPENDICES

APPENDIX A

TABLE A1 : REGRESSION COEFFICIENTS, THEIR STANDARD ERRORS AND LEVELS OF SIGNIFICANCE

TABLE A2 : SIMPLE CORRELATIONS BETWEEN INPUT CATEGORIES

TABLE A3 : COMPUTATION OF GROSS OUTPUT FROM THE ESTIMATED REGRESSION EQUATION

TABLE A4 : COMPUTATION OF MARGINAL VALUE PRODUCTS

(THE FOLLOWING PAGES REPEAT THE ABOVE TABLES FOR ALL FARMS INDIVIDUALLY WITHIN COUNTY PILOT AREAS AND COMBINATIONS OF PILOT AREAS.)

TABLE A1

REGRESSION COEFFICIENTS (b_i's), THEIR STANDARD ERRORS (σb_i), AND LEVELS OF SIGNIFICANCE, ONE HUNDRED AND SIXTY-FIVE PILOT AREA FARMS, 1966-68

Input category	b_i	σb_i	Significance level
Livestock Investment	.617941	.080221	<.0005
Variable Non Labor Costs	.351217	.046438	<.0005
Machinery Costs	.087843	.026632	.001
Adjusted Acres	-.062499	.064451	.334
Labor Units	.132741	.054226	.015

TABLE A2

SIMPLE CORRELATIONS BETWEEN INPUT CATEGORIES

Input category	Livestock Investment	Var. non labor costs	Machinery costs	Adjusted acres	Labor units
Livestock Investment	1.0	.82	.64	.80	.37
Var. non Labor Costs		1.0	.56	.55	.38
Machinery Costs			1.0	.57	.36
Adjusted Acres				1.0	.40
Labor Units					1.0

TABLE A3

COMPUTATION OF GROSS OUTPUT FROM THE ESTIMATED REGRESSION EQUATION ONE HUNDRED AND SIXTY-FIVE PILOT AREA FARMS 1966-68

Input category	Quantity of Inputs*	log GX_i*	b_i's	$b_i \log GX_i$	MVP (Ъ)
Livestock Investment	665.8 (Ъ)	2.82333	.6179	1.74454	.491
Non labor costs	103.5 (Ъ)	2.01485	.3512	.70762	1.794
Machinery costs	24.45(Ъ)	1.38843	.0878	.12190	1.898
Adjusted acres	27.83 A	1.44451	-.0625	-.09028	-1.187
Labor units	1.139	.05620	.1327	.00746	61.585

log constant (a) = .231945

$$\log Y \text{ (gross output)} = \log a + \sum_{i=1}^{5} b_i \log GX_i$$

$$= .23195 + 2.49124$$

$$= 2.7232$$

Antilog E (Y) = 528.6 pounds

TABLE A4

COMPUTATION OF THE MARGINAL VALUE PRODUCTS (Ƅ)
ONE HUNDRED AND SIXTY-FIVE PILOT
AREA FARMS 1966-68

Input category	Quantity in the usual organization	Regression Coefficient
Livestock Investment (X_1)	665.8 (Ƅ)	.6179
Var. Non-labor costs (X_2)	103.5 (Ƅ)	.3512
Machinery costs (X_3)	24.45 (Ƅ)	.0878
Adjusted acres (X_4)	27.83 A	-.0625
Labor units (X_5)	1.139	.1327

Formula for the computation of the marginal value product is:

$$MVP_{x_i} = \frac{b_i\ (EY)}{X_i}$$

$$MVP_{x_1} = \frac{.6179(528.6)}{665.8} = .490571$$

$$MVP_{x_2} = \frac{.3512(528.6)}{103.5} = 1.793665$$

$$MVP_{x_3} = \frac{.0878(528.6)}{24.45} = 1.898203$$

$$MVP_{x_4} = \frac{-.0625(528.6)}{27.83} = -1.187118$$

$$MVP_{x_5} = \frac{.1327(528.6)}{1.139} = 61.584910$$

TABLE A5

REGRESSION COEFFICIENTS (b_i's), THEIR STANDARD ERRORS (σb_i), AND LEVELS OF SIGNIFICANCE, COUNTY CLARE PILOT AREA 1966-68

Input category	b_i	σb_i	Significance level
Livestock Investment	.565902	.150406	<0.0005
Variable Non Labor Costs	.526606	.070370	<0.0005
Machinery Costs	.027079	.041151	0.514
Adjusted Acres	-.014135	.116802	0.904
Labor Units	-.028133	.105304	0.791

TABLE A6

SIMPLE CORRELATIONS BETWEEN INPUT CATEGORIES

Input category	Livestock Investment	Var. non labor costs	Machinery costs	Adjusted acres	Labor units
Livestock Investment	1.0	.77	.67	.87	.63
Var. non labor costs		1.0	.51	.54	.51
Machinery costs			1.0	.64	.34
Adjusted acres				1.0	.61
Labor units					1.0

TABLE A7

COMPUTATION OF GROSS OUTPUT FROM THE ESTIMATED REGRESSION EQUATION, COUNTY CLARE PILOT AREA, 1966-68

Input category	Quantity of Inputs*	log GX_i*	b_i's	$b_i \log GX_i$	MVP (£)
Livestock Investment	857.4 (£)	2.93336	.5659	1.6500	.482
Non labor costs	126.3 (£)	2.10153	.5266	1.1067	3.045
Machinery costs	49.83 (£)	1.69747	.0271	.0460	.397
Adjusted acres	32.93 A	1.51747	-.0141	-.0214	-.313
Labor units	1.248	0.09528	-.0281	-.0027	-16.443

log constant (a) = .074889

log Y (gross output) $= \log a + \Sigma b_i \log GX_i$

$= .074889 + 2.7886$

$= 2.8635$

Antilog = £ 730.3

TABLE A8

COMPUTATION OF THE MARGINAL VALUE PRODUCTS (Ŀ)
CLARE PILOT AREA, 1966-68

Input category	Quantity in the usual organization	Regression Coefficient
Livestock Investment (X_1)	857.4 (Ŀ)	.5659
Var. Non-labor costs (X_2)	126.3 (Ŀ)	.5266
Machinery costs (X_3)	49.83 (Ŀ)	.0271
Adjusted acres (X_4)	32.93 A	-.0141
Labor units (X_5)	1.248	-.0281

Formula for the computation of the marginal value product is:

$$MVP_{x_1} = \frac{.5659(730.3)}{857.4} = .48201$$

$$MVP_{x_2} = \frac{.5266(730.3)}{126.3} = 3.04494$$

$$MVP_{x_3} = \frac{.0271(730.3)}{49.83} = 0.39717$$

$$MVP_{x_4} = \frac{-.0141(730.3)}{32.93} = -.31270$$

$$MVP_{x_5} = \frac{-.0281(730.3)}{1.248} = -16.44345$$

TABLE A9

REGRESSION COEFFICIENTS (b_i's), THEIR STANDARD ERRORS (σb_i), AND LEVELS OF SIGNIFICANCE, COUNTY KERRY PILOT AREA 1966-68

Input category	b_i	σb_i	Significance level
Livestock Investment	.652442	.362482	.099
Variable Non Labor Costs	-.110778	.201112	.593
Machinery Costs	.333206	.101337	.007
Adjusted Acres	.285627	.346509	.427
Labor Units	-.112772	.273581	.688

TABLE A10

SIMPLE CORRELATIONS BETWEEN INPUT CATEGORIES

Input category	Livestock Investment	Var. non labor costs	Machinery costs	Adjusted acres	Labor units
Livestock Investment	1.0	.86	.66	.50	.24
Var. non labor costs		1.0	.75	.37	.39
Machinery costs			1.0	.32	.52
Adjusted acres				1.0	.59
Labor units					1.0

TABLE A11

COMPUTATION OF GROSS OUTPUT FROM THE ESTIMATED REGRESSION EQUATION, COUNTY KERRY PILOT AREA, 1966-68

Input category	Quantity of Inputs*	log GX_i*	b_i's	$b_i \log GX_i$	MVP (Ƅ)
Livestock Investment	798.0 (Ƅ)	2.90200	.6524	1.8933	.522
Non Labor Costs	155.7 (Ƅ)	2.19234	-.1108	-.2429	-.455
Machinery Costs	17.25(Ƅ)	1.23683	.3332	.4121	12.343
Adjusted Acres	35.91 A	1.55527	.2856	.4442	5.082
Labor Units	1.204	.08072	-.1128	-.0091	-59.866

log constant (a) = .30787

$$\log Y \text{ (gross output)} = \log a + \Sigma b_i \log GX_i$$

$$= .30787 + 2.4976$$

$$= 2.80547$$

Antilog = Ƅ 639.0

TABLE A12

COMPUTATION OF THE MARGINAL VALUE PRODUCTS (Ѣ)
KERRY PILOT AREA, 1966-68

Input category	Quantity in the usual organization	Regression Coefficient
Livestock Investment (X_1)	798.0 (Ѣ)	.6524
Var. Non-Labor Costs (X_2)	155.7 (Ѣ)	-.1108
Machinery Costs (X_3)	17.25 (Ѣ)	.3332
Adjusted Acres (X_4)	35.91 A	.2856
Labor Units (X_5)	1.204	-.1128

Formula for the computation of the marginal value product is:

$$MVP_{x_1} = \frac{.6524(639.0)}{798.0} = 0.522411$$

$$MVP_{x_2} = \frac{-.1108(639.0)}{155.7} = -.454728$$

$$MVP_{x_3} = \frac{.3332(639.0)}{17.25} = 12.3429$$

$$MVP_{x_4} = \frac{.2856(639.0)}{35.91} = 5.082105$$

$$MVP_{x_5} = \frac{-.1128(639.0)}{1.204} = -59.8664$$

TABLE A13

REGRESSION COEFFICIENTS (b_i's), THEIR STANDARD ERRORS (σb_i), AND LEVELS OF SIGNIFICANCE, COUNTY GALWAY PILOT AREA 1966-68

Input category	b_i	σb_i	Significance level
Livestock Investment	.639558	.177383	.002
Variable Non Labor Costs	.460205	.088987	<.0005
Machinery Costs	.018253	.075412	.812
Adjusted Acres	-.221189	.132237	.114
Labor Units	.052122	.094181	.588

TABLE A14

SIMPLE CORRELATIONS BETWEEN INPUT CATEGORIES

Input category	Livestock Investment	Var. non labor costs	Machinery costs	Adjusted costs	Labor units
Livestock Investment	1.0	.89	.73	.83	.44
Var. Non Labor Costs		1.0	.61	.62	.35
Machinery Costs			1.0	.77	.47
Adjusted Acres				1.0	.46
Labor Units					1.0

TABLE A15

COMPUTATION OF GROSS OUTPUT FROM THE ESTIMATED REGRESSION EQUATION, COUNTY GALWAY PILOT AREA, 1966-68

Input category	Quantity of Inputs*	log GX_i*	b_i's	$b_i \log GX_i$	MVP (Ł)
Livestock Investment	659.1	2.81888	.6396	1.8029	.502
Non Labor Costs	114.7	2.05949	.4602	.9478	2.077
Machinery Costs	25.71	1.41024	.0183	.0258	.368
Adjusted Acres	29.52	1.47006	-.2212	-.3252	-3.878
Labor Units	1.169	0.06779	.0521	.0035	23.068

log constant (a) = .259193

$$\log Y \text{ (gross output)} = \log a + \Sigma b_i \log GX_i$$

$$= .25919 + 2.4548$$

$$= 2.7140$$

Antilog = Ł 517.6

TABLE A16

COMPUTATION OF THE MARGINAL VALUE PRODUCTS (Ƀ)
GALWAY PILOT AREA, 1966-68

Input category	Quantity in the usual organization	Regression Coefficient
Livestock Investment (X_1)	659.1 (Ƀ)	.6396
Var. Non Labor Costs (X_2)	114.7 (Ƀ)	.4602
Machinery Costs (X_3)	25.71 (Ƀ)	.0183
Adjusted Acres (X_4)	29.52 A	-.2212
Labor Units (X_5)	1.169	.0521

Formula for the computation of the marginal value product is:

$$MVP_{x_1} = \frac{.6396(517.6)}{659.1} = 0.502286$$

$$MVP_{x_2} = \frac{.4602(517.6)}{114.7} = 2.076718$$

$$MVP_{x_3} = \frac{.0183(517.6)}{25.71} = .36842$$

$$MVP_{x_4} = \frac{-.2212(517.6)}{29.52} = -3.87849$$

$$MVP_{x_5} = \frac{.0521(517.6)}{1.169} = 23.06841$$

TABLE A17

REGRESSION COEFFICIENTS (b_i's), THEIR STANDARD ERRORS (σb_i), AND LEVELS OF SIGNIFICANCE COUNTY MAYO PILOT AREA 1966-68

Input category	b_i	σb_i	Significance level
Livestock Investment	.541656	.132935	.001
Variable Non Labor Costs	.401424	.091870	<.0005
Machinery Costs	.151374	.079801	.075
Adjusted Acres	-.161648	.121829	.202
Labor Units	.216232	.077372	.012

TABLE A18

SIMPLE CORRELATIONS BETWEEN INPUT CATEGORIES

Input category	Livestock Investment	Var. non labor costs	Machinery costs	Adjusted costs	Labor units
Livestock Investment	1.0	.65	.42	.69	.16
Var. Non Labor Costs		1.0	.26	.28	.21
Machinery Costs			1.0	.35	.13
Adjusted Acres				1.0	.05
Labor Units					1.0

TABLE A19

COMPUTATION OF GROSS OUTPUT FROM THE ESTIMATED REGRESSION EQUATION, COUNTY MAYO PILOT AREA 1966-68

Input category	Quantity of Inputs*	log GX_i*	b_i's	$b_i \log GX_i$	MVP (Ь)
Livestock Investment	627.3 (Ь)	2.79746	.5417	1.5154	.425
Non Labor Costs	92.87(Ь)	1.96789	.4014	.7899	2.128
Machinery Costs	20.04(Ь)	1.30214	.1514	.1971	3.719
Adjusted Acres	29.32 A	1.46705	-.1616	-.2371	-2.713
Labor Units	1.123	0.05066	.2162	.0110	94.778

log constant (a) = .416007

log Y (gross output) $= \log a + \Sigma b_i \log GX_i$

$= .416007 + 2.2763$

$= 2.6923$

Antilog = Ь 492.3

TABLE A20

COMPUTATION OF THE MARGINAL VALUE PRODUCTS (Ƀ)
MAYO PILOT AREA, 1966-68

Input category	Quantity in the usual organization	Regression Coefficient
Livestock Investment (X_1)	627.3 (Ƀ)	.5417
Var. Non Labor Costs (X_2)	92.87 (Ƀ)	.4014
Machinery Costs (X_3)	20.04 (Ƀ)	.1514
Adjusted Acres (X_4)	29.32 A	-.1616
Labor Units (X_5)	1.123	.2162

Formula for the computation of the marginal value product is:

$$MVP_{x_1} = \frac{.5417(492.3)}{627.3} = .425122$$

$$MVP_{x_2} = \frac{.4014(492.3)}{92.87} = 2.127804$$

$$MVP_{x_3} = \frac{.1514(492.3)}{20.04} = 3.719272$$

$$MVP_{x_4} = \frac{-.1616(492.3)}{29.32} = -2.713359$$

$$MVP_{x_5} = \frac{.2162(492.3)}{1.123} \quad 94.77761$$

TABLE A21

REGRESSION COEFFICIENTS (b_i's), THEIR STANDARD ERRORS (σb_i), AND LEVELS OF SIGNIFICANCE, COUNTY ROSCOMMON PILOT AREA, 1966-68

Input category	b_i	σb_i	Significance level
Livestock Investment	.745517	.291156	.020
Variable Non Labor Costs	.185164	.209281	.389
Machinery Costs	.100843	.129559	.447
Adjusted Acres	-.180642	.240687	.463
Labor Units	-.080596	.176813	.654

TABLE A22

SIMPLE CORRELATIONS BETWEEN INPUT CATEGORIES

Input category	Livestock Investment	Var. non labor costs	Machinery costs	Adjusted costs	Labor units
Livestock Investment	1.0	.84	.59	.88	-.29
Var. Non Labor Costs		1.0	.58	.68	-.06
Machinery Costs			1.0	.61	-.10
Adjusted Acres				1.0	-.36
Labor Units					1.0

TABLE A23

COMPUTATION OF GROSS OUTPUT FROM THE ESTIMATED REGRESSION EQUATION, COUNTY ROSCOMMON PILOT AREA, 1966-68

Input category	Quantity of Inputs*	log GX_i*	b_i's	$b_i \log GX_i$	MVP (Ƀ)
Livestock Investment	486.1 (Ƀ)	2.68668	.7455	2.0029	.502
Non Labor Costs	56.79 (Ƀ)	1.75426	.1852	.3249	1.067
Machinery Costs	14.93 (Ƀ)	1.17395	.1008	.1183	2.210
Adjusted Acres	22.43 A	1.35075	-.1806	-.2439	-2.635
Labor Units	1.013	-0.00558	-.0806	-.0004	-26.042

log constant (a) = .313238

log Y (gross output) = $\log a + \Sigma b_i \log GX_i$

= .3132 + 2.2018

= 2.5150

Antilog = 327.3

TABLE A24

COMPUTATION OF THE MARGINAL VALUE PRODUCTS (£)
ROSCOMMON PILOT AREA, 1966-68

Input category	Quantity in the usual organization	Regression Coefficient
Livestock Investment (X_1)	486.1 (£)	.7455
Var. Non Labor Costs (X_2)	56.79 (£)	.1852
Machinery Costs (X_3)	14.93 (£)	.1008
Adjusted Acres (X_4)	22.43 A	-.1806
Labor Units (X_5)	1.013	-.0806

Formula for the computation of the marginal value product is:

$$MVP_{x_1} = \frac{.7455(327.3)}{486.1} = .501959$$

$$MVP_{x_2} = \frac{.1852(327.3)}{56.79} = 1.067370$$

$$MVP_{x_3} = \frac{.1008(327.3)}{14.93} = 2.209768$$

$$MVP_{x_4} = \frac{-.1806(327.3)}{22.43} = -2.635326$$

$$MVP_{x_5} = \frac{-.0806(327.3)}{1.013} = -26.04183$$

TABLE A25

REGRESSION COEFFICIENTS (b_i's), THEIR STANDARD ERRORS (σbi), AND LEVELS OF SIGNIFICANCE COUNTY SLIGO PILOT AREA, 1966-68

Input category	b_i	σb_i	Significance level
Livestock Investment	.563889	.186436	.006
Variable Non Labor Costs	.352183	.166291	.046
Machinery Costs	.135024	.101378	.197
Adjusted Acres	.181041	.186874	.343
Labor Units	.408233	.178299	.032

TABLE A26

SIMPLE CORRELATIONS BETWEEN INPUT CATEGORIES

Input category	Livestock Investment	Var. non labor costs	Machinery costs	Adjusted costs	Labor units
Livestock Investment	1.0	.87	.49	.68	.39
Var. Non Labor Costs		1.0	.54	.54	.36
Machinery Costs			1.0	.45	.29
Adjusted Acres				1.0	.58
Labor Units					1.0

TABLE A27

COMPUTATION OF GROSS OUTPUT FROM THE ESTIMATED REGRESSION EQUATION, COUNTY SLIGO PILOT AREA, 1966-68

Input category	Quantity of Inputs*	log GX_i*	b_i's	$b_i \log GX_i$	MVP (Ƅ)
Livestock Investment	510.7 (Ƅ)	2.70820	.5639	1.5272	.457
Non Labor Costs	91.98 (Ƅ)	1.96368	.3522	.6916	1.585
Machinery Costs	13.70 (Ƅ)	1.13645	.1350	.1534	4.080
Adjusted Acres	19.06 A	1.28023	.1810	.2317	3.931
Labor Units	1.035	0.01495	.4082	.0061	163.28

log constant (a) = .00696

$$\log Y \text{ (gross output)} = \log a + \Sigma b_i \log GX_i$$

$$= .00696 + 2.6100$$

$$= 2.61696$$

Antilog = Ƅ 414.0

TABLE A28

COMPUTATION OF THE MARGINAL VALUE PRODUCTS (Ƀ)
SLIGO PILOT AREA, 1966-68

Input category	Quantity in the usual organization	Regression Coefficient
Livestock Investment (X_1)	510.7 (Ƀ)	.5639
Var. Non Labor Cost (X_2)	91.98 (Ƀ)	.3522
Machinery Costs (X_3)	13.7 (Ƀ)	.1350
Adjusted Acres (X_4)	19.06 A	.1810
Labor Units (X_5)	1.035	.4082

Formula for the computation of the marginal value product is:

$$MVP_{x_1} = \frac{.5639(414.0)}{510.7} = .457126$$

$$MVP_{x_2} = \frac{.3522(414.0)}{91.98} = 1.58524$$

$$MVP_{x_3} = \frac{.1350(414.0)}{13.7} = 4.0795$$

$$MVP_{x_4} = \frac{.1810(414.0)}{19.06} = 3.93147$$

$$MVP_{x_5} = \frac{.4082(414.0)}{1.035} = 163.28$$

TABLE A29

REGRESSION COEFFICIENTS (b_i's), THEIR STANDARD ERRORS (σb_i), AND LEVELS OF SIGNIFICANCE, COUNTIES CLARE AND KERRY PILOT AREAS, 1966-68

Input category	b_i	σb_i	Significance level
Livestock Investment	.545041	.151128	.001
Variable Non Labor Costs	.341915	.075210	< 0.0005
Machinery Costs	.102737	.037506	.008
Adjusted Acres	.015471	.120116	.898
Labor Units	.059228	.107948	.585

TABLE A30

SIMPLE CORRELATIONS BETWEEN INPUT CATEGORIES

Input category	Livestock Investment	Var. non labor costs	Machinery costs	Adjusted costs	Labor units
Livestock Investment	1.0	.78	.63	.78	.50
Var. Non Labor Costs		1.0	.52	.48	.45
Machinery Costs			1.0	.46	.40
Adjusted Acres				1.0	.58
Labor Units					1.0

TABLE A31

COMPUTATION OF GROSS OUTPUT FROM THE ESTIMATED REGRESSION EQUATION, COUNTIES CLARE AND KERRY PILOT AREAS, 1966-68

Input category	Quantity of Inputs*	log GX_i*	b_i's	$b_i \log GX_i$	MVP (Ь)
Livestock Investment	842.6 (Ь)	2.92563	.5450	1.5945	.457
Non Labor Costs	133.0 (Ь)	2.12391	.3419	0.7262	1.816
Machinery Costs	38.37(Ь)	1.58398	.1027	0.1627	1.891
Adjusted Acres	33.63 A	1.52678	.0155	.0237	.326
Labor Units	1.235	0.09170	.0592	.0054	33.866

log constant (a) = 0.33659

$$\log Y \text{ (gross output)} = \log a + \Sigma b_i \log GX_i$$

$$= .336599 + 2.5125$$

$$= 2.8491$$

Antilog = 706.5

TABLE A32

COMPUTATION OF THE MARGINAL VALUE PRODUCTS (£)
CLARE AND KERRY PILOT AREAS, 1966-68

Input category	Quantity in the usual organization	Regression Coefficient
Livestock Investment (X_1)	842.6 (£)	.5450
Var. Non Labor Cost (X_2)	133.0 (£)	.3419
Machinery Costs (X_3)	38.37 (£)	.1027
Adjusted Acres (X_4)	33.63 A	.0155
Labor Units (X_5)	1.235	.0592

Formula for the computation of the marginal value product is:

$$MVP_{x_1} = \frac{.5450(706.5)}{842.6} = .456969$$

$$MVP_{x_2} = \frac{.3419(706.5)}{133.0} = 1.816183$$

$$MVP_{x_3} = \frac{.1027(706.5)}{38.37} = 1.8910$$

$$MVP_{x_4} = \frac{.0155(706.5)}{33.63} = .325624$$

$$MVP_{x_5} = \frac{.0592(706.5)}{1.235} = 33.86623$$

TABLE A33

REGRESSION COEFFICIENTS (b_i's), THEIR STANDARD ERRORS (σb_i), AND LEVELS OF SIGNIFICANCE, COUNTIES GALWAY, MAYO, ROSCOMMON AND SLIGO PILOT AREAS, 1966-68

Input category	b_i	σb_i	Significance level
Livestock Investment	.624571	.095443	<0.0005
Variable Non Labor Costs	.377935	.061034	<0.0005
Machinery Costs	.060808	.050023	.227
Adjusted Acres	-.081596	.081491	.319
Labor Units	.164600	.062896	.010

TABLE A34

SIMPLE CORRELATIONS BETWEEN INPUT CATEGORIES

Input category	Livestock Investment	Var. non labor costs	Machinery costs	Adjusted costs	Labor units
Livestock Investment	1.0	.82	.61	.77	.23
Var. Non Labor Costs		1.0	.55	.54	.27
Machinery Costs			1.0	.63	.27
Adjusted Acres				1.0	.22
Labor Units					1.0

TABLE A35

COMPUTATION OF GROSS OUTPUT FROM THE ESTIMATED REGRESSION EQUATION, COUNTIES GALWAY, MAYO ROSCOMMON, SLIGO PILOT AREAS, 1966-68

Input category	Quantity of Inputs*	log GX_i*	b_i's	$b_i \log GX_i$	MVP (£)
Livestock Investment	562.0	2.74980	.6246	1.7175	.477
Non Labor Costs	86.4	1.93647	.3779	.7318	1.879
Machinery Costs	17.8	1.24787	.0608	.0759	1.467
Adjusted Acres	24.29	1.38539	-.0816	-.1130	-1.443
Labor Units	1.074	.03070	.1646	.0051	65.840

log constant (a) = .215785

$$\log Y \text{ (gross output)} = \log a + \Sigma b_i \log GX_i$$

$$= .215785 + 2.4173$$

$$= 2.6331$$

Antilog = £ 429.6

TABLE A36

COMPUTATION OF THE MARGINAL VALUE PRODUCTS (Ƀ), GALWAY, ROSCOMMON, MAYO AND SLIGO PILOT AREAS, 1966-68

Input category	Quantity in the usual organization	Regression Coefficient
Livestock Investment (X_1)	562.0 (Ƀ)	.6246
Var. Non Labor Cost (X_2)	86.4 (Ƀ)	.3779
Machinery Costs (X_3)	17.8 (Ƀ)	.0608
Adjusted Acres (X_4)	24.29 A	-.0816
Labor Units (X_5)	1.074	.1646

Formula for the computation of the marginal value product is:

$$MVP_{x_1} = \frac{.6246(429.6)}{562.0} = .477452$$

$$MVP_{x_2} = \frac{.3779(429.6)}{86.4} = 1.879003$$

$$MVP_{x_3} = \frac{.0608(429.6)}{17.8} = 1.467398$$

$$MVP_{x_4} = \frac{-.0816(429.6)}{24.29} = -1.443201$$

$$MVP_{x_5} = \frac{.1646(429.6)}{1.074} = 65.84000$$

APPENDIX B

COMPUTATION OF b_i's TO YIELD MINIMUM RETURNS AND COMPARISONS WITH THE ESTIMATED MARGINAL VALUE PRODUCTS

COMPUTATION OF b_i's TO YIELD MINIMUM RETURNS, ONE HUNDRED AND SIXTY-FIVE PILOT AREA FARMS, 1966-68

$$MVP_{x_i} = \frac{b_i \hat{Y}}{X_i}$$

At the optimum organization $MVP_{x_i} = MFC_{x_i}$

$$b_i^* = \frac{MVP_{x_i} \cdot X_i}{\hat{Y}} = \frac{MFC_{x_i} \cdot X_i}{\hat{Y}}, \text{ at the optimum organization}$$

$$b_1^* = \frac{0.40(665.8)}{528.6} = .5038$$

$$b_2^* = \frac{1.06(103.5)}{528.6} = .2075$$

$$b_3^* = \frac{.24(24.45)}{528.6} = .0111$$

$$b_4^* = \frac{.09(27.83)}{528.6} = .0047$$

$$b_5^* = \frac{455(1.139)}{528.6} = .9804$$

TABLE B1

COMPARISON OF ESTIMATED b_i's AND THE b_i's REQUIRED TO YIELD MINIMUM MARGINAL VALUE PRODUCTS, ONE HUNDRED AND SIXTY-FIVE PILOT AREA FARMS, 1966-68

b_i	Estimated b_i	b_i's to yield minimum return	difference $b_i - b_i^*$	std. error	t value	significance level
b_1	.6179	.5038	.1141	.0802	1.4227	N.S.
b_2	.3512	.2075	.1437	.0464	3.0970	.01
b_3	.0878	.0111	.0767	.0266	2.8835	.01
b_4	-.0625	.0047	-.0672	.0645	1.0419	N.S.
b_5	.1327	.9804	-.8477	.0542	15.6402	.001

Note: All calculations in this Appendix were rounded to four significant decimal places.

COMPUTATION OF b_i's TO YIELD MINIMUM RETURNS
COUNTY CLARE PILOT AREA

$$b_1 = \frac{0.40(857.4)}{730.3} = .4696$$

$$b_2 = \frac{1.06(126.3)}{730.3} = .1833$$

$$b_3 = \frac{.24(49.83)}{730.3} = .0164$$

$$b_4 = \frac{.09(32.93)}{730.3} = .0070$$

$$b_5 = \frac{455(1.248)}{730.3} = .7775$$

TABLE B2

COMPARISON OF ESTIMATED b_i's AND THE b_i's REQUIRED TO YIELD MINIMUM MARGINAL VALUE PRODUCTS, COUNTY CLARE PILOT AREA, 1966-1968

b_i	Estimated b_i	b_i's to yield minimum return	difference $b_i - b_i$*	std. error	t value	significance level
b_1	.5659	.4696	.0963	.1504	.6403	N.S.
b_2	.5266	.1833	.3433	.0704	4.8764	.001
b_3	.0271	.0164	.0107	.0412	.2597	N.S.
b_4	-.0141	.0070	-.0211	.1168	.1807	N.S.
B_5	-.0281	.7775	-.8056	.1053	7.6505	.001

COMPUTATION OF b_i's TO YIELD MINIMUM RETURNS
COUNTY KERRY PILOT AREA, 1966-68

$$b_1 = \frac{0.40(798.0)}{639} = .4995$$

$$b_2 = \frac{1.06(155.7)}{639} = .2582$$

$$b_3 = \frac{.24(17.25)}{639} = .0065$$

$$b_4 = \frac{.09(35.91)}{639} = .0051$$

$$b_5 = \frac{455(1.204)}{639} = .8573$$

TABLE B3

COMPARISON OF ESTIMATED b_i's AND THE b_i's REQUIRED
TO YIELD MINIMUM MARGINAL VALUE PRODUCTS,
COUNTY KERRY PILOT AREA, 1966-68

b_i	Estimated b_i	b_i's to yield minimum return	difference $b_i - b_i$*	std. error	t value	significance level
b_1	.6524	.4995	.1529	.3625	.4218	N.S.
b_2	-.1108	.2582	-.3690	.2011	1.8349	N.S.
b_3	.3332	.0065	.3267	.1013	3.2251	.01
b_4	.2856	.0051	.2805	.3465	.8095	N.S.
b_5	-.1128	.8573	-.9701	.2736	3.5457	.01

COMPUTATION OF b_i's TO YIELD MINIMUM RETURNS
COUNTY GALWAY PILOT AREA, 1966-68

$$b_1 = \frac{.40(659.1)}{517.6} = .5094$$

$$b_2 = \frac{1.06(114.7)}{517.6} = .2349$$

$$b_3 = \frac{.24(25.71)}{517.6} = .0119$$

$$b_4 = \frac{.09(29.52)}{517.6} = .0051$$

$$b_5 = \frac{455(1.169)}{517.6} = 1.0276$$

TABLE B4

COMPARISON OF ESTIMATED b_i's AND THE b_i's REQUIRED TO YIELD MINIMUM MARGINAL VALUE PRODUCTS, COUNTY GALWAY PILOT AREA, 1966-68

b_i	Estimated b_i	b_i's to yield minimum return	difference $b_i - b_i$*	std. error	t value	significance level
b_1	.6396	.5094	.1302	.1774	.7339	N.S.
b_2	.4602	.2349	.2253	.0890	2.5315	.05
b_3	.0183	.0119	.0064	.0754	.0849	N.S.
b_4	-.2212	.0051	-.2263	.1322	1.7118	N.S.
b_5	.0521	1.0276	-.9755	.0942	10.3556	.001

COMPUTATION OF b_i's TO YIELD MINIMUM RETURNS
COUNTY MAYO PILOT AREA, 1966-68

$$b_1 = \frac{.40(627.3)}{492.3} = .5097$$

$$b_2 = \frac{1.06(92.87)}{492.3} = .2000$$

$$b_3 = \frac{.24(20.04)}{492.3} = .0098$$

$$b_4 = \frac{.09(29.32)}{492.3} = .0054$$

$$b_5 = \frac{455(1.123)}{492.3} = 1.038$$

TABLE B5

COMPARISON OF ESTIMATED b_i's AND THE b_i's REQUIRED TO YIELD MINIMUM MARGINAL VALUE PRODUCTS, COUNTY MAYO PILOT AREA, 1966-68

b_i	Estimated b_i	b_i's to yield minimum return	difference $b_i - b_i^*$	std. error	t value	significance level
b_1	.5417	.5097	.0320	.1329	.2400	N.S.
b_2	.4014	.2000	.2014	.0919	2.1915	.05
b_3	.1514	.0098	.1416	.0798	1.7744	N.S.
b_4	-.1616	.0054	-.1670	.1218	1.3711	N.S.
b_5	.2162	1.0380	-.8218	.0774	10.6176	.001

COMPUTATION OF b_i's TO YIELD MINIMUM RETURNS
COUNTY ROSCOMMON PILOT AREA, 1966-68

$$b_1 = \frac{.40(486.1)}{327.3} = .5940$$

$$b_2 = \frac{1.06(56.79)}{327.3} = .1839$$

$$b_3 = \frac{.24(14.93)}{327.3} = .0110$$

$$b_4 = \frac{.09(22.43)}{327.3} = .0062$$

$$b_5 = \frac{455(1.013)}{327.3} = 1.4082$$

TABLE B6

COMPARISON OF ESTIMATED b_i's AND THE b_i's REQUIRED TO YIELD MINIMUM MARGINAL VALUE PRODUCTS, COUNTY ROSCOMMON PILOT AREA, 1966-68

b_i	Estimated b_i	b_i's to yield minimum return	difference $b_i - b_i^*$	std. error	t value	significance level
b_1	.7455	.5940	.1515	.2912	.5203	N.S.
b_2	.1852	.1839	.0013	.2093	.0062	N.S.
b_3	.1008	.0110	.0898	.1296	.6929	N.S.
b_4	-.1806	.0062	-.1744	.2407	.7246	N.S.
b_5	-.0806	1.4082	-1.4888	.1768	8.4208	.001

COMPUTATION OF b_i's TO YIELD MINIMUM RETURNS
COUNTY SLIGO PILOT AREA, 1966-68

$$b_1 = \frac{.40(510.7)}{414} = .4934$$

$$b_2 = \frac{1.06(91.98)}{414} = .2355$$

$$b_3 = \frac{.24(13.7)}{414} = .0079$$

$$b_4 = \frac{.09(19.06)}{414} = .0041$$

$$b_5 = \frac{455(1.035)}{414} = 1.1375$$

TABLE B7

COMPARISON OF ESTIMATED b_i's AND THE b_i's REQUIRED TO YIELD MINIMUM MARGINAL VALUE PRODUCTS, COUNTY SLIGO PILOT AREA, 1966-68

bi	Estimated b_i	b_i's to yield minimum return	difference $b_i - b_i^*$	std. error	t value	significance level
b_1	.5639	.4934	.0705	.1864	.3782	N.S.
b_2	.3522	.2355	.1167	.1663	.7017	N.S.
b_3	.1350	.0079	.1271	.1014	1.2535	N.S.
b_4	.1810	.0041	.1769	.1869	.9465	N.S.
b_5	.4082	1.1375	-.7293	.1783	4.0903	.001

COMPUTATION OF b_i's TO YIELD MINIMUM RETURNS, COUNTIES CLARE AND KERRY PILOT AREAS, 1966-68

$$b_1 = \frac{.40(842.6)}{706.5} = .4771$$

$$b_2 = \frac{1.06(133.0)}{706.5} = .1995$$

$$b_3 = \frac{.24(38.37)}{706.5} = .0130$$

$$b_4 = \frac{.09(33.63)}{706.5} = .0043$$

$$b_5 = \frac{455(1.235)}{706.5} = .7954$$

TABLE B8

COMPARISON OF ESTIMATED b_i's AND THE b_i's REQUIRED TO YIELD MINIMUM MARGINAL VALUE PRODUCTS, COUNTIES CLARE AND KERRY PILOT AREAS, 1966-68

b_i	Estimated b_i	b_i's to yield minimum return	difference $b_i - b_i^*$	std. error	t value	significance level
b_1	.5450	.4771	.0679	.1511	.4494	N.S.
b_2	.3419	.1995	.1424	.0752	1.8936	N.S.
b_3	.1027	.0130	.0897	.0375	2.3920	.05
b_4	.0155	.0043	.0112	.1201	.0933	N.S.
b_5	.0592	.7954	-.7362	.1079	6.8230	.001

COMPUTATION OF b_i's TO YIELD MINIMUM RETURNS, COUNTIES GALWAY, MAYO, ROSCOMMON AND SLIGO PILOT AREAS, 1966-68

$$b_1 = \frac{.40(562.0)}{429.6} = .5233$$

$$b_2 = \frac{1.06(86.4)}{429.6} = .2132$$

$$b_3 = \frac{.24(17.8)}{429.6} = .0099$$

$$b_4 = \frac{.09(24.29)}{429.6} = .0051$$

$$b_5 = \frac{455(1.074)}{429.6} = 1.1375$$

TABLE B9

COMPARISON OF ESTIMATED b_i's AND THE b_i's REQUIRED TO YIELD MINIMUM MARGINAL VALUE PRODUCTS, COUNTIES GALWAY, MAYO, ROSCOMMON AND SLIGO PILOT AREAS, 1966-68

b_i	Estimated b_i	b_i's to yield minimum return	difference $b_i - b_i$*	std. error	t value	significance level
b_1	.6246	.5233	.1013	.0954	1.0618	N.S.
b_2	.3779	.2132	.1647	.0610	2.7000	.01
b_3	.0608	.0099	.0509	.0500	1.0180	N.S.
b_4	-.0816	.0051	-.0867	.0815	1.0638	N.S.
b_5	.1646	1.1375	-.9729	.0629	15.4674	.001

APPENDIX C

AVERAGE SIZE OF THE DAIRY HERD IN THE PILOT AREAS STUDIED, 1966-67 AND 1967-68.

TABLE C1

AVERAGE SIZE OF DAIRY HERD IN THE PILOT AREAS STUDIED, 1966-67 AND 1967-68

Pilot areas	Average size of dairy herd (cow numbers)	
	1966-67	1967-68
Clare	9.6	9.6
Kerry	10.4	10.9
Galway	6.7	7.0
Mayo	6.2	6.4
Roscommon	-	-
Sligo	5.2	5.2

APPENDIX D

SUMMARY OF AVERAGE GROSS OUTPUT, EXPENSES AND INPUT DATA FOR EACH PILOT AREA FARM IN THE STUDY OVER THE 1966-68 PERIOD

TABLE D1

CLARE PILOT AREA DATA

Farm No.	Total Gross Output (Ƀ)	Livestock Investment (Ƀ)	Variable Non Labor Costs (Ƀ)	Machinery Costs (Ƀ)	Labor Units	Adjusted Acres
1	2,228	2,187	332	183	1.3	95
2	1,834	2,017	272	223	3.0	91
3	1,355	1,880	189	24	1.3	63
4	1,405	1,267	309	27	1.6	38
5	1,504	1,338	368	134	1.2	52
6	1,695	1,798	386	237	2.0	90
7	1,209	1,272	154	63	2.0	65
8	1,207	1,709	165	119	1.0	49
9	1,206	1,453	241	45	1.4	55
10	1,143	1,088	120	138	1.5	44
11	1,128	1,396	131	132	1.8	48
12	1,208	1,512	209	147	1.3	45
13	969	942	106	38	1.9	40
14	1,115	1,325	120	127	1.8	51
15	940	974	132	16	1.3	44
16	1,004	1,346	178	20	2.6	49
17	1,713	2,149	198	433	1.7	74
18	1,101	1,324	164	110	2.3	39
19	1,032	1,195	233	26	1.9	29
20	815	797	112	49	1.2	54
21	1,372	1,280	400	194	1.2	31
22	822	876	129	28	1.2	35
23	844	1,113	167	20	1.0	34
24	1,036	1,556	236	107	1.3	56
25	814	799	146	19	1.2	35
26	894	910	92	149	1.1	31
27	939	1,172	184	33	1.3	19

TABLE D1--Continued

Farm No.	Total Gross Output (Ƀ)	Livestock Investment (Ƀ)	Variable Non Labor Costs (Ƀ)	Machinery Costs (Ƀ)	Labor Units	Adjusted Acres
28	678	674	106	21	1.0	24
29	764	732	183	27	1.3	20
30	640	645	101	39	1.2	24
31	691	834	96	92	1.0	35
32	644	572	147	27	1.3	23
33	605	687	136	20	1.3	25
34	590	876	59	42	1.0	46
35	544	538	76	49	1.0	20
36	604	363	171	18	1.5	22
37	571	441	97	17	0.5	11
38	785	1,019	232	115	1.1	42
39	705	938	128	56	1.1	45
40	626	770	86	115	1.1	42
41	916	932	277	196	1.2	40
42	450	337	126	12	1.5	9
43	591	600	137	115	1.0	19
44	388	470	66	24	1.3	16
45	569	689	84	172	1.0	27
46	367	470	63	25	1.0	21
47	241	520	32	17	1.1	30
48	226	199	38	12	0.3	8
49	180	331	36	17	0.7	15
50	197	395	48	19	1.0	12
51	150	392	33	17	1.0	20
52	68	289	12	15	1.0	27
Total	45,322	51,388	8,043	4,120	68.9	1979
Average	871.6	988.2	154.7	79.23	1.33	38.05

TABLE D2

KERRY PILOT AREA DATA

Farm No.	Total Gross Output (£)	Livestock Investment (£)	Variable non labor costs (£)	Machinery Costs (£)	Labor Units	Adjusted Acres
1	2,582	2,243	1,175	145	1.9	45
2	1,310	1,567	318	44	1.2	49
3	1,130	1,509	221	25	1.7	70
4	955	945	242	15	1.6	30
5	903	820	160	21	1.2	44
6	813	1,021	187	18	1.2	49
7	768	938	231	15	1.0	50
8	961	852	374	110	1.0	23
9	727	848	243	12	1.4	48
10	1,109	1,080	310	256	1.4	30
11	464	764	67	18	1.7	47
12	495	701	109	13	2.0	28
13	379	198	19	9	2.0	41
14	583	1,208	260	10	1.1	42
15	258	472	21	-	0.2	16
16	317	412	107	11	0.9	17
17	75	282	59	-	1.0	27
Total	13,829	15,860	4,103	722	22.5	656
Average	813.47	932.94	241.35	42.47	1.32	38.59

TABLE D3

GALWAY PILOT AREA DATA

Farm No.	Total Gross Output (£)	Livestock Investment (£)	Variable Non Labor Costs (£)	Machinery Costs (£)	Labor Units	Adjusted Acres
1	3,221	3,611	1,145	373	2.8	140
2	1,146	995	329	18	1.4	35
3	1,456	1,842	339	190	1.9	82
4	1,076	963	330	15	1.3	30
5	901	942	227	14	1.0	33
6	1,092	1,163	324	30	2.0	25
7	671	991	84	19	1.3	26
8	670	668	135	23	1.5	23
9	674	1,426	119	33	1.0	90
10	616	635	146	30	1.7	40
11	522	428	129	21	0.5	15
12	629	811	228	26	1.1	21
13	451	549	90	22	1.1	17
14	479	548	110	16	0.6	19
15	448	556	83	25	1.8	40
16	585	722	178	27	0.4	41
17	357	494	78	19	2.0	30
18	316	640	40	46	1.0	35
19	166	186	20	12	1.2	13
20	104	295	20	10	1.0	25
21	147	186	27	16	0.7	10
22	90	183	23	14	1.1	18
Total	15,817	18,834	4,204	999	28.4	808
Average	718.95	856.09	191.1	45.41	1.29	36.73

TABLE D4

MAYO PILOT AREA DATA

Farm No.	Total Gross Output (Ƚ)	Livestock Investment (Ƚ)	Variable Non Labor Costs (Ƚ)	Machinery Costs (Ƚ)	Labor Units	Adjusted Acres
1	954	1,514	149	17	2.0	56
2	1,208	1,013	356	29	1.4	45
3	923	1,042	161	27	1.7	24
4	703	775	108	30	1.2	31
5	739	1,082	115	28	1.4	27
6	743	612	183	29	1.0	28
7	705	719	72	95	1.2	32
8	614	967	119	11	0.9	31
9	602	395	146	10	1.8	16
10	549	1,043	92	24	2.0	59
11	512	534	96	20	2.0	30
12	523	693	118	14	0.8	30
13	507	929	84	26	1.0	70
14	401	544	42	14	1.1	25
15	440	614	102	20	1.5	20
16	493	977	121	33	0.5	50
17	365	384	62	19	1.1	13
18	409	688	77	13	0.4	28
19	303	300	53	16	1.5	24
20	283	369	39	14	0.9	35
21	227	281	55	15	1.5	20
22	205	326	43	14	1.0	24
23	201	311	71	14	0.4	18
Total	12,609	16,112	2,464	532	28.3	736
Average	548.22	700.52	107.13	23.13	1.23	32.00

TABLE D5

ROSCOMMON PILOT AREA DATA

Farm No.	Total Gross Output (£)	Livestock Investment (£)	Variable Non Labor Costs (£)	Machinery Costs (£)	Labor Units	Adjusted Acres
1	1,050	1,923	98	35	0.3	86
2	749	1,006	165	19	1.1	28
3	902	1,188	197	33	1.2	48
4	613	939	117	22	1.2	40
5	540	763	88	14	1.0	40
6	492	505	53	17	1.1	18
7	347	365	32	15	1.2	24
8	319	347	26	10	0.5	15
9	334	493	67	20	1.0	18
10	273	489	47	7	1.0	20
11	255	354	31	8	2.0	12
12	254	284	44	13	1.0	21
13	261	374	63	4	1.0	13
14	249	426	45	12	0.6	24
15	271	285	42	35	1.6	13
16	311	436	82	20	0.9	28
17	403	1,004	83	20	1.3	38
18	261	425	62	18	0.8	12
19	209	263	36	12	1.2	15
20	231	330	52	25	1.0	18
21	231	699	51	25	1.0	48
22	102	139	17	4	1.0	10
23	148	342	44	11	1.1	16
Total	8,805	13,379	1,542	399	24.1	584
Average	382.8	581.7	67.0	17.3	1.04	25.4

TABLE D6

SLIGO PILOT AREA DATA

Farm No.	Total Gross Output (£)	Livestock Investment (£)	Variable Non Labor Costs (£)	Machinery Costs (£)	Labor Units	Adjusted Acres
1	1,047	1,372	184	22	1.3	28
2	999	1,274	237	13	1.1	30
3	820	1,053	169	13	1.0	30
4	744	661	84	26	1.2	27
5	933	1,124	192	40	1.6	38
6	741	594	186	6	1.5	18
7	737	817	133	31	1.1	22
8	721	785	146	14	1.3	22
9	572	583	86	8	1.0	25
10	546	536	77	17	1.2	20
11	549	821	76	9	0.6	17
12	556	543	99	17	1.1	15
13	500	380	91	18	1.1	12
14	781	1,041	204	18	1.1	28
15	429	333	64	15	1.4	50
16	465	436	114	23	1.0	15
17	384	324	91	13	1.1	15
18	394	473	93	46	1.0	22
19	329	486	81	10	1.0	15
20	269	412	37	7	1.9	24
21	419	415	132	18	0.7	15
22	294	303	77	20	1.2	18
23	358	707	94	17	1.0	15
24	376	814	176	9	0.9	20
25	102	162	23	5	1.0	14
26	89	164	24	5	0.7	10
27	96	175	47	7	1.0	8
28	56	157	30	7	0.3	9
Total	14,306	16,945	3,047	454	30.4	582
Average	510.9	605.1	108.8	16.2	1.1	20.8