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AGGREGATE CROP PRODUCTION FUNCTIONS IN FINNISH AGRICULTURE IN 1956/57—1968/69

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SELOSTUS:
KASVINVILJELYN TUOTANTOFUNKTIOT SUOMEN MAATALOUDESSA SATOVUOSINA 1956/57—1968/69

AGGREGATE LIVESTOCK AND TOTAL PRODUCTION FUNCTIONS IN FINNISH AGRICULTURE IN 1956/57—1969/70

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SELOSTUS:
KOTIELÄIN- JA KOKONAISTUOTTOFUNKTIOT SUOMEN MAATALOUDESSA SATOVUOSINA 1956/57—1969/70

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Foreword

This publication includes a two-part study on production functions in Finnish agriculture. As a matter of fact, such a division should not have been made. Because the first part was, however, conceived of as an academic work and because it includes a uniform theoretical analyses of production functions, it was thought reasonable to publish it as such.

Part II was restricted to giving only the main points of the estimation and results of animal and total production functions. Part I was used in Part II to make a prediction of agricultural production in Finland for the near future. Therefore, the two studies well complete each other.

Finally, the authors wish to thank the Board of the Agricultural Economics Research Institute for including these studies in the Institute's publication series.

Helsinki, April 1972

The authors

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Selostus:
Kasvinviljelyn tuotantofunktiot Suomen
maataloudessa satovuosina 1956/57-1968/69

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Preface

Initially this study was submitted to the Graduate School of the University of Minnesota as partial fulfillment of the requirements for the degree of M.Sc. Since that time only minor revisions have been made.

The author wishes to express his sincere appreciation to Professors W.L. Peterson, B.M. Buxton, and D.E. Welsch for their guidance and helpful comments during the course of this study. The final English text has been checked by Dr. Theodore E. Doty who also presented some valuable comments. The typing was performed by Miss Monica Skogström. For all these benefits I express the deepest gratitude. Of course, only the author takes responsibility for any errors.

I am also indebted to the Department of Agricultural and Applied Economics, University of Minnesota for providing computer time and other facilities for this study.

Helsinki, April 1972

Juhani Rouhiainen

CONTENTS

1. INTRODUCTION

1.1. Background

Agriculture in Finland is characterized by small, diversified farming units in which dairying is the predominant enterprise. In 1969, of the total of 264,000 farms having 2 hectares (ha.) or more of arable land, more than 65 per cent are under 10 hectares, the average size being about 10 hectares.[1] Virtually all farms have forests, the average area being 35 hectares, from which supplementary incomes are obtained.

Over the past few years cash crops have accounted for only about 15 per cent of the gross return of agriculture. Despite this relative small contribution of crop sales to farm income, it should be noted that crop production accounts for practically all feed stuffs consumed in the livestock sectors.

During the last two decades, Finnish agriculture has undergone considerable development. Self-sufficiency in agriculture has been achieved in practically all major farm products in the 1960's with the exception of sugar, vegetable fats and some other fairly insignificant products.

As measured in terms of feed units (f.u.)[2] the total yield per hectare in the crop year 1956/57 averaged 1,553 f.u./ha. In

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[1] In the Finnish Agricultural Statistics holdings having less than 2 ha. of arable land are not considered as "farms". This is because the major source of income of people living on these farms is other than agriculture.

[2] A feed unit is a measure used commonly in the Finnish Agricultural Statistics in order to sum up different crops and feed stuffs. A feed unit is defined as the productive potential equal to 1 kilogram of barley in milk production. The feeding trials of determining feed unit values for various crops and feed stuffs are discussed by Lauri Paloheimo in <u>Kotieläinhoidon perusteita</u>, (Jyväskylä: K.J. Gummerus Oy, 1956), pp. 251-275. The convertion tables are presented in this book on pages 590-599.

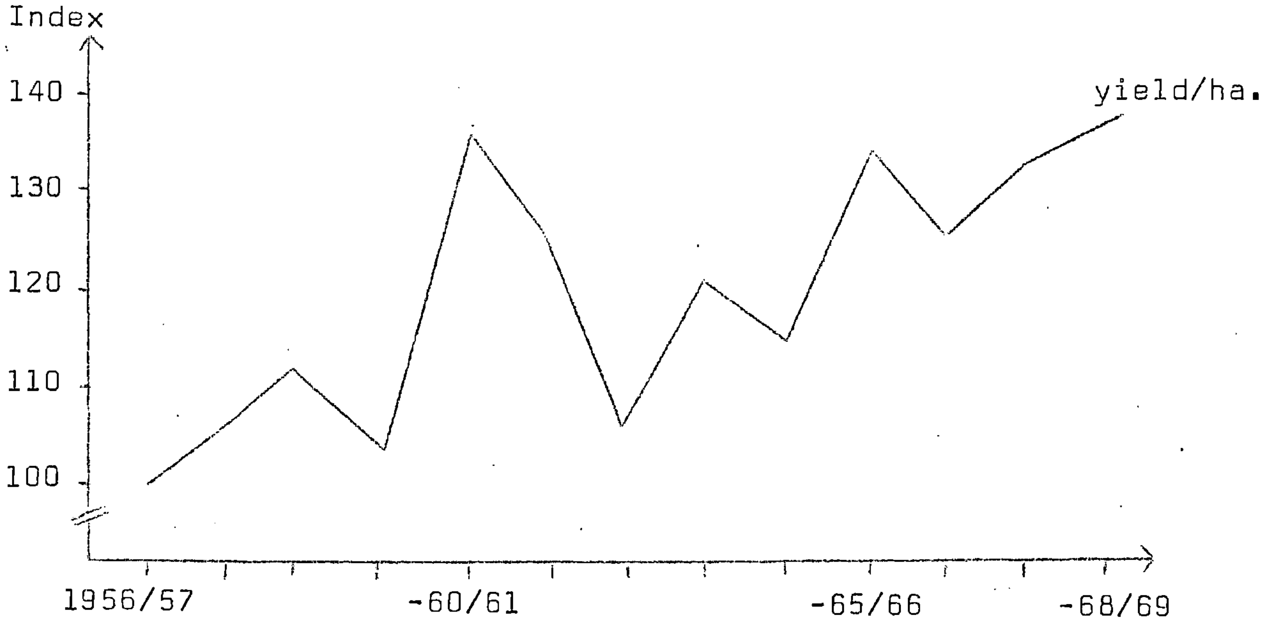

Figure 1.1. Average total yield in feed units per hectare, 1956/57 to 1968/69 (1956/57 = 100). Source: Data from the Board of Agriculture, Helsinki.

1968/69 the corresponding figure was 2,109. Despite marked fluctuations, caused mainly by varying weather conditions during this period, a steadily rising trend is observable since 1956/57 with the increase in the average total yield measured in feed units amounting to some 35 per cent by 1968/69 (Figure 1.1.).[1]

It is quite evident as indicated in Appendix 2, that a considerable part of the increase in crop output has been due to increased use of various inputs: the utilization of fertilizer and lime within the time period in question has more than doubled (208 %); a similar trend can be observed in the use of farm machinery (188 %); there has been a large increase in the utilization of agricultural chemicals (508 %). By comparison the labor input has dropped by more than half (64 %).

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[1] The total yield of each crop from 1956/57 to 1968/69 is given in Appendix 1.

In addition to this quantitative increase in non-labor input utilization it is also fairly certain that the introduction of improved inputs and new techniques, in other words, technical change in agriculture, has also played a significant role in raising the output of Finnish agriculture.

1.2. The Problem and Objectives of Study

With only 7.7 per cent of the total GNP in 1970, the agricultural sector of the Finnish economy is of relatively minor importance. On the other hand, persons engaged primarily in agriculture, or dependent upon agriculture as their principal source of income made up some 19 per cent of the population in 1970. Thus the formulation and implementation of an agricultural policy which can maintain or improve the income situation in the agricultural sector while at the same time maintaining reasonable levels of consumer prices for agricultural products is a matter of major importance in the over-all planning and development of the Finnish economy.

In spring 1969 the governmental agricultural committee set clear targets for farm production for the near future. In general the target was self-sufficiency, meaning that, with certain exceptions, production of all major farm products that can reasonable be produced in the country should match the domestic consumption. The major exceptions are sugar and vegetable fats. The committee set a 20 per cent domestic production as the self-sufficiency level in sugar and in vegetable oils and fats needed by the margarine industry.

Some measures have already been taken to reach these goals. In spring 1969, in an effort to reduce surpluses of dairy products and soft wheat, Finland initiated Western Europe's first soil bank program called the "Act on Limiting the Use of Fields". In 1970 the soil bank program was modified and supplemented by special subsidies to farmers selling all their cows for slaughter and giving up milk production for three years.[1/]

As a result of these policies, by the end of 1969 the previous total of 2.7 mill. ha. of arable land under cultivation had been reduced by 85,700 ha. The corresponding figure at the end of 1970 was 138,500 ha.

Despite the favorable development in the reduction of arable land, there is still a high priority for better information about the structure of agricultural production and forces affecting it in order to guide Finnish agricultural policy towards the goal of balanced supply and consumption of farm products.

The purpose of this study is, therefore, to investigate the input-output structure of the crop sector of Finnish agriculture. The specific objectives are:

1. To estimate marginal physical products for the various inputs.
2. To examine the values of marginal products of inputs with regard to their respective prices.
3. To measure the technical change in crop production.

1.3. Previous Studies

Production function analysis of Finnish agriculture have been limited. The earliest studies date from the mid 1950's. In his 1955 study Tennberg[2/] estimated the impact of fertilizer in different regions on the various crops of different types of soils. Tennberg's results, which were based on field trials from 1922 to 1952,

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[1/] For further details see Matias Torvela and Juhani Rouhiainen, "The Importance of Dairy Farming to Finnish Agriculture", Research Reports of the Agricultural Economics Research Institute (AERI), No. 15, (Helsinki: 1971, Mimeographed), pp. 1-9, and U.S. Department of Agriculture, E.R.S. - Foreign 311, The Agricultural Situation in Western Europe, Review of 1970 and Outlook for 1971 (Washington, D.C.: Government Printing Office, 1971), pp. 10-11.

[2/] F. Tennberg, "Väkilannoitteissa annettujen ravinteiden satoa lisäävästä vaikutuksesta Suomessa", Pellervo-Seura, Väkilannoitteet maataloutemme kohottajina (Helsinki: Yhteiskirjapaino Oy, 1955), pp. 118-177.

indicate that the response of various crops to different plant nutrients was clearly dependent on soil type and geographic region. Also in 1955 an attempt to measure the contribution of fertilizer to crops using aggregate data was made by Pihkala.[1/] The method used was to compare the "theoretical" impact of fertilizer to "actual" impact. Pihkala concluded that from 1920 to 1954 the "law of diminishing returns" to the use of fertilizer was not yet prevailing. The study was continued by Lasola[2/] to include the years 1955 to 1968, but there was no change in the conclusions which had been reached by Pihkala.

A production function analysis of Finnish agriculture was first made in the late 1960's. In his study of 1966, Torvela[3/] employing cross-section data estimated production functions for farms specialized in different crops and animal products. Production functions were also derived for various farm size classes. This study was based on data obtained from the bookkeeping farms in Southern Finland. The results of this study indicate that the productivity of labor was low especially in small farms. The same was true with farm machinery. However, its use was clearly profitable in bigger farms. In each farm size class the productivity of fertilizer was high. A more comprehensive study, also based on data from the bookkeeping farms in Southern Finland was conducted by Kettunen and Torvela[4/] in 1970. Basically this study is similar to the study by

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[1/] Kaarlo U. Pihkala, "Väkilannoitteiden tuotantovaikutuksen ilmeneminen maataloustilastossa", Pellervo-Seura, Väkilannoitteet maataloutemme kohottajina (Helsinki: Yhteiskirjapaino Oy, 1955), pp. 178-186.

[2/] Tapani Lasola, "Väkilannoitteiden tuotantovaikutus valtakunnan satotilaston valossa vv. 1955-1968", Pellervo, LXX (Elokuu, 1969), pp. 794-795.

[3/] Matias Torvela, Tuotantopanosten käytöstä ja käytön edullisuudesta maataloudessa Etelä-Suomen alueen kirjanpitoviljelmillä, (Summary: On the Use of Agricultural Inputs on Bookkeeping Farms in South Finland), AERI Publication No. 8, (Helsinki: Maalaiskuntien liiton kirjapaino, 1966).

[4/] Lauri Kettunen and Matias Torvela, "The Intensity and Interdependence of Gross Return and Factors of Production in Agriculture", AERI Publication No. 19, (Helsinki: 1970, Mimeographed).

Torvela but the variables and functional forms used are more numerous. The results of this study are generally similar to results in the study by Torvela. Ryynänen [1] has estimated production functions for the bookkeeping farms in Central Finland. His study covers the years 1960/61 - 1962/63 and 1966. According to Ryynänen the intensity in the use of fertilizer is clearly below the optimum level. The productivity of labor turned out to be low also in this study.

This study is the first production function analysis based on a time series of aggregate data, the reason being that no reliable data covering a longer period of time have been available until recently.

As for the productivity studies in Finnish agriculture, the study by Suomela [2] should be mentioned. According to Suomela the average annual growth of productivity from 1935/36 to 1954/55 was some 1.0 - 1.5 per cent. The most recent productivity study of Finnish agriculture by Ihamuotila [3] indicates that the annual increase in the total net productivity averaged 3 per cent during the period 1950-69.

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[1] Viljo Ryynänen, Tutkimuksia maatalouden tuotantofunktioista Sisä-Suomen kirjanpitoviljelmillä vuosina 1960-1966, (Summary: Production Function Analyses of Farm Management Survey Data in Central Finland in 1960-1966), Publications of the Scientific Agricultural Society of Finland No. 120, (Hämeenlinna: Arvi A. Karisto Oy, 1970).

[2] Samuli Suomela, Tuottavuuden kehityksestä Suomen maataloudessa, (Summary: Development of Productivity in Finnish Agriculture), AERI Publication No. 1, (Helsinki: Valtioneuvoston kirjapaino, 1958), p. 113.

[3] Risto Ihamuotila, "Productivity and Aggregate Production Functions in the Finnish Agricultural Sector 1950-1969", AERI Publication No. 25, (Helsinki: 1971, Mimeographed), p. 89.

2. CONCEPTUAL FRAMEWORK

2.1. The Production Function Concept

Since the method used in this study is production function analysis, this chapter presents some basic concepts and definitions related to the production function. First, let us focus our attention on the concept of the production function.

The production function is usually represented as a mathematical equation. However, it may also be represented in the form of an arithmetic table or it may be illustrated geometrically by means of a graph. Undoubtedly the algebraic equation is most common.

The production function in the form

$$(2.1.) \qquad Q = f(X_1, X_2, \ldots, X_n)$$

shows the maximum amount of output (Q) that can be produced from any set of inputs ($X_1, X_2, \ldots, X_n$), given the existing technology (f). In this equation both Q and $X_1, X_2, \ldots, X_n$ are expressed in physical units.

We should bear in mind that the properties of a production function are defined by the mathematical form of the function. Another feature peculiar to the production function is that it does not consider any economic aspects. The production function is purely a technical relationship between the inputs and the output and also between the various inputs.1/

1/ The related concepts and the economic aspects of the production function are not discussed in this study. Good presentations are available in several textbooks, for example C.E. Ferguson, Microeconomic Theory (Homewood, Ill.: Richard D. Irwin, Inc., 1969), and Earl O. Heady, Economics of Agricultural Production and Resource Use (New York: Prentice-Hall, Inc., 1952).

2.2. The Specification of the Production Function

2.2.1. Selection of Variables

Before a production function can be estimated the dependent and the independent variables, and the algebraic form of the function must be specified. Because the obtained results will be directly effected by the variables and functions used, their selection is of great importance.

Usually the problem under examination will provide relatively clear guidelines for the selection of at least the most relevant variables. Thus, logical variables may be selected on the basis of one's knowledge of the production process. Often a major problem is that not all variables selected are measurable, or that quantitative data about them are unattainable. This is true especially with variables pretaining to the level of technology. This problem will be discussed in more detail later.

One possibility in solving the problem of variable selection is to use certain statistical methods, for example factor analysis. This method was applied in the Kettunen-Torvela study as a preliminary step preceding their production function analysis.[1/] Factor analysis makes it possible to varify or support the selection of variables made on the basis of the research worker's judgement and knowledge about the production process. By employing factor analysis it is also possible to get some a priori knowledge of the relative importance of the various variables in the model to be estimated.

Another possibility is the application of the stepwise regression analysis. In this method the "weakest" variable of the model will be dropped out in each step, until only one independent variable is left.

Another purely statistical method is the selective regression analysis. It selects out of a great number of variables those which, according to specific criteria, best explain the variations of the

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[1/] Lauri Kettunen and Matias Torvela, op. cit., pp. 38-56. They also discuss the procedure of factor analysis on pages 38-42.

dependent variable. A limitation of both of these methods of variable selection is the possibility of spurious correlation. A trend may, for instance, produce wrong conclusions.

Also it is necessary to keep in mind that these statistical methods can only help the researcher to choose the "strongest" variables he has selected. They cannot stipulate which variables should be investigated in the first place.

The procedure used in this study was to initially select variables on the basis of prior knowledge of and familiarity with the crop production process involved. The reasoning behind the selection of each variable is given in Chapter 3. Two alternative functions are then fit to the data in Chapter 4. The regressions are re-calculated several times, leaving out variables that do not appear to add to understanding the problem. Although not as methodical as the stepwise regression procedure, it is based upon the same principle.

2.2.2. Selection of Algebraic Form

Selection of the algebraic form of the production function is important in obtaining a "good" fit. The goodness of fit is generally denoted by the R^2-value of the estimated function.

Similar to choosing variables, the characteristics of the production process should be known in order to specify the algebraic form of the production function. Usually, the relationship to be studied itself provides some indication of the appropriate functional form. For example, an aggregate consumption function is commonly hypothetized to be linear with constant marginal propensity to consume. On the other hand diminishing returns to a variable factor (decreasing MPP) are assumed to prevail in production processes, especially in agricultural production.

Vestergaard-Jensen 1/ has set certain requirements to be met by production functions. Vestergaard-Jensen's criteria can be summarized as follows:

1/ E. Vestergaard-Jensen, "Bestemmelse af produktionsfunktioner för fläskeproduktionen", (Uppsala: 1958, Mimeographed), p. 1.

The production function should be

1. consistent with economic theory;
2. consistent with the underlying physical relationships;
3. calculateable with available statistical tools, data, and computational facilities.

The specification of the production function is most commonly based on the criterion of decreasing marginal physical product (MPP). Several functions which meet this condition are available. Among these, the most widely applied types are the Cobb-Douglas function and quadratic functions.

Another possibility that is not so commonly used is the hyperbolic function

$$Q = \frac{ax}{b + x} \tag{2.2.}$$

This is the same function as the Törnqvist-function used in demand analysis. A study by Ihamuotila [1] gives an interesting example of this type of function's application in a crop yield-fertilizer relationship. The function also enables the estimation of the point of maximum output because the function approaches a maximum as an asymptote. A disadvantage of the Törnqvist-function is its non-linearity of parameters, which means that the least-squares method of estimating the parameters of this function cannot be used.

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[1] Risto Ihamuotila, The Effect of Increasing Nitrogen Fertilization on the Economic Result in Corn Production, AERI Publication No. 21, (Helsinki: Valtion painatuskeskus, 1970), pp. 8-14. The properties of the most common production functions are discussed, for example in Lauri Kettunen, "Om produktionsfunktionens form", Nordisk Jordbruksforskning, XXX (1966), pp. 9-19.

Another criterion for the selection of the form of the production function equation could be the maximum point of the function. In this respect the Cobb-Douglas function is at a disadvantage, because it does not define a maximum. However, the maximum point of the production function is of minor importance, because the level of input use can be expected to lie only in the second stage of production (the range of diminishing marginal physical product) which is the rational area of resource use. However, if an uncontrolled factor, such as weather, is included there may also be observations which fall in the third stage. In this stage of production the marginal product of a given input is negative.

A major consideration for the selection of the appropriate functional form is the elasticity of substitution between inputs. In certain cases the Cobb-Douglas function may be unsatisfactory, because it implies an elasticity of substitution of one. The linear arithmetic production function is not commonly used, because of its implied elasticity of substitution of infinity. Also the constant marginal product of this type of function is not realistic.

A difficulty in choosing the form of the production function is our ignorance of the range of data. In other words without any a priori knowledge it is hard to determine whether we should include an inflection or maximum point. As a result it is often assumed that observations fall only within the second stage of production. Also economic theory suggests that producers will use inputs only in the second stage, if they wish to maximize profits.

2.3. The Problem of Measuring Technical Change

2.3.1. The Concept

Technical change in economics is usually defined as shifts in the production function. For example, Solow [1/] has described it "as a shorthand expression for any kind of shift in the production function". In this perspective slowdowns, speedups, improvements in

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[1/] R.M. Solow, "Technical Change and Aggregate Production Function", The Rev. of Econ. and Stat., XXXIX (August, 1957), p. 312.

the education in the labor force and similar variations in factors affecting the production process will appear as technical change. However, any definition of technical change should also embrace the concept of modification of the production function, or shifting from one production function to a completely new one.

In Finnish agriculture technical progress in the time period in question can be expected to appear as: 1) improved biological and mechanical technology, for example, in new plant varieties and machinery; 2) higher level of education of farm people; and 3) new inputs, for example, agricultural chemicals which have been introduced during the two past decades.

As noted above the definition of the production function implies that the technology of the production process is constant. However, over time technology undeniably changes. Thus, in a time series study, such as the present one, the annual observations of inputs and output can be expected to lie on different production functions unless all inputs are included and properly measured. Accordingly the problem of measuring technical change in time series studies is one of fitting the observations from different years to a single production function.

In this chapter we will first examine the different characteristics of technical change. Later some methods of measuring technical progress will be discussed.

Brown [1/] has divided the characteristics of technical change into four categories: 1) the efficiency of a technology, 2) technologically determined economies of scale, 3) the capital intensity of a technology, and 4) the ease with which capital is substituted for labor or the elasticity of substitution. Changes in the two first categories are regarded as neutral technical change, i.e., it alters the production function but does not affect the rate of substitution. Changes in the two latter categories consist of a non-neutral change.

[1/] M. Brown, On the Theory and Measurement of Technological Change (Cambridge: Cambridge Univ. Press, 1966), p. 12.

Let us investigate the characteristics mentioned above a little closer. 1) The efficiency of a technology refers to the possibility of obtaining different levels of output from a given combination of inputs or conversely of obtaining the same output from different levels of input use. Efficiency is said to improve if, through a different technique, a greater output is obtained from the same inputs or the same output is obtained from fewer of the inputs. In terms of the Cobb-Douglas production function this implies a change in the scale parameter. 2) Economies of scale can be defined as situations in which changes in inputs at higher levels of production effect greater than proportional increases in output. 3) The capital intensity of a technology changes as the L/K ratio varies as a result of different productivity changes in capital or labor. In other words the reason is purely technical. 4) The elasticity of substitution refers to the rate at which input factors can be substituted for one another, and is said to have changed when, for example, a decline in output caused by a decrease in the labor force can be made up for by substitution of a smaller amount of capital than would have been required before the change.

As for technical change in agriculture, farm innovations can be classified as: [1/] 1) biological, 2) mechanical, and 3) biological-mechanical. "Biological" innovations are those which have a physiological effect in increasing the total output from a given land base. "Mechanical" innovations refer to changes such as machinery which substitute capital for labor but do not change the physiological outcome of the plants or animals to which it is applied. The innovations which have both effects are termed "biological-mechanical". Thus, we can conclude that in general a biological technical change is a substitute for land and a mechanical one is a substitute for labor.

[1/] Earl O. Heady, "Basic Economic and Welfare Aspects of Farm Technological Advance", Journal of Farm Economics (JFE), XXXI (May, 1949), pp. 296-297.

Schertz [1] has specified the nature of mechanization more closely. According to Schertz, mechanization can 1) permit the completion of tasks with more precision, 2) accomplish work more quickly, 3) develop resources not presently being utilized, and 4) accomplish tasks not possible with traditional techniques.

As regards the nature of biological technique, the introduction of new plant varieties is most likely the most important feature of it. It can be observed that biological improvement, such as the innovations embodied in high yielding varieties, are typically associated with higher levels of fertilizer use. Accordingly, it should be noted, as Hayami and Ruttan [2] have pointed out, that with the introduction of new varieties we move along a long-run production function which they refer to as a "metaproduction function" or a "potential production function". What usually is observed is not the metaproduction function but the different short-run production functions associated with different varieties.

Although technical improvements are generally viewed in terms of increasing production, it should be noted that they may also serve to reduce losses or to reduce uncertainty and risk.

Finally, it should be born in mind that the type of influence that technical change has on the net revenue of agriculture will depend on the type of innovation and its related costs and the price elasticity of demand. In some cases the effect of technical change on net revenue might be even negative. [3]

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[1] L.P. Schertz, "The Role of Farm Mechanization in Developing Countries", Foreign Agriculture, VI (November, 1968), p. 3.

[2] Y. Hayami and V.W. Ruttan, Agricultural Development: An International Perspective (Baltimore: The Johns Hopkins Press, 1971), p. 82.

[3] Earl O. Heady, op. cit., (1949), pp. 297-301.

2.3.2. Methods of Measuring

The methods of measuring technical change can be divided into two categories: the production function approach and the index number approach. In the former approach either shifts of the production function are measured or a correction for technical change is made in recording input-output data to reduce the observations to a single member of the family of production functions. In the index number approach technical change is measured using indices of the output and the inputs.

Because the production function approach was used in this study it will be discussed in some detail. The index number approach was not employed because of certain drawbacks involved in this method which will be reviewed briefly.

2.3.2.1. Production Function Approach

2.3.2.1.1. Measuring Shifts in the Function

Characteristic of this method is an introduction of a variable that is thought to be correlated with technical change. With this approach an attempt is made to measure technical progress indirectly. This method also implies that technical change is included in the residual. However, attributing the entire residual to technical change may not be correct. This is because in addition to technical change, the residual can include the following components: 1) errors in measuring or/and aggregating variables, 2) incorrect means of estimating the parameters, 3) errors in the hypothesis of the functional form, and 4) errors caused by omitting one or more variables. [1/]

The variable that is usually introduced to explain technical change is the trend term e^{bt}. In other words e^{bt} is an expression for returns of education, research, improvement in labor skill etc.

[1/] Strictly speaking the existence of technical change is due to our inability to accurately measure quality changes in inputs or to include entirely new inputs.

However, it is to be noted that this model assumes that these forces have only a neutral effect on technology (see above). This is a relatively easy solution to the problem and will also be used in this study.

Attempts have been made to measure or take account of quality improvements in the labor variable by including a variable that measures the level of education. Niitamo[1/] has used the proportion of secondary school graduates in the potential labor force as a measure of technical change. Use of this variable resulted in a better fit than the trend term. A similar method was used by Griliches [2/] in his 1963 study of U.S. agriculture. In this study, the education of farm people turned out to be a statistically significant variable.

The inclusion of research expenditures is sometimes used to explain technical progress. In 1964 Griliches [3/] explicity introduced the level of public expenditures on agricultural research and extension as a variable in the aggregate production function. This study was based on three cross-sections of data (1949, 1954, and 1959). In his study the research and extension variable was found to be statistically significant. A similar result was obtained by Peterson [4/] in his estimation of a poultry production function.

[1/] O. Niitamo, Tuottavuuden kehitys Suomen teollisuudessa vuosina 1925-1952, (Summary: The Development of Productivity of Finnish Industry in 1925-1952), Kansantaloudellisia tutkimuksia XX, (Helsinki, Sanoma Oy, 1958), p. 101.

[2/] Zvi Griliches, "Estimates of the Aggregate Agricultural Production Function from Cross-Section Data", JFE, XVL (May, 1963), p. 424.

[3/] Zvi Griliches, "Research Expenditures, Education, and Aggregate Agricultural Production Function", The American Econ. Rev., (AER), LIV (December, 1964), p. 966.

[4/] Willis L. Peterson, "Return to Poultry Research in the United States". JFE, IXL (August, 1967), p. 667.

A similar method of measuring technical change has also been used by Solow.[1/] In his analysis Solow corrects the output for technical change. The correction factor is simply the trend term A(t). His starting point is a simple production function

(2.3.) $Q = F\ (K,\ L,\ t)$

The variable t for time appears to allow for technical change. Solow assumes the technical change to be neutral. So the production function takes the special form

(2.4.) $Q = A\ (t)\ F\ (K,\ L)$

After obtaining an estimate for A (t) he is able to correct output for technical change.

2.3.2.1.2. Measuring Quality of Inputs

The other alternative of the production function approach is the measurement of the quality of inputs.[2/] In this approach the inputs used should be measured in productivity units rather than in ordinary physical units. As mentioned earlier the observations of inputs should be reduced to a simple production function. This method is sometimes referred to as "service-flow method".[3/]

[1/] R.M. Solow, op. cit., pp. 312-320.

[2/] It was found that roughly one-third of the observed productivity increases of the U.S. agriculture in 1940-60 was due to improvements in the quality of inputs. For further details see Zvi Griliches, "The Sources of Measured Productivity Growth: United States Agriculture, 1940-60", The Journal of Political Economy, LXXI (August, 1963), p. 346.

[3/] O. Niitamo, "Tuotantofunktio, sen jäännöstermi ja teknillinen kehitys", Tilastollisen päätoimiston monistettuja tutkimuksia No. 9, (Helsinki: 1969, Mimeographed), p. 4.

If: 1) the correction of the inputs is carried out properly; 2) there are no errors in measuring and aggregating inputs; 3) the estimation method and functional form are correct; and 4) all relevant dependent variables are included, no residual should be observed. The service-flow method also implies that there will be no technically determined economies of scale. Since by this method the correction for technical change is effected through the input variables, a change in inputs is reflected as a change in output. In other words there will be no technically determined economies of scale and no shift in the production function.

The main problem in using the service-flow method is determining how the corrections for quality should be made. Thus, considering the services of tractors as an input variable one possibility would be to measure them in terms of horsepower hours rather than in money value. In the present study, the measurement of the machinery input in terms of productivity units is especially important. One way to do this is to express machinery in vintages and assume that the older machinery is less productive than the newer. However, as Griliches [1/] has pointed out, very little is known regarding how much the productivity of machines actually declines with age. Lack of information on productivity units of machinery prohibited a machine quality adjustment in this study.

One possibility for measuring biological technology is to use a seed improvement index as Hayami and Ruttan did in their study. [2/] A somewhat similar index was constructed and used in this study.

Also the labor force should be adjusted for improvements in its skill and education. Many possibilities are available. For example, the share of high school graduates among the farm population could be used as an adjustment factor. However, due to

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[1/] Zvi Griliches, "Capital Stock in Investment Functions: Some Problems of Concept and Measurement", in Measurement in Economics, ed. by Christ and others (Stanford Univ. Press, 1963), p. 121.

[2/] Y. Hayami and V.W. Ruttan, op. cit., p. 221.

difficulties associated with measuring qualitative characteristics of the labor force no such correction was attempted in this study. An additional problem is the "learning by doing" phenomena. This implies that better skills and knowledge can take place in a firm also without external education. A proposal to measure the effect of learning by doing has been made by Arrow [1], but for the same reason as mentioned above no attempt to correct the labor force for this fact is made in this study.

2.3.2.2. Index Number Approach

The other approach of measurement of technical change is the index number method. In this method an increase of output is measured per unit of input. According to the number of inputs, this method can be broken down into various partial productivity indexes as well as a total productivity index.

Output per unit of labor is a frequently used partial productivity measure, because of its convenience. A major shortcoming of this productivity measure is the existence of factor substitution resulting from changes in relative factor prices. Because of the increase in the price of labor relative to capital in most industries, labor productivity usually results in an upward bias. This method is also subject to bias from various other factors. [2]

In the total productivity approach a more comprehensive index is calculated from the relationship of the output index to an index of all inputs. The main problem in application of this method is how to combine the inputs (sometimes also outputs). If this is done by using Laspeyres or Paasch indexes these are

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[1] K.J. Arrow, "The Economic Implications of Learning by Doing", The Rev. of Econ. Studies, XXIX (June, 1962), p. 157.

[2] Willis L. Peterson, "The Measurement of Technological Change: The Index Number Approach", Unpublished Paper, Univ. of Minnesota 1967, pp. 2-6.

subject to bias.[1] Only under quite restrictive assumptions, (no change in the price of inputs relative to each other, equilibrium of the industry, neutrality of technological change, and constant returns to scale), as pointed out by Ruttan [2], will these indexes give unbiased estimates of technical progress. Another way to combine inputs is to use as weights the factor shares derived from a Cobb-Douglas production function. This is a more correct way of combining the different inputs, but it should also be noted that in this case the production function must be known.

As mentioned earlier the index number approach was not used in the current study because of the shortcomings of this method which have been noted.

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[1] The Laspeyres quantity index, $\frac{\sum_i P_{oi} X_{1i}}{\sum_i P_{oi} X_{oi}}$ which uses base period prices as weights leads to a downwards bias. On the other hand the Paasch index, $\frac{\sum_i P_{1i} X_{1i}}{\sum_i P_{1i} X_{oi}}$ which uses end period prices leads to an upwards bias. Using the two indexes we are able to bracket the range within which the "true" index falls.

[2] V.W. Ruttan, Technological Progress in the Meat Packing Industry, U.S. Department of Agriculture, Marketing Research Report No. 59 (Washington D.C.: Government Printing Office, 1954), p. 15.

3. THE DATA AND FUNCTIONAL FORMS USED

3.1. The Data

Aggregate data were used in this study covering the crop years 1956/57 - 68/69. The main sources of the data are the "Total Calculation of Agriculture" conducted by the Agricultural Economics Research Institute, Helsinki, and the Agricultural Statistics collected by the Board of Agriculture, Helsinki. In the Total Calculation of Agriculture a volume index, (a value index at constant price) for the various inputs (except labor), is calculated. In that calculation agriculture is considered as a single production unit.

First, data on a per hectare basis were used since this is the traditional Finnish way of reporting agricultural statistics. Since the data in this form did not give satisfactory production function estimates the data were later converted into a per farm basis. 1/ Actually handling the data in this manner also is more realistic, since an individual farm is the production unit rather than a hectare. This procedure also allowed testing for economies of scale. All the data used are presented in Appendix Tables 2 and 3.

3.2. The Variables

The dependent variable in the production function model is crop output.

Crop output consists of the total yield of all crops harvested. It is measured in terms of feed units (f.u.) to allow a common basis for summation of different crops. In applying this practice we are able to avoid the use of any prices in the aggregation process which might otherwise give biased results. Those data are calculated by the Board of Agriculture, Helsinki.

1/ Since the number of farms is reported only for 1959 (285,000), and 1969 (264,000), the intermediate years were interpolated, assuming a constant annual decrease of 0.78 per cent.

Seven different input variables were defined for inclusion in the functional model.

1. The fertilizer and lime variable represents the total consumption of all fertilizers and lime. This figure has been obtained as follows. The total sales of all fertilizer and lime in terms of plant nutrients are reported annually by the producers. This has been deflated by the price index of fertilizer (quantity weighted price index) to get the volume of fertilizer and lime used.

2. Agricultural chemicals was taken to consist of all chemicals used on farms (pesticides, herbicides, insecticides, etc.). This figure has been calculated in a similar way. The wholesale and retail margins and the turnover tax have been added to the annual value of production (at producer's price). This has been deflated by the price index of agricultural chemicals.

3. Farm machinery, represents the service flow of farm machinery as measured by the annual depreciation and maintenance cost of machinery per hectare of the bookkeeping farms (some 1,200 farms located in different parts of the country). Because it has been observed that these farms are more intensively farmed than farms on the average a 25 per cent deflation of the raw data was made. [1] To obtain a per farm figure for the entire country this has been multiplied by the total area of the arable land and divided by the number of farms. Finally, the real value is obtained by deflating this figure by the price index of farm machinery.

4. Rainfall was chosen as a proxy variable for the weather factor. The average precipitation that the entire country received in June was used. To measure the real effect of rainfall a time period of a month may be too long because the precipitation may come in a relatively few days or it may be distributed more or less evenly over the entire period. The manner in which precipitation occurs will obviously make a difference in the growth of plants.

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[1] Samuli Suomela, *op. cit.*, pp. 81-82.

Of course, rainfall is not the only weather factor that affects the yield. To measure the total impact of weather, temperature and solar energy during the growing season should also have been taken into consideration. However, several studies[1/] have indicated that inadequate rainfall during the early growing season is the most important weather factor influencing the quantity of crop output. On the other hand the quality of harvest is affected by the weather conditions in late August and September. In some years, for example in 1962, the harvest deteriorated substantially because of fall rains.

5. Labor, the labor devoted to crop production only is not available in the Finnish agricultural statistics. Only the total labor is reported. The labor used in crop production was calculated on the basis of information from the bookkeeping farms. These data (from 1966-69) indicate that in 1966 the relative share of labor used on crops was 40.3 per cent of total agricultural labor and that its share decreases at an annual rate of 5.2 per cent. Thus, the share of crop labor of total farm labor was assumed to be 67.4 per cent in 1956/57 and 35.6 per cent in 1968/69. Based on this information the total agricultural labor was divided into labor consumed in crop production and labor used in other farm activities.

6. Land is the total arable land area divided by the number of farms. So, this figure indicates the average farm size.

7. Area sown using new varieties represents an attempt to measure the effect of biological technology by introducing a variable that indicates the area sown each year using "new" plant varieties. As shown in Appendix 4 a major shift in the utilization of plant varieties has occurred within 15 years. The varieties introduced during the period of study were considered "new". These are:

[1/] For example O. Pohjanheimo, "Lämpö- ja sadeolojen vaikutuksesta kevätviljoihin Jokioisissa", (Referat: Einfluss der Temperatur und Niederschlagshöhe auf die Entwicklung der Sommergetreide in Jokioinen in den Jahren 1930-54), Maatalous ja koetoiminta, XIII (1959), p. 92.

Winter wheat	Spring wheat	Rye	Barley	Oats
Elo	Ruso	Voima	Otra	Hannes
Linna			Karri	Kyrö
Nisu			Pomo	
Jyvä			Paavo	

In order to avoid observations with a zero value in the early part of the study period one "old" variety was included, too. This is the winter wheat Vakka. It's popularity has increased steadily in the late 1950's and through 1960's. The variable "area sown using new varieties" represents the summation of the area sown in new cereal varieties each year. Because the data showing the use of various varieties are given only for every fifth year the intermediate years were interpolated linearly.

Admitedly this is a very crude measure. A more desireable measure would have been the increased yield potential of the new varieties. This information is, however, unavailable at the present.

3.3. The Functional Forms

Two different forms of production functions were used in this study. As mentioned before, no statistical method was used in the selection of functional forms. The first was the traditional Cobb-Douglas function

$$(3.1.) \qquad Q = aX_1^{b_1} X_2^{b_2} \dots X_n^{b_n}$$

It was used for its ease of estimation and interpretation. Also the implied characteristics of declining MPP of inputs and a unitary elasticity of substitution between inputs conform somewhat to what we would expect in Finnish crop production.

The Cobb-Douglas function provides an easy way of examining economies of scale of the associated industry. If $\sum_i b_i = 1$, constant returns to scale prevail. If $\sum_i b_i > 1$, the industry is operating in the situation of economies of scale. If $\sum_i b_i < 1$, we have diseconomies of scale.

The marginal physical product of the Cobb-Douglas function is

$$(3.2.)\qquad MPP_{X_i} = b_i \frac{Q}{X_i}$$

The elasticity of production of input X_i is equal to the regression coefficient b_i.

Recently the Cobb-Douglas function has been critized for its unity elasticity of substitution and the constant elasticity of substitution function (CES) has been developed to substitute for it. On the other hand, Zarembka [1] has demonstrated that in most industries in the United States the elasticity of substitution between labor and capital is not statistically different from unity. Hence, he suggests that for most empirical purposes the elasticity should be assumed equal to unity and Cobb-Douglas function employed rather than the CES function.

For estimation purposes the function (3.1.) was converted to the logarithmic form

$$(3.3.)\qquad \log Q = \log a + \sum_i b_i \log X_i \qquad (i = 1,2,\ldots, n)$$

The other type of function used was a transcendental function of the form

$$(3.4.)\qquad Q = aX_1^{b_1} e^{c_1X_1} X_2^{b_2} e^{c_2X_2} \ldots X_n^{b_n} e^{c_nX_n}$$

This function is applied along with the traditional Cobb-Douglas function in order to offer some alternative functional forms.

One of its advantages over the Cobb-Douglas function is its flexibility. It gives a wide range of functional forms and marginal products depending on the regression coefficients and their signs.[2]

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[1] P. Zarembka, "On the Empirical Relevance of the CES Production Function", The Rev. of Econ. and Stat., LII (February, 1970), p. 53.

[2] See Lauri Kettunen and Matias Torvela, op. cit., p. 62.

The marginal physical product of the transcendental function is

$$(3.5.) \qquad MPP_{X_i} = \left(\frac{b_i}{X_i} + c_i \right) Q$$

and the function reaches its maximum when

$$(3.6.) \qquad X_i = - \frac{b_i}{c_i}$$

The elasticity of production of this function is

$$(3.7.) \qquad E_{p_{X_i}} = b_i + c_i X_i$$

With $c_i = 0$ the transcendental function becomes the Cobb-Douglas function.[1]

For estimation purposes the function was converted to the form

$$(3.8.) \qquad \log Q = \log a + \sum_i b_i \log X_i + \sum_i c_i X_i$$

$$(i = 1,2,\ldots,n)$$

The least-squares method was used in estimating the parameters. This method is applicable, because the functions can be transformed into a linear form.

The models are also assumed to contain only a one way dependency between the dependent and independent variables. However, it has sometimes been argued[2] that in a production function instead of the single relation Q = f(K,L), all the

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[1] In more detail this function has been discussed in A.N. Halter and others, "A Note on the Transcendental Production Function", JFE, XXXIX (November, 1957), p. 967.

[2] See, eg. O. Niitamo, op. cit., (1969), p. 26.

other relations, K = f(Q,L) etc. should be considered. In other words, a production function should be estimated in the framework of a simultaneous equation model.

Durbin-Watson statistics were used to test the existence of autocorrelation (serial correlation) of the residuals. This problem can be particularly troublesome in a time series regression.[1]

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[1] The Durbin-Watson test value d is compared with the theoretical values d_l and d_u. The following conclusions can be drawn: If $d < d_l$ the residuals are positively autocorrelated. If $d_u < d$ the residuals are not positively autocorrelated. If $d_l \leqq d \leqq d_u$ no conclusions can be made. If d turns out to be greater than 2 (a negative autocorrelation), 4-d is to be substituted for it. It is to be noted that with respect to the power of test the Durbin-Watson test is weak. The test is discussed in J. Durbin and G.S. Watson, "Testing for Serial Correlations in Least-Squares Regression", Biometrika, XXXVII (1950), pp. 409-428 and XXXVIII (1951), pp. 159-178.

4. PRODUCTION FUNCTION ANALYSIS

4.1. The Results Using a Cobb-Douglas Function

A Cobb-Douglas type of production function was used as the first approach to the problem. The following model was estimated using per hectare data.

$$Q = f\,(X_1, X_2, X_3, X_4, X_5, X_6) \qquad (4.1.)$$

where Q = Crop output, f.u./ha.
X_1 = Fertilizer & lime, mk./ha.[1]
X_2 = Agr. chemicals, mk./ha.
X_3 = Farm machinery, mk./ha.
X_4 = Rainfall in June, mm
X_5 = Labor, working days/ha.
X_6 = Time

No test was used to prove the existence of a unitary elasticity of substitution between labor and all the other inputs. This elasticity was a priori assumed to equal one.[2]

The results of fitting the function are given in Table 4.1. Because of their minor importance the Q-intercepts are not presented. From a theoretical point of view they should equal zero. In testing the regression coefficients a 2-tail t-test was used. The most prominent feature of Equation 1 in that Table is that only the regression coefficient of rainfall is statistically significant. The coefficients of time and labor are very close to zero. The negative regression coefficient of agricultural chemicals is clearly unacceptable. A negative coefficient could be conceivable if agricultural chemicals were used only when there were serious outbreaks

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[1] Finnish marks per hectare

[2] A test is discussed by Zvi Griliches, op. cit., (1964), pp. 963-964. His results indicate that in U.S. agriculture the elasticity of substitution does not significantly differ from unity.

Table 4.1. Cobb-Douglas production function, using per hectare data. Dependent variable = total yield, d = Durbin-Watson test value, standard errors of the regression coefficients in the brackets.

Equation		Fertil. & lime $\ln X_1$	Agr. Chem. $\ln X_2$	Machinery $\ln X_3$	Rainfall $\ln X_4$	Labor $\ln X_5$	Time $\ln X_6$
1.	$\bar{R}^2 = 0.706$ $d = 3.06$	0.639 (0.351)	-0.309 (0.173)	0.524 (0.695)	0.295*** (0.079)	0.034 (0.302)	0.016 (0.089)
2.	$\bar{R}^2 = 0.747$ $d = 3.01$	0.662* (0.303)	-0.321* (0.149)	0.616 (0.442)	0.297*** (0.073)	0.057 (0.253)	
3.	$\bar{R}^2 = 0.777$ $d = 3.03$	0.619** (0.222)	-0.324* (0.139)	0.585 (0.395)	0.295*** (0.068)		
4.	$\bar{R}^2 = 0.747$ $d = 2.76$	0.747** (0.218)	-0.156* (0.086)		0.280*** (0.071)		
5.	$\bar{R}^2 = 0.690$ $d = 2.46$	0.373*** (0.075)			0.201** (0.062)		

The significance of the regression coefficients is denoted as follows:

* significant at the 0.10 level,
** - " - 0.05 - " -
*** - " - 0.01 - " -

The $\bar{R}^2$-values are the coefficients of multiple correlation adjusted for degrees of freedom. The formula is given, eg., in M. Ezekiel and K.A. Fox, Method of Correlation and Regression Analysis (New York: John Wiley & Sons, Inc., 1959), p. 486.

of disease or pest. In such a case, the pest or disease outbreak would reduce output, and the positive increase in amount of chemicals applied would show up in the regression as a negative coefficient. However, in Finland there has not been any such serious plant disease threat.

A possible explanation for the negative coefficient of agricultural chemicals could lie in the fact that they are used in very small amounts and on relatively few farms. It is also to be noted that almost the only crop which has received agricultural chemicals is wheat of which the share of the total crop yield is low (6-10 %, see Appendix 5). Accordingly, it is plausible that the relatively low level of agricultural chemical use on this relatively small proportion of total crops has not been reflected as improving crop yield at the aggregate level.

The correlation coefficient matrix (Table 4.2.) reveals that the simple linear correlations between some inputs are extremely high. In fact, it is very plausible that this should be the case. For example, fertilizer and agricultural chemicals call for a certain minimum amount of rainfall to be effective. The interdependency between labor and machinery is quite obvious. As regards

Table 4.2. Correlation coefficient matrix of the per hectare data.

	Crop Output Q	Fertil. & lime X_1	Agr. Chem. X_2	Machinery X_3	Rainfall X_4	Labor X_5	Time X_6
Q_1	1.0						
X_1	0.684	1.0					
X_2	0.669	0.934	1.0				
X_3	0.690	0.936	0.962	1.0			
X_4	0.268	-0.318	-0.142	-0.181	1.0		
X_5	-0.695	-0.967	-0.960	-0.990	0.215	1.0	
X_6	0.704	0.965	0.967	0.989	-0.218	-0.998	1.0

the effect of multicollinearity, it can be concluded that theoretically the estimates are unbiased, even though there was intercorrelation among the inputs. The standard errors, however, easily become large.

One can ask what is the highest acceptable level of multicollinearity. A criterion is given by Klein.[1/] According to him the multicollinearity of a production function can be as high as 0.8 - 0.9, given the existence of an R-value higher than 0.95, without disturbing the validity of regression coefficients. Recently, however, researchers have avoided setting any criteria for a "harmful" multicollinearity. Valentine[2/] points out that it is impossible to set up a clear-cut measure of effect of correlation and that the decision of a harmful level of multicollinearity depends on many factors, some of them subjective to the investigator.

Accordingly it can be concluded that the statistically insignificant coefficients for the inputs are at least partly due to the multicollinearity.

The effect of multicollinearity upon the magnitude of regression coefficients and their standard errors was studied by excluding some and combining other variables. First the time variable was omitted (Table 4.1. Equation 2). As a result, in addition to rainfall, the coefficients for fertilizer and agricultural chemicals turned out to be significant. The failure of a time variable as a proxy for technical progress is likely caused by the upward trend of almost every input. Another attempt to measure technical change will be described later.

[1/] L.R. Klein, An Introduction to Econometrics (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1962), p. 101.

[2/] T.J. Valentine, "A Note on Multicollinearity", Australian Economic Papers, VIII (June, 1969), p. 102. In more detail the problem is discussed in D.E. Farrar and R.R. Glauber, "Multicollinearity in Regression Analysis: The Problem Revisited", Rev. of Econ. and Stat., XXXIX (January, 1967), pp. 92-1 7.

In the next step the labor variable was dropped (Table 4.1. Equation 3). The reasoning behind this was the almost perfect negative correlation with the machinery input. A slight improvement in the significance of the rest of the regression coefficients can be observed in Equation 3. However, the coefficients themselves are almost unchanged.

To consider labor as an entirely separate input in agricultural production is questionable as Torvela has pointed out.[1/] This is true especially in crop production. It is hard to believe that by increasing only labor and leaving the other inputs unchanged yields would be increased. Basically crop production is a biological process. Hence, after committing the basic factors (land, fertilizer, and water) to plant production, further increase only in labor is likely to have no substantial contribution to the output. The quality of harvest, however, might be improved.

In the next step the machinery variable was deleted. All the regression coefficients of Equation 4 (Table 4.1.) are statistically significant. The negative sign of the coefficient for agricultural chemicals is, however, inconsistent with economic theory.

Finally, the agricultural chemicals variable was also excluded. In this step the coefficient of fertilizer was reduced from 0.747 to 0.373. A slight reduction occurred also in X_4.

In the interpretation of functions excluding one or more variables the bias of the remaining variables has to be considered. Griliches[2/] has presented a method to find out the direction of bias. However, no quantitative measurement can be made. According

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[1/] Matias Torvela, op. cit., p. 95.

[2/] Zvi Griliches, "Specification Bias in Estimates of Production Functions", JFE, XXXIX (February, 1957), p. 11, See also W.G. Brown, "Effect of Omitting Relevant Variables in Economic Research", Oregon Agri. Experiment Station Techn. Paper No. 2723, (Corvallis 1970: Mimeographed), pp. 1-12, and Y. Mundlak, "Empirical Production Function Free of Management Bias", JFE, XLIII (February, 1961), pp. 44-56.

to this analysis a conclusion that the omission of the variable X_2 has biased X_1 is not very clear. However, it is plausible that fertilizer and agricultural chemicals are positively correlated. Hence, omission of X_2 should result in an upward bias of X_1. It is obvious that the increased utilization of fertilizer calls for more use of machinery and labor. Thus, the auxiliary coefficient between fertilizer and these two variables also should be positive. Accordingly by excluding machinery and labor we could expect to bias the coefficient of X_1 upwards. Further, it is reasonable to think that with the introduction of new plant varieties more fertilizer will be used. Hence, the omission of biological technology, once again will likely bias the estimate of X_1 upwards. Similarly, fertilizer and farm machinery are probably also positively correlated. So, leaving out X_3 should bias X_1 upward. On the other hand it is hard to imagine that omission of these variables would result in any bias to the rainfall coefficient.

Combining inputs was also employed in an attempt to reduce multicollinearity. The fertilizer and agricultural chemicals inputs were considered as complements and they were combined by simple addition.[1/] The results are presented in Table 4.3. Again in Equation 1 of that table only the rainfall coefficient is statistically significant. The estimate for the combination of X_1 and X_2 is somewhat lower than that for X_1 alone (Table 4.1.). In this model the signs of machinery and labor turned out to be negative. Some variables were also excluded from this function. Equation 4 in this table seems fairly acceptable, However, the coefficients of $(X_1 + X_2)$ and X_5 are not significant.

[1/] A method of grouping inputs into complements and substitutes is discussed by Glenn L. Johnston, "Classification and Accounting Problems in Fitting Production Functions to Farm Record and Survey Data", in Resource Productivity, Returns to Scale, and Farm Size, ed. by Heady and ohters (Ames: The Iowa State College Press, 1956), pp. 90-91.

Table 4.3. Cobb-Douglas production function using per hectare data, combining some variables. Dependent variable = total yield, d = Durbin-Watson test value, standard errors of the regression coefficients in the brackets.

Equation		Fertil. & lime $\ln X_1$	Agr. Chem. $\ln X_2$	Machinery $\ln X_3$	Labor $\ln X_5$	Rainfall $\ln X_4$	Time $\ln X_6$
1.	$\bar{R}^2 = 0.597$	0.466		-0.458	-0.041	0.219^{**}	0.083
	$d = 2.68$	(0.420)		(0.537)	(0.358)	(0.081)	(0.096)
2.	$\bar{R}^2 = 0.610$	0.571		-0.129	0.087	0.216^{**}	
	$d = 2.39$	(0.395)		(0.373)	(0.320)	(0.079)	
3.	$\bar{R}^2 = 0.650$	0.500		0.175		0.212^{**}	
	$d = 2.43$	(0.281)		(0.314)		(0.074)	
4.	$\bar{R}^2 = 0.648$	0.524			0.138	0.207^{**}	
	$d = 2.35$	(0.353)			(0.271)	(0.071)	
5.	$\bar{R}^2 = 0.674$	0.349^{***}				0.194^{**}	
	$d = 2.45$	(0.072)				(0.064)	
6.	$\bar{R}^2 = 0.721$	0.628	-0.200	-0.046		0.282^{***}	0.063
	$d = 3.10$	(0.357)	(0.112)	(0.409)		(0.075)	(0.059)

Also the machinery and labor inputs were grouped. 1/ In Finnish agriculture labor and machinery can be considered as complements in the short run. In the long run, however, they are substitutes. The results are presented in Equation 6. However, the sign of the coefficients of $(X_3 + X_5)$ turned out to be negative in this model. Some variables were also omitted from this function without any better results. Also a model with two combined variables $(X_1 + X_2$ and $X_3 + X_5)$ was estimated but the result was unsatisfactory.

1/ The combining was done by evaluating the labor input using a constant price (that of 1961/62) and then summing the labor and machinery inputs.

Bias due to omitting variables should also be considered in interpretation of these functions, but, as in the discussion of the previous model, omission of variables did not result in any noticeable improvement. Similarly, grouping of variables in this model did not provide any useful solution to the problem of multicollinearity.

Because the time variable did not give statistically significant estimates for technical change an attempt was made to measure biological technology by introducing a variable that indicates the area sown each year using "new" plant varieties. The new varieties variable indicates the proportion of the area under these varieties to the total arable land area.

The results are given in Table 4.4. The new varieties variable provided no better results than the trend term as an indicator of technical progress. Its negative sign is clearly unacceptable. Moreover, the magnitude of the coefficient is close to zero. The rest of the coefficients are somewhat higher than was the case using the time variable (see Table 4.1.). Because the new varieties variable was highly correlated with the other inputs (r's around 0.95) some variables were deleted from the model. The exclusion of labor or machinery did not improve the significance of X_7, the new varieties variable. However, in Equation 3 (Table 4.4.) its sign was changed from negative to positive. In Equation 4 both labor and machinery variables were omitted. The results are similar to Equation 4 in Table 4.1.

The reason for the failure to measure technical change by considering the impact of new varieties is undoubtedly due to the fact that it does not provide any additional information to the data already used. The area sown using new varieties exhibits an upward trend similar to almost all the other inputs.

In a further attempt to remove the intercorrelation among the independent variables a first difference equation was estimated (Table 4.5.). Again only the rainfall and agricultural chemicals variables resulted in significant coefficients. The $\bar{R}^2$-value was, of course, reduced compared to that in the ordinary Cobb-Douglas

Table 4.4. Cobb-Douglas production function using per hectare data and a measure of biological technology. Dependent variable = total yield, d = Durbin-Watson test value, standard errors of the regression coefficients in the brackets.

Equation		Fertil. & lime $\ln X_1$	Agr. Chem. $\ln X_2$	Machinery $\ln X_3$	Rainfall $\ln X_4$	Labor $\ln X_5$	Proportion of area sown using new varieties $\ln X_7$
1.	$\bar{R}^2 = 0.742$ $d = 3.07$	1.040* (0.506)	-0.192 (0.204)	1.147 (0.721)	0.360*** (0.100)	0.465 (0.504)	-0.081 (0.087)
2.	$\bar{R}^2 = 0.748$ $d = 3.03$	0.630** (0.239)	-0.307* (0.160)	0.633 (0.452)	0.302*** (0.077)		-0.012 (0.043)
3.	$\bar{R}^2 = 0.686$ $d = 2.92$	0.566 (0.452)	-0.254 (0.221)		0.263** (0.087)	-0.155 (0.353)	0.027 (0.059)
4.	$\bar{R}^2 = 0.717$ $d = 2.80$	0.729** (0.242)	-0.181 (0.140)		0.275*** (0.079)		0.010 (0.043)

Table 4.5. Cobb-Douglas production function using first differences of the variables per ha. Dependent variable = total yield, standard errors of the regression coefficients in the brackets.

Equation	Fertil. & lime $\ln X_1$	Agr. Chem. $\ln X_2$	Machinery $\ln X_3$	Rainfall $\ln X_4$	Labor $\ln X_5$	Proportion of area sown using new varieties $\ln X_7$
1. $\bar{R}^2 = 0.385$	43.642 (26.254)	-491.122* (234.469)	55.995 (52.403)	15.043** (5.634)	60.141 (151.833)	26.217 (20.548)
2. $\bar{R}^2 = 0.472$	38.561 (21.236)	-494.357** (217.240)	48.237 (45.061)	14.615** (5.126)		27.285 (18.882)
3. $\bar{R}^2 = 0.461$	29.247 (19.573)	-387.924* (195.156)		14.114** (5.157)		20.925 (18.109)

function. No Durbin-Watson test value was calculated because of the different nature of a first difference equation. One advantage of using a first difference equation is that it allows the omission of a variable in which the first differences are constant. In other words a variable that increases or decreases at a constant rate can be excluded. Such variables here are the labor and machinery inputs. In Equation 2 (Table 4.5.) the latter was omitted and in 3 both of them are omitted. Yet the results are not improved.

The examination of the first difference data reveals that only rainfall shows much variation. The other inputs vary relatively little. This can explain the unsatisfactory results.

Next the data were converted from per hectare basis to per farm basis. In this case we should also include land as a separate variable. So far, it has not been explicitly included.

The results of estimating the function using per farm data are presented in Table 4.6. As shown in Table 4.7. intercorrelation among most of the inputs is still substantial. In fact the results are similar to those obtained using per hectare data. The magnitudes of the coefficients are almost unchanged except that of labor. The coefficient for agricultural chemicals turned out to be negative in this model also. The trend term was replaced by the new varieties variable without resulting in any better estimate for technical progress. Some variables were excluded also from this model. Equation 5 (Table 4.6.) includes only the fertilizer and rainfall inputs. Their coefficient estimates are somewhat higher than in the corresponding per hectare function (see Table 4.1.). The new varieties variable was included in this equation, but it resulted in an estimate similar to Equation 2 (Table 4.6.).

No conclusion about economies of scale can be drawn on the basis of these results. However, it is reasonable to expect that at least some economies of scale have been achieved. While farms have not grown very much in size, some specialization has taken place, which in some respects has effects similar to the results obtained from larger scale production units

Table 4.6. Cobb-Douglas production function using per farm data. Dependent variable = total yield, d = Durbin-Watson test value, standard errors of the regression coefficients in the brackets.

Equation		Fertil. & lime $\ln X_1$	Agr. Chem. $\ln X_2$	Machinery $\ln X_3$	Rainfall $\ln X_4$	Labor $\ln X_5$	Time $\ln X_6$	Area sown using new varieties $\ln X_7$	Land $\ln X_8$
1.	$\bar{R}^2 = 0.830$	0.695	-0.421	0.622	0.318**	0.768	-0.145		3.800
	$d = 2.31$	(0.377)	(0.233)	(0.925)	(0.087)	(0.865)	(0.203)		(7.070)
2.	$\bar{R}^2 = 0.865$	1.076*	-0.184	1.250	0.373***	0.837		-0.099	-2.804
	$d = 3.01$	(0.444)	(0.173)	(0.970)	(0.092)	(0.572)		(0.071)	(5.119)
3.	$\bar{R}^2 = 0.866$	0.702**	-0.302*	0.525	0.296***	0.240			
	$d = 2.93$	(0.265)	(0.143)	(0.383)	(0.072)	(0.363)			
4.	$\bar{R}^2 = 0.876$	0.620**	-0.305*	0.550	0.290***				
	$d = 3.08$	(0.226)	(0.138)	(0.367)	(0.069)				
5.	$\bar{R}^2 = 0.839$	0.481***			0.212***				
	$d = 2.47$	(0.061)			(0.061)				
6.	$\bar{R}^2 = 0.836$	0.667**			0.259***			-0.028	
	$d = 2.44$	(0.212)			(0.080)			(0.031)	

Table 4.7. Correlation coefficient matrix of the data per farm.

	Crop Output Q	Fertil. & lime X_1	Agr. Chem. X_2	Machinery X_3	Rainfall X_4	Labor X_5	Time X_6	Area sown using new varieties X_7	Land X_8
Q	1.0								
X_1	0.839	1.0							
X_2	0.823	0.949	1.0						
X_3	0.849	0.958	0.968	1.0					
X_4	0.115	-0.303	-0.155	-0.192	1.0				
X_5	-0.737	-0.912	-0.904	-0.882	0.239	1.0			
X_6	0.858	0.973	0.967	0.993	-0.218	-0.875	1.0		
X_7	0.836	0.963	0.975	0.954	-0.217	-0.963	0.956	1.0	
X_8	0.854	0.968	0.959	0.993	-0.213	-0.860	0.999	0.944	1.0

Also the functions were estimated using first difference equations of per farm data. The outcome was similar to the results of the corresponding per hectare data. These results are not presented.

The Durbin-Watson test value was calculated for all the functions estimated except the first difference equations to test for the existence of autocorrelation (see Chapter 3.). The conclusion with regard to most of the functions was that the residuals are not positively autocorrelated at the 5 % level of significance. In some cases the d-value fell into the range where no conclusion could be made.

In evaluating the results some reservations have to be made. It is plausible that the composition of crop output has changed over the study time period thus leading to disturbed results. Examination of Appendix 5 reveals, however, that the relative shares of the different crops have remained fairly stable. Only the proportions of wheat and barley have grown somewhat at the expense of those of potatoes and hay. The development of the price of wheat and barley relative to the rest of the cereals has been favorable for these two crops. The examination of the composition of the various inputs is more difficult. However, it is reasonable to assume that the composition of agricultural chemicals has changed along with the introduction of new products. The change in the composition of the stock of machinery is most likely substantial.

Another factor that might bias the results is land reclamation. Land reclamation during the two past decades has taken place mainly in Northern Finland. Hence it might be presumed that the total arable land area has increased relatively more in the north where conditions for agricultural production are less favorable. Yet, as shown by the following data, only a slight increase in Northern Finland's share of arable land has occurred.

	1956	1968
Southern Finland [1/]	49.7 %	47.0 %
Northern Finland	50.3 %	53.0 %
	100.0 %	100.0 %

[1/] The arable land area of the 10 southern most agricultural societies is denoted by "Southern Finland" and the rest of the area is referred to as "Northern Finland" (see Appendix 6).

It is likely that arable land has improved in quality particularly through increased drainage. As indicated in a study of the capital stock of Finnish Agriculture by Ihamuotila and Stanton [1] the volume of drainage stock (at constant price) has more than tribled during the period of study. The results most likely have been effected by this fact.

The utilization of manure was assumed to have remained unchanged. If we examine the change in the number of livestock and horses this is in broad terms true. The former has grown but the latter has decreased steadily.

4.2. The Results Using a Transcendental Production Function

The other functional form used was a transcendental production function. The main characteristics of this function were discussed briefly in Chapter 3. The transcendental function was chosen for its flexibility. It gives a wide range of functional forms and marginal products. The comparison of these to marginal products derived from a traditional Cobb-Douglas function will be of interest. A transcendental function also allows other than a unitary elasticity of substitution between inputs. A disadvantage of that function is the high intercorrelation between the logarithmic and linear terms with the result that the standard errors tend to be larger.

The results using per hectare data are presented in Table 4.8. The lack of degrees of freedom did not allow the inclusion of all the inputs into the model at the same time. First the new varieties variable was omitted (Equation 1, Table 4.8.). In this equation there are no statistically significant coefficients.

The form of function of the inputs is of special interest. The form of function with respect to fertilizer, rainfall, and labor turned out to be that of type 1 (Figure 4.1.). As a production function this type is realistic because it exhibits first increasing

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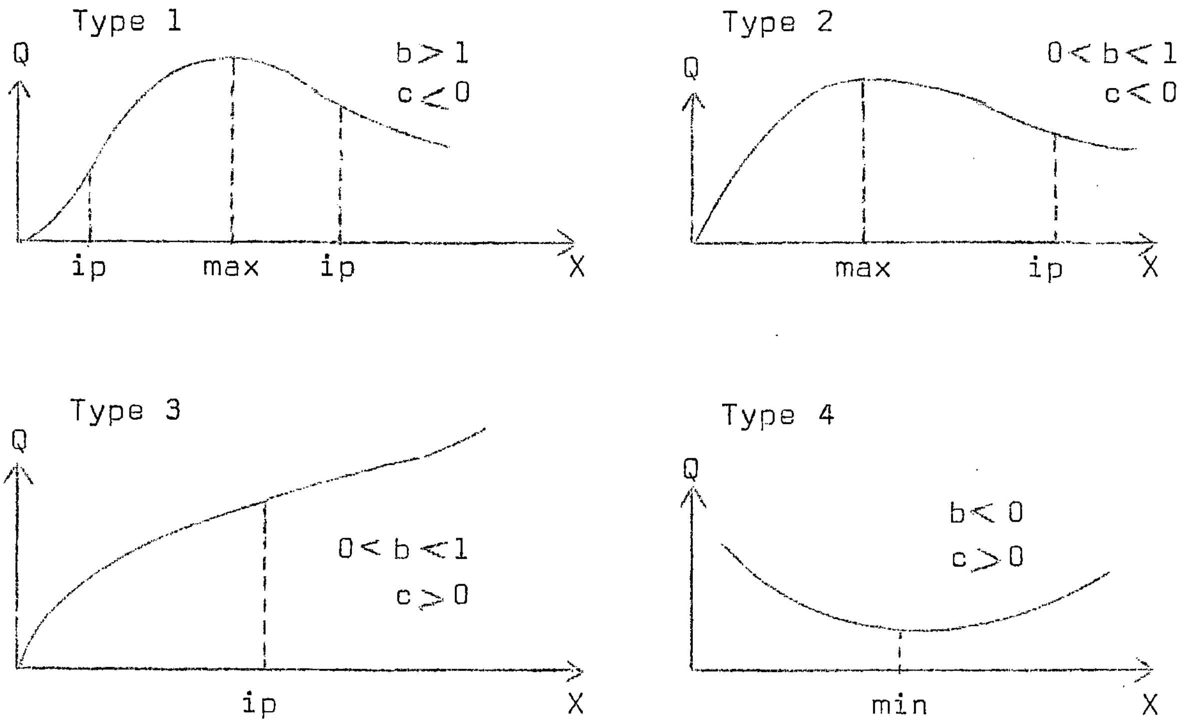
[1] Risto Ihamuotila and B.F. Stanton, " A Balance Sheet of Agriculture for Finland", AERI Publication No. 20, (Helsinki: 1970, Mimeographed), p. 27.

Table 4.8. Transcendental production function using per hectare data. Dependent variable = total yield, d = Durbin-Watson test value, standard errors of the regression coefficients in the brackets.

Equation	1		2		3		4		5	
	lnX	X	lnX	X	lnX	X	lnX	X	lnX	X
Fert. & lime	19.539 (9.241)	-0.290 (0.142)	10.739* (3.635)	-0.155 (0.055)	5.567*** (1.252)	-0.077*** (0.020)	0.595 (0.895)	-0.004 (0.015)	4.126** (1.294)	-0.055** (0.021)
Agr. Chem.	-1.449 (0.152)	0.790 (0.393)	-0.556 (0.399)	0.266 (0.120)	-0.871*** (0.201)	0.238** (0.067)			-0.687** (0.230)	0.188** (0.077)
Machinery	-16.776 (12.032)	0.220 (0.161)	-2.034 (2.356)	0.016 (0.037)						
Rainfall	1.780 (0.637)	-0.021 (0.009)	1.095 (0.382)	-0.012 (0.007)	0.929** (0.271)	-0.011* (0.005)	0.177 (0.413)	0.0005 (0.0082)	0.362** (0.065)	
Labor	4.853 (4.084)	-0.235 (0.192)								
Proportion of area sown using new varieties			-0.095 (0.094)	0.003 (0.004)						
$\bar{R}^2$	0.870		0.861		0.892		0.617		0.837	
d	3.38		2.96		3.38		2.48		3.38	

Figure 4.1. Some functional forms of a transcendental production function, $Q = aX^{b}e^{cX}$, ip = inflection point, max = maximum point, min = minimum point.



and then decreasing MPP. At higher input levels MPP is, however, negative. The functional form of agricultural chemicals and machinery was not realistic (type 4). This type of function includes negative MPP, when a given input is used in small quantities which is contrary to economic theory.

In Equation 2 labor was replaced by the new varieties variable. The outcome was similar to Equation 1 (Table 4.8.). The coefficient estimates for the new varieties variable were close to zero, and the functional form was unrealistic (type 4).

Because of the high multicollinearity some variables were dropped out. Equation 3 (Table 4.8.) includes only those variables in Equation 1 and 2 with significant coefficients. However, the functional form of agricultural chemicals was still inconsistent with economic theory. The form of function with respect to rainfall was changed from type 1 to type 2. Equation 4 (Table 4.8.) includes only the fertilizer and rainfall inputs. None of the coefficients

Table 4.9 Transcendental production function using per farm data. Dependent variable = total yield, d = Durbin-Watson test value, standard errors of the regression coefficients in the brackets.

Equation	1		2		3		4		5	
	lnX	X	lnX	X	lnX	X	lnX	X	lnX	X
Fert. & lime	9.787^{*} (3.160)	-0.014 (0.005)	24.052 (16.346)	-0.036 (0.026)	10.853 (7.123)	-0.016 (0.011)	4.346^{**} (1.428)	-0.066^{**} (0.002)	3.036^{**} (1.029)	-0.004^{*} (0.002)
Agr. Chem.	-0.471 (0.341)	0.026 (0.012)	-3.720 (2.770)	0.169 (0.133)	-0.762 (0.540)	0.036 (0.016)	-0.800^{**} (0.250)	0.023^{**} (0.010)	-0.594^{**} (0.228)	0.016^{*} (0.008)
Machi-nery	-2.760 (2.071)	0.002 (0.003)	-7.588 (4.713)	0.007 (0.003)	-5.726 (14.050)	0.006 (0.019)		-0.0002 (0.0006)		
Rain-fall	1.115 (0.390)	-0.012 (0.008)	2.725 (1.689)	-0.035 (0.024)	1.161 (0.473)	-0.013 (0.008)	0.967 (0.375)	-0.012^{*} (0.007)	0.347^{***} (0.070)	
Labor			86.118 (79.161)	-0.175 (0.162)						
Area sown using new varieties	-0.103 (0.081)	0.0004 (0.0004)								
Land					-28.769 (192.026)	3.773 (19.005)				
$\bar{R}^2$	0.922		0.907		0.889		0.906		0.893	
d	3.11		3.44		3.41		3.37		3.43	

is statistically significant. The functional form of rainfall was changed in this equation from type 2 to type 3. It seems that the inclusion of agricultural chemicals was necessary to have significant estimates for the rest of the variables.

A number of combinations leaving the linear and/or logarithmic term of each variable out were investigated. Out of these Equation 5 (Table 4.8.) turned out to be the "best" one. The production elasticity of rainfall in this function was slightly higher than that in the corresponding Cobb-Douglas model. To conclude that the utilization of fertilizer has reached a saturation level is questionable even though the function with respect to fertilizer included a maximum point.

Transcendental production functions were also estimated from per farm data (Table 4.9.). The magnitudes of the coefficients and the functional forms were similar to results using per hectare data. The new varieties variable turned out to give unsatisfactory results (Equation 1). Its functional form was also unrealistic (type 4). The form of function with respect to labor in Equation 2 was realistic (type 1), but the coefficients were not significant. The land variable resulted in neither significant nor realistic estimates (Equation 3).

Out of the combinations leaving one or more of the logarithmic or/and linear terms out the Equations 4 and 5 gave the "best" results. The estimate of the machinery coefficient was very close to zero, but its sign was unacceptable. Equation 5 is similar to the corresponding function derived from per hectare data.

4.3. Interpretation of the Results

In this section the marginal products and value of marginal products for fertilizer and rainfall are presented for both the Cobb-Douglas and transcendental functions. The analysis is limited to the fertilizer and rainfall variables because of the generally insignificant and inconsistent results obtained on the other variables studied.

All the functions derived above are aggregate functions. Hence, the interpretation of the obtained results has to be made in broad terms. Only the production functions for the individual crops would show how the resources should be allocated properly to the various crops. This is, however, beyond the scope of this study. An estimate for technical change would have been the most important result. Because of the high multicollinearity among the independent variables no reliable estimate was obtained, however.

The marginal products of fertilizer for the entire period of study are as follows

Cobb-Douglas function f.u./mk.[1]	Transcendental function f.u./mk.
22.2	25.3

The marginal products of Cobb-Douglas function have been derived from Equation 4 in Table 4.1, and the transcendental ones from the corresponding transcendental equation (number 3) in Table 4.8. These equations were chosen because they resulted in statistically significant regression coefficients of the fertilizer, rainfall, and agricultural chemicals. The marginal products were calculated using the average intensity of each variable in the study period. It is to be noted that the effect of fertilizer is likely to be overestimated here because of the upwards bias in the regression coefficient of fertilizer. As demonstrated above this is caused by the omission of the labor, machinery, and technical change variables.

Here both the Cobb-Douglas and transcendental functions seem to give similar results.

The marginal product of 22.2 can be interpreted that an increase of 1 mark in fertilization would have brought forth an increase of 22.2 f.u./ha. in yield.

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[1] feed units per mark.

In order to get information of the change of the marginal physical product of fertilizer over time its MPP was calculated for the early period (1956/57-61/62) and the latter period (1962/63-1968/69). These were as follows:

	Cobb-Douglas Function f.u./mk.	Transcendental Function f.u./mk.
1956/57-61/62	23.6	52.3
1962/63-68/69	21.3	2.1

In these calculations the agricultural chemicals and rainfall were held constant at their average for the whole period. Because the production elasticity for the entire period was used in calculation of the MPP's for the two periods the MPP for the early period is likely to be biased downwards and the MPP for the latter period upwards. However, the relatively short period of study was not sufficient for estimating more than one elasticity coefficient.

The MPP's derived from the Cobb-Douglas function indicate that the marginal physical product of fertilizer has not declined very much. The results from the transcendental function show, however, a big change. This is most likely due to the flexibility of the transcendental function (see page 25).

The profit maximizing condition under perfect competition in the factor and product markets is given as

$$P_Q \times MPP_X = P_X$$

where P_Q is the price of the output, MPP_X is the marginal physical product of fertilizer, and P_X is the price of fertilizer. The weighted average of the prices of all crops was used as the price of a feed unit. The quantities of crops were used as the weights. For the entire period the VMP (value of marginal product, $P_Q \times MPP_X$) was 8.0 marks (0.36 mk. x 22.2). In other words the increase in fertilizer use would have been clearly profitable. As noted before this figure is likely biased upwards.

The results on the profitability of fertilizer use obtained by Torvela[1] and Ryynänen[2] are similar to results of this study.

On the other hand, the present study is the first which has considered a weather factor in production function analysis in Finland.

The marginal products of rainfall were derived from the same equations. Their values for the entire period are as follows:

Cobb-Douglas Function f.u./mm.[3]	Transcendental Function f.u./mm.
10.3	9.7

Again the magnitude of the MPP's from the Cobb-Douglas and transcendental functions are similar. As discussed earlier the regression coefficient of rainfall is not biased. Thus, the corresponding MPP should not be subject to bias either. According to the MPP of 10.3 from the Cobb-Douglas function an increase of 10 mm in precipitation in June would have increased the crop output 103 f.u./ha.

A transcendental production function enables the estimation of the maximum output in the use of a given input. According to Equation 3 (Table 4.8.) the maximum output would be achieved at 84.5 mm of rainfall. The other functions gave similar results. In the study period the rainfall averaged 50.0 mm. It can be concluded that, the average amount of precipitation in June is much less than the optimum. Hence, inadequate rainfall in the early growing season would appear to be a major obstacle in obtaining increased yields.

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[1] Matias Torvela, *op. cit.*, p. 114.

[2] Viljo Ryynänen, *op. cit.*, p. 56.

[3] feed units per millimeter

An increase of 30 mm in precipitation would have increased the output 309 f.u./ha. Given the price of a feed unit (0.44 mk.) in 1968/69, the VMP would amount to 136 marks. In 1969 the cost of sprinkler irrigation of 30 mm/ha. has been estimated to be 120 mk./ha.[1] Thus, the use of irrigation would appear to be profitable.

However, if water is increased by means of sprinkler irrigation systems, which is the only method of irrigation used in Finland, even higher marginal products can be expected. This is because the water can be applied to plants at the right time and in proper doses. Research in this area has indicated, for example, that an application of 30-37 mm. of water resulted in increased wheat yields of 500-1000 f.u./ha. The results on barley and oats were even better.[2]

Considering the fact that in the summer of 1971, out of the total arable land area of 2.6 mill.ha. only some 40,000 - 50,000 ha. were irrigated, it can be concluded that prospects for increasing yields by means of sprinkler irrigation seem favorable.

No marginal products could be determined for agricultural chemicals, machinery, and labor. However, it seems clear that the latter is relatively low.

1/ O. Kara, "Sadetus ja siihen tarvittavat laitteet", Karjatalous, XLVI (Kesä-Heinäkuu, 1970), p. 283.

2/ P. Elonen, and others, "Sprinkler Irrigation on Clay Soils in Southern Finland", Journal of the Scientific Agricultural Society of Finland, XXXIX (June, 1967), p. 87.

5. CONCLUSIONS

The purpose of this study was to investigate the input-output structure of the crop sector of Finnish agriculture. Production functions were fitted to aggregate data from crop years 1956/57-1968/69.

In the present situation of surpluses of dairy products and wheat, better information of the structure of agricultural production and forces affecting it is needed. An attempt was also made to measure technical change.

The following variables were chosen to explain the variations of crop output: fertilizer & lime, agricultural chemicals, farm machinery, rainfall, labor, and land. In addition the time variable and a variable indicating the relative area sown in "new" plant varieties were used as proxy for technical change. Both per hectare and per farm data were used.

Two types of production functions were used. These were a Cobb-Douglas production function and a transcendental production function.

First the models were estimated using a Cobb-Douglas function. The least-squares method was used as the estimation method. Only the fertilizer and rainfall variables resulted in statistically reliable coefficients. Some of the coefficients of the other variables turned out to be negative. The major problem in estimating the functions appeared to be the high degree of intercorrelation between the independent variables.

In an effort to ease this problem some inputs were excluded. A slight improvement in the significance of the coefficients of the remaining variables occurred. Combining inputs and first difference equations also were used in an attempt to avoid the multicollinearity. The results, however, were not improved.

The results using per farm data were similar to those of per hectare data. No economies of scale could be determined.

The results using a transcendental production function were generally unsatisfactory. Also in this case only fertilizer and rainfall inputs gave statistically significant results and realistic functional forms.

The marginal physical product estimates from the Cobb-Douglas and transcendental production functions were of the same magnitude at the average intensity of input use. At higher or lower levels of input utilization the MPP estimates from the two functions differed.

Conclusions based on this study are limited. The results emphasize the importance of fertilizer and rainfall in crop production.

The results indicate that crop yields could be improved by increased use of fertilizer. Given the present prices of crops and fertilizer it seems clear that more use of fertilizer would be profitable. It is also to be noted that because the prices of main farm products are guaranteed by law no decline in prices with increased supply is expected.

The amount of rainfall in June which it was estimated would produce maximum yields was 84.5 mm. However, the average precipitation has been only 50.0 mm in 1956/57-68/69. Considering also the fact that at present only a small proportion of the total arable land area is irrigated, prospects for increased irrigation seem favorable. Given the present cost of irrigation, increased use of sprinkler irrigation would be profitable.

As for agricultural policy implications it can be concluded that increasing use of fertilizer and irrigation in the future would indicate that the soil bank program should be expanded if surpluses are to be avoided.

Obviously further study is needed. Cross-section data would be helpful in obtaining more reliable estimates. Use of such data could possibly avoid the problem of multicollinearity which was the major obstacle to obtaining statistically significant results in this study.

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Selostus

KASVINVILJELYN TUOTANTOFUNKTIOT SUOMEN MAATALOUDESSA SATOVUOSINA 1956/57 - 1968/69

Juhani Rouhiainen

Parin viime vuosikymmenen aikana on maataloutemme kehittynyt ripeästi. Selvimpänä osoituksena tästä on omavaraisuusasteen jatkuva kohoaminen, joka 1960-luvulla on johtanut vaikeasti markkinoitaviin ylijäämiin. Tapahtunut kehitys käy selvästi ilmi, jos tarkastelemme tuotannon kehitystä keskimääräisten satotulosten valossa. Satovuonna 1956/57 keskimääräinen hehtaarisato oli 1553 rehuyksikköä (ry), joka satovuoteen 1968/69 mennessä oli kohonnut 2109 rehuyksikköön. Huolimatta varsin voimakkaasta vuosittaisesta vaihtelusta voimme kuitenkin todeta, että keskimääräinen satotaso on mainittujen 13 vuoden aikana kohonnut noin 35 %:lla (kuvio 1.1.).

Kasvinviljelyllä ei sinänsä ole Suomen maataloudessa suurempaa merkitystä, sillä kasvinviljelytulot muodostavat vain noin 15 % viljelijöiden kaikista tuloista. On kuitenkin huomattava, että maataloudellemme ominainen intensiivinen kotieläintuotanto perustuu lähes kokonaan kotimaassa tuotettuun rehuun. Viime vuosina on rehun tuonti sen kokonaiskulutukseen nähden ollut erittäin vähäistä.

Etsittäessä syitä hehtaarisatojen nopeaan kasvuun, kiinnittyy huomio ensiksi tuotantopanosten käytön lisääntymiseen. Vuosien 1956/57 - 68/69 aikana on esimerkiksi väkilannoitteiden käyttö enemmän kuin kaksinkertaistunut, maatalouskoneiden käytön lisäys on ollut suurinpiirtein samaa luokkaa ja mainitun ajanjakson kuluessa on otettu käyttöön eräitä uusia tuotantopanoksia (esimerkiksi kasvinsuojeluaineet). Mainittujen seikkojen lisäksi voimme olettaa, että satotaso on noussut myös uusien viljelymenetelmien ja viljelijöiden parantuneen ammattitaidon seurauksena. Viimeksi mainittuja seikkoja kutsutaan taloustieteessä yleisesti tekniseksi kehitykseksi.

Maatalouskomitea hahmoitteli maataloutemme pääsuuntaviivat lähivuosia varten keväällä 1969 jättämässään osamietinnössä. Tämän mietinnön mukaan kaikkien tärkeimpien tuotteiden tuotanto on sopeutettava vastaamaan kulutusta. Poikkeuksena tästä säännöstä ovat sokeri ja kasviöljyt, joiden tuotannon tulee kattaa 20 % omavaraisuudesta.

Sittemmin on valtiovallan toimesta otettu käyttöön useita tuotantoa rajoittavia toimenpiteitä, joista tärkeimpänä mainittakoon pellonvarausjärjestelmä. Puuttumatta lähemmin tähän järjestelmään, todettakoon, että sen piiriin kuului vuoden 1971 lopussa noin 172 000 hehtaaria eli noin 6.4 % kokonaispeltoalasta (2,7 milj.ha).

Vaikka näillä toimenpiteillä on ollut tärkeä merkitys tuotannon kasvun hillitsemisessä on kaikelle informaatiolle, joka auttaa maatalouspolitiikkamme johtamista kohti tasapainoista kulutusta ja tuotantoa annettava suuri arvo. Makrotasolla tunnemme esimerkiksi liian vähän väkilannoitteiden ja muiden tuotantopanosten vaikutuksesta kokonaissatoihin sekä sääolojen ja teknisen kehityksen merkitystä. Tämän tutkimuksen tarkoituksena on ollut selvittää edellä mainittuja seikkoja kasvinviljelyn osalta. Taloustieteen termein lausuttuna tutkimuksen avulla on pyritty 1) estimoimaan eri tuotantopanosten rajatuotot, 2) tutkimaan tuotantopanosten käytön edullisuutta ja 3) mittamaan teknistä kehitystä kasvinviljelytuotannossa.

Maassamme on suoritettu useita tuotantofunktioanalyysejä maatalouden alalta. Kaikki mainitut tutkimukset perustuvat kuitenkin poikkileikkausanalyysiin, jolloin niiden käyttö sellaisenaan maatalouspolitiikan ohjaamisessa ei ole mahdollista.

Tutkimusmenetelmänä tässä tutkimuksessa on käytetty aikasarjaan perustuvaa tuotantofunktioanalyysiä. Tutkimusajanjakso kattaa satovuodet 1956/57 - 68/69. Käytetty aineisto perustuu pääosiltaan Maatalouden taloudellisen tutkimuslaitoksen suorittamiin ns. kokonaislaskelmiin ja Maatilahallituksen julkaisemiin virallisiin maataloustilastoihin.

Ennen kuin tuotantofunktioanalyysiä voidaan soveltaa empiiriseen aineistoon on tutkijan ratkaistava kaksi seikkaa: funktion muoto ja funktion muuttujat.

Funktiomuodon valinta perustuu usein tutkijan a'priori olettamuksiin kyseessä olevasta tuotantotoiminnasta. Niin on asian laita myös tässä tutkimuksessa. Lukuisista tarjolla olevista funktioista on tähän tutkimukseen valittu Cobb-Douglas tuotantofunktio

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

ja transcendentaalinen tuotantofunktio

$$Q = aX_1^{b_1} e^{c_1 X_1} X_2^{b_2} e^{c_2 X_2} \ldots X_n^{b_n} e^{c_n X_n}$$

Nämä funktiot sopivat hyvin yhteen maatalouden alalla vallitsevasta a'priori olettamuksesta vähenevästä rajatuotosta. Lisäksi valitut funktiot ovat estimoinnin suhteen suhteellisen yksinkertaisia. Puuttumatta lähemmin transcendentaalisen funktion ominaisuuksiin, voimme todeta sen saavan useita eri funktiomuotoja riippuen parametrien suuruudesta ja etumerkistä. Eräissä tapauksissa tämä funktio saavuttaa tietyn maksimiarvon, mikä ominaisuus tekee sen käyttökelpoiseksi estimoitaessa sellaisten tuotantopanosten vaikutusta, joiden käyttöä ei voida säädellä. Tällöin tulevat lähinnä kysymykseen erilaiset säätekijät. Huomattakoon lisäksi, että jätettäessä transcendentaalifunktiosta lineaarinen termi pois, siitä tulee Cobb-Douglas tuotantofunktio.

Tuotantofunktion muuttujien valinnassa voidaan käyttää eräitä tilastollisia menetelmiä. Niiden avulla on mahdollista valita suuresta joukosta muuttujia ne, jotka tiettyjä kriteerejä käyttäen parhaiten selittävät annettua riippuvaa muuttujaa. Toisena mahdollisuutena on jättää estimoidusta regressioyhtälöstä pois asteittain se muuttuja, joka vähiten selittää selitettävää ilmiötä. Koska tuotantofunktion muuttujat ovat kuitenkin varsinkin aikasarjatutkimuksessa voimakkaasti toisistaan riippuvia saattaa pelkästään tilastollisten menetelmien soveltaminen johtaa virhepäätelmiin. Tässä tutkimuksessa käytetyt muuttujat on valittu käyttämällä ainoastaan a'priori olettamusta kasvinviljelyyn vaikuttavista tekijöistä. Eräissä funktioissa on kuitenkin lähinnä multikollineaarisuudesta johtuen eräitä tekijöitä jätetty harkinnanvaraisesti pois.

Selitettävänä muuttujana (Q) on käytetty koko maan keskimääräistä rehuyksikkösatoa (ry/ha). Selittävinä muuttujina on käytetty seuraavia:

X_1 = väkilannoitteet ja kalkki, mk/ha,
X_2 = kasvinsuojeluaineet, mk/ha,
X_3 = maatalouskoneet, mk/ha,
X_4 = kesäkuun sademäärä, mm,
X_5 = työpanos, työpäivää/ha,
X_6 = aika, 1956/57 = 1 ...

Kaikki markkamääräiset muuttujat on laskettu kiintein hinnoin käyttäen satovuoden 1961/62 hintoja.

Niin kuin aikaisemmin jo mainittiin, on satotaso noussut tuotantopanosten käytön lisääntymisen ohella myös teknisen kehityksen seurauksena. Teoreettisesti on teknistä kehitystä ja sen mittaamistapoja käsitelty tässä tutkimuksessa varsin laajasti. Teknisen kehityksen mittaamiseksi on tarjolla kaksi menetelmää: tuotantofunktiomenetelmä ja indeksimenetelmä. Edellistä sovellettaessa voidaan mitata joko tuotantofunktion siirtymistä ylöspäin tai tuotantopanosten laadun muutoksia. Koska indeksimenetelmää voidaan soveltaa vain tiettyjen olettamusten ollessa voimassa on tässä tutkimuksessa käytetty tuotantofunktiomenetelmää. Teknistä kehitystä on mitattu sisällyttämällä selittäviin muuttujiin aikatekijä (X_6). Käytetty mittaamistapa on epäsuora: toisin sanoen teknisen kehityksen on ajateltu korreloituneen aikatekijään.

Koska tämä menetelmä ei tuottanut tyydyttävää tulosta pyrittiin teknistä kehitystä mittamaan muuttujan avulla, joka kuvaa biologista teknologiaa. Tämä muuttuja on muodostettu "uusista" viljalajikkeista. Tässä yhteydessä "uusina" lajikkeina pidetään niitä, jotka on otettu käyttöön tutkimusajanjakson kuluessa. Nämä ovat syysvehnä: Elo, Linna, Nisu, Jyvä, kevätvehnä: Ruso, ruis: Voima, ohra: Otra, Karri, Pomo, Paavo, kaura: Hannes ja Kyrö. Biologista teknologiaa kuvaava muuttuja (X_7) ilmaisee edellämainittujen lajikkeiden suhteellisen osuuden koko viljalle kylvetystä alasta.

Edellämainitut muuttujat on laskettu hehtaaria kohti. Eräitä tuotantofunktioita estimoitiin käyttäen myös tilaa kohti laskettua aineistoa. Tällä tavoin oli mahdollista sisällyttää maa eli keskimääräinen tilakoko tuotantofunktion muuttujaksi. Tätä muuttujaa on merkitty X_8:lla.

Tuotantofunktioita estimoitaessa käytettiin aluksi hehtaaria kohti laskettua aineistoa ja Cobb-Douglas funktiomuotoa. Kaikki funktiot estimoitiin tavanomaisella pienimmän neliösumman menetelmällä. Tulokset on esitetty taulukossa 4.1. Ensimmäisessä yhtälössä vain sateen regressiokerroin on merkitsevä. Regressiokertoimien alhainen merkitsevyysaste johtuu ilmeisesti muuttujien suurehkosta multikollinearisuudesta (ks. taulukko 4.2.). Voimakas lineaarinen riippuvuus muuttujien välillä nostaa standardipoikkeamien arvoa ja näin ollen alentaa regressiokertoimien merkitsevyyttä.

Multikollinearisuuden välttämiseksi jätettiin yhtälöstä 1 asteittain pois eräitä selittäviä muuttujia. Näin päädyttiin funktioon 5

$$Q = \ln 5.203 + \underset{(0.075)}{0.373} \ln X_1 + \underset{(0.062)}{0.201} \ln X_4 ,$$

joka regressiokerrointen merkitsevyyteen nähden on funktioista paras. Tämän funktion regressiokertoimet voidaan tulkita esimerkiksi seuraavasti: 10 % lisäys lannoituksessa antaa 3,7 % sadon lisäyksen ja vastaavasti 10 % lisäys kesäkuun sademäärässä nostaa satoa 2,0 %.

Kaikkien funktioiden selvitysaste ($\bar{R}^2$, vapausasteet otettu huomioon) on suhteellisen korkea. Residuaalien välinen autokorrelaatio oli useimmissa funktioissa vähäistä.

Aikatekijä ei antanut tyydyttävää tulosta teknisen kehityksen selittäjänä multikollinearisuudesta johtuen. Yhtälöistä 2-5 on tämä tekijä jätetty pois. Myöskään työlle ei saatu merkitsevää regressiokerrointa. On ilmeistä, että pelkästään työn lisäämisellä samalla kun muut panokset pysyvät muuttumattomina on vähän merkitystä satojen kohottajana.

Kasvinsuojeluaineet ovat saaneet kaikissa yhtälöissä (taulukko 4.1.) negatiivisen arvon. Negatiivinen regressiokerroin saattaisi olla mahdollinen, jos kasvinsuojeluaineita käytettäisiin vain silloin, kun on odotettavissa joku suurempi kasvitaudin tai tuholaisen uhka. Suomen oloissa vakavien kasvitautien ja tuholaisten vaara on kuitenkin harvinaista. Eräs mahdollinen selitys kasvinsuojeluaineiden negatiiviselle kertoimelle saattaa olla siinä, että niitä on käytetty suhteellisen pieniä määriä ja käyttäjinä on ollut vain suhteellisen harvat tilat. On myöskin huomattava, että kasvinsuojeluaineita on käytetty pienelle peltopinta-alalle kokonaisalaan nähden. Koska kasvinsuojeluaineiden käyttö on ollut näin pientä on ilmeistä, että niiden vaikutus ei ole tullut näkyviin kokonaissatotasolla.

Tulkittaessa funktioita, joista joitakin tekijöitä on jätetty pois, jäljellä olevien regressiokertoimen harhaisuus on otettava huomioon. Näin ollen väkilannoitteiden kerroin olisi liian suuri, sen sijaan sateen regressiokerroin on harhaton. Eräillä seikoilla, joita tässä ei ole voitu ottaa huomioon saattaa myös olla vaikutusta saatuihin tuloksiin. Näitä ovat esimerkiksi muuttujien heterogeenisuus, pellonraivaustoiminta ja perusparannukset.

Eräiden muuttujien yhdistämistä (taulukko 4.3.) ja muuttujien erotuksista muodostettuja funktioita (taulukko 4.5.) käytettiin keinoina välttää multikollinearisuus. Tässä ei kuitenkaan täysin onnistuttu.

Aikamuuttujan korvaaminen biologista teknologiaa kuvaavalla muuttujalla ei tuottanut tyydyttävää tulosta (taulukko 4.4.). Tämä johtuu ilmeisesti siitä, että se ei tuo analyysiin uutta informaatiota. Myös tämän muuttujan trendi suuntautuu ylöspäin kuten aikatekijänkin.

Tulokset tilaa kohti lasketusta aineistosta ovat suurinpiirtein samanlaisia kuin hehtaaria kohti lasketustakin. Keskimääräiselle tilakoolle ei saatu merkitsevää regressiokerrointa.

Transcendentaalifunktion tulokset on esitetty taulukossa 4.8. Transcendentaalifunktiota sovellettaessa kiinnittyy huomio erityisesti saatuihin funktiomuotoihin. Lannoitteiden ja sateen suhteen ovat funktiomuodot loogisia (tyyppi 1, kuvio 4.1.). Muiden tuotantopanosten suhteen saatiin tulokseksi epärealistisia funktiomuotoja ja marginaalituotoksia.

Niin kuin taulukosta 4.8. käy ilmi ovat vain hyvin harvojen tuotantopanosten regressiokertoimet tilastollisesti merkitseviä. Tämä johtuu transcendentaalisen funktion lineaarisen ja logaritmisen termin välisestä voimakkaasta multikollineaarisuudesta, joka on tämän funktion eräitä pahimpia epäkohtia. Funktioista jätettiin eräitä muuttujia pois multikollinearisuuden välttämiseksi, mutta tulokset eivät kuitenkaan parantuneet.

Tilaa kohti lasketusta aineistosta saatiin jälleen samanlaisia tuloksia kuin hehtaaria kohti lasketusta.

Tuotantopanosten käytön edullisuutta on tutkittu niiden rajatuotosten ja rajatuottojen avulla. Väkilannoitteiden rajatuotokseksi saadaan Cobb-Douglas funktiosta (funktio 4, taulukko 4.1.) 22.2 ry/mk. Vastaavasta transcendentaalifunktiosta (funktio 3, taulukko 4.8.) laskettuna saadaan rajatuotoksen arvoksi 25.3 ry/mk. Nämä rajatuotokset on saatu muiden panosten koko tutkimusperiodia vastaavilla keskimääräisillä intensiteettitasoilla. Koska väkilannoitteiden regressiokerroin oli harhainen ylöspäin on vastaava rajatuotoskin jonkin verran liian suuri. Väkilannoitteiden rajatuotos 22.2 ry/mk voidaan tulkita siten, että yhden markan lannoituksen lisäyksestä saadaan hehtaaria kohti 22.2 rehuyksikön sadon lisäys. Väkilannoitteiden rajatuotos laskettiin useammalle eri aikaperiodille. Niiden perusteella voidaan päätellä, että väkilannoitteiden rajatuotos on jonkin verran pienentynyt.

Lannoituksen kannattavuutta on tutkittu väkilannoitteiden marginaalituoton avulla. Marginaalituotoksi koko tutkimusajanjaksolle saatiin 8.0 mk. Koska yhden markan lannoituskustannus on tuottanut 8.0 mk:n sadon lisäyksen, on väkilannoitteiden käyttö ollut selvästi kannattavaa. On kuitenkin muistettava, että saatu rajatuotto on ilmeisesti liian korkea.

Sateen rajatuotokseksi saadaan Cobb-Douglas funktiosta 10.3 ry/mm ja vastaavasta transcendentaalifunktiosta 9.7 ry/mm. Toisin sanoen 10 mm:n sateen lisäys keskimääräiseen sademäärään kesäkuussa toisi noin sadan rehuyksikön sadon lisäyksen hehtaaria kohti.

Niin kuin aikaisemmin jo mainittiin transcendentaalisen funktion avulla on mahdollista estimoida se tuotantopanoksen käyttöaste, joka tuottaa maksimituotoksen. Yhtälön 3 (taulukko 4.8.) maksimisato saavutetaan sademäärän ollessa 84.5 mm. Koska kesäkuun keskimääräinen sademäärä koko tutkimusperiodilla on ollut vain 50.0 mm, voimme päätellä, että riittämätön sademäärä kasvukauden alussa on eräs pahimmista satojen alhaisuuteen vaikuttavista tekijöistä.

Jos ajattelemme sateen määrää kesäkuussa lisättäväksi 30 mm:llä tuottaisi tämä 309 ry:n sadon lisäyksen hehtaaria kohti. Jos tämä hinnoitellaan vuoden 1968/69 keskimääräisellä rehuyksikön hinnalla saadaan sadon lisäyksen arvoksi 136 markkaa. Vuonna 1969 on kolmenkymmenen millimetrin sadetuksesta aiheutuneet kustannukset arvioitu 120 markaksi. Näin ollen on sadetus ollut selvästi kannattavaa. Lisäksi on huomattava, että sadetuksena annettu vesi on huomattavasti tehokkaampaa kuin sateena tullut vesi. Eräiden tutkimusten mukaan 30-37 mm sadetus on nostanut satoja 500-1000 ry/ha. Koska toisaalta maassamme on viime vuosina sadetettu vain 40 000 - 50 000 hehtaaria, mahdollisuudet satojen lisäämiseen sadetuksella ovat erittäin suotuisat.

Yhteenvetona voidaan lopuksi todeta seuraavaa. Väkilannoitteiden käytöllä ja sadetuksella on erittäin suuri merkitys hehtaarisatojemme lisääjinä. Jos lannoitteiden käytön lisäys jatkuu entisen suuruisena (noin 8 % / vuosi) ja sadetuksen käyttö yleistyy, päädymme ennen pitkään lisääntyviin ylijäämiin. Tämän vuoksi tulisi pellonvaraustoimintaa ja muita tuotannon supistamistoimenpiteitä edelleen voimakkaasti jatkaa. Samalla voitaisiin nyt tämän toiminnan alaisuudessa olevia peltoja käyttää muihin tarkoituksiin. Koska maataloutemme tuotosta noin 85 % on muuta kuin kasvinviljelystuottoa ei väkilannoituksen ja sadetuksen vaikutuksia kokonaistuottoon ole voitu ottaa huomioon tässä tutkimuksessa. Tätä seikkaa tarkastellaan julkaisun toisessa osassa.

Appendix 1. Total crop yields of Finnish agriculture 1956/57 to 1968/69, millions of feed units.

Crop year	1956/57	-57/58	-58/59	-59/60	-60/61	-61/62	-62/63	-63/64	-64/65	-65/66	-66/67	-67/68	-68/69
Wheat	198.7	176.7	215.2	246.6	368.0	460.8	421.5	397.0	462.5	500.7	368.2	506.8	515.5
Rye	123.7	155.2	110.9	162.0	186.1	126.7	101.3	124.1	163.4	189.7	118.6	162.7	133.9
Barley	286.4	347.9	406.4	331.7	440.1	365.2	270.1	492.3	369.7	501.6	596.7	680.8	717.7
Oats	549.1	581.8	665.4	580.2	924.5	784.2	513.1	683.4	618.4	850.1	734.0	783.2	886.4
Mixed grain	32.0	38.9	40.3	29.1	47.4	41.7	32.5	61.1	37.2	54.3	46.8	54.9	46.2
Peas	12.6	13.3	10.0	6.8	7.7	4.5	3.1	2.7	3.1	4.1	3.2	3.4	3.3
Potatoes	338.7	251.1	276.1	215.6	343.3	211.4	190.0	244.2	170.0	251.4	213.3	176.1	181.6
Sugar beets	57.5	55.6	52.6	57.1	91.3	101.4	81.5	101.2	95.8	90.6	101.6	96.1	85.8
Swede	11.3	16.5	14.8	11.7	16.9	14.6	13.8	20.8	16.9	17.3	17.8	17.3	15.5
Turnip	4.4	5.2	5.9	4.9	7.7	4.9	5.0	6.4	4.9	5.3	5.6	4.2	3.8
Roots for fodder	12.2	9.5	7.7	6.4	11.2	9.0	7.3	10.3	8.1	6.8	6.9	6.0	5.2
Big leafed turnip	6.5	5.7	4.9	4.7	13.1	9.3	9.9	14.7	13.8	17.0	18.1	14.8	10.6
Fodder rape	-	8.9	2.5	1.0	1.2	0.5	0.4	0.7	0.3	0.3	0.3	1.2	0.8
Marrow kale	-	4.8	7.1	3.7	6.8	5.5	7.1	9.8	12.4	20.5	18.9	20.5	17.2
Green fodder	34.5	37.9	46.8	17.5	23.7	19.5	17.5	17.0	17.7	17.5	19.8	18.6	18.1
Hay	1,288.9	1,468.9	1,379.5	1,380.7	1,633.3	1,678.1	1,678.0	1,535.0	1,505.5	1,562.4	1,524.5	1,530.2	1,503.7
Silage	28.0	42.2	40.4	30.4	23.3	26.3	29.2	29.5	26.8	27.3	36.8	47.2	65.4
Sugar beet leaves	21.6	20.9	19.7	25.7	41.1	45.6	36.7	45.5	43.1	40.8	45.7	43.2	38.6
Other leaves	5.5	6.0	5.4	5.7	8.9	7.2	6.5	9.5	7.6	7.4	7.6	7.0	6.2
Oil plants	16.4	9.0	20.4	41.7	7.1	10.7	13.1	13.3	15.1	11.2	4.7	15.3	9.9
Straw	386.1	404.8	479.8	419.1	639.7	584.1	425.6	579.0	507.6	652.2	610.7	675.0	729.7
Total	3,414.1	3,620.8	3,811.8	3,578.5	4,842.4	4,511.2	3,863.2	4,397.5	4,099.9	4,828.5	4,499.8	4,864.3	4,935.1

Source: Data from the Board of Agriculture, Helsinki.

Appendix 2. The variables used in the production function analysis. Per hectare data, all the money values at 1961/62 prices.

	Crop Output f.u.	Fertilizer & lime mk	Agricultural Chemicals mk	Farm Machinery mk	Rainfall in June mm	Labor, working days	Proportion of Area Sown Using New Varieties %
1956/57	1,553	42.6	1.3	37.2	50.5	39.4	0.09
1957/58	1,657	42.3	1.2	38.1	65.3	37.8	0.12
1958/59	1,728	45.1	1.1	39.8	41.1	36.1	0.06
1959/60	1,565	53.9	1.4	43.6	26.2	32.9	0.27
1960/61	2,091	55.0	2.1	48.6	68.6	31.2	1.51
1961/62	1,936	53.5	2.8	52.0	83.5	28.3	2.21
1962/63	1,640	53.2	3.5	54.7	55.2	27.2	3.11
1963/64	1,871	65.8	3.5	57.3	37.9	25.1	4.21
1964/65	1,723	75.0	3.7	59.2	37.8	21.5	5.71
1965/66	2,052	73.9	3.8	61.1	48.2	19.8	7.70
1966/67	1,909	72.2	4.7	70.4	41.3	17.6	9.07
1967/68	2.059	81.9	5.4	69.5	48.6	16.3	10.65
1968/69	2.109	88.7	6.6	70.1	45.4	14.2	13.09

Source: Data from the Agricultural Economics Research Institute, Helsinki and the Board of Agriculture, Helsinki.

Appendix 3. The variables used in the production function analysis. Per farm data, all the money values at 1961/62 prices.

	Crop Output f.u.	Fertilizer & lime mk	Agricultural Chemicals mk	Farm Machinery mk	Rainfall in June mm	Labor, working days	Land ha.	Area Sown Using New Varieties 10^{-3} ha.
1956/57	13,855	380	12.4	332	50.5	522	8.92	7.6
1957/58	14,989	383	11.1	345	65.3	533	9.05	11.1
1958/59	15,843	414	10.5	365	41.1	544	9.17	5.3
1959/60	14,578	502	13.4	407	26.2	531	9.32	25.5
1960/61	19,785	520	20.7	460	68.6	538	9.46	142.6
1961/62	18,579	514	27.3	499	83.5	521	9.60	212.0
1962/63	15,959	518	34.8	532	55.2	532	9.73	302.8
1963/64	18,459	650	35.4	566	37.9	526	9.87	415.3
1964/65	17,215	750	37.9	592	37.8	478	9.99	570.0
1965/66	20,772	749	38.9	619	48.2	471	10.12	779.8
1966/67	19,548	740	48.9	712	41.3	445	10.24	929.0
1967/68	21,289	847	56.5	719	48.6	437	10.34	1,101.3
1968/69	22,014	926	69.4	732	45.4	417	10.44	1,366.6

Source: Data from the Agricultural Economics Research Institute, Helsinki and the Board of Agriculture, Helsinki.

Appendix 4. Proportion of respective crop area sown in different varieties.

	1955	1960	1965	1970
		Percent		
Winterwheat:				
Vakka	4.4	27.5	40.3	54.2
Elo[a)]	-	-	13.1	18.6
Linna[a)]	-	-	0.6	10.1
Nisu[a)]	-	-	-	7.9
Jyvä[a)]	-	-	-	1.7
Varma	56.8	27.6	18.8	1.6
Antti	-	24.2	-	1.4
Norre	-	-	-	0.4
Virtus	8.7	-	-	-
Others	30.1	20.7	27.2	4.1
Springwheat:				
Ruso[a)]	-	-	-	29.7
Apu	10.9	43.9	27.5	19.6
Nörrona	-	12.0	14.3	11.4
Drott	-	-	1.4	7.5
Svenno	1.5	13.9	35.3	6.5
Touko	-	1.6	1.2	6.3
Timantti II	25.0	11.0	4.8	5.0
Timantti I	27.8	6.9	6.9	4.1
Nora	-	-	0.3	3.1
Veka	-	-	-	1.7
Ring	-	-	0.8	1.1
Others	34.8	10.7	7.5	4.0

Source: Monthly Review of Agricultural Statistics, 1961, No. 4 and 1971 No. 3. Board of Agriculture, Helsinki.

a) Considered as a "new" variety in this study.

Appendix 4. (continued)

	1955	1960	1965	1970
		Percent		
Rye:				
Pekka	13.3	17.6	22.4	23.8
Toivo	21.1	18.4	18.3	21.1
Ensi	16.9	18.2	16.6	16.8
Voima a)	-	-	-	7.9
Sangaste	12.8	9.8	11.1	5.4
Maatiainen	18.0	7.8	5.5	3.4
Visa	-	1.1	2.6	2.6
Oiva	1.4	2.4	1.6	1.1
Others	16.5	24.7	21.9	17.9
Barley:				
Otra a)	-	4.7	24.5	35.6
Pirkka	5.1	46.1	43.9	26.8
Karri a)	-	-	-	9.3
Ingrid	-	-	0.7	8.5
Pomo a)	-	-	-	5.7
Paavo a)	-	0.5	4.4	5.7
Tammi	36.6	23.1	10.9	1.5
Mari	-	-	0.9	0.9
Balder	25.5	11.3	8.2	0.9
Birgitta	-	-	-	0.2
Binder	15.0	3.5	1.0	0.2
Others	17.8	10.8	5.5	4.7
Oats:				
Hannes a)	-	-	3.7	26.6
Pendek	-	11.4	22.6	21.9
Tiitus	-	-	-	14.2
Sisu	29.1	18.1	14.4	9.7
Kyrö a)	-	3.8	19.6	7.5
Sol II	5.2	6.3	7.1	4.8
Eho	16.1	14.2	8.3	2.6
Nip	-	4.3	3.0	2.1
Tammi	23.2	20.7	6.2	0.8
Kultasade II	15.5	3.8	1.0	0.4
Others	10.9	17.4	14.1	9.4

Appendix 5. Each crop's percentage of total crop output (feed units) in 1956/57 - 68/69.

	1956/57	-57/58	-58/59	-59/60	-60/61	-61/62	-62/63	-63/64	-64/65	-65/66	-66/67	-67/68	-68/69
	%	%	%	%	%	%	%	%	%	%	%	%	%
Wheat	5.8	4.9	5.6	6.8	7.6	10.2	10.9	9.0	11.3	10.4	8.2	10.4	10.3
Rye	3.6	3.2	2.9	4.5	3.8	2.8	2.6	2.8	4.0	3.9	2.6	3.3	2.7
Barley	8.4	9.6	10.7	9.3	9.1	8.1	7.0	11.2	9.0	10.4	13.3	14.0	14.4
Oats	16.1	16.1	17.5	16.2	19.1	17.4	13.3	15.5	15.1	17.6	16.3	16.1	17.7
Mixed grain	0.9	1.1	1.1	0.8	1.0	0.9	0.8	1.4	0.9	1.1	1.0	1.1	0.9
Peas	0.4	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Potatoes	9.9	6.9	7.2	6.0	7.1	4.7	4.9	5.6	4.1	5.2	4.7	3.6	3.6
Sugar beets	1.7	1.5	1.4	1.6	1.9	2.2	2.1	2.3	2.3	1.9	2.3	2.0	1.7
Swede	0.3	0.5	0.4	0.3	0.3	0.3	0.4	0.5	0.4	0.4	0.4	0.4	0.3
Turnip	0.1	0.1	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Roots for fodder	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.1	0.1
Big leafed turnip	0.2	0.2	0.1	0.1	0.3	0.2	0.3	0.3	0.3	0.4	0.4	0.3	0.2
Fodder rape	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Marrow kale	0.0	0.1	0.2	0.1	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.4	0.3
Green fodder	1.0	1.0	1.2	0.5	0.5	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.4
Hay	37.8	40.5	36.1	38.7	33.8	37.3	43.4	35.0	36.7	32.3	33.9	31.5	30.2
Silage	0.8	1.2	1.1	0.8	0.5	0.6	0.8	0.7	0.7	0.6	0.8	1.0	1.3
Sugar beet leaves	0.6	0.6	0.5	0.7	0.8	1.0	0.9	1.0	1.1	0.8	1.0	0.9	0.8
Other leaves	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1
Oil plants	0.5	0.2	0.5	1.2	0.1	0.2	0.3	0.3	0.4	0.2	0.1	0.3	0.2
Straw	11.3	11.2	12.6	11.7	13.2	13.0	11.0	13.2	12.4	13.5	13.6	13.9	14.6
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Data from the Board of Agriculture, Helsinki.

Appendix 6. The arable land area by Agricultural Societies in 1956 and 1968.

	1956 Arable Land 1000 ha.	 %	1968 Arable Land 1000 ha.	 %
1. Uudenmaan läänin	160.9	6.2	160.3	5.8
2. Nylands svenska	101.7	3.9	93.6	3.4
3. Varsinais-Suomen	260.5	10.1	261.4	9.5
4. Finska Hushållningss.	36.9	1.4	36.6	1.3
5. Satakunnan	226.4	8.8	233.6	8.5
6. Hämeen-Satakunnan	90.8	3.5	88.6	3.2
7. Hämeen läänin	163.8	6.3	168.0	6.1
8. Itä-Hämeen	95.9	3.7	93.4	3.4
9. Kymenlaakson	75.8	2.9	81.6	3.0
10. Länsi-Karjalan	75.3	2.9	76.7	2.8
11. Mikkelin läänin	120.2	4.8	126.1	4.6
12. Kuopion	168.8	6.5	184.1	6.7
13. Pohjois-Karjalan	114.1	4.4	142.6	5.3
14. Keski-Suomen	108.9	4.2	127.6	4.6
15. Etelä-Pohjanmaan	280.2	10.9	294.5	10.7
16. Österbottens svenska	130.2	5.0	130.3	4.7
17. Keski-Pohjanmaan	79.6	3.1	86.5	3.1
18. Oulun l. Talousseura	194.3	7.5	224.1	8.2
19. Kajaanin	40.4	1.7	59.8	2.2
20. Peräpohjolan	48.6	1.9	66.9	2.4
21. Lapin Maatalousseura	6.7	0.3	14.1	0.5
Entire Country	2,580.0	100.0	2,750.4	100.0

Source: Annual Statistics of Agriculture 1956 and 1968,
The Official Statistics of Finland, III:49, and III:64.

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AGGREGATE LIVESTOCK AND TOTAL PRODUCTION FUNCTIONS IN FINNISH AGRICULTURE IN 1956/57 - 1969/70

LAURI KETTUNEN AND JUHANI ROUHIAINEN

Selostus:
Kotieläin- ja kokonaistuottofunktiot Suomen
maataloudessa satovuosina 1956/57-1969/70

Helsinki 1972

Preface

This study is the second part of production function analysis of Finnish agriculture, the first part of which is the crop production function analysis, Part I of this publication. It has been completed cooperatively by the Economics Department, University of Helsinki and the Agricultural Economics Research Institute. The authors wish to thank Prof. Matias Torvela, the head of the Institute, for the valuable support in preparing and completing the study. Our gratitude is also for Mrs. Monica Jaatinen for painful typing and to Dr. Theodore E. Doty for checking the English text of the study and for making many valuable corrections and comments on the text.

It is not possible to point out certain parts of the study which might be done only by one of the authors, and therefore, the responsibility for the study belongs equally to both of them.

Helsinki, April 1972

The authors

CONTENTS

1. INTRODUCTION

1.1. Background of the Study

A production function expresses the functional relationship between output and inputs. A macro economic production function based on data covering the whole agricultural sector may, thus, give valuable information for agricultural decision makers. It may help them in choosing the most efficient and optimal use of the factors of production; it can indicate how the total production might be expected to increase if the use of inputs can be predicted, and it can thus be an aid in selecting agricultural policy strategies geared to the specific targets of agriculture. Applied to Finnish situation, a total agricultural production function could help in pursuit of the goal of a more balanced production and consumption, for example it might indicate the extent to which arable land should be retired in order to abolish the overproduction within a reasonable period of time.

Some production function studies are available [1/] but they are mainly based on cross-section farm data so that they may be utilized only for the aims of farm management. A production function suited for agricultural policy making has to be based on the time series data from the whole agricultural sector. The lack of such functions was an incentive for this study. The problem as such is a difficult one and the authors are well aware of the complexity of the factors involved. The present study may perhaps provide a partial solution to this problem. At any rate the authors hope through the current study at least to develop a frame-work for handling the most central factors and relationships.

[1/] The studies will be discussed in Chapter 3.

1.2. The Purpose of the Study

The purpose of this study is to estimate livestock and total production functions of Finnish agriculture. These estimates should give a picture of input-output relationships as such, i.e. by indicating how production will increase if an input is increased by a certain amount. In this study the estimates are also applied in examination of the profitability of the use of each input by computing the values of marginal products at different input levels, and by determining whether the marginal value products are greater than the respective marginal costs. Furthermore, the functions estimated are used for making prognoses of total production up to 1980, and for calculations of the implications these prognoses would have for arable land area adjustment in pursuit of balancing production and consumption of agricultural products in the long run. The previous projections of agricultural production in Finland available are based more or less on past trends of production. The production functions of this study make it possible to go a step further and to predict the development of agricultural production on grounds of factors of production especially with regard to fertilizer, which in addition to the land input is obviously of great importance. On the whole, therefore, the purpose of this study is not only to estimate the models, but also to place emphasis on the examination and application of the results.

The annual time series data used covers crop years 1956/57-1969/70. The small number of observations is obviously a shortcoming with regard to a succesfull time series analysis, but no reliable data prior to year 1956 are available.

The research project also includes crop production functions, the estimates of which have been presented in Part I of this publication. The production function has been discussed theoretically in Part I, and hence the present Part II concentrates on the problems of empirical estimation and on examination of the estimates of the models.

2. PRODUCTION FUNCTIONS IN GENERAL

A production function is one of the most central concepts in economic theory, and thus it has been examined comprehensively. Therefore, it is not always necessary to form a new theory of production for an empirical analysis, but it is rather a problem of selecting a particular theory out of the vast selection available which is suitable for each particular case and which is appealing to the investigator. The large number of theories is, on the other hand, an indication that none of them is fully satisfactory. There are certain shortcomings in each of them as regards their suitability for empirical research.

A production function gives the maximum output which can be obtained by certain amounts of inputs. It requires that the use of inputs is optimal, i.e. that the ratios of the marginal products to the prices of the corresponding factors of production are equal. At the micro level this means that every farmer must know the production function and the prices of the factors of production. Furthermore, the inputs have to be divisible in order to achieve optimality. All of these assumptions are hardly fullfilled and therefore the empirical production functions do not exactly correspond to the theory on which they are based.

One of the problems in production function theory is aggregation. The specification of a model is often made at the micro level, and thus input-output relationships and variables are rather easy to determine. To aggregate it at the macro level requires that different input-output variables are homogeneous, otherwise summing up the functions is not possible. Capital input is a good example. It is a common variable in most production functions, even though it is not always clear how it contributes to output. Its composition is also often rather complex, ranging from operational capital like equipment to fixed capital like land. A change in the composition may obviously have effect on output, even though the change as such is not observable in the capital input. To have an operational variable for capital is a problem, too. Solutions vary from one study to another, and thus the estimates are not strictly comparable to each other.

Specification of the form of a production function is central to the main problems of estimating production functions. It can be viewed in terms of the marginal products and their interdependences, and on the degree of substitution between factors of production. Formation of the function may proceed in this direction, or it may be possible to select the function, which then implies certain assumptions regarding marginal products and elasticities of substitution. The form of the function may also be derived by assuming a certain constant or variable elasticity of substitution of inputs, which then leads to a particular functional form. The implications of different forms of functions have been a starting point to the development of different production function theories. Moreover, growth theories can be considered as production function theories, which, of course, adds to the number of choices.

A further problem is selecting method of estimation. This will not be discussed here; the method of least squares is obviously sufficient for the purposes of this study.

In the empirical analysis presented in the following the most usual theories and estimation methods are applied. The data available does not allow for a more thorough analysis, since the errors of measurement of the variables cannot be avoided by complicated estimation methods. Instead the attempt is made to apply them for purposes of agricultural policy.

3. SPECIFICATION OF MODELS

3.1. General

There are a great number of theoretical and empirical studies available for selection of variables and the form of the function in specifying agricultural production functions. Generally, the models applied in this study do not differ from the corresponding models of previous studies. The small number of observations in the available annual time series data, 14 altogether, sets limits to the selection of the explanatory variables, and hence only the most important variables could be included in the functions to be estimated.

The paucity of data also puts restraints on the use of different forms of the function. In addition to the usual Cobb-Douglas function

$$(3.1.) \qquad Q = aX_1^{b_1}X_2^{b_2} \ldots X_n^{b_n}$$

the transcendental function

$$(3.2.) \qquad Q = aX_1^{b_1}X_2^{b_2} \ldots X_n^{b_n} e^{c_1X_1} e^{c_2X_2} \ldots e^{c_nX_n}$$

was also applied, even though in this case the loss of degrees of freedom is substantial.

The specification of the production functions to be estimated is reviewed in broad outline in the following. They are also compared with the models of corresponding earlier studies. The description of the variables is given in detail in Chapter 4.

3.2. Livestock Production Functions

An individual animal can be considered as the basic producing unit, and therefore output as well as inputs have to be computed on per animal unit basis. The difficulty associated with this method is in expressing the different animals in comparable production units. In this study all animals were converted to animal units by using general conversion coefficients.

The dependent variable of the animal production function is the total value of animal production per animal unit (a.u.). The explanatory input variables are also expressed per animal unit.

The selection of the most important explanatory input variables is relatively easy; feed is obviously the first one to be included in the model. Only the feed used directly in production processes has to be taken into account. Thus, for example, the feed consumed by horses is not taken into consideration. Due to decrease of the number of horses, an increasing amount of feed is being saved for animal production proper, which is estimated to contribute about 25 per cent to the total agricultural surplus. [1/] Feed consumption refers to the feed crop harvested during the summer prior to the crop year beginning in September. Therefore, this lag is indicated in some contexts by t-1. In addition a feed input lagged by two years was applied. It can be justified by the consideration that good feed may contribute to increased meat production which often requires more than a year. [2/]

Hay yield has been applied as an alternative indicator of the feed crop, since it forms the greatest part of the feed input. The use of this variable can be justified by the fact that it is relatively easy to measure and it may possible better indicate the variations of feed input. Hay yield lagged by two years also was used as an independent variable for the same reason as the feed input lagged by two years.

In this study capital as an over-all concept is not considered to be an explanatory variable explaining the variations of production. This does not mean that capital is unnecessary for agricultural production. On the contrary it is only a consequence of

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1/ In 1968 Suomela estimated that out of the agricultural surpluses one fourth was due to the decrease in the number of horses, one fourth due to land reclamation and a half due to other factors. Samuli Suomela, "Agricultural Policy Overshadowed by a Mountain of Butter", Economic Review No. 4, Published by Kansallis-Osake-Pankki, Helsinki 1968, p. 151.

2/ Lauri Kettunen, Demand and Supply of Pork and Beef in Finland, AERI (Agricultural Economics Research Institute) Publication No. 11, (Helsinki: Valtion painatuskeskus, 1968), p. 52.

the convention which has been adopted of defining production functions on either a per animal or per hectare basis whereby most of the "basic" capital has been eliminated. (On the other hand, the variation of the remaining capital is so small, that it may not have any discernable effect on output.) It is clear that a certain amount of capital is needed for production, but after this limit is exceeded, production effect can be assumed to be negligible. A machinery and equipment variable was used as an independent variable in crop production functions. In plant cultivation the quantity and quality of machinery and equipment may improve production possibilities and thus increase production. Contrarily, no capital variable was considered plausible to be included in animal production functions.

Labor, along with capital, is one of the most commonly used explanatory variables. As to an agricultural production function it is questionable whether labor inputs above a recognized minimum have any noticeable impact on highly mechanized production. Its contribution to production process is rather indirect; labor input commonly varies in direct proportion to other factors such as mechanization and more readily measurable inputs like fertilizer and feed. A reason for its inclusion in the livestock production function might be that more intensive care of animals could effect the production level to some extent.

A trend variable was included as an explanatory variable in the model. It is an indicator of the technological change in the same way as in crop production functions.

The basic models to be estimated are as follows:

$$(3.3.) \qquad Q_1 = f(X_4, X_5, X_8, X_{10})$$

or

$$(3.4.) \qquad Q_1 = f(X_6, X_7, X_8, X_{10})$$

where

Q_1 = the volume of animal production, mk./a.u.[1]
X_4 = feed input (t-1), f.u./a.u.[2]
X_5 = lagged feed input (t-2), f.u./a.u.
X_6 = hay crop (t-1), f.u./a.u.
X_7 = lagged hay crop (t-2), f.u./a.u.
X_8 = animal husbandry work, working days/a.u.
X_{10} = trend variable, 1956/57 = 1...

The basic models were varied by omitting some variables in order to test the reliability and significance of the estimates of the regression coefficients.

The previous animal production functions available for comparison are all based on cross section data, which makes their specification different from that of the functions of this study which are based on time series data.[3] There are some factors which vary by farm eg. the quality of arable land, and therefore, they are important as explanatory variables in cross section functions. With regard to time series data, however, the quality of arable land is practically unchanged, and obviously it cannot explain any of the variation of total output. The number of observations in cross section data is usually large and therefore sets no restrictions on the number of explanatory variables. However, there are only 14 observations in the time series data used here, and therefore only a limited number of variables may be included in the models.

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[1] Finnish marks per an animal unit

[2] Feed unitsper an animal unit

[3] Matias Torvela, *Tuotantopanosten käytöstä ja käytön edullisuudesta maataloudessa Etelä-Suomen alueen kirjanpitoviljelmillä*, (Summary: On the Use of Agricultural Inputs on Bookkeeping Farms in South Finland) AERI Publication No. 8, (Helsinki: Maalaiskuntien liiton kirjapaino, 1966).

Lauri Kettunen and Matias Torvela, "The Intensity and Interdependence of Gross Return and Factors of Production in Agriculture", AERI Publication No. 19, (Helsinki: 1970, Mimeographed).

Viljo Ryynänen, *Tutkimuksia maatalouden tuotantofunktioista Sisä-Suomen kirjanpitoviljelmillä vuosina 1960-1966*, (Summary: Production Function Analyses of Farm Management Survey Data in Central Finland in 1960-1966), Publications of the Scientific Agricultural Society of Finland No. 120. (Hämeenlinna: Arvi A. Karisto Oy, 1970).

Purchased feed, labor input and feed input are the main explanatory variables in the studies mentioned above. In addition, Torvela used machinery and equipment cost as an substitute for capital input. Ryynänen included milk production per cow as an indicator of the production capacity of a milk cow, even though there are some difficulties in applying this variable, because the milk production level is also an indicator of total output and effected by feed consumption.

3.3. Total Production Functions

Total production functions consist of crop and animal production functions, hence aggregation is far more difficult than in specifying them separately. Usually, as also in the present study, this problem is solved by expressing output and inputs on per hectare basis. This method is not fully consistent with the formation of animal production function, where the variables were expressed per animal unit, but since Finnish animal production is based on domestic feed, total production depends mainly on arable land and on the intensity of cultivation, and so the method seems to be rather plausible. The explanatory variables of the total production function are determined by the variables of the crop and animal production functions. The independent variables of crop production functions are fertilizer and lime, agricultural chemicals, rainfall in June, labor, and the trend variable, which except agricultural chemicals were included in the basic model. Since the estimates of regression coefficients of agricultural chemicals were illogical by their sign in crop production functions (see Part I, p. 29), this variable was omitted. Taking into account the variables of animal production functions presented in section 3.2., the basic total production function can be written as follows:

$$(3.5.) \qquad Q_2 = f(X_1, X_2, X_3, X_9, X_{10})$$

where

Q_2 = total agricultural production at constant prices, mk./ha. [1]
X_1 = fertilizer and lime, mk./ha.
X_2 = farm machinery, mk./ha.
X_3 = rainfall in June, mm.
X_9 = total labor input, working days/ha.

and other variables as on page 8. Hay yield variables X_6 and X_7 were also used as substitutes for feed input variables X_4 and X_5. Also in this case several alternative models were estimated by omitting some of the variables.

As to the previous studies of total production functions the same studies by Kettunen & Torvela, Torvela and Ryynänen can be mentioned for comparison. They are all cross section studies, and therefore, they may not be applied directly for purposes of this study for the same reasons as in animal production functions. One of the explanatory variables used in the studies by Torvela and Ryynänen is the line of production (eg. animal production as per cent of gross return). However, in time series data the variation of this variable is obviously small and cannot contribute much to the variation of dependent variable, total production. Kettunen & Torvela and Ryynänen have used land improvement costs as an independent variable in their models. In addition, the study by Ihamuotila which is based on time series analysis should be mentioned. [2] Ihamuotila used external inputs, labor input, capital input, knowledge and skill factor, technological factor and time as independent variables for explaining the formation of gross output. All of the studies mentioned above differ somewhat as to the variables which are employed, and it may considered that they support each other well in forming a picture of Finnish agriculture.

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[1] Finnish marks per hectare

[2] Risto Ihamuotila, "Productivity and Aggregate Production Functions in the Finnish Agricultural Sector 1950-1969", AERI Publications No. 25, (Helsinki: 1971, Mimeographed).

4. THE DATA AND VARIABLES

This study is based on official Finnish agricultural data covering the crop years 1956/57 - 69/70. The dependent and independent variables were calculated from data published by the Board of Agriculture and the so-called "total calculation of agriculture" published by the Agricultural Economics Research Institute, (AERI), Helsinki.

Two dependent variables were used.

The volume of animal production, Q_1, (mk./a.u.) was used as the dependent variable in the animal production functions. A volume index of different animal products was calculated using constant prices (those of 1961/62). Because in the animal production process an individual animal is the production unit this variable and all the other variables in animal production functions were calculated on a per animal basis. The share of horses was substracted from the total of animal units (see page 13). The different animal product items and their proportions of the total animal production are given in Appendix 3. Of the various products milk is clearly the most important one. For example its share in 1956/57 was nearly 70 per cent. The homogeniety of this variable was examined through a comparison of the relative proportions of the different product items in the beginning and at the end of the study period (see Appendix 3). The appendix reveals that the relative importance of milk has declined at the expense of beef and pork. However, it is hardly possible to conclude whether these changes have any noticealbe impact on the results obtained.

The volume of total agricultural production, Q_2, (mk./ha.) was used as the dependent variable in the production functions explaining the volume of total agricultural production. Its calculation is similar to that of the volume of animal production. Total production function is expressed on per hectare basis. The various items and their relative shares are presented in Appendix 4. Animal production has in 1956/57 accounted for about 86 per cent of the total agricultural production, and therefore milk plays the most important role out of the various items. In 1956/57 its share of the total production was nearly 60 per cent. Some structural changes have, however, taken place. Over the study period (1956/57 - 69/70) the share of milk decreased to 50 per cent and the share of the most important cash crops (wheat and rye) increased from 6.5 per cent to 11.8 per cent. Again, it is difficult to conclude how much impact these changes have had on the results obtained.

The following independent variables were used.

Fertilizer & lime, X_1, (mk./ha.) is the same as the corresponding input variable in the first part of this publication. In order to clarify that agricultural output and fertilizer & lime use belong to different periods of production process this variable was subscripted t-1.

Farm machinery, X_2, (mk./ha.). This variable was also used in the first part of the publication. The way it was calculated is discussed on page 22.

Rainfall in June, X_3, (mm [1]). Rainfall in June was used as a proxy variable for all weather factors. As for a detailed discussion of this variable see page 22 of the first part of this publication.

Feed, X_4, (f.u./a.u., f.u./ha.). The annual consumption of all feed stuffs is indicated by this variable. Because the number of horses has declined markedly over the time period studied [2], and because their feed accounts for a substantial part of the total of feed consumption (in 1956/57 32.8 per cent), the feed consumed by horses was substracted from the total feed stuffs available. The reason for omitting horse feed is the absence of the corresponding output item in the dependent variables. The reduction of horse feed was based on the number of horses and the daily feed consumption which was estimated to equal 6.8 f.u.

1/ millimeters

2/ In 1956 the number of horses totaled 297,000. In 1969 the corresponding figure was 111,000.

Also the homogeniety of feed variable was examined. Appendix 5 reveals that hay has maintained its relative share. On the other hand, cereals, especially barley, have been used increasingly as feed. A noticeable decline has occurred in the relative share of imported feed stuffs.

Admittedly, the feed input is subject to certain shortcomings. For example, fodder from pasture is not included in the total feed consumption. In addition, changes in quality and storage were omitted. These might, of course, have some impact on the results obtained. To emphasize the time lag involved in the production process the subscript (t-1) was also used with this variable.

Feed, lagged by two periods, X_5, (f.u./a.u., f.u./ha.). In certain models this variable was used along with X_4.

Hay yield, X_6, (f.u./a.u., f.u./ha.). In some functions hay yield was substituted for the total consumption of feed (X_4). The feed consumed by horses was substracted also from this variable.

Hay yield lagged by two periods, X_7, (f.u./a.u., f.u./ha.) was used along with X_6.

Animal husbandry work, X_8, (working days/a.u.) was constructed through dividing the total of agricultural labor into two categories: labor consumed in crop production and labor consumed in animal production. The method is discussed in the first part of the publication (page 23). Because the division was done quite formally this variable may be somewhat distorted. In addition, problems in aggregating labor per animal unit are obvious. With increasing number of animals the labor input per animal unit does not necessarily change proportionately.

Total labor, X_9, (working days/ha.). The agricultural labor statistics published by the Board of Agriculture, Helsinki was used in this study. It is to be noted that slightly different data on agricultural labor consumption are available.[1/] Obviously the

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[1/] A comparison of the different labor input data is available in Risto Ihamuotila, op. cit., p. 95.

particular labor statistics used is, however, of minor importance, since considering labor as a discrete variable in agricultural production is questionable at any rate.[1/]

Trend, X_{10}. A trend term, e^{bt} was also used in this study as a proxy variable for technical change.

The data used are given in Appendices 1,2,6 and 7.

[1/] See, Matias Torvela, _op. cit._, p. 95.

5. ESTIMATES OF THE PARAMETERS

5.1. Estimates of Livestock Production Functions

The regression coefficient estimates and their statistical significance measures for the Cobb-Douglas type of livestock production functions obtained by the method of least squares are given in Table 5.1., which also includes the alternative functions obtained by modifying the explanatory variables either arbitrarily or according to the principles given in Chapter 3. Generally the multiple correlation coefficients (no adjustment was made with regard to degrees of freedom) of the functions are rather high indicating a good fit. However, the correlation coefficient as such is not always necessarily sufficient indicator of the fit, and some other statistical measures should also be applied for this purpose. In this study the standard error of the residuals is taken as an additional measure of the fit. It shows the average magnitude of the error of explanation. The test of autocorrelation of the residuals is usually an integral part of a time series analysis. Since the number of observations is limited in this study, the number of degrees of freedom is also small, and therefore, the residual analysis should not be overly emphasized. However, the Durbin-Watson statistics are given in the table. They show that the residuals are not necessarily autocorrelated in general, because d-values fall in the range where the test is inconclusive.

With regard to estimates of the regression coefficients, it may be concluded at first, that they are logical by their sign; an increase of an input always increases output. However, the size of the estimates varies according to which variables are included in the model. This is obviously a result of the multicollinearity of the independent variables (see Appendix 8). The best models in Table 5.1. are functions number 1, 2 and 4. In terms of significance of the estimates, function no. 2 is clearly the best. In other models the standard errors of estimates became large due to the multicollinearity and accordingly the regression coefficients

Table 5.1. Cobb-Douglas production function, dependent variable = animal production, d = Durbin-Watson test value, s_u = standard errors of the residuals, standard errors of the regression coefficients in the brackets.

Equation		Feed t-1 $\ln X_4$	Feed t-2 $\ln X_5$	Hay yield t-1 $\ln X_6$	Hay yield t-2 $\ln X_7$	Animal husbandry work $\ln X_8$	Trend $\ln X_{10}$
1.	$R^2 = 0.864$ $d = 1.39$ $s_u = 0.037$	0.161 (0.140)				0.041 (0.362)	0.067 (0.072)
2.	$R^2 = 0.852$ $d = 1.46$ $s_u = 0.037$	0.253 (0.098)				0.350 (0.143)	
3.	$R^2 = 0.772$ $d = 1.62$ $s_u = 0.044$	0.446 (0.070)					
4.	$R^2 = 0.845$ $d = 1.20$ $s_u = 0.038$		0.234 (0.097)			0.361 (0.147)	
5.	$R^2 = 0.867$ $d = 1.30$ $s_u = 0.037$	0.165 (0.128)	0.131 (0.124)			0.293 (0.152)	
6.	$R^2 = 0.764$ $d = 0.73$ $s_u = 0.047$			0.014 (0.122)		0.624 (0.213)	
7.	$R^2 = 0.815$ $d = 0.86$ $s_u = 0.043$			-0.052 (0.120)	0.206 (0.124)	0.313 (0.272)	

loose their statistical significance. Function no. 2 includes feed and labor inputs as explanatory variables, and the estimates are logical and correspond to a priori expectations. As to the other independent variables, the trend variable does not contribute very much to the explanation of the variation of the dependent variable and the estimate is not statistically significant. This coefficient as well as other coefficients are directly elasticities of production with respect to inputs. This means that when trend variable increases by one from one year to another, technological change effects from 0.5 to 1.0 per cent increase in animal production depending on the particular point in the time series which is being considered.

Changing of independent variables did not substantially effect the estimates of various coefficients; only the substitution of feed input by hay yield lowered the correlation coefficient to some extent, and at the same time the residuals became autocorrelated, indicating perhaps that there are specification errors in the model. Similarly the inclusion of lagged variables (feed or hay yield) did not improve the explanation, but rather the estimates lost their statistical significance entirely. The reason for that was obviously the multicollinearity of the independent variables as can be seen from Appendix 8. The correlation table also shows that each of the independent variables correlate rather highly with the dependent variable, i.e. animal production. The estimates are examined in more detail in Chapter 6.

The estimates of the parameters of the transcendental production function are given in Table 5.2. The advantage of this type of function is its flexibility, i.e. it gives many types of paths of the function, and so the investigator does not need to determine beforehand the final form of the function.[1/] Logically the results of this estimation were not satisfactory, since the estimates indicate first decreasing and then increasing productivity of each

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[1/] See eg. Lauri Kettunen and Matias Torvela, op. cit., pp. 61-62, or Part I of this study, p. 44.

Table 5.2. Transcendental production function, dependent variable = animal production, d = Durbin-Watson test value, s_u = standard errors of the residuals, standard errors of the regression coefficients in the brackets.

Equation		Feed t-1 $\ln X_4$	X_4	Feed t-2 $\ln X_5$	X_5	Animal husbandry work $\ln X_8$	X_8	Trend $\ln X_{10}$
1.	R^2 = 0.944 d = 2,52 s_u = 0,027	-0.705 (0.678)	0,0004 (0,0004)			-3.562 (1.433)	0.103 (0.039)	0.108 (0.054)
2.	R^2 = 0.916 d = 2.28 s_u = 0,031	-0.748 (0.779)	0,0005 (0,0005)			-2.217 (1.450)	0.078 (0.042)	
3.	R^2 = 0.925 d = 1.86 s_u = 0,033	-0.274 (1,243)	0,0002 (0,0009)	-0.412 (1.508)	0.0004 (0.0011)	-2.305 (1.592)	0.080 (0.046)	
4.	R^2 = 0.885 d = 1.49 s_u = 0,034	-1.138 (0.835)	0.0009 (0,0005)			0.449 (0.145)		

variable which obviously can not be true. The correlation coefficients of these models are, however, higher than those of the Cobb-Douglas functions. A weakness of the transcendental function also became apparent in this case; the standard errors of estimates became large due to the intercorrelation of the linear and logarithmic terms of each variable. These models were not considered worthy of further examination.

5.2. Estimates of Total Production Functions

The estimates of the parameters of the log-log total production function are given in Table 5.3. The same general observations can be made here as in the case of animal production functions: the correlation coefficients are large, the standard errors of residuals are small and according to the Durbin-Watson statistic, the residuals are not autocorrelated.

When reviewing the estimates of single regression coefficients, it may be concluded initially that the size of the estimate of fertilizer and lime varies considerably from one model to another. In Part I of the study this variable was the most important variable in crop production functions, but since crop production accounts only for about 15 per cent of the total gross product, this variable cannot be of great importance in this context. The estimate of the regression coefficient of farm machinery is rather stable in the different models and the results obtained are also generally good. The regression coefficient of rainfall in these functions is negative in sign, but on the other hand it is small and statistically insignificant which may be due to the relatively small share of crop production, and hence effect of rainfall in total production. This deficiency hardly disturbs models 1 and 2 which otherwise are logical.

The omission of variables mostly effects the estimates of variables explaining animal production, as can be seen from Table 5.3. (see functions no. 1 and 3). As a whole, the variables effecting animal production "behave" in about the same manner in the total production function as in the specific animal production function. The estimates are far from being statistically significant in every case, the obvious reason being, as earlier, the multicollinearity of independent variables (see Appendix 9).

Table 5.3. Cobb-Douglas production function, dependent variable = total production, d = Durbin-Watson test value, s_u = standard errors of the residuals, standard errors of the regression coefficients in the brackets.

Equation		Fertil. & lime t-1 $\ln X_1$	Farm machinery $\ln X_2$	Rainfall $\ln X_3$	Feed t-1 $\ln X_4$	Feed t-2 $\ln X_5$	Hay yield t-1 $\ln X_6$	Hay yield t-2 $\ln X_7$	Total labor $\ln X_9$	Trend $\ln X_{10}$
1.	R^2 = 0.890 d = 2.38 s_u = 0.034	0.029 (0.249)	0.195 (0.306)	-0.053 (0.042)	0.205 (0.262)				0.267 (0.387)	0.025 (0.068)
2.	R^2 = 0.888 d = 2.50 s_u = 0.032	0.091 (0.173)	0.288 (0.161)	-0.056 (0.039)	0.173 (0.233)				0.378 (0.225)	
3.	R^2 = 0.865 d = 2.16 s_u = 0.036	0.032 (0.259)	0.208 (0.318)		0.020 (0.227)				0.150 (0.391)	0.040 (0.069)
4.	R^2 = 0.861 d = 2.31 s_u = 0.036	0.128 (0.191)	0.413 (0.221)		-0.056 (0.195)	-0.055 (0.158)			0.330 (0.248)	
5.	R^2 = 0.845 d = 1.64 s_u = 0.036	0.037 (0.144)	0.172 (0.220)				-0.037 (0.093)	0.111 (0.109)		
6.	R^2 = 0.779 d = 1.90 s_u = 0.041	0.263 (0.203)			0.130 (0.198)				0.164 (0.266)	
7.	R^2 = 0.768 d = 1.57 s_u = 0.040				0.269 (0.128)	0.176 (0.118)				

Applying the transcendental model to the total agricultural production function produced logical results (Table 5.4.). Except for rainfall, all estimates indicate classical decreasing productivity for each factor, which is consistent with the expectations for overall agricultural productivity. Especially function no. 1 is good, if the insignificance of the estimates, which is the result of multicollinearity, is disregarded.

Table 5.4. Transcendental production function, dependent variable = total production, d = Durbin-Watson test value, s_u = standard errors of the residuals, standard errors of the regression coefficients in the brackets.

Equation	Fertil. & lime		Farm machinery		Rain-fall		Feed t-1		Total labor	
	$\ln X_1$	X_1	$\ln X_2$	X_2	$\ln X_3$	X_3	$\ln X_4$	X_4	$\ln X_9$	X_9
1. R^2 = 0.979	-0.028	-0.004	1.634	-0.036	-0.226	0.003	2.161	-0.002	-0.060	-0.018
d = 3.16	(0.719)	(0.012)	(1.139)	(0.021)	(0.119)	(0.002)	(2.058)	(0.002)	(2.653)	(0.051)
s_u = 0.023										
2. R^2 = 0.938	-0.863	0.011	3.158	-0.057			0.443	-0.0004	-1.836	0.025
d = 2.76	(0.729)	(0.012)	(1.210)	(0.024)			(2.356)	(0.0025)	(3.300)	(0.062)
s_u = 0.030										
3. R^2 = 0.905	0.015		1.607	-0.025			-1.494	0.002		
d = 2.32	(0.138)		(0.613)	(0.011)			(1.654)	(0.002)		
s_u = 0.030										

6. A DETAILED EXAMINATION OF THE ESTIMATES

In this section the estimated models are examined in terms of marginal physical products (MPP) and the values of marginal products (VMP). Assuming the profit maximizing condition under perfect competition in the factor and product markets it is possible to test whether the various inputs are used optimally. As all the functions derived are aggregate production functions this analysis is necessarily carried out in broad terms. The marginal rate of substitution (MRS) will be examined only between the inputs which are expected to be substituties in the production process involved. Finally, the stability of the parameters over time will be discussed briefly.

6.1. The MPP's and VMP's in the Livestock Production Functions

The marginal physical products of the inputs used in the livestock production functions no. 2 (Table 5.1.) are presented in Table 6.1. The formula for the MPP of a Cobb-Douglas function is [1]

$$(6.1.) \qquad MPP_{X_i} = b_i \frac{Q}{X_i}$$

The MPP's for the entire study period have been calculated using the average intensity of each variable. In order to obtain information about the change of MPP's at different levels of input use, they were also calculated using the respective average input utilization figures corresponding to the time periods 1956/57 - 62/63, 1959/60-66/67 and 1963/64 - 69/70.

The results can be interpreted for example as follows. In 1956/57 - 69/70 an additional feed unit used has brought forth an increase of 0.16 marks in animal production. Correspondingly the marginal product of an additional working day has been 8.65 marks. No noticeable decline has occurred in the marginal physical product of feed with increasing use of feed stuffs. Also the changes in the

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[1] Lauri Kettunen, "Om produktionsfunktionens form", Nordisk Jordbruksforskeres Forening, hefte 1-1966, p. 12.

Table 6.1. The marginal physical products (MPP) and the values of marginal physical products (VMP) of the inputs in the livestock production function no. 2, (Table 5.1.).

	Feed (t-1), X_4		Labor, X_8	
	MPP mk.	VMP mk.	MPP mk.	VMP mk.
1956/57 - 69/70	0.16	0.16	8.65	8.65
1956/57 - 62/63	0.17	0.16	8.81	9.47
1959/60 - 66/67	0.16	0.16	8.46	7.24
1963/64 - 69/70	0.15	0.15	8.48	5.39

MPP of labor have been fairly insignificant. At this point it is worth emphasizing that in the case of a Cobb-Douglas function the marginal physical product of a given input is directly affected by the intensity of all the other inputs.

Marginal physical products do not enable one to conclude whether inputs are used optimally. For this purpose one has to calculate the values of marginal products (VMP) and compare these with the prices of the respective inputs. Due to the manner of deriving physical products (from a production function with variables at constant price) the MPP's for the entire period equal VMP's. 1/ The values of marginal products for other periods were adjusted to correspond to the price ratio of a given input and output in the middle of the time period in question. The price indices used are given in Appendix 7.

The VMP's of both feed (0.16 mk.) and labor (8.65 mk.) are low with respect to the price of a feed unit and the cost of a working day. On the other hand, it is difficult to conclude whether these inputs are used economically from the point of view of an individual farm. This is because the function applied is a macro model and, generally, there is no alternative use for feed, especially,

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1/ Strictly speaking the VMP's are in this case "marginal value products" (MVP).

roughage. Similarly, in several cases in the short run, the only alternative to farm labor is unemployment and therefore the related marginal cost is close to zero. At any rate, compared with their market prices additional use of conventional feed and labor seems to be unprofitable.

Derived from function no. 3 (Table 5.1.) which includes only the feed input the VMP of feed is somewhat greater (0.27 mk.).

6.2. The MPP's and VMP's in the Total Production Functions

The MPP's and VMP's of the inputs used in total production functions are examined in the same way as before. The results are presented in Table 6.2.

The VMP of fertilizer indicates that further use of fertilizer is profitable; for the whole study period an additional mark in fertilizer has brought forth an increase of 1.12 marks in the total production. At higher levels of fertilizer utilization in later periods its MPP has declined slightly.

According to the results of this study the use of farm machinery has been especially profitable. The VMP of farm machinery (3.86 mk.) is, however, likely to be too high, because it is difficult to imagine that increasing use of machinery alone would increase total production so much.

As in the livestock production functions the VMP of feed and labor are low in these models also.

Even though the use of farm machinery calls for a certain labor input, making them complements in the short run, machinery and labor can be considered as substitutes in the long run. The marginal rate of substitution between labor and machinery is defined as

$$MRS_{X_2 for X_9} = - \frac{MPP_{X_9}}{MPP_{X_2}} = - \frac{5.50}{3.86} = - 1.42$$

This result can be interpreted that an additional mark in machinery is a substitute for a labor input of 1.42 marks. Accordingly, further replacement of labor by machinery would be profitable.

Table 6.2. The marginal physical products (MPP) and the values of marginal products (VMP) of the inputs in the total production function no. 2, (Table 5.3.).

	Fertilizer & lime (t-1), X_1		Farm machinery X_2		Feed (t-1), X_4		Labor X_9	
Period	MPP mk.	VMP mk.	MPP mk.	VMP mk.	MPP mk.	VMP mk.	MPP mk.	VMP mk.
1956/57 - 1969/70	1.12	1.12	3.86	3.86	0.13	0.13	5.50	5.50
1956/57 - 1962/63	1.35	1.33	4.49	4.67	0.13	0.13	4.64	5.07
1959/60 - 1966/67	1.15	1.22	3.85	3.96	0.13	0.13	5.47	4.65
1963/64 - 1969/70	0.96	1.06	3.36	3.74	0.12	0.12	6.49	4.73

6.3. The Stability of the Parameters over Time

One of the objectives of this study was to make a prognosis of the development of agricultural production in the near future. Accordingly, in terms of the reliability of the prognosis, the stability of the parameters of production functions used is of major importance. For this purpose the basic models were estimated for some sub-periods. First, a brief discussion will be devoted to the additional information that can be obtained by this method.

In all the functions above the intercept values were not presented since they were considered to be of minor importance. However, if production functions are estimated for different time periods the neutral technical change can be measured through changes in the intercepts. The procedure is discussed in more detail in Part I (page 13).

Secondly, a sub-period analysis enables examination of changes in the regression coefficients over time. However, it is to be noted that such changes in regression coefficients of a Cobb-Douglas production function do not necessarily reflect changes in corresponding MPP's. Respectively the MPP of a given input may vary even though the regression coefficient would remain unchanged. This is due to the implied characteristic of a Cobb-Douglas function that its MPP depends directly on the intensity of each input. Accordingly, it is not possible to draw conclusions from changes of regression coefficients that the corresponding MPP's would change at the same time. [1]

The livestock production function no. 2 (Table 5.1.) that was considered as the basic model, was estimated for four time periods; 1956/57-66/67, 1957/58-67/68, 1958/59-68/69 and 1959/60-69/70. Because the number of observations is reduced (11 observations) the reliability of the estimates is lower than in the functions for the whole period.

The estimated functions, and the MPP's and VMP's of the inputs are given in Table 6.3. For comparative purposes the corresponding function for the whole period is also presented. As to the intercept, the result is contrary to economic theory; its magnitude declines over time which would suggest a decline in the technology. The regression coefficient of feed in all the sub-period functions is lower than that for the entire period, but between periods it varies only little. On the other hand, the coefficient of labor increases substantially with time.

As to the stability of the MPP's and VMP's it can be concluded that those of feed remain practically unchanged. On the contrary the MPP and VMP of labor increase. The result is logical from the point of view of economic theory; with a decreasing use of labor its MPP increases.

Any conclusions from the above analysis whether or not real changes have occurred in the estimated parameters (and also in the MPP's) are hard to draw. There are a number of reasons for this.

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[1] Because a MPP of a linear production function is constant and independent from the use of other inputs, a linear function would appear to be suitable for testing the assumption of stable MPP's by varing the time period. However, certain features of a linear production function (eg. a constant MPP and an infinite elasticity of substitution) makes it in general less suitable for a production function analysis.

Table 6.3. The estimates of the animal production function no. 2 (Table 5.1.) for various time periods and the MPP's and VMP's of the respective inputs.

Period	Intercept $\ln a$	Feed t-1 $\ln X_4$	Labor $\ln X_8$	R^2	d	s_u
1956/57 - 69/70	3.717 (0.435)	0.253 (0.098)	0.350 (0.143)	0.852	1.46	0.037
1956/57 - 66/67	4.355 (0.655)	0.133 (0.136)	0.414 (0.159)	0.783	1.27	0.039
1957/58 - 67/68	3.702 (0.571)	0.127 (0.117)	0.604 (0.198)	0.815	1.30	0.035
1958/59 - 68/69	3.143 (0.665)	0.104 (0.115)	0.803 (0.279)	0.796	1.62	0.034
1959/60 - 69/70	2.468 (0.794)	0.133 (0.108)	0.929 (0.312)	0.805	2.22	0.034

	MPP mk.	VMP mk.	MPP mk.	VMP mk.
1956/57 - 69/70	0.16	0.16	8.65	8.65
1956/57 - 66/67	0.08	0.08	10.20	10.20
1957/58 - 67/68	0.08	0.08	14.63	13.42
1958/59 - 68/69	0.06	0.06	19.39	16.60
1959/60 - 69/70	0.08	0.08	22.55	18.72

Undoubtedly one of the most important is the multicollinearity between independent variables which makes the standard errors of the regression coefficients large. Secondly, when estimating functions for sub-periods the results are affected by the limited number of observations. Despite the shortcomings demonstrated above the systematic changes would allow one to conclude that the MPP and VMP of animal husbandry labor have increased. Respectively, the MPP and VMP of feed can be considered to have remained fairly constant.

The changes in the parameters of the total production function no. 2 (Table 5.3.) were examined in a similar way. The results are presented in Table 6.4. In these functions the regression coefficients do not change systematically. On the other hand, they do not remain constant either. It should also be noted that the low regression coefficients are associated with a function having a low R^2-value (1959/60 - 69/70).

With regard to the facts mentioned above it is difficult to draw conclusions whether any significant changes have occurred in the parameters. However, the increase in the intercept (from 2.123 to 4.380) would indicate that some neutral technical progress has been achieved. On the other hand, nothing can be concluded as to the changes of MPP's and VMP's of inputs.

Table 6.4. The estimates of the total production function no. 2 (Table 5.3.) for various time periods and the MPP's and VMP's of the respective inputs.

	Inter- cept lna	Fertil. & lime, t-1 $\ln X_1$	Farm Ma- chinery $\ln X_2$	Rain- fall $\ln X_3$	Feed, t-1 $\ln X_4$	Total labor $\ln X_9$	R^2	d	s_u
1956/57 - 69/70	2.614 (1.461)	0.091 (0.173)	0.288 (0.161)	-0.056 (0.039)	0.173 (0.233)	0.378 (0.225)	0.888	2.50	0.032
1956/57 - 66/67	2.123 (2.281)	0.112 (0.255)	0.229 (0.302)	-0.078 (0.081)	0.257 (0.434)	0.416 (0.428)	0.854	2.33	0.040
1957/58 - 67/68	1.916 (2.201)	0.150 (0.265)	0.269 (0.318)	-0.072 (0.081)	0.206 (0.451)	0.471 (0.409)	0.832	2.65	0.040
1958/59 - 68/69	3.013 (3.059)	0.149 (0.259)	0.264 (0.290)	-0.040 (0.108)	0.089 (0.512)	0.373 (0.405)	0.724	2.53	0.039
1959/60 - 69/70	4.380 (2.866)	0.054 (0.265)	0.114 (0.275)	-0.042 (0.049)	0.170 (0.302)	0.137 (0.469)	0.646	2.33	0.036

	MMP mk.	VMP mk.	MMP mk.	VMP mk.	MMP mk.	VMP mk.	MMP mk.	VMP mk.
1956/57 - 69/70	1.12	1.12	3.86	3.86	0.13	0.13	5.50	5.50
1956/57 - 66/67	1.50	1.50	3.03	3.03	0.19	0.19	5.65	5.65
1957/58 - 67/68	1.94	1.98	3.70	3.70	0.15	0.14	6.72	6.17
1958/59 - 68/69	1.81	1.92	3.45	3.55	0.07	0.07	5.49	4.67
1959/60 - 69/70	0.62	0.66	1.42	1.57	0.13	0.13	2.10	1.75

7. THE USE OF THE ESTIMATES FOR PREDICTION

7.1. On the Problems of Prediction

All estimation should be not only of informative but also of applicable value. The models estimated should be a means for the decision maker, either a private farmer or a decision maker of the public sector, i.e. the agricultural policy maker. The application of the models to be estimated is obviously the final target to most economic studies, but very often this part of the research has been left to the practical man, who may not be able to utilize fully the results of the study.

In the following the aim is to continue the analysis of the functional estimates by trying to apply them for predictive purposes. The models estimated are macro models, and therefore they are mainly suitable for application to questions of agricultural policy as a whole. It is most natural then to apply them for predictions which serve policy makers whose objectives include the balancing of production and consumption of agricultural products. Thus, if the development of production per hectare and the consumption per capita can be predicted, then it may be asked if it is possible to conclude what implication that development has for the arable land area. 1/

Prediction may be performed in several ways. The purest prediction model is the one by which the prediction of the future development is made based on data available at the moment the prediction is made. Most prediction models are, however, conditional in the sense that when a function is applied the prognoses of the future development of the explanatory variables are necessary before a prediction for the dependent variable can be made. Thus, the possible forecasting error is doubled. A typical and commonly used

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1/ The Agricultural Committee headed by Samuli Suomela suggested that the long run target of wheat and rye production should be 100 per cent self sufficiency and that of animal production 105 per cent. Maatalouskomitean mietintö III, Komiteamietintö 1969: B 40, p. IV. (Helsinki: 1969, Mimeographed).

method is to use projections which are based on the past trend of the variable to be predicted. This implies that the development of factors affecting the variable is assumed to continue as in the past.

The models estimated in this study are suitable only for conditional prognoses. The prediction method was simplified by applying only the models which contain the most important variables, usually from 1 to 3 variables. On the other hand, however, those models are the most logical, and finally, only the development of the use of fertilizer and lime had to be assumed exogenously to the models for the predictions. Since there are several models available, the extreme value estimates were used to get the limits for the predictions.

As to previous projections on the production and consumption of agricultural commodities in Finland the study by the Agricultural Committee in 1967 should be mentioned first. The Committee estimated that the annual growth rate of agricultural production per hectare would vary between 0-3 per cent by 1975.[1/] The Agricultural Committee in its third report in 1969 settled on a 1.5 per cent annual growth rate.[2/] That study was based purely on past trend of farm production. For comparison it may be mentioned that OECD estimated the overall annual production growth rate in Finland to be 2.1 per cent for the period 1965-75 and 1.4 per cent for 1975-85.[3/] The OECD study is also primarily based on past trends of consumption and production. In some cases cross section analysis was also used. In the OECD projections the aim has been to predict the production likely to arise from the continuation of recent trends. The general assumptions have been that present policies remain broadly unchanged and that prices and costs will continue to develop in approximately

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[1/] Maatalouskomitean mietintö I, Komiteamietintö 1967: B 66, (Helsinki: 1967, Mimeographed), p. 46.

[2/] Maatalouskomitean mietintö III, *op. cit.*, p. VII

[3/] *Agricultural Projections for 1975 and 1985*, OECD Publication, (Paris, 1968), p. 50.

the same way as in the recent past. Certain livestock products are the main exceptions to the above approach. The production projections of these commodities are generally based on the development of demand. The projections by FAO can also be mentioned. They are generally similar to those by OECD. [1]

7.2. Predictions for Livestock and Total Production

By the models estimated in this study, it is possible to make production predictions either a) by applying the total production functions or b) by first predicting the crop production which then determines the feed supply available. The feed input inserted in the livestock production function gives the final prediction of animal production. The latter method was applied in this study, since the total production function requires a prediction of the feed consumption, and then it is more natural to apply it directly to the livestock production function.

The great number of the models estimated causes some difficulties in selecting the model to be applied. As was mentioned earlier, the simplest models were considered the best for predictions since they are most logical. At the same time the difficulty of predicting the development of many explanatory variables was avoided.

According to the crop production functions the elasticity of production with respect to fertilizer and lime varies between 0.37 and 0.75 depending on the explanatory variables in the model. The latter figure, 0.75, however, came from a model were the estimate of the regression coefficient of agricultural chemicals is negative obviously making the elasticity with respect to fertilizer high. Therefore, it is hardly plausible to apply this figure for predictions as it only gives the upper limit. The basic model applied was the one, where the explanatory variables are fertilizer and lime consumption, with the regression coefficient (elasticity) 0.37,

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[1] Agricultural Commodity Projections 1970-1980, Vol. I and Vol. II, FAO Publication, (Rome, 1971).

and rainfall, regression coefficient 0.20 (function no. 5, page 29, Part I). Since the rainfall cannot be forecast, the prediction depends solely on the consumption of fertilizer and lime.

In 1960/61 - 1969/70 the fertilizer consumption increased by 8 per cent a year on the average. According to international comparison [1] and the values of marginal products of this study which are higher than one, it may be assumed that the development will be the same in the future. The corresponding increase of crop production per year is according to the basic model 0.37 x 8 = 3.0 per cent, which is a rather reasonable result. The higher elasticity mentioned earlier, 0.75, would yield a 6.0 per cent annual increase (0.75 x 8 = 6.0), which in its turn seems to be too high.

For predictions of animal production it is necessary to know the development of feed consumption. It can be estimated predicting first crop production and substracting from it the share of human consumption which consists mainly of rye, wheat and potatoes. According to the food balance sheet the consumption of rye and wheat was in 1970/71 about 465 mill.kg. a level which has remained steady for several years. This was only 8.6 per cent of the total crop production (5400 mill.f.u.) in 1970/71. The consumption of potatoes can also be considered constant or slightly decreasing. Its share of the total crop production is less than 1 per cent. The total human consumption of the total crop production is thus about 10 per cent. If the human consumption is kept constant which means a slight decrease of the per capita consumption, and if the whole increase of crop production is used for feed, feed consumption increases about 10 per cent faster than crop production. Thus, a 3 per cent increase of crop production would mean a 3.3 per cent increase in feed consumption. - In the following, feed consumption is, however, assumed to increase 3 per cent per year, since the use of decimals does not seem sensible due to large standard errors. Keeping the arable land area unchanged this is also the increase of total feed input.

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[1] FAO Annual Fertilizer Review 1970, Rome 1971, p. 38.

The basic model applied for predictions of animal production was the function no. 3 in Table 5.1. It includes only feed consumption as an explanatory variable, and therefore, it is easy to apply. In addition, the function no. 2 was used as an alternative. Assuming that labor input is going to remain constant then the prediction from this model also depends solely on the feed consumption. The elasticities of production with respect to feed consumption are respectively 0.45 and 0.25 in these functions nos. 3 and 2. Thus, if the feed consumption increases 3 per cent a year, the corresponding increase of animal production would be 1.35 and 0.75 per cent. Basically, these figures refer to the increase per animal unit, but they indicate well the development of total animal production. For example, a change in the number of animal units means an equal change of feed input in the opposite direction, and therefore it is easiest to make the predictions by assuming the number of animal units constant.

Both predictions, 1.35 and 0.75 per cent increases, seem quite reasonable. As mentioned earlier, the Agricultural Committee ended up with a predicted 1.5 per cent annual increase of the total production. Since the animal production is about 85 per cent of total production, the estimates are comparable to each other.

The fertilizer consumption has a decisive role in the predictions. By changing assumptions about its development, different predictions for animal production are obtained as is seen from Table 7.1., where in addition to the 8 per cent increase two other alternatives, 5 and 10 per cent increases of fertilizer consumption are also used as the basis for predictions. These are included as alternative agricultural policy targets rather than for predictions.

If the elasticity of crop production with respect to fertilizer consumption is changed from 0.37 to 0.75 the predictions are doubled. The range would then be from 0.98 to 3.34 per cent increase a year. The upper limit seems to be too high.

The predictions above are based on the assumption of constant arable land area. In order to estimate how much the arable land area should be reduced to balance production and consumption a prognosis of human consumption is needed first. A common assumption

Table 7.1. Forecasts of the annual increase of crop and animal production based on different assumptions of fertilizer use and elasticities, and estimates of decrease of arable land needed in balancing production and consumption at the present level.

No.	Increase of the use of fertilizer, per cent	Crop production Elasticity	Crop production Increase per cent	Animal production Elasticity	Animal production Increase per cent	Decrease of arable land, hectares
1	8	0.37	3.0	0.45	1.35	34,000
2	8	0.37	3.0	0.25	0.75	19,000
3	5	0.37	1.9	0.45	0.86	22,000
4	5	0.37	1.9	0.25	0.48	12,000
5	10	0.37	3.7	0.45	1.67	42,000
6	10	0.37	3.7	0.25	0.93	23,000

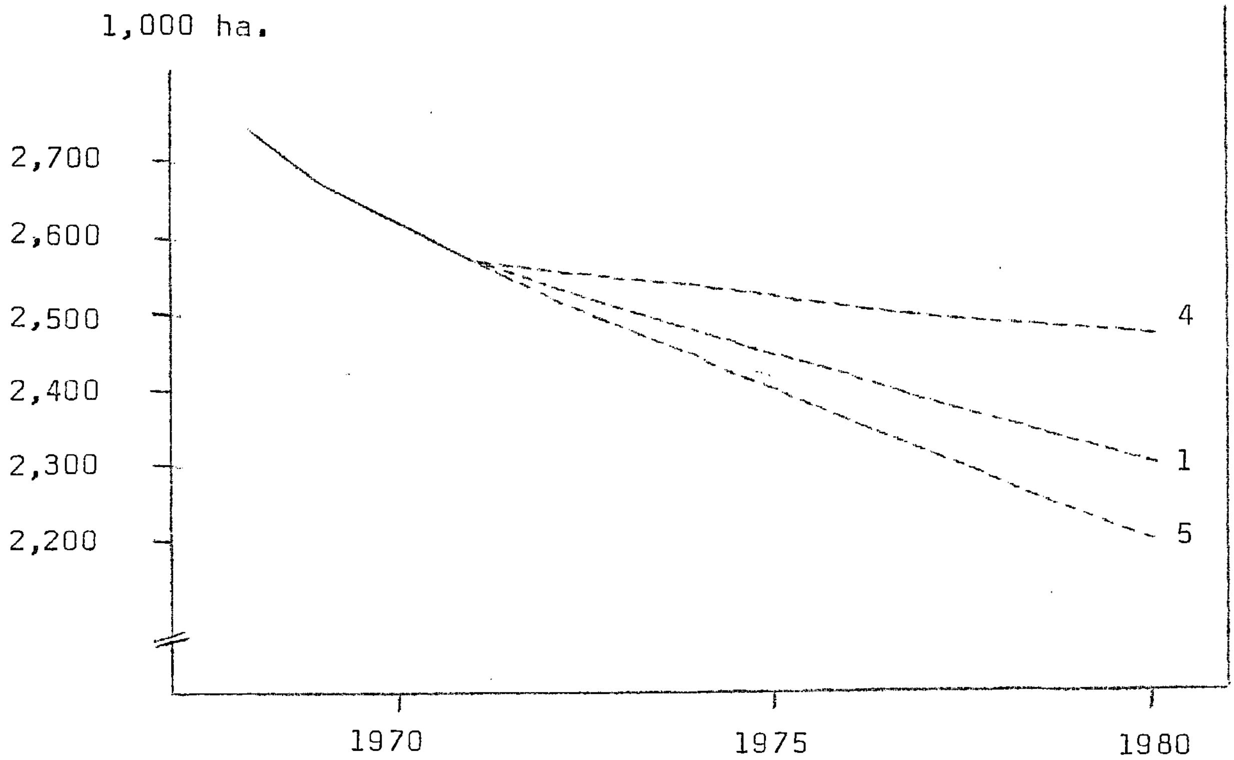

Figure 7.1. Different alternatives for reducing the arable land for balancing production and consumption. The numbers refer to the corresponding prognoses in Table 7.1.

is that consumption will not increase at all. Rather the per capita calorie intake is slightly decreasing, but since at the same time the diet changes in favor of low calorie products, it is reasonable to assume a constant consumption per capita for the near future. The other important factor, the total consumption depends on, is the annual growth rate of population. Due to the recent changes in the population growth it is rather difficult to make any reliable estimate of the future number of population. Here also it is assumed to be zero. The two assumptions indicate that the annual total consumption will remain unchanged. However, alternative predictions can be easily inserted to the following calculations.

The decrease of arable land area needed for balancing the growth of production and consumption at the present level of overproduction corresponding to each prediction are given in Table 7.1. The range of predictions up to 1980 is depicted in Figure 7.1. Balancing production at the present level refers to constant absolute overproduction. In relative terms this overproduction is estimated to be about 20 per cent at the present time. If the target is, say 105 per cent self sufficiency, the rate of arable land decrease has to be correspondingly faster depending on the time horizon of the planning. According to Figure 7.1. the observed development in 1969-71 has been a little faster than the prediction would suggest for the future. The decrease of arable land area under the soil bank program has been quite rapid, but it is to be noted that the target has been rapid reduction of total production to get a better balance of production and consumption, and thus to lessen the burden placed on state finances by export subsidies. However, the production has not yet decreased due to the increase of productivity and due to the obviously low productivity of that arable land which has been temporarily taken out of cultivation. Without the stabilization measures the overproduction would certainly be more serious. The future development evidently does not require as heavy policy measures as those in the past three years, since the arable land has already been reduced considerably.

8. SUMMARY

One of the central targets of agricultural policy is to try to achieve as efficient production as possible and to adjust the level of production to the needs of domestic consumption. Applied to the Finnish situation, the goal is to reduce the present overproduction to a level which is closer to the target of 105 per cent self sufficiency in crop production set by the Agricultural Committee in 1969. In this task, aggregate production functions would be valuable, but the studies available are based mainly on cross section data and, thus, not easily applicable for the declared purpose. This was the background and the incentive for this study.

Aggregate crop production functions were delt in Part I of this publication, and so the purpose of this Part was to estimate the livestock and total production functions of Finnish agriculture, to examine in terms of values of marginal products the profitability of inputs at various levels of intensity, to make prognoses of the development of crop and animal production based on the estimates obtained, and to calculate what implications they would have for the area of arable land under production in view of the stated goal of balancing the production and consumption.

The study was based on the official statistics of Finnish agriculture and the "total calculations of agriculture" by the Agricultural Economics Research Institute. The time series data used covers the crop years 1956/57 - 1969/70.

Due to the limited number of observations only a few explanatory variables could be included in the functions to be estimated. In the case of the livestock production functions in which the value total production was the dependent variable, the following explanatory variables were included: feed consumption, labor input in animal husbandry, time as an indicator of technology, hay yield as a substitute for feed, and lagged values of feed and hay yield. This function was expressed on a per animal unit basis.

The total production functions were expressed on per hectare basis with the total production of agriculture as the dependent variable and the explanatory variables of the crop and livestock production functions as the independent variables. Several alternative functions were estimated by omitting some of the independent variables.

Generally, the Cobb-Douglas type of functions estimated corresponded well to a priori expectations; the estimates were logical and the multiple correlation coefficients were rather high. Many times, however, the estimates were not significant, obviously due to the high multicollinearity of the independent variables.

The elasticity of animal production with respect to feed consumption is 0.25 in a function which also includes the labor input, and 0.45 if feed is the only explanatory variable in the model (Table 5.1.). These estimates were considered to be most suitable for further examination.

The estimates of the total production functions are given in Table 5.3. Again, on the whole, the results are satisfactory. The only shortcomings are the negative signs of rainfall and the variation of the estimate of fertilizer and lime consumption. This can, however, be practically explained by the consideration that these are basically determinants of crop production. Furthermore, since crop production accounts for only about 15 per cent of the total production, they cannot have much influence on total production. On the other hand, the total production functions do not on the whole seem very sensitive since they are a sum of crop and animal production functions and since there are certain unavoidable problems of aggregation in their formation.

The estimates were further examined by calculating the values of marginal products. According to the results, the use of additional fertilizer and machinery seems to be profitable. On the contrary, the values of the marginal products of labor and feed inputs turned out to be relatively low. However, there is seldom alternative use for them on a single farm, i.e. their marginal cost is close to zero and so no definite conclusion regarding their profitability can be made.

Another part of the further examination of the models was to estimate the functions based on data from different time periods. These estimates turned out to be rather stable.

In Chapter 7, an attempt was made to apply the estimated functions for predictive purposes. Only most simple models were selected for this procedure. Beginning with the crop production function it was possible to estimate the annual growth rate of crop production assuming that the fertilizer consumption would continue to increase at the past rate of 8 per cent a year. The growth of crop production then enabled estimation of the increase of feed input. Inserting this estimate into the animal production function gave the final prediction. The range of predicted animal production varied between 0.48 to 1.67 (Table 7.1.). These predictions were then applied for estimating the necessary decrease of the arable land area which would be necessary to balance the production and consumption at the present level of overproduction. The basic assumptions and models resulted in a reduction of the arable land area of 34,000 ha. Taking into account all the other assumptions the limits of this reduction were estimated to be from 12,000 to 42,000 hectares per year.

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Selostus

KOTIELÄIN- JA KOKONAISTUOTTOFUNKTIOT SUOMEN MAATALOUDESSA SATOVUOSINA 1956/57 - 1969/70

Lauri Kettunen Juhani Rouhiainen

Tuotantofunktio ilmaisee tuotoksen ja tuotantopanosten välisen riippuvuussuhteen. Siten koko maataloussektorista saadun aineiston perusteella estimoitu tuotantofunktio voi olla hyödyllinen väline haettaessa optimaalista tuotannontekijöiden käyttöastetta. Samoin sitä voidaan käyttää arvioitaessa tuotannon kehitystä, jos joidenkin tuotannontekijöiden kuten esimerkiksi väkilannoitteiden käyttö voidaan ennustaa. Suomen olosuhteisiin sovellettuna tuotantofunktiota voidaan siis ilmeisestikin käyttää ennustettaessa kokonaistuotannon kehitystä sekä edelleen arvioitaessa, miten peltopinta-alan tulisi vähetä, jotta saavutettaisiin esimerkiksi Maatalouskomitean vuonna 1969 asettamat tuotantotavoitteet, 105 %:n omavaraisuus kotieläintuotannossa ja 100 %:n omavaraisuus leipäviljan viljelyssä.

Suomessa on tehty useitakin maataloutta koskevia tuotantofunktiotutkimuksia, mutta ne ovat olleet luonteeltaan pääasiassa poikkileikkaustutkimuksia ja siten yllä esitettyihin tarkoituksiin soveltumattomia. Tämän tutkimuksen tarkoituksena oli pyrkiä korjaamaan tätä puutetta. Julkaisun ensimmäisessä osassa on esitetty kasvinviljelytuottofunktioiden estimaatit, ja niin tämän tutkimuksen tehtäväksi jäi ensiksikin estimoida kotieläin- ja kokonaistuottofunktiot, toiseksi tutkia rajatuottojen avulla tuotannontekijöiden käytön edullisuutta eri intensiteettitasoilla, kolmanneksi tehdä saatujen estimaattien avulla ennusteita kasvinviljelyn ja kotieläintuotannon kehityksestä sekä arvioida, miten peltopinta-alan tulisi vähetä pyrittäessä tasapainottamaan tuotanto ja kulutus nykyiselle ylituotantotasolle. Asetettujen omavaraisuustavoitteiden saavuttaminen riippuu suunnitteluvälistä eikä siihen haluttu ottaa kantaa tässä yhteydessä.

Tutkimuksessa käytettiin Maatalouden taloudellisen tutkimuslaitoksen kokonaislaskelmia ja virallista maataloustilastoa satovuosilta 1956/57 - 1969/70.

Havaintoaineiston pienuuden takia tutkimuksessa jouduttiin käyttämään vain tärkeimpiä selittäviä muuttujia, joiden valinnassa oli esikuvana aikaisemmat tutkimukset. Kotieläintuottofunktioiden selittäjinä olivat rehun käyttö, kotieläinten hoitoon käytetty työpanos ja teknologian kehitystä kuvaava aikatekijä. Lisäksi käytettiin viivästettyä rehupanosta sekä kokeiltiin rehun käytön tilalla heinäsatoa joko yksin tai lisäksi vuodella viivästettynä. Kokonaistuottofunktioiden selittäjinä käytettiin kasvinviljely- ja kotieläintuottofunktioiden selittäjiä.

Pienimmän neliösumman menetelmällä estimoiduista kotieläintuottofunktioista voidaan ensiksikin mainita, että kertoimet ovat yleensä loogisia ja mallien selitysaste on melko korkea. Kotieläintuoton jousto rehun käytön suhteen vaihtelee 0.25:sta 0.45:een malliin otettujen muuttujien mukaan. Molemmat estimaatit tuntuvat sinänsä mahdollisilta. Työpanoksen suhteen kertoimet tuntuvat liian suurilta, ja niin perusmallina pidettiin myöhemmin funktiota, joka sisältää vain rehun käytön selittäjänä jouston ollessa tällöin edellä mainittu 0.45. Teknillisen kehityksen vaikutus näyttäisi olevan tutkimuksen mukaan noin 0.5 %:n luokkaa vuodessa.

Kokonaistuottofunktioiden osalta voidaan samoin ensin mainita mallien suhteellisen hyvä loogisuus ja selittävyys. Toisaalta voidaan yleensä suhtautua varauksellisesti kokonaistuottofunktioihin, koska ne muodostuvat selvästikin kahdesta komponentista, kasvinviljely- ja kotieläintuotosta, ja näin ollen on luonnollisempaa käsitellä niitä erillisinä, kuten tehtiinkin mm. ennusteiden kohdalla. Kokonaistuottofunktioiden kaksiosaisuuden vuoksi kasvinviljelytuottofunktioiden selittäjien kertoimet eivät olleet kovinkaan pysyviä, kun taas kotieläintuottofunktioiden selittäjien kertoimet muodostuivat lähes samalla tavalla kuin varsinaisissa kotieläintuottofunktioissa. Tälle on luonnollisena selityksenä kotieläintuoton dominoiva osuus, noin 85 % kokonaistuotosta.

Estimoitujen mallien parametreja tutkittiin lähemmin tarkastelemalla rajatuottoja erilaisilla tuotannontekijäin intensiteettitasoilla. Tulokseksi saatiin, että väkilannoitteiden käytön ja koneistamisen lisääminen näyttäisi olevan kannattavaa. Sen sijaan rehu- ja työpanosmuuttujien osalta rajatuotot ovat pieniä, ja siten näiden tuotannontekijäin käytön lisääminen on estimaattien mukaan epäedullista, mutta toisaalta on otettava huomioon, että kummallekaan ei ole aina vaihtoehtoiskäyttöä yksityisellä tilalla, joten vastaava rajakustannuskin on lähes nollan suuruinen.

Parametrien pysyvyyttä tutkittiin estimoimalla mallit eri ajanjaksoille. Havaintoaineiston pienuus vaikeuttaa kuitenkin johtopäätösten tekoa, mutta yleisesti ottaen saadut estimaatit eivät poikenneet oleellisesti toisistaan, toisin sanoen parametrien estimaatit näyttivät melko pysyviltä.

Viimeisenä vaiheena tutkimuksessa oli saatujen mallien soveltaminen ennustamiseen. Kun käytettiin vain yksinkertaisimpia malleja, oli riittävää tuntea vain väkilannoitteiden käytön kasvu, jonka oletettiin jatkuvan samanlaisena kuin viime vuosina eli noin 8 % vuodessa. Tämä olettamus näyttää realistiselta, sillä ensiksikin väkilannoitteiden käytön lisääminen osoittautui tämän tutkimuksen mukaan kannattavaksi ja toiseksi väkilannoitteiden käyttö on Suomessa vielä paljon pienempi kuin muualla Euroopassa. Koska väkilannoitteiden käytöllä on ennusteissa ratkaiseva asema, sovellettiin lisäksi vaihtoehtoina 5 %:n ja 10 %:n suuruista väkilannoitteiden käytön kasvua. Näin saatiin joukko ennusteita, joiden mukaan kotieläintuoton kasvu vaihtelee 0.48 %:n ja 1.67 %:n välillä vuodessa.

Lopuksi arvioitiin vielä, miten peltopinta-alaa olisi vähennettävä, jotta saavutettaisiin tasapaino tuotannon ja kulutuksen kasvussa, eli toisin sanoen tasapainotettaisiin tuotanto ja kulutus nykyiselle ylituotantotasolle. Kokonaiskulutuksen oletettiin pysyvän vakiona, sillä per capita kulutus tuskin lisääntyy ja väestön kasvun ennustetaan pysähtyvän kokonaan. Näin päädyttiin arvioihin, joiden mukaan peltopinta-alaa olisi vähennettävä vuosittain 12 000 - 42 000 ha vaihtoehdosta riippuen perusmallin eli kaikkein todennäköisimmän vaihtoehdon ollessa 34 000 ha vuodessa. Jos halutaan saavuttaa asetetut omavaraisuustavoitteet, on peltopinta-alaa vähennettävä vieläkin nopeammin.

Appendix 1. The variables used in the livestock production function analysis, Per animal unit data, all the money values at 1961/62 prices.

	Animal production mk.	Feed t-1 f.u.	Hay yield t-1 f.u.	Labor working days
1956/57	825.8	1,198.6	348.4	28.3
1957/58	805.0	1,190.5	462.0	30.9
1958/59	866.9	1,261.8	434.4	35.1
1959/60	888.8	1,189.0	439.6	36.7
1960/61	880.0	1,581.1	590.6	38.2
1961/62	889.0	1,527.2	597.7	37.1
1962/63	907.8	1,441.7	609.0	39.7
1963/64	966.9	1,477.3	553.0	41.1
1964/65	1,009.6	1,515.6	595.3	40.5
1965/66	985.3	1,714.2	650.7	41.0
1966/67	982.7	1,728.9	662.6	39.8
1967/68	1,009.8	1,793.5	691.5	39.9
1968/69	1,051.8	1,915.7	727.3	43.2
1969/70	1,061.0	1,960.2	582.1	41.9

Source: Data from the Agricultural Economics Research Institute, Helsinki and the Board of Agriculture, Helsinki.

Appendix 2. The variables used in the total production function analysis. Per hectare data, all the money values at 1961/62 prices.

	Total production mk.	Fertil. & lime t-1 mk.	Farm machinery mk.	Rainfall in June mk.	Feed t-1 f.u.	Hay yield t-1 f.u.	Labor working days
1956/57	647.5	37.7	37.2	50.5	808.1	234.8	58.5
1957/58	632.0	42.6	38.1	65.3	814.0	315.8	58.9
1958/59	664.3	42.3	39.8	41.1	834.4	287.2	59.3
1959/60	700.5	45.1	43.6	26.2	778.5	287.8	56.9
1960/61	723.3	53.9	48.6	68.5	1,059.2	395.6	56.8
1961/62	751.0	55.0	52.0	83.5	1,064.8	416.7	54.2
1962/63	711.6	53.5	54.7	55.2	998.3	421.7	54.7
1963/64	780.8	53.2	57.3	37.9	1,009.0	377.7	53.2
1964/65	782.4	65.8	59.2	37.8	983.9	386.4	47.8
1965/66	762.5	75.0	61.1	48.2	1,112.1	422.1	46.4
1966/67	750.0	73.9	70.4	41.3	1,119.4	429.0	43.4
1967/68	766.8	72.2	69.5	48.6	1,149.4	443.2	41.9
1968/69	777.6	81.9	70.1	45.4	1,176.0	446.5	40.7
1969/70	805.2	88.7	72.7	22.0	1,217.2	361.5	39.2

Source: Data from the Agricultural Economics Research Institute, Helsinki and the Board of Agriculture, Helsinki.

Appendix 3. The composition of animal production in 1956/57 and 1969/70, all the money values at 1961/62 prices.

		1956/57			1969/70		
		Quantity mill.kg.	Value mill.mk.	%	Quantity mill.kg.	Value mill.mk.	%
1.	Milk	3,061.2	994.6	69.2	3,369.1	1,094.6	60.4
2.	Beef	65.3	176.8	12.3	119.2	322.7	17.8
3.	Veal	4.1	9.4	0.6	0.8	1.8	0.1
4.	Pork	61.5	164.6	11.5	94.4	252.7	13.9
5.	Mutton	3.1	9.7	0.7	1.1	3.5	0.2
6.	Horse meat	6.2	9.5	0.7	4.6	7.1	0.4
7.	Wool	0.5	3.3	0.2	0.2	1.3	0.0
8.	Eggs	31.0	68.4	4.8	58.9	129.9	7.2
	Total		1,436.3	100.0		1,813.6	100.0

Source: Data from the Agricultural Economics Research Institute, Helsinki.

Appendix 4. The composition of total production in 1956/57 and 1969/70, all the money values at 1961/62 prices.

		1956/57			1969/70		
		Quantity mill.kg.	Value mill.mk.	%	Quantity mill.kg.	Value mill.mk.	%
1.	Wheat	129.0	60.4	3.7	446.7	209.2	9.4
2.	Rye	94.9	46.4	2.8	109.9	53.7	2.4
3.	Barley	53.4	17.2	1.0	89.7	28.9	1.3
4.	Oats	34.8	8.4	0.5	25.0	6.0	0.3
5.	Peas	1.9	1.3	0.0	0.5	0.3	0.0
6.	Potatoes, for industry	470.0	69.0	4.1	375.3	55.1	2.5
7.	- " - , for human cons.	99.0	6.7	0.4	127.0	8.6	0.4
8.	Sugar beets	242.2	21.8	1.3	341.0	30.7	1.4
9.	Winter turnip rape	5.6	4.5	0.3	7.9	6.4	0.3
10.	Swede	25.3	3.2	0.2	32.3	4.1	0.2
	Crop production, total		238.9	14.3		403.0	18.2
11.	Milk	3,061.2	994.6	59.4	3,369.1	1,094.6	49.4
12.	Beef	65.3	176.8	10.5	119.2	322.7	14.6
13.	Veal	4.1	9.4	0.5	0.8	1.8	0.0
14.	Pork	61.5	164.6	9.8	94.4	252.7	11.4
15.	Mutton	3.1	9.7	0.6	1.1	3.5	0.2
16.	Horse meat	6.2	9.5	0.6	4.6	7.1	0.3
17.	Wool	0.5	3.3	0.2	0.2	1.3	0.0
18.	Eggs	31.0	68.4	4.1	58.9	129.9	5.9
	Animal production, total		1,436.3	85.7		1,613.6	81.8
	Total		1,675.2	100.0		2,216.6	100.0

Source: Data from the Agricultural Economics Research Institute, Helsinki.

Appendix 5. The composition of feed input in 1956/57 and 1969/70.

	1956/57		1969/70	
	mill.f.u.	%	mill.f.u.	%
1. Wheat for feed	41.9	2.0	20.6	0.6
2. Rye for feed	17.3	0.8	6.8	0.2
3. Barley for feed	171.4	8.2	831.2	24.8
4. Oats for feed	420.0	20.1	1,030.0	30.8
5. Mixed grain	32.0	1.5	55.1	1.6
6. Potatoes for feed	160.5	7.7	73.6	2.2
7. Root crops for feed	27.9	1.3	6.8	0.2
8. Big leafed turnip	6.5	0.3	8.6	0.3
9. Marrow kale	-	-	12.8	0.4
10. Fodder rape	-	-	0.9	0.0
11. Green fodder	34.5	1.7	15.8	0.5
12. Silage	28.0	1.3	78.4	2.3
13. Hay[1]	606.0	29.2	994.6	29.7
14. Root crop leaves	27.0	1.3	39.3	1.2
15. Meadow hay	14.8	0.7	1.9	0.0
16. Skim milk	111.1	5.3	88.3	2.6
17. Imported feed stuffs[2]	386.0	18.6	85.9	2.6
	2,084.9	100.0	3,350.6	100.0

1) Feed consumed by horses excluded

2) Including imported cereals used as feed

Source: Data from the Board of Agriculture, Helsinki.

Appendix 6. The arable land area and the number of livestock units in 1955-1969.

	Arable land area ´000 ha.	Livestock units Total `000	Excl. horses
1955	2,565.7	2,175.8	1,792.4
1956	2,580.0	2,090.5	1,725.5
1957	2,596.1	2,077.8	1,739.4
1958	2,611.2	2,096.6	1,774.9
1959	2,633.4	2,037.3	1,726.6
1960	2,654.1	2,030.6	1,724.3
1961	2,670.7	2,064.8	1,778.0
1962	2,686.7	2,139.2	1,862.1
1963	2,703.2	2.127.8	1,860.5
1964	2,716.7	2,099.0	1,846.2
1965	2,731.2	1,989.0	1,763.7
1966	2,741.2	1,974.6	1,771.9
1967	2,746.2	1,948.1	1,774.8
1968	2,750.4	1,915.2	1,759.9
1969	2,752.8	1,832.7	1,688.4

Source: Annual Statistics of Agriculture 1955-69, Helsinki.

Appendix 7. The price indices of some variables used in the production function analysis.

	Total production	Animal production	Fertil. & lime	Farm Machinery	Feed concentrates	Labor[1]
1956/57	84.7	86.1	72.3	82.5	82.6	80.9
1957/58	88.3	88.5	83.2	89.3	94.3	84.0
1958/59	92.2	91.9	91.6	93.5	97.5	87.5
1959/60	99.1	98.0	100.3	95.3	102.6	90.7
1960/61	99.9	101.2	98.0	97.6	98.1	96.4
1961/62	100.0	100.0	100.0	100.0	100.0	100.0
1962/63	103.3	103.2	101.1	103.3	108.2	112.5
1963/64	112.0	112.8	105.8	108.9	116.2	131.8
1964/65	126.2	126.1	117.9	114.4	124.3	151.9
1965/66	130.3	131.6	122.5	116.8	128.1	167.6
1966/67	134.7	136.1	122.1	120.9	132.6	184.8
1967/68	150.7	155.1	131.0	132.9	144.4	201.1
1968/69	160.2	165.9	136.5	141.2	149.7	219.6
1969/70	164.1	169.4	136.5	148.8	150.6	240.3

1) Includes social costs

Source: Data from the Agricultural Economics Research Institute, Helsinki.

Appendix 8. Correlation coefficient matrix of the variables used in livestock production functions.

	Animal production Q_1	Feed t-1 X_4	Feed t-2 X_5	Hay yield t-1 X_6	Hay yield t-2 X_7	Animal husbandry work X_8	Trend X_{10}
Q_1	1.0						
X_4	0.879	1.0					
X_5	0.873	0.883	1.0				
X_6	0.764	0.857	0.801	1.0			
X_7	0.897	0.880	0.957	0.837	1.0		
X_8	0.882	0.797	0.788	0.842	0.895	1.0	
X_{10}	0.969	0.944	0.944	0.849	0.943	0.876	1.0

Appendix 9. Correlation coefficient matrix of the variables used in total production functions.

	Total production Q_2	Fertil. & lime t-1 X_1	Farm Machinery X_2	Rain-fall X_3	Feed t-1 X_4	Feed t-2 X_5	Hay yield t-1 X_6	Hay yield t-2 X_7	Total labor X_9	Trend X_{10}
Q_2	1.0									
X_1	0.839	1.0								
X_2	0.884	0.952	1.0							
X_3	-0.307	-0.330	-0.329	1.0						
X_4	0.836	0.910	0.915	-0.024	1.0					
X_5	0.815	0.850	0.917	-0.228	0.838	1.0				
X_6	0.718	0.705	0.783	0.216	0.838	0.756	1.0			
X_7	0.868	0.798	0.898	-0.241	0.835	0.949	0.805	1.0		
X_9	-0.812	-0.971	-0.962	0.394	-0.863	-0.861	-0.658	-0.790	1.0	
X_{10}	0.893	0.970	0.990	0.377	0.908	0.913	0.754	0.895	-0.970	1.0

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