MAATALOUDEN TALOUDELLISEN TUTKIMUSLAITOKSEN JULKAISUJA N:o 25
PUBLICATIONS OF THE AGRICULTURAL ECONOMICS RESEARCH INSTITUTE, FINLAND, No. 25

PRODUCTIVITY AND AGGREGATE PRODUCTION FUNCTIONS IN THE FINNISH AGRICULTURAL SECTOR 1950—1969

RISTO IHAMUOTILA

SELOSTUS:

TUOTTAVUUDESTA JA TUOTANTOFUNKTIOISTA SUOMEN MAATALOUDESSA VUOSINA 1950—1969 MAKROTALOUDELLINEN TUTKIMUS

HELSINKI 1972

MAATALOUDEN TALOUDELLISEN TUTKIMUSLAITOKSEN JULKAISUJA N:o 25
PUBLICATIONS OF THE AGRICULTURAL ECONOMICS RESEARCH INSTITUTE, FINLAND, No. 25

PRODUCTIVITY AND AGGREGATE PRODUCTION FUNCTIONS IN THE FINNISH AGRICULTURAL SECTOR 1950—1969

RISTO IHAMUOTILA

SELOSTUS:

TUOTTAVUUDESTA JA TUOTANTOFUNKTIOISTA SUOMEN MAATALOUDESSA VUOSINA 1950—1969 MAKROTALOUDELLINEN TUTKIMUS

HELSINKI 1972

Helsinki 1972. Valtion painatuskeskus

PREFACE

This study was carried out to create, additional information about the development of output, inputs and productivity in Finnish agriculture especially from macroeconomic standpoint. The other purpose of the study was to estimate aggregate production functions to explain variations in output. Such production functions also can be sources of information when evaluating the advantages of investments as substitute for the declining labour force of agriculture.

The study was conducted at the Agricultural Economics Research Institute. Following its completion, the author now expresses his thanks to the persons who made their own contributions to this study. The assistance of Mr. Markku Nevala, Mr. Esa Ikäheimo and Mr. Juhani Rouhiainen was valuable in many respects. Mrs. Marketta Björses very painstakingly took care of typing the manuscript. The author is especially indepted to Dr. Theodore E. Doty who read the manuscript, prepared the author's English to more fluent form and also presented valuable suggestions. The author is entirely responsible, however, for the contents and possible errors in the study.

Finally, the author expresses his gratitude to August Johannes and Aino Tiura Foundation for Agricultural Research for the grant awarded for this study. The author also thanks the Board of the Agricultural Economics Research Institute for approving this study into the series of publications of the Institute.

The study has been published mimeographed in November 1971. Some minor additions have been made for the printed issue, however.

Helsinki, February 1972

Risto Ihamuotila

CONTENTS

1. INTRODUCTION

The term productivity has been a much used concept in economics and economic policy. A major reason for its use has been that economic growth, and thus also, rises in standards of living have been largely a result of improved productivity. The significance of productivity increase has been crystalized by a well-known American economist John W. KENDRICK (1961 a, p. 3) as follows: »The story of productivity, the ratio of output to input, is at heart the record of man's efforts to raise himself from poverty.»

Productivity is an equally relevant measure in both micro and macro levels, in other words within a firm, between firms, between industries and between countries. There are differences in absolute productivity within and between the cases above, which means that factors of production tend to shift from sectors of lower productivity to sectors where productivity is higher. Differences between firms and industries also occur in the rate of productivity increase. A young expanding industry often has a higher rate of growth than an older and more stable one. On the other hand, a given industry usually experiences periodic changes in the rate caused both by business cycles and/or unpredictable variables such as weather and so on.

Questions and problems of productivity have traditionally commanded a great deal of economists'interest and energy. The concept productivity has been used in economic literature since physiocratic era. Nowadays numerous studies of productivity are available. Of interest in this regard are the works of e.g. KUZNETS (1946), CLARK (1951) and KENDRICK (1961 a), who have estimated very long run trends in national product, inputs and productivity. Recently, economists have concentrated on analyses of the relationships between product and inputs, or in other words on production function analyses. At an early stage it was recognized that the real net product of a given industry, or an economy as a whole, had risen markedly more than could have been expected solely from increases of labour and capital inputs. Thus, more recently much attention has been paid to the influence of such factors as technological advance and improved human knowledge upon the the rise of productivity (SOLOW 1957, ARROW et.al. 1961, LAVE 1962).

The productivity analysis of the agricultural sector probably meets more difficulties than that of most other sectors or industries. The output of agriculture is sensitive to occasional variations caused especially by weather conditions. Such fluctuations always necessitate utilization of long run trends to estimate productivity. Since agricultural production is largely based on utilization of natural resources, difficulties also arise in the appraisal and evaluation of output and inputs in this industry. Nevertheless, several studies have been made on the productivity of agriculture, too. Information of productivity in the agricultural sector has been presented in the large works of CLARK (1951) and KENDRICK (1961 a) which were referred to above. Besides them the studies of LOOMIS & BARTON (1961), where productivity trends were established ever since 1870, NOU & NILSSON (1955) and GULBRANDSEN & LINDBECK (1969, p. 27—33, 175—181 and 262) can be mentioned. In Finland SUOMELA (1958) has made a fundamental study on the productivity in Finnish agriculture from 1935/36 to 1954/55. Due to paucity of available statistics he had to base the study solely upon bookkeeping farm accounts, although attempts were also made to estimate figures for the agricultural industry as a whole. No definitive studies on aggregate productivity in Finnish agriculture have been produced since then, evidently because of deficient information of labour and capital inputs. A few concise clarifications (e.g. KAARLEHTO & STANTON 1966) have been made, however, in recent years.

Up-to-date information of the productivity in Finnish agriculture would be very relevant, probably more relevant than in many other countries for two main reasons. First, the average size of farms in Finland has been small through time, but a fairly substantial decline in the number of farms is expected to take place in the 1970's. This fact should make it possible to achieve better results than previously through rationalization. Knowledge of the effect of this process on agricultural productivity will be valuable at both the micro and macro levels. Secondly, the official regulation of farmers' incomes in Finland during the last twenty years has mainly been accomplished through the so-called agricultural price laws. To evaluate the influence of these policy measures, information of actual changes in productivity during that period would have been of greatest importance. This also holds true currently, when agriculture can receive a compensation for rises in input prices only indirectly through the price law and must negotiate with the Government about possible additional actions. The purpose of those actions, as is expressed by the law, is »to aim at improving the income level in agriculture in ratio to rises in income levels of comparable groups taking into consideration changes in agricultural productivity».

The purpose of this study is to present new information about productivity in Finnish agriculture and also to estimate the aggregate production functions for this industry. At first, the concept and measurement problems of productivity will be discussed. Secondly, the trends in production, inputs and productivity will be worked out and various productivity measures will be used. The study will cover a period of twenty years since 1950 and is based both on aggregate statistics and bookkeeping farm accounts. The last part of study contains a production function analysis where the relationships of gross and net output of agriculture to various inputs including technological change and the level of human knowledge, will be investigated.

2. THE CONCEPT OF PRODUCTIVITY AND PROBLEMS OF MEASUREMENT

2.1. On the concept

The contents of the productivity concept in all its variations has been much discussed in general and agricultural economics (e.g. GEUTING 1954, SUOMELA 1958, NIITAMO 1958 and RUSTEMEYER 1964). In this study, therefore, conceptual problems will not be fundamentally treated. Some theoretical questions having special interest from this study's point of view will be discussed, however.

Productivity is a measure of the efficiency with which resources are converted into commodities and services that men want (KENDRICK 1961, p. 35). According to general definition productivity expresses the ratio of output to one or several inputs used to produce this output. Designating Q as output and I as input or inputs, the productivity, P, can be simply written as:

$$P = \frac{Q}{I}$$

This is the generally approved form of productivity although both output and input may have wider or more concise contents. If the *gross output* — meaning volume of production — and every input to produce it are taken into account the result is a concept called here *total gross productivity*. Thus, the total gross productivity of e.g. Finnish agriculture in a given year can be expressed by the ratio of the volume of all commodities — in commensurate units — produced in that year to all inputs — again in commensurate units — used in the same year. As a concept total gross productivity is sensible and theoretically correct one, despite the fact that only few economists (e.g. SUOMELA 1958 and LOOMIS & BARTON 1961) have used it.

In contrast to total productivity, various kinds of *partial productivity* concepts, where output is expressed in ratio to only one (or a few) input(s), are commonly used in economic literature. When calculating the gross output per labour input, capital input or acreage, we can speak about *partial gross productivity* of labour, capital or acreage, respectively (if more information is wanted, see SUOMELA 1958, p. 11).

Total gross productivity cannot — at least if only one concept is used — be considered the best possible productivity measure. This is particularly so if one wants to clarify the change in productivity that has taken place in a given industry as a result of internal influences. This holds especially true in industries (or firms) where production is largely based on utilization of purchased raw materials such as is more and more the case in agriculture. To estimate such internally caused change in productivity, gross output should be reduced by that share of it which is accountable to external inputs. When knowledge of that share is deficient, as is usually the case, an amount corresponding the volume of external inputs has to be subtracted from the gross output.

One step in this direction is the use of various *reduced gross outputs* as numerators in productivity calculations. For instance PRIEBE (1952, p. 168) has subtracted only the volume of purchased seed and concentrates from gross output. If one is using such reduced outputs, it would be, however, more rational or consistent to subtract all purchased inputs. This kind reduced gross output equals the concept gross domestic product (at constant prices) used in national income statistics. Sometimes this deflated quantity has been divided by labour input to calculate partial productivity of labour. This method — like other ones using gross or reduced gross outputs as numerators and only one input factor as denominator — is not, however, correct as will be pointed out in the following paragraphs.

Net output is the result of reducing gross output by both external inputs and depreciation. Net output is commonly used as a basis for productivity calculations. It has also been widely discussed whether or not depreciation should be deducted in the calculation of net output. (If not deducted, net output would equal the last mentioned reduced gross output above). There are strong arguments defending the method of deducting depreciation from net output and this standpoint has been adopted by several economists (NIITAMO 1954, p. 180—181, KENDRICK 1961 a, p. 24, etc.). Theoretically depreciation is also comparable to external inputs because it represents the constant use of capital goods that are purchased outside of the industry in question. In agriculture one could argue that the share of depreciation of buildings and land improvements which is due to farmers' own work in construction should not be deducted from net output. However, since that work is not considered as a part of the labour input in the production of agricultural commodities, it would be theoretically erroneous not to deduct the corresponding share of depreciation from net output in productivity calculations.

Based on net output various kinds of *net productivity* concepts can be derived. When productivity is expressed as a ratio of net output to corresponding inputs, a concept here designated as *total net productivity*, is in question. The corresponding inputs referred to above are the internal ones that were not deducted from gross output; i.e., labour input and capital input [1] (interest on capital measured at constant prices). Total net productivity can be written as follows:

$$P_{NT} = \frac{Q-G}{L+C},$$ where

P_{NT} = total net productivity
Q = gross output
G = external inputs
$Q-G$ = thus net output
L = labour input
C = capital input

As defined above total net productivity represents the output produced by internal inputs in ratio to these inputs (assuming the output of external inputs to equal the volume of those inputs). Actually one more internal input factor, namely the quality of human effort or ability has also contributed to production and should be theoretically taken into account in productivity calculations. Due to measurement problems this input is generally ignored in the denominator of the form above. A similar situation exists with regard to the quality of capital inputs as influenced through technological advance. Ignorance of these two factors explains the common phenomenon in developed countries that net output has risen through time much more than could have been expected merely on the basis of increases in labour and capital inputs measured in the traditional way. Input measurement problems are treated later in more detail.

The concept total net productivity has been used by only few economists (e.g. RUSTEMEYER 1964, p. 25). Instead, partial productivity measures based on net output are generally used, especially the one where net productivity is expressed as the ratio of net output to labour input. This concept is by far the most common one in economic literature (BÖKER 1952, p. 163, GEUTING 1954, p. 473, NIITAMO 1958, p. 56, etc.) and can be expressed as follows:

$$P_{L(P)} = \frac{Q-G}{L},$$ where $P_{L(P)}$ = partial net productivity of labour (other symbols are the same as above)

In this study the concept above is called *partial net productivity of labour*. Inspite of its common use the concept cannot, however, be considered the

[1]) Any separation is made neither between entrepreneurs' and hired labour nor between entrepreneurs'own or borrowed capital.

most correct one because it expresses net productivity in terms of only one internal input. Since capital input has also contributed to net output, the latter should also be deflated by the amount of this input's contribution in order to achieve a suitable indicator of the net output of labour. In turn, dividing this indicator by labour input results in a measure designated here as *net productivity of labour*. The mentioned concept is expressed as:

$$P_L = \frac{Q - G - C}{L}, \text{ where } \quad P_L = \text{net productivity of labour}$$

$$Q - G - C = \text{net output of labour}$$

Correspondingly, the concept of *net productivity of capital* can be defined. The form is as follows:

$$P_C = \frac{Q - G - L}{C}, \text{ where } \quad P_C = \text{net productivity of capital}$$

$$Q - G - L = \text{net output of capital}$$

These two concepts are not easily found in economic literature. However, RUSTEMEYER (1964, p. 32—35) speaks of corresponding net labour productivity and corresponding net capital productivity, which are consistent with the two concepts presented above.

One more concept of same relevance is developed here. It is the *net productivity of land*. It can be obtained by subtracting capital input excluding the share of land from net output of capital and dividing the residual by the input of land [1]) as follows:

$$P_m = \frac{Q - G - L - c}{m}, \text{ where } \quad P_m = \text{net productivity of land}$$

$$m = \text{land input}$$

$$c = \text{capital input other than land}$$

$$Q - G - L - c = \text{net output of land}$$

Similarly net productivity of other capital components could be defined correspondingly. There is, however, a factor limiting the use of such productivity measures. When determining, for instance, net productivity of land from a given data series, relatively wide fluctuations may appear, because all occasional variation in gross output is thus attributed to net output of land which often is actually only a small share of gross output. This disadvantage will also apply to measures of net productivity of labour and capital, and even total net productivity, although in lesser degree. Thus, in following a trend e.g. of net productivity of labour, the prerequisite that

---

[1]) Value of land at constant prices.

the productivity of other inputs would equal 1 is assumed to prevail and the essential development is reflected in labour productivity only. To avoid this drawback, however, there should be perfect knowledge available about which shares of gross output have been produced by each external input, labour input and capital input (and level of human knowledge). If the share produced by labour input is noted by Q_L, the real productivity of labour P_L could be expressed by $P_L = \frac{Q_L}{L}$. Due to lack of knowledge labour and other corresponding productivities must be expressed by the conventional methods presented above. The only concept where such conventionality does not exist is total gross productivity. SUOMELA (1958, p. 23) suggests that the use of the partial (and net [1])) productivity concepts should be limited to cases where one wants to study the productivity just from the standpoint of a single factor.

As said above productivity in a general sense is understood as the ratio of output to input(s). Some economists (KLAUDER 1953, p. 508 and 511 and NOU & NILSSON 1955, p. 177) have also presented inverse forms, in other words ratios of input to output. KLAUDER speaks about »output emphasizing productivity» [2]) corresponding to the general productivity concept, and about the inverse form as »input emphasizing productivity» [2]). NOU & NILSSON call the inverse form »productivity mirror» [2]) defending its use in calculations concerning partial productivity. It is, of course, possible, and in some cases even sensible, to apply the mentioned concept, though to avoid confusions it would be desirable not to use the term »productivity» in connection with it.

Theoretically productivity reflects the relationship between physical product and productive physical input(s). Because of problems of measurement (which are treated more explicitly later on) physical measures generally must be replaced by monetary ones. In some cases, like cross-sectional studies, the use of current prices gives suitably correct results. On the other hand, in serial studies only feasible measure is a fixed price unit which must be used for the whole period in question. At any rate, misuse of monetary units in some previous productivity calculations has led to confusion or erroneous interpretation of results. One example of such, easily misleading method is the division of the productivity concept into technical-, economic- and technical-economic productivity by NOU & NILSSON (1955, p. 180—183). In the first of these subdivisions both output and input are expressed in technical or physical units. Since this is possible only in such simple cases like yield per hectare, output per man hour, or production per cow etc., it seems questionable to speak about productivity in that context at all.

[1]) Author's note
[2]) Author's free translations

Technical-economic productivity means that the output is expressed in monetary and input in technical units. This points out that the concept can only be used to show partial productivity. In economic productivity both output and input are measured by monetary units. The above division is criticized by SUOMELA (1958, p. 20). He notes that the use of fixed-price units as weights instead of technical units does not mean any change in concept but is rather only a practical solution. That is why the division may raise some confusion around productivity concept. This holds especially true because it is obvious that even NOU & NILSSON (p. 182—183) equalize or at least link the mentioned concept to profitability. Also AUSTAD's (1957, p. 22) analysis is consistent with that of NOU & NILSSON.

For the sake of clarity it seems to be relevant here to accurately define and distinguish between the contents of the concepts *productivity* and *profitability*. As emphasized a few times in this study already, productivity expresses the ratio of output to input theoretically in physical measures. Any changes in current prices of both output and inputs ought not to be allowed to affect the productivity figures. According to the definition generally approved in business economics (KAITILA 1964, p. 149—150) profitability shows profits (gross return minus costs of production excluding interest charge on own capital) in ratio to own capital. In agricultural economics the profitability concept is usually understood as a more diversified one. It can be expressed for instance as the ratio of net return [1]) to all capital or as coefficient of profitability where return to labour and the value of labour input are also included. Regardless of the exact definition of profitability which is used, in any case changes in current prices *always* affect the profitability results. It is precisely this fact which makes explicit the difference between productivity and profitability. RUSTEMEYER (1964, p. 3—4) speaks of the »degree of economy» (wirtschaftlichkeit) as a third related concept. This one expresses the ratio of the value of output to the value of input. While RUSTEMEYER does not explicitly define this concept he is apparently referring to the ratio of gross return to operating costs [2]). Thus this concept is, like profitability, dependent on current prices of output and inputs. On the other hand, this concept resembles productivity because output is expressed in ratio to inputs, although at current prices. This fact may raise confusion, however, and also a question if there is actually any need of such an intermediate concept between productivity and profitability.

In connection with discussions on productivity a concept of *efficiency* has also been used at times. In agricultural economics there is still another concept — capacity — which is also related to productivity. According to the definitions used (e.g. TAYLOR 1949, HEADY 1952, p. 302 and WESTER-

[1]) Puhdas tuotto
[2]) Costs of production except interest charge on capital.

MARCK 1956, p. 327) capacity shows the ability of fixed factor of production to utilize other variable factors of production, while efficiency expresses how intensified the utilization of factors is in reality. Productivity is then obtained by multiplying capacity by efficiency. The two last mentioned concepts are thus the two dimensions of productivity.

The theory outlined above is deficient, however, because it is feasible only if productivity is understood as output per a given fixed input, in other words in a very simple form like production per cow. Capacity here expresses the ability of the cow to utilize feed — without marginal product becoming zero or negative — and can be measured by feed-units per cow. Efficiency in this case shows the amount of milk produced by a unit of feed.

When speaking of productivity in a larger and also more common sense — for instance productivity of an enterprise or an industry — the concepts above are not longer applicable. Thus, efficiency as defined above, applied to a whole industry, would express the same thing which is understood as productivity. Also SUOMELA (1958, p. 13) points out the close conceptual consistency of the above efficiency with the general productivity concept. Productivity itself in a way expresses some kind of efficiency (see KENDRICK 1961 a, p. 35).

Another interpretation for the concept efficiency is presented by NIITAMO (1958, p. 39). He defines this concept as follows:

$$E = \frac{Q}{Q_{Max}},$$ where E = efficiency
Q = actual output
Q_{Max} = maximum possible output with actual resources available

In the above form actual output is expressed in ratio to that output which could be attained if all resources were optimized. Theoretically this concept seems to be more applicable to macro or whole-firm discussion than the previously mentioned one. In addition, since actual output is compared with the feasible maximum one and not with input, the possibility for confusion does not exist in any significant scale.

Since efficiency, according to the author's ideas, should be expressed by inputs rather than outputs, the following formula to calculate efficiency is suggested:

$$E = \frac{B_{Min}}{B},$$ where E = efficiency
B = actually used inputs
B_{Min} = minimum amount of inputs that is able to produce actual output

The author's formula differs from NIITAMO's in the sense that instead of comparing actual output with the feasible maximum, the comparison is made between the minimum possible amount of inputs capable of producing the actual output, and the actual amount of inputs used. In both cases optimum conditions have been reached if efficiency equals 1. Because of practical problems in measurement of Q_{Max} or B_{Min} this efficiency concept will remain theoretical for the present.

Productivity here has been understood exclusively as a ratio of output to input. In some connections (see e.g. NIITAMO 1958, p. 14—15) another interpretation has been presented, too. This one is based on the functional relationship between output and inputs in a special case. If we have a Cobb-Douglas type production function

$Q' = a\,L^{\alpha}\,C^{\beta}$, where Q' is net output (Q—G) and a, α and β are parametres

expressing the dependency of net output on the two inputs above, the parametres α and β have been called productivities. These parametres can be also presented as follows:

$$\alpha = \frac{\frac{\triangle Q'}{Q'}}{\frac{\triangle L}{L}} \quad \text{and} \quad \beta = \frac{\frac{\triangle Q'}{Q'}}{\frac{\triangle C}{C}}$$

In the formulas above, α for example, which is the partial elasticity of Q' in ratio to L (see HEADY & DILLON 1966, p. 76), shows the relative change in net output in ratio to the relative change in labour input in conditions where capital input is constant.

There is reason, however, to take a cautious attitude in considering elasticity as productivity because of possible confusions between the above concept and the traditional one. Confusions may arise precisely around the theoretically relevant concept of *marginal productivity*. For instance marginal productivity of labour (MP_L), generally described as $MP_L = \frac{\triangle Q'}{\triangle L}$ can also be expressed when derived from the formula of above as $MP_L = \alpha \cdot \frac{Q'}{L}$ where both the labour productivity presented above and the traditional one are involved.

2.2. Problems in measuring productivity

As emphasized above productivity is a concept of technical character. Thus, measures of productivity would not be allowed to be affected by changes in current prices of output and input. Theoretically both output and input should be expressed in technical measures. This is possible, however, only in very simple cases, where output of one product or some mutually similar products is presented in ratio to one input factor only. In such cases it has also been attempted to measure output not only in kilos, liters, etc. but also for instance in crop-units, feed-units and calories (Nou & Nilsson 1955, p. 169—174). Anyway, difficulties appear when converting e.g. grain, milk, pork and wool into commensurate units. In the input side such a conversion is entirely impossible. So, when measuring the productivity and especially total productivity of a firm or an industry as a whole, the above kinds of units must be replaced by monetary ones. Because productivity figures would not be allowed to reflect any changes in price ratios, it is necessary to use prices of a given limited time (often one year) if productivity trends of longer period are studied. Application of constant prices is currently an established practice in productivity calculations.

There are various methods available to eliminate changes in prices. The most general one is the *Laspeyres index method* that was originally developed to eliminate the influence of changing quantities in price index calculations. According to this method a given base year is selected the prices of that year being used for the whole period studied. It may be noted that the base year can be any year within that period. The Laspeyres formula can be expressed as follows:

$$Q_{oi} = \frac{\Sigma p_o q_i}{\Sigma p_o q_o},$$ where
Q = index of gross output
p = price of a single product
q = quantity of a single product
o = symbol of base year
i = symbol of comparable year (1, 2, 3 . . . k)

The formula presented above for the output side is, of course, consistent for the input side, too.

It is common that changes may take place in price ratios of various products through time. The same phenomenon is also observable in the price ratios of inputs. Thus, it is possible to get quite a variable picture of the development of productivity according to how the base year is chosen. For example, during the long run a remarkably different result may be obtained if prices of the last year are used as the base instead of those of the first year. To reduce the influence of price relationships in one specific year *Paasche index* formula:

$$Q_{oi} = \frac{\Sigma p_i q_i}{\Sigma p_i q_o},$$ is available. This method uses the prices of each compar-

able year as weights for that particular year itself and for the base year with which the comparison thus is made in each case. The index of output (and input) shown by Paasche formula is higher or lower than that of the Laspeyres type depending on whether the price changes which have occurred have been higher or lower relative to the average changes in quantities compared to the base year. Paasche index always emphasizes the price ratios of the part of study period furthest from the base year whereas the Laspeyres index emphasizes those of just the base year. If the last year of the time series is chosen as the base and the calculations are made by Laspeyres method, the results obtained closely resemble those attained by Paasche formula using the first year as the base. Upon closer examination one may find that the index numbers obtained for the first and the last year are the same in both systems above but differences may appear in the intervening numbers. If the first year is taken as the base in both systems, the results obtained for the last years may differ markedly. A clear example of this fact based on actual Finnish circumstances is presented later on (p. 21).

Neither of the above indices will give entirely unbiased results except under quite specific conditions described by Ruttan (1964, p. 11) as follows:

1) The industry must operate conditions of equilibrium through the whole period in question.

2) The underlying production function must exhibit constant returns to scale.

3) There must be no change in the price of inputs relative to each other nor in the price of products relative to each other. Price of output may change relative to price of inputs, however.

4) Technological change must be neutral. This means that any shift in the production function must leave the marginal rates of substitution between inputs unaffected.

The requirements above are difficult or almost unrealistic to meet in practical circumstances. Consider, for example Finnish agriculture, where cronic disequilibrium has prevailed, with respect to point 1) in the list above. It should also be noted that arithmetically weighted indices such as those of the Laspeyres and Paasche types imply that the underlying production function is arithmetically linear. On this point Griliches (1957, p. 17) states, »In particular, if we believe that the underlying function is of the form of the Cobb-Douglas function, we should, in order to minimize bias, use geometric sums (i.e. products) rather than arithmetic sums in aggregating our inputs.»

Another line of reasoning in criticism of these indices has been followed by Ladd (1957) and can be summarized by turning to Figure 1. In that figure the influence of two variable inputs L and C upon the output Q is

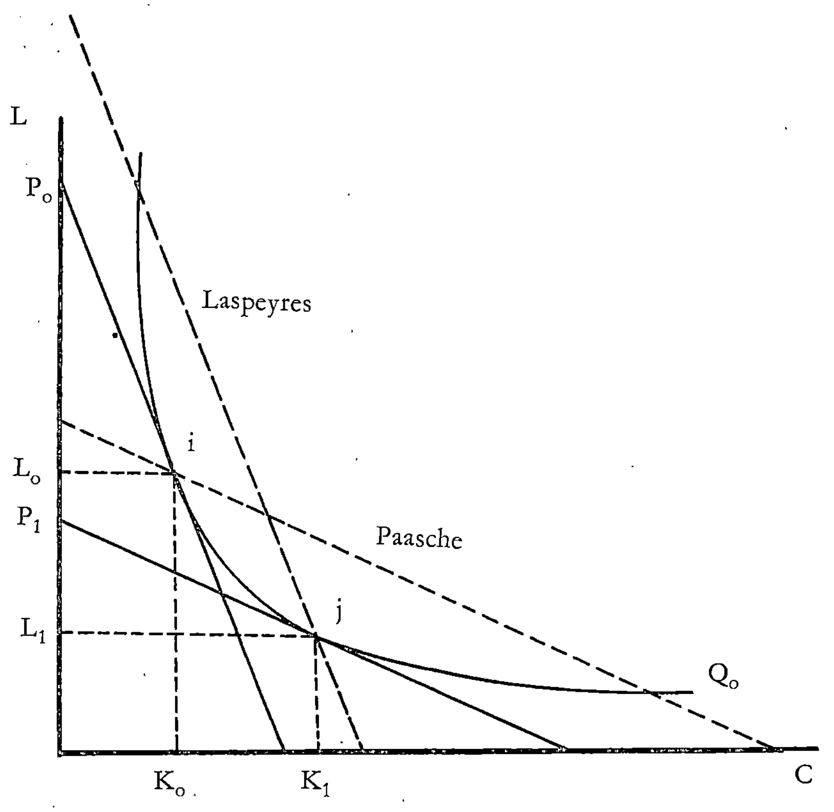

Figure 1. Illustration of bias indicated by Laspeyres and Paasche type input indices in given conditions

presented. The slope of P_0 illustrates the initial price ratio between inputs while Q_0 represents a production isoquant showing the alternative combinations of L and C which can be employed to produce the given level of output. At point i the cost of producing Q_0 is minimized using the amount L_0 of L and the amount C_0 of C. Let us then assume that a change in input price ratio has taken place resulting in P_1 the slope of which represents the price ratio at the end of the study period. If the optimum use of inputs is continuously pursued the combination of inputs will change until point j is reached. L_1 and C_1 show the amounts of inputs L and C used in this particular situation. If the real volume of inputs will be measured by Laspeyres index using initial prices as weights the result will be an upward biased estimate of the volume of inputs needed in the final period to produce the given output. The reason for this result is the obvious fact that any point on isoquant Q_0 different from i will represent a higher volume of inputs with base period prices that that at point i. Thus, the Laspeyres index shows a reduction of productivity when in fact none has occurred.

On the other hand Paasche index in emphasizing end period prices, will indicate an increase in productivity where actually none has occurred. Here for a given output, the volume of inputs needed in the base period when measured in end period prices is higher than the input volume in the end period. The description above can be presented regarding the use of output indices as well.

In order to avoid the weaknesses of the Paasche and Laspeyres indices as discussed above Irving Fisher developed a new index called *Fisher's ideal index*. This is the geometric mean of Laspeyres and Paasche type indices. It is clear, however, that the influence of changing prices upon productivity figures cannot be entirely eliminated by Fisher's method either. The same holds true regarding the *Edgeworth index* which also tries eliminate the worst drawbacks of Laspeyres and Paasche indices. In Edgeworth index the mean of base and comparable year prices have been used as weights. The index can be written as follows:

$$Q_{oi} = \frac{\Sigma q_i \, 1/2\,(p_o + p_i)}{\Sigma q_o \, 1/2\,(p_o + p_i)}$$

It may be mentioned here that the index above has been used by KENDRICK (1961 a, p. 55) in his monumental work.

The following setting of numbers shows how different results can be obtained by measuring the volume of the joint input of fertilizer, machinery and equipment and hired labour in Finnish agricultural industry [1]) by three various index methods.

Crop year	Laspeyres index	Paasche index	Fisher index	Edgeworth index
1951/52	100	100	100	100
1956/57	100	98	99	99
1961/62	110	108	109	108
1966/67	131	110	120	116
1969/70	148	112	129	121

The numbers above represent, of course, an extreme example with strong changes in mutual price ratios. If noting each price ratio in 1951/52 as 100, the ratios of 1969/70 were as follows: wages to machinery 172, wages to fertilizers 161 and fertilizers to machinery 107. The real volumes changed correspondingly (1951/52 = 100): fertilizers 365, machinery 303 and wages 19. Thus, mutually very opposite changes had taken place in the volume of the inputs above, too. If gross output and all inputs are taken into account, closer, but evidently still different results would be obtained by the three

[1]) Source: Total accounts of agriculture. Agric. Econ. Research Institute.

formulas in question. Some of SUOMELA's (1958, p. 22) figures are at least indicative of the kind of results which could be obtained in this manner. In the present study, however, it has not been practicable to work out all of the information which would be needed for this kind clarification.

In addition to the problems in determining the volume of production and inputs already mentioned, some other difficulties often arise when studying productivity trends in a given sector or in the economy as a whole. The development of productivity depends, namely, both on the internal factors within firms and industries, and on structural factors between industries. The former cause *internal or technical* increases in productivity, i.e., through technological advance individual production processes become more efficient. *Structural* increases in productivity, on the other hand, take place when factors of production shift from firms, branches or industries of relatively lower- to those of relatively higher productivity. Such structural increases have occurred, for instance, in the Finnish economy through the shift of labour out of agriculture and into other more productive sectors.

Certain problems appear, however, in attempting to study how the development of productivity in a given sector or the economy as a whole has been affected by internal and structural changes. These difficulties have been extensively discussed and clarified in the literature, (e.g. NIITAMO 1954, p. 183—187), hence only a few selected questions will be examined here.

A major problem in addressing the question of sectoral or total economy productivity is how to eliminate the influence of structural changes. Essentially there are two alternatives:

1) By defining a set of representative products of the economy or a composite sectoral output and determining the quantity and/or quality of inputs necessary for its production at various points of time; or

2) By selecting a given combination of inputs and comparing how much it would produce at various points of time.

After making that selection another problem must also be resolved in either case: that is to determine what period in the time series is to be used as the base period for the defined set of outputs or inputs. In other words the choice between Laspeyres and Paasche methods must be made. There are also a few additional possibilities as presented earlier. At any rate there is no absolutely correct way to solve that problem. It is also clear that different results may be obtained depending upon which alternative is chosen as demonstrated in the numerical example on page 21.

Sometimes (see e.g. NIITAMO 1954, p. 187) the difference in the natures of structural- as compared with internal productivity has been emphasized. It has been even stated that an increase in productivity caused by structural changes could not essentially be considered as an increase in productivity but only as a change caused by the shift of inputs to more productive branches. Anyway, a great share of the increase in national product per labour input in Finland, for example, has been affected just by the change in the structure of production. The influence of such change was recognized already in the late 1 600's by Sir William Petty. CLARK (1951, p. 395—439) calling this the *Petty-effect* has used this concept extensively in studying the influence of shifts from primary industries to secondary and tertiary ones upon productivity and national income.

One additional major problem in productivity calculations is that of how to measure labour and capital inputs. Labour input, for example, can be measured in terms of the number of people able to work, the number of man-years, or the number of working hours. NIITAMO (1958, p. 49) prefers actual working hours recorded over man-years as a measure because changes which occur in the length of normal days, work weeks and legislated vacations. In this last cited study, however, NIITAMO has employed a labour input index weighted by the sums of wages of various worker categories, thus taking into account the structural changes between those categories.

None of the above alternatives eliminates the real underlying problem, i.e., that the skill and knowledge of workers have increased remarkably in each worker category through time. This means, for example, that a work hour of an agricultural worker in 1970 differs conspicuously as an input from that of the worker of 1920. Thus, a work hour as a measure of labour input does not show the real contents of this input regarding its ability to produce a given output. The measurement of the improved skill and knowledge of workers is, of course, an extremely difficult task. In economic literature some attempts have been made to take these properties into account although not included in labour input but as an independent input. The measurement of this input will be treated in detail later on.

Problems also exist regarding the measurement of capital input. Besides the normal problems like the determination of depreciation and obsolescence there arises among other things, the question of whether to base the study on 1) the total volume of capital invested or on 2) the actual utilization of productive capital (NIITAMO 1958, p. 51). The second alternative would mean measuring the flow of actually used capital services and would thus also include consideration of degree of capital capacity utilization. NIITAMO adopted this solution, but has defined the relevant input in terms of the utilized capacity of machinery (in horse powers) and the consumption of electricity. KENDRICK (1961 b, p. 106—110) presents two indirect approaches to real capital measurement: 1) Capital as embodied labour and 2) capital as capacity. The former alternative prefers, rather than to measure capital directly in conventional terms, to express it in terms of labour time required to produce it. The latter alternative equals NIITAMO's selection to measure capital input.

Technological advance affects the quality of capital inputs in the same way as the improved skill and knowledge affect labour input. Thus, compared with an average unit of capital invested in agriculture in 1920, a unit invested in 1970 has — even when properly deflated — a superior productive capacity. There is, however, apparently no generally feasible way, to measure the volume of capital which takes into account the accumulation of technological advance.

Based on the arguments above it can be stated that theoretically net output should always equal the sum of labour and capital inputs in most industries. The advance in the quality of labour and capital should be reflected in the volumes of those inputs. As a matter of fact the improved skill and technology are distributed over the entire range of inputs, including the external ones, because the quality of these inputs or their services are affected by the technological change in industries which produce them or the sectors from which they are derived. Thus, the gross output should equal the sum of all inputs. In agriculture, however, the changes in output cannot be entirely explained by inputs, even following the theory above, because of the unpredictable influence of weather. If, however, weather is considered as a non-controllable external input, then the statement that the gross output should equal the sum of all inputs should also hold for the case of agriculture.

The solutions to the various problems of measurement which have been employed in the present study are presented in connection with the description of the corresponding empirical data in the following chapter.

3. THE DEVELOPMENT OF PRODUCTIVITY IN 1950—1969

The development of productivity in Finnish agriculture will be presented by various productivity measures in the following chapter. Total gross productivity, total net productivity and net productivity of labour defined in chapter 2.1. will be the main concepts used. In addition a few other concepts will be applied in some specific connections. The empirical study is based on various aggregate data on production, inputs and contribution of agriculture to national income. The study will cover the period from 1950 to 1969. To clarify the influence of structural change upon productivity also the data of bookkeeping farm accounts will be used. For that part, the study will be restricted to comprehend the period of 1960's only. The formation of output and inputs in agriculture will be discussed in chapter 3.1. and 3.2. and the productivity figures will be presented and criticized in chapter 3.3.

3.1. Gross and net output of agriculture

Before detailed empirical study a general view over agriculture's position and significance in Finland might be necessary. Table 1 is presented to give a picture of agriculture's contribution to the total economy. According to it the gross domestic product (at factor cost) increased by more than 7 times during the period under consideration while that of agricultural sector grew around 3.5 times. Even though both of these rates of growth far surpass those of most other periods in the country's history, it is clear that the agricultural sector has not contributed as much to the national economic growth as some other sectors. Agriculture's share of gross domestic product has declined from 16 percent in 1950 (being 20 percent in 1948) to 8 percent in 1969 and the relative decline appears to have been even greater in the more recent years. This trend is similar to that found in most other developed countries during the same period.

During this period of general expansion agricultural prices as well as those in the rest of the economy increased quite rapidly. Inflation was somewhat greater than in many other European countries but did not get out of hand. A devaluation of Finnish currency was necessary, however.

4 7077—72

Table 1. Some facts about agriculture's position in the Finnish economy in 1950—1969

Year	Gross-domestic product (at current prices)		Gross domestic product of agriculture (at current prices)			Index of prices received by farmers (1950=100)	General cost of living index (1950=100)
	Mil. marks	Index	Mil. marks	Index	Percent of total		
1950	4 772.3	100.0	752.3	100.0	15.8	100	100
1951	6 975.0	146.2	861.6	114.5	12.4	121	116
1952	7 159.8	150.0	898.7	119.5	12.6	126	121
1953	7 101.2	148.8	932.0	123.9	13.1	123	124
1954	7 950.5	166.6	943.5	125.4	11.9	122	124
1955	8 992.2	188.4	1 021.3	135.8	11.4	135	120
1956	9 911.3	207.7	1 115.7	148.3	11.3	154	133
1957	10 552.1	221.1	1 195.0	158.8	11.3	156	148
1958	11 376.5	238.4	1 355.3	180.2	11.9	163	158
1959	12 503.5	262.0	1 450.7	192.8	11.6	168	161
1960	14 082.2	295.1	1 506.8	200.3	10.7	179	165
1961	15 708.1	329.2	1 632.3	217.0	10.4	179	169
1962	16 770.0	351.4	1 655.0	220.0	9.9	182	177
1963	18 532.4	388.3	1 788.4	237.7	9.7	190	185
1964	21 140.3	443.0	1 999.8	265.8	9.5	205	204
1965	23 145.7	485.0	2 040.6	271.2	8.8	227	214
1966	24 746.1	518.5	2 165.8	287.9	8.8	231	222
1967	26 680.2	559.1	2 300.3	305.8	8.6	244	233
1968	30 063.8	630.0	2 665.7	354.3	8.8	276	253
1969	34 312.3	719.0	2 773.2	368.6	8.1	281	258

Sources: Marjomaa 1968. National income statistics for agriculture 1948—1965. Repr. Tilastokats. 9: 1—66. National accounting 1964—1970/I—II. 1970 Central Stat. Office, Report 5. Pellervo Society: Price indices.

in late 1967. Agricultural prices increased somewhat more rapidly than consumer prices but the two series moved together rather consistently. The consumer prices have been partially regulated since devaluation.

Even though the development of producer prices was generally favourable, per capita incomes in agriculture increased at a somewhat slower pace than in other sectors of the economy. Also the average income level of farmers has consistently been below that of most other groups. These facts, combined with increased substitution of capital for labour in agriculture, have encouraged migration out of this sector into other industries. Unfortunately, the pace of development in other sectors was not rapid enough to absorbe all of the excess agricultural labour in addition to some labour which was displaced through rationalization and adaptation of new technology in other industries. As a result, there may continue to be some underemployment of labour in Finnish agriculture despite the general increase in productivity over the past 20 years which will be described later on.

In turning to examine the development of productivity in detail, the formation and trend of gross and net output must first be discussed. The determination of those two measures is based on the national income account of Central Statistical Office (CSO) on the one hand, and on the so-called »total accounts of agriculture» prepared by the Agricultural Economics Research Institute (AERI) on the other. In the former statistics »agricultural sector» in addition to agriculture in the strictest sense, includes truck farming, nurseries and reindeer, bee and fur animal husbandry (MARJOMAA 1968, p. 44). In the AERI total accounts of agriculture statistics, only basic agriculture, without the ancillary production branches noted above, is included. No attempts are made in this study to reduce the influence of the above mentioned branches upon gross and net output because of the difficulties and risks of error connected with such a procedure.

According to an estimate made by the government agricultural committee (Komiteanmietintö 1969: B 26, p. 46) in one attempt to refine the figure for the contribution of agriculture to net national product of current prices to the »strictly agricultural» component, the gross CSO-figure of 1 826.3 million marks for the year 1966 was reduced to 1 765.1 million marks. Even so, in making this estimate the committee was not able to remove all of the »not strictly agricultural» components. According to the total accounts of agriculture of the AERI, on the other hand, the net national product of essential agriculture in the crop year 1965/66 was 1 750.3 million marks and in 1966/67 1 728.3 millions which approximate the reduced figure above. Although no reductions of CSO-figures are made in this study, it is evident that no significant bias will exist in productivity estimates because this study is primarily concerned with the development, not the absolute levels, of output and inputs. On the other hand, it is not plausible that the ratio of output to input would have changed much differently in the related branches other than essential agriculture than it would have in the more narrowly defined agricultural industry itself. The results of this study will also support this position as will be seen later on.

In the determination of gross and net output the Laspeyres quantity index is used here. To avoid the deficiencies of this index presented in chapter 2.2. the base year has been chosen close to the middle part of study period. The intent of this procedure is not to give too much emphasis to the price ratios of the extreme parts of the period. Specifically, there exist, especially in the input side, clear trends in price ratios. Thus, in many cases, the middle part represents the whole period better than either of the extremes. In other words, the system chosen here will give results lying somewhere halfway between result obtained by the usual Laspeyres and Paasche's methods.

For the AERI data the output and input quantities are weighted by the prices of crop year 1961/62. There has been no practical possibility to select a corresponding year as a base for the CSO data, however. Therefore, since the year 1964 has been used as the base in constant price calculations

Table 2. Gross and net output of agriculture in 1950—1969
(at constant prices) [1])

Year [2])	Gross output CSO [3])		Gross output AERI [3])		Net output CSO		Net output AERI	
	Mil. marks	Index	Mil. marks	Index	Mil. marks	Index	Mil. marks	Index
1950	1 811.4	100	1 450.0[4])	100	1 349.4	100	1 140.0[4])	100
1951	1 840.7	102	1 507.4	104	1 330.3	99	1 159.3	102
1952	2 018.4	111	1 540.2	106	1 440.7	107	1 196.2	105
1953	1 984.1	110	1 606.9	111	1 410.3	105	1 233.2	108
1954	2 030.4	112	1 544.2	107	1 409.2	104	1 125.5	99
1955	1 958.4	108	1 580.6	109	1 237.0	92	1 095.4	96
1956	2 059.7	114	1 675.2	116	1 233.6	91	1 169.9	103
1957	2 149.2	119	1 649.1	114	1 340.6	99	1 188.8	104
1958	2 204.3	122	1 745.7	120	1 432.1	106	1 265.7	111
1959	2 334.6	129	1 853.1	128	1 552.2	115	1 300.2	114
1960	2 490.4	138	1 931.6	133	1 579.1	117	1 362.5	120
1961	2 558.8	141	2 018.1	139	1 635.4	121	1 427.0	125
1962	2 574.1	142	1 966.8	136	1 587.1	118	1 263.4	111
1963	2 711.5	150	2 118.2	146	1 555.6	115	1 430.0	125
1964	2 828.8	156	2 135.4	147	1 711.0	127	1 422.9	125
1965	2 788.5	154	2 096.8	145	1 579.7	117	1 377.7	121
1966	2 837.4	157	2 067.7	143	1 608.0	119	1 324.9	116
1967	2 872.9	159	2 114.2	146	1 587.3	118	1 335.2	117
1968	2 971.3	164	2 138.6	148	1 608.2	119	1 331.8	117
1969	3 049.8	168	2 216.6	153	1 587.0	118	1 368.0	120

[1]) At 1964 prices in CSO-series and crop-year 1961/62 prices in AERI-series.

[2]) In AERI-series crop years 1950/51—1969/70 (Crop year = the period from Sept. 1 to Aug. 31).

[3]) CSO is abbreviation of Central Statistical Office and AERI of the Agricultural Economics Research Institute. These abbreviations will be used constantly in this study.

[4]) Figures on crop year 1950/51 are based partly on estimation only and they are not so accurate as those of other years.

of national income accounts, that year has also been adopted for this study. The difference of a little more than two years between the respective base periods has no significant influence upon the mutual comparability of the results obtained from the two data sources used here.

Table 2 shows the development of gross and net output derived from the two respective data sources. The changes of some important individual items of gross output are also presented in Figure 2. The series of CSO on gross output show somewhat faster rise in the 1960's than those of AERI. This might be affected by the expansion of the branches other than essential agriculture. In comparison the net output series are quite parallel, particularly if the changes between single years, which are influenced by the difference between calendar and crop year reporting periods, are ignored (see footnote [2]) in Table 2). Linear trends are estimated here for both groups of series. In the equations Y = respective output in million marks, and X = time series 1, 2, 3, ... (1950 = 1).

Gross output (CSO): $Y = 1\,755.6 + 68.2\,X;\ r^2 = 0.97$
(2.66)

Gross output (AERI): $Y = 1\,443.9 + 42.5\,X;\ r^2 = 0.94$
(7.95)

Net output (CSO): $Y = 1\,315.3 + 18.3\,X;\ r^2 = 0.61$
(3.30)

Net output (AERI): $Y = 1\,140.2 + 14.3\,X;\ r^2 = 0.62$
(2.50)

As can be seen the trend equations explain the changes in gross output quite well, while, only around 60 percent of the changes in net output can be explained by the linear trends. This is due to fairly large irregular and chance variation in the observed values of net output, and also to the fact that the observed values levelled off in the late 1960's and thus did not conform to the linear trend assumption. The average growth of gross output calculated from the observed values was 2.8 percent per year in CSO-series and 2.3 percent in AERI-series. Calculated from the trend lines the growth were exactly same. On the basis of observed values net output rose 1.0 percent per year according to both sets of data. The determination of percentage growth from trend lines is not quite valid in this case because of the bias appearing in the late 1960's.

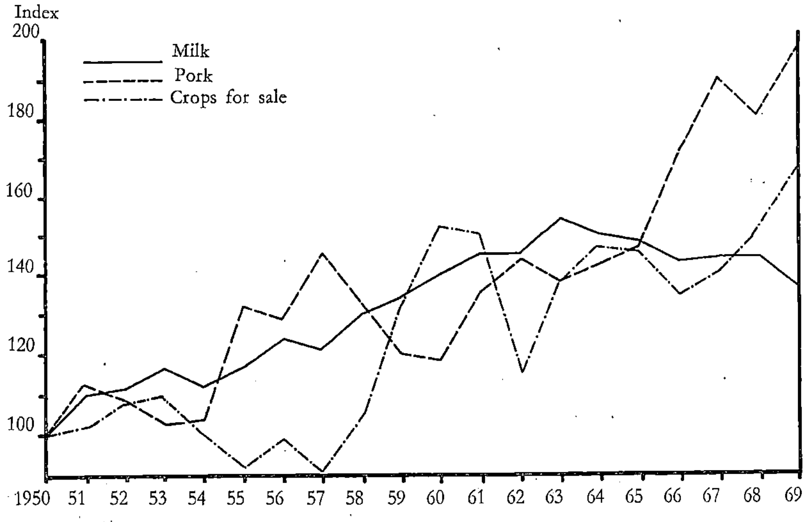

Figure 2. The development of output of selected products in 1950—1969 (AERI-aggregates, at 61/62 prices)

Some comments on the mutual difference of the absolute level of numbers between each CSO- and AERI-series could, obviously, also be valuable. Between the two series on net output a rather constant difference of somewhat less than one fifth prevails through time. Comparing the AERI net output figure of 1 602.6 million marks at current prices for crop year 1963/64 (being nearest the calendar year 1964) with the respective 1964 CSO-figure of 1 711.0 millions it can be seen that besides the above difference there is still a difference of around 180 million marks between the two series which is primarily due to the difference in base year. Had 1964 also been used as the base year in the AERI-series, the mutual difference between the series throughout the study period would only have amounted to around 5 percent. In the case of gross output the AERI-figure in crop year 1963/64 is 2 365.8 million marks at current prices compared with 2 135.4 millions at 1961/62 prices and with 2 828.8 millions in CSO-statistics in 1964 at current prices. Thus, even with a comparable base period, there would have been a clear absolute difference between the two series due mainly to the difference in the definition of the agricultural sector which they embraced. Also the difference in their respective trend slopes would remain independent on the choice of base year.

The third source of data employed in this study is the bookkeeping farm accounts of the Agricultural Economics Research Institute, which embrace the diverse economic activities of some 1 000 to 1 200 participating farm units. In this study data has been utilized from three various groupings of the bookkeeping farms. The first embraced all bookkeeping farms with the respective figures calculated as weighted averages by weighting the corresponding data for each farm group (farm size classes in various regions) in ratio to the distribution of all farms in the country. This weighting procedure, which is commonly used to improve the comparability of results in the mentioned accounts, has been carried out because the distribution of bookkeeping farms in various farm size classes and regions differs from that of all farms of the country. The two other groups of farms from which data has been utilized represent size classes I—II (under 10 hectares of arable land per farm) and VI (more than 50 hectares of arable land per farm) in the research region of South-Finland. Through this selection an attempt will be made to point out possible differences in productivity trends in these extreme size classes in the most important agricultural region in the country. Although it had also been desirable to study the development of productivity in other groups of farms, this was not practical since, except for the two classes considered here, the farms were reclassified in 1966. Thus, it would have required a great deal of effort to adjust the relevant data either for the years prior to or since 1966.

Table 3. The development of gross and net output as indices in all bookkeeping farms (weighted average) and in South Finland in farm size classes I—II (under 10 hectares of arable land) and VI (over 50 hectares) in the fiscal years 1959/60—1969

Fiscal year [1]	Gross output (1959/60 = 100)			Net output (1959/60 = 100)		
	All farms	Size class I—II	Size class VI	All farms	Size class I—II	Size class VI
1959/60	100	100	100	100	100	100
1960/61	110	113	111	116	119	116
1961/62	110	109	108	108	108	109
1962/63	111	108	98	103	104	85
1963/64	120	116	114	114	109	108
1965	117	126	115	99	110	107
1966	124	131	110	100	113	97
1967	130	128	136	108	109	137
1968	125	121	140	85	91	119
1969	131	114	151	86	76	132

[1]) Fiscal year covered the period from July 1 to June 30 until 1965 when it was changed to equal calendar year.

In the determination of gross and net output the current price figures of gross return and the costs in question have been divided into subgroups (milk, pork, wheat, fertilizers etc.) each group being deflated into 1961/62 level by the official price indices of corresponding products and inputs. Thus, it has not been possible to use the actual quantities as a base as in the two aggregate statistics series discussed above.

The development of gross and net output in the indicated groups of bookkeeping farms are presented in Table 3. The volume of production as an average of all bookkeeping farms indicates a somewhat higher increase than the gross output estimated from the two aggregate statistics. This can be seen from the following detailed comparison (gross output of 1960 = 100):

Year	CSO aggregates	AERI aggregates	All bookkeeping farms
1960	100	100	100
1961	103	104	110
1962	103	102	110
1963	109	110	111
1964	114	111	120
1965	112	109	117
1966	114	107	124
1967	115	109	130
1968	119	111	125
1969	122	115	131

Some of the more rapid rise in bookkeeping farms can be explained by half a year longer coverage of time (because of a shift from crop year, July 1—June 30 to calender year reporting periods in the beginning of 1965) than the other data, and by the fact that there was a clear general rise in gross output from 1959 to 1960 which was partially included in bookkeeping results. These factors, however, cannot explain the whole difference between bookkeeping estimates and AERI-series which both consider only essential agriculture. One additional reason affecting the difference is the fact that mean yields seem to have risen a little faster on bookkeeping farms than in the country's agriculture as a whole.

Table 3 shows that internal variations in growth also exist between various groups of bookkeeping farms. The data from size class I—II in South-Finland reflects quite a reasonable growth until 1966 but a surprising fall thereafter. Probably a major reason for this is the considerable drop in number of farms in this size class, especially in the late 1960's. Thus, the composition of the farm groups clearly changed. The composition of size class VI group also changed, but opposite to that of the size class I—II. The number of farms increased markedly from 1966 to 1967 including several specialized wheat and hog enterprises, which helps to explain the clear upward shift just at that time. Thus, neither of the size classes selected for this study seems to be very representative during the last years of study.

Allowing for variations between single years each of the data series indicates a slightly rising trend in net output up to 1968 when each of them dropped by 20 percentage points. Examining the possible reasons for such a marked fall it should be noted that 1968 marked the change-over to a new system of taxation of agricultural income. The new system was based on actual receipt and expenditure data for each farm in comparison to the earlier system in which taxes had been based on income estimates which were derived from factors such as farm size, location and so on. At the same time the accounting system for bookkeeping farms was adjusted to be more compatible with the new system. Among other things the depreciation rates employed in the bookkeeping accounts were raised sharply.

Adoption of higher depreciation rates in the accounting system likewise a few other changes made had an effect of making the net output appear less than it was in real terms. That is why, an attempt was made to take such factors into consideration in the construction of the series for the last years of the time series. Thus, while the adjusted indices of net output of all bookkeeping farms for 1968 and 1969 were 85 and 86, respectively, the unadjusted figures for these years would have been as low as 75 and 73.

3.2. Inputs used for production

The determination of inputs is based in this study on the same method, of course, as regards the gross output. In other words, when calculating the volume the prices of the base periods mentioned earlier are used as weights.

The development in the use of external inputs, in other words the real volume of purchased goods including depreciation, obsolescence and maintenance of capital goods is presented in Table 4. The absolute difference in level between CSO- and AERI-series is partly due to different base year and partly to the differences in comprehension of the agricultural sector as was mentioned in chapter 3.1. above. The two series have developed rather consistently until mid 1960's after which the rise in CSO-figures has been more rapid than in those of the AERI-series, the former more than tripling during the period of study. A reason for the widening difference may be that the other than essentially agricultural branches included in CSO-series had expanded faster than traditional agriculture and thus have had a more rapidly growing need for purchased inputs. Another explanation might be found from the differences in accounting systems of the two series regarding interfarm purchases of products. In CSO-series these transactions are considered both in output- and input-accounts, but in the AERI-series they are ignored. When agriculture is becoming more commercialized and specialized, these interfarm purchases increasingly widen the gap between the two series. This fact is also a source of absolute difference between series. If average growth rates are estimated for both series from linear

Table 4. The use of external inputs in the agricultural sector in 1950—1969. CSO- and AERI-series [1])

Year [1])	CSO-series [2])		AERI-series [3])	
	Million marks	Index (1950 = 100)	Million marks	Index (1950 = 100)
1950	462.0	100	310.0	100
1951	510.4	110	348.1	112
1952	577.7	125	344.0	111
1953	573.8	124	373.7	121
1954	621.2	134	418.7	135
1955	721.4	156	485.2	157
1956	826.1	179	505.3	163
1957	808.6	175	460.3	148
1958	772.2	167	480.0	155
1959	782.4	169	552.9	178
1960	911.3	197	569.1	184
1961	923.4	200	591.1	191
1962	987.0	214	703.4	227
1963	1 155.9	250	688.2	222
1964	1 117.8	242	712.5	230
1965	1 208.8	262	719.1	232
1966	1 229.4	266	742.8	240
1967	1 258.6	272	779.0	251
1968	1 363.1	295	806.8	260
1969	1 462.8	317	848.6	274

[1]) See footnotes of Table 2.
[2]) At year 1964 prices.
[3]) At crop year 1961/62 prices.

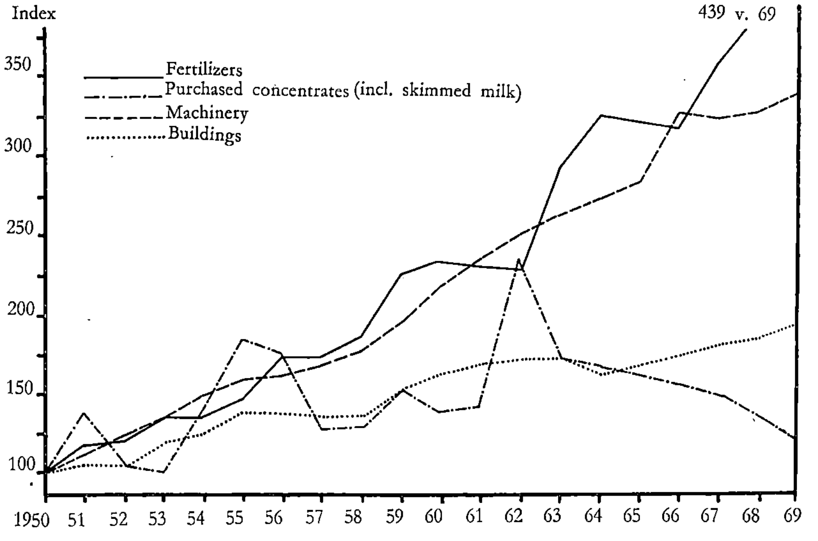

Figure 3. The development of selected inputs in 1950—1969 (AERI-aggregates, at 61/62 prices)

trends [1]) a figure of 5.4 percent a year is obtained for CSO-series and 4.9 percent for the AERI-series. Thus, the difference is not yet particularly significant. The development of some important items of external inputs are presented in Figure 3.

Changes in use of external inputs in the selected groups of bookkeeping farms are presented below (fiscal year 1959/60 = 100):

Fiscal year	All farms	Size class I—II	Size class VI
1959/60	100	100	100
1960/61	102	103	105
1961/62	114	111	107
1962/63	123	114	115
1963/64	129	126	123
1965	144	152	125
1966	159	158	128
1967	163	157	136
1968	184	169	168
1969	197	172	176

For the average of all bookkeeping farms the amount of external inputs nearly doubled in around ten years. This change is clearly more rapid than

[1]) The trends are as follows:
For CSO-series $Y = 441.8 + 49.7X$; $r^2 = 0.97$
For AERI-series $Y = 303.7 + 28.2X$; $r^2 = 0.98$

indicated by the two aggregate series in Table 4 where the trend of CSO-figures shows an increase of about 60 percent from 1960 to 1969 and that of AERI-figures approximately 50 percent. In size class I—II the development is rather consistent with that of all bookkeeping farms until 1968. In the large farms the growth was comparatively slow until the jump upwards between 1967 and 1968 which was the most conspicuous change that occurred in the bookkeeping farm groups of this study. The reasons for the general change in these farms between mentioned years were treated of in the preceding section.

The data regarding labour input in Finnish agriculture have been continuously deficient. One annual series on aggregate labour input published by the Ministry of Labour has been available since 1958, and another has been published by the Board of Agriculture since 1961. In addition some information is given by the censuses of agriculture of 1950 and 1959. Evidently the most accurate data on labour input within farms is produced by the bookkeeping farm accounts. Compared with all farms of the country, however, the bookkeeping accounts are likely to give somewhat biased results because of difference in distribution of farms into size classes and regions. In addition, bookkeeping accounts cannot, of course, give any direct information about the changes in the total labour input caused by structural factors. As a source for studying internal changes this statistics is valuable, however.

Changes in agriculture labour input indicated by the above mentioned statistical series are presented in Table 5. Adjusting the data of the census of agriculture in 1959 and that of a large sample taken in 1960 the series of Board of Agriculture has been extended backwards to cover the mentioned years, too. Both the »normal» arithmetic average and the weighted one

Table 5. The development of labour input in agriculture in 1959—1969 according to some statistics and estimates of agricultular population

Year	Statistics of Board of Agric. Mil. workdays	Labour force statistics 1 000's man-years	Bookkeeping farms, hours per hectare: Arith. average	Bookkeeping farms, hours per hectare: Weighted average	Agricultural population 1 000's
1959	133.7	444	320	389	1 143.2
	=100.0	=100.0	=100.0	=100.0	=100.0
1960	102.7	95.5	99.7	101.0	97.8
1961	104.0	101.1	96.3	98.5	95.9
1962	109.4	93.7	95.9	99.2	94.0
1963	105.2	98.2	88.1	93.8	92.1
1964	102.9	91.0	87.2	89.7	90.2
1965	91.8	88.7	81.6	90.7	88.4
1966	91.3	89.0	74.4	86.9	86.7
1967	84.6	81.5	72.8	84.1	84.9
1968	83.9	77.3	73.1	85.6	83.3
1969	80.8	74.8	67.8	81.0	81.6

(see p. 30) are calculated from bookkeeping farm data. The series on agricultural population is an estimate made by the Agricultural Economics Research Institute based on population censuses of 1950 and 1960.

When comparing the two aggregate series on labour force opposite change between single years can be noticed especially in the early part of period. There is not much difference in the slopes of the trends, however, as is apparent in the following presentation which also includes corresponding figures from the other series of Table 5.

Data	Percent change per year in 1959—1969 from trend line
Board of Agriculture	—2.6
Labour force statistics	—2.8
Bookkeeping farms, simple average	—4.1
Bookkeeping farms, weighted average	—2.3
Agricultural population	—2.0

Linear trend does not fit into the series of Board of Agriculture too well, however. Anyway, there are no significant differences in the development of these two series if annual fluctuations are ignored. It is somewhat surprising that the decline indicated by the simple average of bookkeeping farms is faster than in either of the aggregate series which should also express the effect of structural change. The average size of bookkeeping farms has increased, however, from 17.15 hectares of arable land in 1959/60 to 20.45 hectares in 1969 which change has, of course, influenced the use of labour input. This increase in average size is primarily caused by changes in composition of the group of farms which cooperate in the bookkeeping account system (the new farms coming into the accounting system are larger than the average of all previously cooperating farms), and only to a small extent through enlargement of individual farms. Thus, this data does not express internal changes in labour input exclusively, but also reflects structural influences. This holds true in the case of the weighted average figures, too, but to a lesser degree because the same weights have been used throughout the 1960's. This means that the effects of changes in the distribution of farms into various size classes have been eliminated from the figures. Changes in composition within size classes cannot considered by the weighted average, however.

The fifth column in Table 5 illustrates the trend of agricultural population. This series, presented here for control only, has been derived by extrapolation of the trend between population censuses of 1950 and 1960 and certain additional information. This series show a drop of 2 percent annually or slightly less than either of the aggregate series on labour force. Unfortunately, data from the census of 1970 has not yet been released and is not available for this study. Preliminary data on selected areas indicate a more rapid decline, however, than presented by the estimated series in Table 5.

Information of agricultural population is also given by the 1959 and 1969 censuses of agriculture [1]). Unfortunately, these two sources of information are not comparable and do not therefore, provide any significant contribution in resolving the basic problem of lack of knowledge in this area. According to these two censuses the number of farmers on farms of more than 1 hectare of arable land decreased from around 325 thousands in 1959 to approximately 252 thousands in 1969 or by some 22.5 percent. Thus, the decline would have been greater than that which was indicated for labour input according to the two aggregate series of Table 5. This appears illogical, of course, because the reduction in labour input first affects hired labour and the labour of family members and only then farmers themselves. In 1969 the farmer was taken into account in the statistics, however, only if he (or she) had worked more than 150 days in agriculture, while in the 1959 census there was no such a restriction at all. In the former year there were more than 90 thousand farmers on farms of less than 5 hectares of arable land. A large share of these farmers probably would not have met the indicated requirement of the 1969 census. So, there is not much basis for estimating which share of the 73 000 decline in number of farmers between 1959 and 1969 indicated by the respective censuses represents a real decline. The information about the development of the agricultural population other than farmers is still more deficient and not worth while mentioning in this connection.

There are some other problems in the aggregate statistics (columns 1 and 2 Table 5) on labour input, too. Much of them are treated in detail by a special commission that studied the comparative development of farmers' incomes. Therefore only the report [2]) of that commission is referred to here.

Because of deficiencies described above and the lack of direct statistics in the 1950's an attempt is made in this study to construct a series on labour input for agriculture. This attempt is based on the series which are available, on certain other special information, and on logical assumptions. Since the bookkeeping accounts are the only data based on continuous records on daily working hours and are also the only source of information covering the 1950's, these statistics have been taken as a basis for constructing a new, hopefully more reliable series. The weighted average series of agricultural labour input on bookkeeping farms has been selected here because it illustrates best the internal development of labour input in farms. Weighted averages have been calculated in bookkeeping accounts since fiscal year 1959/60.

---

[1]) SVT III: 53, 1962, Vol. 1, p. 168—169 and SVT III: 67, 1970, Vol. 2, p. 96—105.

[2]) Maa- ja metsätalousministeriön asettaman työryhmän selvitys maatalouden tulotason kehityksestä 1968—1971, p. 36—42.

In this study calculations have been made on the same basis for fiscal years 1950/51—1958/59. The weights used for the whole study period (1950/51—1969) are based on the size class distribution in 1959 given by the census of agriculture. To take structural changes in labour input into account also, the series above is adjusted by a constructed index of the number of farms in the country. For the years from 1950 to 1959, when the number of farms increased slightly, no adjustment was made, however. The constructed new series is presented in Table 6.

Since the CSO and AERI aggregate series on gross output and external inputs used in this study have different coverage regarding agricultural sector, it would also be necessary for consistency to consider this difference in the labour input series, when calculating productivity of labour. Thus, an attempt is made here to construct two separate series for the purpose above.

As a first step in this procedure the here constructed series (column 2, Table 6) is converted to million work-days to correspond the series of Board of Agriculture. It has been assumed at first, that calculated as work-days the constructed series would equal the observed value in the statistics of the Board of Agriculture in 1964 (the base year of CSO) or 137.6 million work-days. Multiplying the 331 hours per hectare in the constructed series in 1964 by the corresponding total area of arable land in the country to get the absolute labour input in hours, and then, assuming the average length of a work-day to equal 8 hours, approximately 110 million work-days, are resulted. Since there are practically no farms of less than 5 hectares of arable land in the bookkeeping accounts, it is clear that the real number of work hours per hectare as an average of all farms in the country would markedly exceed that of shown by the weighted average in Table 6. Thus the assumption made above in considered to be valid.

The constructed series converted to million work-days (column 3, Table 6) is considered to comprehend the labour input of agricultural sector as covered by AERI-statistics. To construct corresponding series for CSO-statistics or for agriculture in a larger sense, some additional procedures are made as follows.

At first the labour input contribution of hired labour is calculated from AERI-statistics dividing the value of wages at constant prices by the wage per work-day of the base year [1]).

The result is indicated in the fifth column of Table 6. The labour input contribution of farm family members is derived by subtraction (column 7). The hired labour input for CSO-series is calculated in the same manner as for AERI-series and the results are represented in the sixth column of

[1]) The average hourly wage (weighted by the number of men and women) in 1961/62 multiplied by the assumed length of a work-day = 8 hours, gives a result of 10,— marks a day.

Table 6. Formation of the constructed series on labour input in agricultural sector in 1950—1969

Year	Total labour input				Hired labour input million work-days		Labour input of farm family mil. work-days	Total labour input for CSO	
	Bookkeeping farms Weighted ave. hours per hectare	Adjusted by farm number index hours/ hectare	Adjusted for mil. work-days	AERI Index (1950 = 100)	AERI-stat.	CSO-stat.		mil. work-days	Index (1950 = 100)
1950	473	473	196.6	100	23.4	24.1	173.2	197.3	100
1951	438	438	182.0	93	22.6	23.3	159.4	182.7	93
1952	435	435	180.8	92	20.5	21.9	160.3	182.2	92
1953	423	423	175.9	89	18.5	20.5	157.4	177.9	90
1954	410	410	170.5	87	17.6	19.3	152.9	172.2	87
1955	405	405	168.4	86	16.6	18.1	151.8	169.9	86
1956	392	392	162.9	83	15.7	17.1	147.2	164.3	83
1957	395	395	164.2	84	14.7	15.5	149.5	165.0	84
1958	396	396	164.6	84	13.6	14.5	151.0	165.5	84
1959	389	389	161.7	82	12.8	14.4	148.9	163.3	83
1960	393	389	161.7	82	12.1	12.5	149.6	162.1	82
1961	383	375	155.9	79	10.8	12.1	145.1	157.2	80
1962	386	374	155.5	79	10.2	12.5	145.3	157.8	80
1963	365	350	145.4	74	8.4	10.7	137.0	147.7	75
1964	349	331	137.6	70	8.0	11.6	129.6	141.2	72
1965	353	331	137.6	70	7.7	10.6	129.9	140.5	71
1966	338	313	130.2	66	6.7	10.6	123.5	134.1	68
1967	327	300	124.7	63	5.9	9.3	118.8	128.1	65
1968	333	302	125.5	64	5.4	9.5	120.1	129.6	66
1969	315	282	117.2	60	4.8	9.4	112.4	121.8	62

Table 6. Assuming the labour input of farm families to be the same in both series the total labour input corresponding to the CSO-series can be calculated and is presented in the two last columns of Table 6. The assumption above is, of course, slightly in error since the more inclusive agricultural sector of the CSO-series should also include more labour input by entrepreneurs than in the case of the AERI-series. There is no basis, however, to estimate that difference. Anyway, it seems clear that most of the difference in total labour input actually represents difference in hired labour because the other than essentially-agricultural enterprises included in CSO-statistics are, regarding the turnover, larger than average farms and, therefore, obviously are using relatively more hired labour than essential agriculture.

Inspection of the two new series on total labour input reveals a decline of approximately 40 percent during the period of study. Based on the observed values of the AERI-series an average decline of 2.6 percent per year is calculated for the whole period. The respective rates of decline are 2.1 percent per year during 1950—1959 and 3.1 percent during the latter part of the period. In the CSO-series the corresponding declines are 2.0 and 2.9, respectively and 2.5 percent per year for the time span as a whole. The development shown by the two series above parallels that of the series of labour force statistics since 1959. The average decline after that point of time calculated from corresponding trend line is 2.8 percent a year for the AERI- and 2.7 percent for the CSO-series compared with 2.8 percent in labour force statistics and 2.6 percent in the series of the Board of Agriculture. From 1963 the reduction indicated by the latter data series was faster than that shown by the series constructed here. Linear trends estimated from the constructed series for the whole study period indicate average declines of 2.3 percent per year for the AERI- and 2.1 percent for the CSO-series.

Table 6 gives some information of the changes in distribution of the total labour input between hired and family labour. The rapid decline in the use of hired labour on farms has been a typical phenomenon in Finland. The development of the share of hired labour input of total according to AERI-series is presented below.

Year	Hired labour input percent of total	Year	Hired labour input percent of total
1950	11.9	1960	7.5
1951	12.5	1961	7.0
1952	11.4	1962	6.7
1953	10.6	1963	5.9
1954	10.4	1964	6.0
1955	9.9	1965	5.7
1956	9.7	1966	5.3
1957	9.0	1967	4.9
1958	8.3	1968	4.4
1959	8.0	1969	4.3

The input of hired labour has declined fairly rapidly this phenomenon also being common in other Western Countries. The percentages above relate quite closely those calculable from the series of Board of Agriculture. From that data a number of 7.2 percent is obtained for the year 1961, 6.3 percent for 1965 and 4.7 percent for 1969.

In the groups of bookkeeping farms included in this study the development of total labour input is presented in Table 7. The weighted average of all bookkeeping farms presented in Table 6 is repeated here for comparison.

The labour input has fallen in size class VI much faster than in size class I—II which trend seems very natural, however. The difference in absolute level between the average of all farms and size class I—II in South-Finland is surprisingly wide. It must be emphasized, however, that in the latter group the number of working hours per hectare has been quite regularly higher than in other groups and also than in the same size class in other regions. When evaluating the development in the size class VI one has to remember that a rather general change from milk production to grain and pork production has taken place. In addition, the sharp decline between

Table 7. The total labour input in agriculture in bookkeeping farms. Fiscal years 1959/60—1969

Fiscal year	All farms weighted average		Size class I—II [1] South-Finland		Size class VI [2] South-Finland	
	hours per hectare	Index (1959/60 = 100)	hours per hectare	Index (1959/60 = 100)	hours per hectare	Index (1959/60 = 100)
1959/60	389	100	519	100	202	100
1960/61	393	101	532	103	199	99
1961/62	383	98	501	97	176	87
1962/63	386	99	519	100	169	84
1963/64	365	94	488	94	142	70
1965	353	91	475	92	135	67
1966	338	87	477	92	137	68
1967	327	84	455	88	107	53
1968	333	86	473	91	116	57
1969	315	81	445	86	105	52

[1]) Less than 10 hectares of arable land
[2]) More than 50 hectares of arable land

1966 and 1967 was affected by the new large farms coming into this size class in 1967.

The labour input series developed in this study based initially on work hours per hectare illustrate the actual use of labour on farms rather than the number of working population, labour force or even man-years. Thus the pratical solution here corresponds rather closely to that of Niitamo (1958, p. 49—50) which was mentioned earlier.

The method used to develop the series as well as the results obtained are, of course, open to criticism. A given systematic approach has been necessary, however, to establish a series covering the whole period of study. The rather similar development in the 1960's to the two aggregate series available gives some defense to the new series. In addition, the year to year changes in it are more logical than those of the two other series. Finally, it must be emphasized that the method used was developed for this study only and its applicability in the future may be questionable. Therefore, a well designed and reliable statistical series on labour input in agriculture would be both necessary and desirable for many research purposes.

The information regarding capital input in Finnish agriculture has likewise been rather deficient for a long time. In 1970 a study presenting a balance sheet for Finnish agriculture (Ihamuotila & Stanton 1970) was published where the amount and development of the capital stock as well as its distribution into various capital categories (land, buildings, machinery etc.) was analyzed in detail. That study covered the period of 1948—1967 but the author has subsequently continued the series up to 1970 (Ihamuotila 1971). The capital stock from 1950 to 1969 is presented in Table 8 both at current

Table 8. The capital stock in Finnish agriculture at current and constant prices in 1950—1969 and estimated annual capital input

Year	Capital stock at current prices		Capital stock at constant prices [1]		Capital input [2]
	Mil. marks	Index (1950=100)	Mil. marks	Index (1950=100)	Mil. marks
1950	3 461.9	100	7 873.8	100	315.0
1951	4 271.4	123	8 086.6	103	323.5
1952	4 558.1	132	8 453.7	107	338.1
1953	4 572.8	132	8 593.1	109	343.7
1954	4 710.3	136	8 751.7	111	350.0
1955	5 182.1	150	8 945.7	114	357.8
1956	5 973.3	173	9 061.7	115	362.5
1957	6 117.8	177	9 201.2	117	368.0
1958	6 715.7	194	9 308.8	118	372.4
1959	7 073.8	204	9 424.0	120	377.0
1960	7 614.7	220	9 705.4	123	388.2
1961	7 842.2	227	9 907.6	126	396.3
1962	8 234.7	238	10 025.8	127	401.0
1963	8 990.0	260	10 242.2	130	409.7
1964	10 357.9	299	10 357.9	132	414.3
1965	11 016.7	318	10 497.1	133	419.9
1966	11 263.6	325	10 546.6	134	421.9
1967	12 070.4	349	10 614.8	135	424.6
1968	13 640.2	394	10 602.9	135	424.1
1969	14 043.9	406	10 599.0	135	424.0

[1]) Using the current value of 1964 as a base figures for other years were obtained in ratio to changes in series where capital volume was calculated at 1954 prices (see text).
[2]) 4 percent interest on real capital volume.

and constant prices. In the study above the real capital stock was initially calculated at 1954 prices. In order to develop series for AERI and CSO the current value of capital stock in 1962 and 1964 respectively were taken as bases, and figures for other years were obtained, based on the studies noted above, as ratios to the changes in 1954-price series. The figures in Table 8 represent those formed for CSO-series. If more information about the distribution of capital between real estate and working capital, for instance, is desired, the study referred to above is recommended.

Table 8 shows that the capital stock at current prices has more than quadrupled during the period of study but it also shows that most of the rise has been affected by inflation. The real volume has risen only by 35 percent, with the increase being faster in the earlier half of period than in the latter half when the number of farms started to decrease.

In measuring the capital input there are two alternatives (p. 23), either to use the capital stock or the actual utilization of productive capital as the base. The latter means the flow of actually used capital services also taking into account the degree of capital capacity utilization. NIITAMO (1958, p. 51—52) has listed several possibilities for using the latter alternative which he preferred. Unfortunately, there are no practical possibilities for reliable measurement of such capital flow in agriculture due both to lack of information and the difference in nature from other industries. Thus, the capital input (last column in table 8) is expressed simply by 4 percent interest charge on the real volume of capital. This capital input reflects, of course, just changes in the stock but it is more rational than the stock figure when measuring the productivity of capital.

Although there was a shortage of aggregate information about capital stock in agriculture, the bookkeeping farm accounts do, however, provide information about the amount of capital and its distribution into subcategories in the farms involved. Following the normal bookkeeping procedure the value of single capital groups has not changed except through depreciation if no purchases or sales have taken place. Because of rather strong inflation which has prevailed in Finland during the post-war years, an underestimation of capital stock has tended to increase through time. This holds true especially in the case of permanent or semi-permanent capital items such as land, land improvements and buildings. To eliminate the influence of inflation the bookkeeping values of capital items have been raised twice, i.e., in 1951 and 1968, to correspond current market values. In the interim, however, underestimation has increased. This fact makes it difficult to utilize the data in question here. Although there is merely a need of the real volume of capital in this study, the deflation procedure raises problems since underestimated results are obtained when deflating the initially underestimated current values. This procedure had to be used anyway, to achieve some information for comparison. The capital input (interest charge on capital) in the three groups of bookkeeping farms included in this study is presented in Table 9. The general wholesale price index was used as a deflator.

Table 9. Capital input at constant (1961/62) prices in bookkeeping farms in the fiscal years 1959/60—1969

Fiscal year	All farms		Size class I—II, South-Finland		Size class VI, South-Finland	
	Marks per hectare	Index (1959/60 = 100)	Marks per hectare	Index (1959/60 = 100)	Marks per hectare	Index (1959/60 = 100)
1959/60	108	100	134	100	93	100
1960/61	110	102	137	102	96	103
1961/62	117	108	140	104	98	105
1962/63	121	112	143	107	100	108
1963/64	118	109	143	107	100	108
1965	119	110	144	107	103	111
1966	118	109	143	107	103	111
1967	121	112	145	108	105	113
1968	129	119	150	112	110	118
1969	130	120	145	108	114	123

The figures of all bookkeeping farms in Table 9 show that there has not been too much difference in development from the series of Table 8, however, except the two last years affected by the reappraisal of assets in 1968. Size class of under 10 hectares of arable land shows a clearly slower trend than the others. Finally it should be mentioned that depreciation has been handled similarly to the earlier system used in the accounts and not to the current one in effect since 1968 and using the system in taxation (see arguments in page 32). When determining the capital stock, the value of farm dwellings has been taken into account in this study neither in bookkeeping figures nor in the aggregate estimates. Thus, dwellings have not been considered as representing capital category necessary for agricultural production itself.

When combining external inputs, labour input and capital input, total input corresponding cost of production at constant prices is obtained. To calculate this, labour input is converted to monetary units using the average daily wage [1]) in crop year 1961/62 for AERI-series and that of calendar year 1964 for CSO-series as multipliers. Total input and internal input covering labour and capital inputs are presented in Table 10 as aggregate figures for the agricultural sector.

Total input expressed by CSO-series has remained rather constant through time. In contrast, a slightly falling trend is indicated by AERI-series covering only essential agriculture. The small difference between series is affected by the difference in external inputs since the contents of internal inputs is substantially the same in each series which also is reflected by their similar development. Table 10 also indicates the changes which occurred in input structure, too. According to AERI-data the share of internal inputs of the total declined from 88 percent in 1950 through 77 percent in 1959 to 64 percent in 1969. Since a few unsignificant input items have not been included in AERI-series of external inputs, the percent numbers above indicate a small over-estimation of the share of internal inputs all the time. According to CSO-data the mentioned percentage share has declined somewhat faster than that of AERI, largely because in the former series farmers'purchases of feed and seed from other farmers have been taken into account as inputs (likewise corresponding sales were included in output) which has not been the case in AERI calculations. At any rate, the decrease of the share of internal inputs reflects increasing commercialization and rationalization in Finnish agriculture.

The bookkeeping results in Table 11 indicate a clearly different development from that of the aggregate estimates as regards both total input and internal inputs. In each case bookkeeping results do not reflect the influence of structural change in agriculture (through decline of number of farms

[1]) 10,— marks in 1961/62 and 13,20 marks in 1964 based on average hourly wages and assumption on 8 hours in a work-day.

Table 10. Total input and internal inputs (at constant prices [1])) in agricultural sector in 1950—1969

Year	Total input				Internal inputs			
	For CSO- series		For AERI-series		For CSO-series		For AERI-series	
	Mil. marks	Index	Mil. marks	Index	Mil. marks	Index	Mil. marks	Index
1950	3 372	100	2 535	100	2 910	100	2 225	100
1951	3 236	96	2 434	96	2 726	97	2 086	94
1952	3 302	98	2 430	96	2 725	97	2 086	94
1953	3 239	96	2 415	95	2 666	92	2 041	92
1954	3 222	96	2 411	95	2 601	89	1 993	90
1955	3 302	98	2 463	97	2 581	89	1 978	89
1956	3 339	99	2 432	96	2 513	86	1 927	87
1957	3 344	99	2 405	95	2 535	87	1 944	87
1958	3 317	98	2 432	96	2 545	87	1 952	88
1959	3 294	98	2 473	98	2 511	86	1 920	86
1960	3 434	102	2 505	99	2 523	87	1 936	87
1961	3 378	100	2 476	98	2 454	84	1 884	85
1962	3 441	102	2 588	102	2 454	84	1 884	85
1963	3 484	103	2 479	98	2 331	80	1 790	81
1964	3 348	99	2 429	96	2 231	77	1 716	77
1965	3 445	102	2 440	96	2 236	77	1 721	77
1966	3 370	100	2 391	94	2 141	74	1 649	74
1967	3 356	100	2 375	94	2 071	71	1 596	72
1968	3 444	102	2 410	95	2 081	72	1 604	72
1969	3 434	102	2 369	94	1 971	68	1 520	68

[1]) Calendar year 1964 for CSO-series and crop year 1961/62 for AERI.

and labour force) in the same scale as the aggregate figures do. (Also bookkeeping results include some structural effects because of the enlargement of average farm size like was pointed out in page 36). This fact probably explains most of the difference. The relatively high figures in the years 1968 and 1969, especially as to total input, possibly indicate, however,

Table 11. Total input and internal inputs as indices (1959/60 = 100) in bookkeeping farms. Fiscal years 1959/60—1969

Fiscal year	Total input			Internal inputs		
	All farms	Size class I—II [1])	Size class VI [1])	All farms	Size class I—II	Size class VI
1959/60	100	100	100	100	100	100
1960/61	101	101	104	100	101	102
1961/62	110	106	102	107	103	99
1962/63	111	106	104	104	102	96
1963/64	111	109	103	100	99	88
1965	116	118	102	99	99	84
1966	118	118	96	93	96	71
1967	118	116	97	91	93	67
1968	128	122	114	93	95	72
1969	131	120	116	90	91	71

[1]) In South-Finland.

that those results could not have been entirely reduced by the effects of the change in bookkeeping system in 1968 (see p. 32). Regarding internal inputs a marked difference in the rate of decline exists between size class VI and other groups of Table 11. On those large farms the falling trend has clearly been even more rapid than that of the aggregate figures in Table 10.

3.3. Productivity trends

Productivity figures can be calculated on the basis of various input and output measures established in the two preceding subchapters. Total gross and total net productivities in the agricultural sector are presented in Table 12.

The series of CSO and AERI productivity measures in Table 12 are quite consistent. A few differences exist between single observed values, however, which are primarily caused by the difference in the reporting periods (calendar year versus crop year) upon which the observations are based. However, the trends do indicate similar long run development. One distinct feature in the rising trends is the rather rapid growth of productivity during a few years in the middle of the study period. Another conspicuous detail, especially in the crop year based figures, is the dramatic drop in productivity in 1962

Table 12. Total gross and total net productivity in agriculture in 1950—1969. Indices (1950 = 100)

Year [1]	Total gross productivity		Total net productivity	
	CSO-series	AERI-series	CSO-series	AERI-series
1950	100.0	100.0	100.0	100.0
1951	106.0	108.2	105.2	108.6
1952	113.8	110.8	114.0	112.1
1953	114.0	116.3	114.0	118.0
1954	117.3	111.9	116.8	110.4
1955	110.4	112.2	103.2	108.2
1956	114.9	120.5	105.8	118.5
1957	119.7	119.9	114.0	119.3
1958	123.6	125.5	121.3	126.8
1959	132.0	130.9	133.2	132.2
1960	135.0	134.8	134.9	137.5
1961	141.2	142.5	143.5	147.9
1962	139.3	132.9	139.4	130.9
1963	144.9	149.5	144.0	156.1
1964	157.4	153.7	165.3	161.9
1965	150.7	150.2	152.2	156.4
1966	156.8	151.2	161.9	157.0
1967	159.4	155.6	165.3	163.5
1968	160.7	155.1	166.6	162.3
1969	165.4	163.6	173.5	175.8

[1] In AERI-series crop years 1950/51—1969/70.

which was affected by the crop failure in that year. A picture of average rise of productivity in percent per year is presented below:

Period and base of calculation	Total gross productivity CSO	Total gross productivity AERI	Total net productivity CSO	Total net productivity AERI
1950—69 from trend line	2.7 ± 0.1	2.5 ± 0.1	3.1 ± 0.2	2.9 ± 0.2
1950—69 » actual observations	2.8	2.7	3.1	3.2
1950—59 »	3.2	3.1	3.4	3.3
1959—69 »	2.3	2.4	2.8	3.1

The rate of growth from trend line [1]) is calculated by the compound interest method. The average rise of productivity obtained from succeeding actual observations differs somewhat from those ones estimated from the trends which is a rather usual phenomenon. One reason for this difference may be the structure of variations in observed values around the trend. It may be mentioned that the trend functions explained 96 percent of the variance of total gross productivities and 92 and 93 percent of the variance of total net productivity in the CSO- and AERI-series, respectively. The changes in observations indicate a somewhat faster increase in productivity during the earlier half of the study period than in the later half. Actually, there are two periods of rather rapid growth in the former part, namely from 1950 to 1953 and from 1955 continuing to 1961. This fact as well as the over-all development of both of the productivity measures according to AERI-series is presented in Figures 4 and 5 where the corresponding trend lines are also indicated.

The development of net productivity of labour and partial net productivity of labour is presented in Table 13 and also for the AERI-series in Figures 4 and 5. Regarding these measures of productivity the general development indicated by the AERI- and CSO-series is quite consistent as was the case with the measures of Table 12. When comparing the series of Table 13 with those presented in Table 12, one readily notices the faster rates of growth in the former as well as the relatively strong annual fluctuations especially as regards net productivity of labour. The influence of these fluctuations are reflected by correlation coefficients and t-values (regression coefficient in ratio to its standard error) estimated from linear trends, which are presented below.

Measure and data	r^2	t (b/s_b)
Partial net productivity of labour, AERI	0.94	16.97
» » » » » CSO	0.93	15.66
Net productivity of labour, AERI	0.90	13.46
» » » » CSO	0.89	12.05

[1]) The trend equations are obtainable from the author.

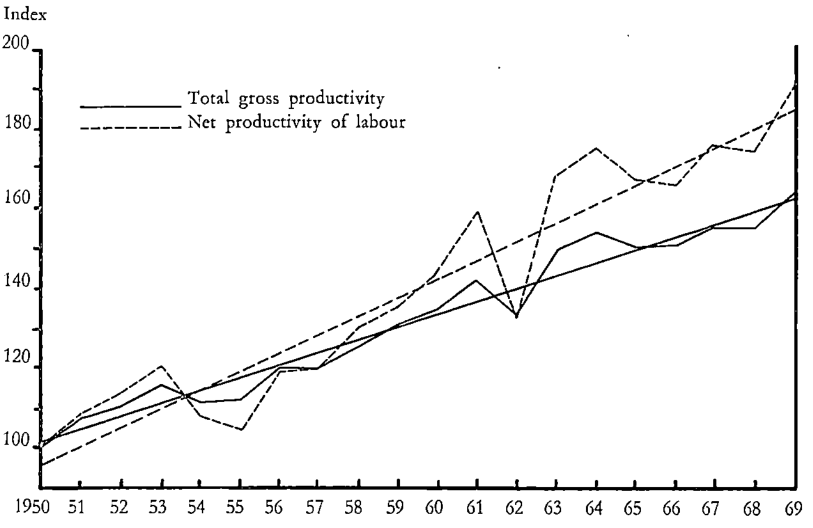

Figure 4. The development of total gross productivity and net productivity of labour in 1950—1969 and estimated linear trends

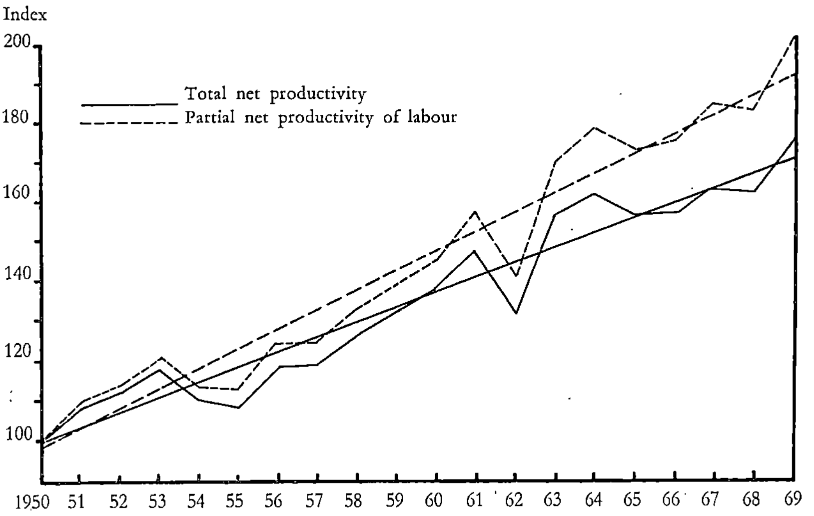

Figure 5. The development of total net productivity and partial net productivity of labour in 1950—1969 and estimated linear trends

Table 13. Net productivity of labour and partial net productivity of labour in agriculture in 1950—1969. Indices (1950 = 100)

Year [1]	Net productivity of labour		Partial net productivity of labour	
	CSO	AERI	CSO	AERI
1950	100.0	100.0	100.0	100.0
1951	105.0	108.6	106.4	109.8
1952	115.5	113.3	116.1	114.1
1953	115.1	120.6	116.9	120.9
1954	117.8	108.3	120.5	113.8
1955	99.1	104.8	107.0	112.1
1956	101.4	118.4	110.3	123.8
1957	112.3	119.7	119.0	124.7
1958	122.4	129.8	126.7	132.6
1959	137.9	135.6	139.9	138.6
1960	139.7	143.8	142.3	145.3
1961	150.7	158.4	152.9	157.8
1962	144.7	132.1	148.8	140.0
1963	149.3	167.9	155.8	169.5
1964	179.0	175.2	181.2	178.3
1965	159.8	167.0	167.3	172.6
1966	173.1	166.3	180.1	175.5
1967	177.2	175.9	184.4	184.7
1968	179.0	174.0	186.6	182.9
1969	188.1	192.7	197.3	201.2

[1]) Crop years 1950/51—1969/70.

The t-values, though high in absolute terms, indicate more fluctuation when shifting from partial net to »correct» net productivity of labour. These fluctuations, of course, follow those of total gross productivity but are more than proportionate to them.

The rates of growth of the two measures of net labour productivity clearly exceed those of total gross- and total net productivities. This is expressed in the figures below where the average rise of the net labour productivity measures is presented as percent per year.

Period and base of calculation	Net productivity of labour		Partial net productivity of labour	
	CSO	AERI	CSO	AERI
1950—69 from trend line	3.7 ± 0.3	3.7 ± 0.3	3.8 ± 0.2	3.7 ± 0.2
1950—69 » actual observations	3.7	3.9	3.8	3.9
1950—59 »	4.0	3.8	4.0	3.7
1959—69 »	3.4	4.1	3.7	4.1

As indicated in the figures presented on page 47 the rates of growth derived from trend lines in both AERI-series differ slightly from those calculated straight from observations. No such differences appear in CSO-series. It is hard to find a logical explanation for that fact, though one reason might be found in the steep rise between the two last observations in each of the AERI-series which raise the actual value of the last year substantially above the corresponding trend value.

Another fact, easily noticeable from the two sets of figures above as well as from Tables 12 and 13, is the difference in rate of growth between the measures used. Total gross productivity rose less rapidly through time than the other measures used. The average annual rate of increase indicated by total net productivity was 0.4 percentage points faster than that of total gross productivity, whereas partial net productivity of labour had the highest rate of growth. This order is quite logical for following reasons. Total gross productivity being the most rational concept, expresses all that has been produced in a firm or industry in ratio to all inputs needed to bring about that production. Total net productivity was defined to express the productivity of the two inputs, i.e. labour and capital, which are internal to the firm or industry used in the production process. Because of lack of knowledge the share of gross output produced by external inputs had to be considered equal to the value of these inputs (at constant prices). Thus, to determine total net productivity both gross output and the sum of all inputs had to be deducted by the same amount, i.e. the value of external inputs. In other words the average productivity of these inputs was considered to equal 1 and to remain constant through time. In reality, however, the productivity of these inputs increases through technological advance. This increase accumulates in total net productivity which, therefore, indicates higher rate of growth than total gross productivity.

To obtain net productivity of labour the procedure above has to be applied to the capital input, too. Thus, the increase of productivity both of external and capital inputs accumulate in net productivity of labour indicating a higher rate of growth than either of the first mentioned measures. This can also be clearly seen from Tables 12 and 13. Partial net productivity of labour, expressing net output in ratio to labour input exclusively, completely ignores capital in the input side i.e. even though no share produced by capital input has been subtracted from output side. Thus, this productivity measure may indicate a rate of growth which is higher than the actual rate of increase in the net productivity of labour. In the present study no significant difference appears, however. A difference exists, of course, in the absolute levels of productivity (not presented above) but there need not be a difference in trend which depends on the mutual changes of net output and labour and capital inputs.

The difference in the average rate of growth between total gross productivity and the measures looking at productivity from more limited points of view, seems to be widening. This can be recognized from the rates calculated for each half of the study period. For example, the average annual rise per year of net productivity of labour (in AERI-series) during the first half of the period was about 20 percent greater than that of total gross productivity, but during the later half, it was already more than 70 percent greater. This is, of course, in part caused by the facts explained above, but it is emphasized by the increasing growth in the volume of external inputs in 1960's on the one hand, and by the increasing rate of decline in labour input on the other.

Besides the productivity concepts used above, a few other such as net productivity of capital were defined in chapter 2.1. It is not possible to derive empirical estimates for Finnish agriculture by using this concept, however. This is due to the comparatively low ratio of net output to the sum of the two corresponding inputs, i.e. labour and capital. Thus in the base year (1964) of the CSO-series, for example, net output was clearly exceeded solely by the value of labour input, and this difference was even wider in earlier years. If the value of labour input were deducted from net output the resulting contribution of capital to net output would be negative and the calculation of net productivity of capital would give illogical results. By the same reasoning it would be even more unrealistic, e.g. to determine net productivity of land, defined earlier (p. 13), where net output should be reduced not only by the value of the labour input, but also by the value of capital inputs other than land with the residual being expressed in ratio to input of land.

The facts above may raise a question about the logic of the method used, i.e. of calculating residuals and expressing them in ratio to corresponding input(s). An alternative method would be, e.g., to calculate the shares of net output related to the values of labour and capital inputs, and thus to avoid the appearance of negative residuals. Since shares of net output calculated in this manner evidently would not equal the real contributions of labour and capital which are determined by their marginal productivities, it would be questionable to replace the common method used here with another which is just as inexact. Anyway, the results and discussion here point out once again that if one is using partial and net productivity measures it would also be desirable for correct interpretation of results to have some measure of total gross productivity at the same time.

Table 14 indicates the development of total gross productivity, total net productivity and net productivity of labour in the selected groups of bookkeeping farms. Once again, the numbers indicate that it has not been possible to eliminate completely the influence of the 1968 change in the bookkeeping system (see p. 32) from the results. Also the effect of changes in the composition of farms which occurred in each of the selected size classes (see p. 32) has accumulated in the corresponding numbers of Table 14. Thus, in size class VI there is a conspicuously unrealistic and unplausible jump upwards from 1967 to 1968 regarding total net productivity and net productivity of labour. In each of the farm groups a rather marked variation between years makes it difficult to define any particular trends. In size

Table 14. The development of total gross productivity, total net productivity and net productivity of labour in bookkeeping farms in the fiscal years 1959/60—1969. Indices (1959/60 = 100)

Fiscal Year	Total gross productivity			Total net productivity			Net productivity of labour		
	All farms	Size [1]) class I—II	Size [1]) class VI	All farms	Size [1]) class I—II	Size [1]) class VI	All farms	Size [1]) class I—II	Size [1]) class VI
1959/60 ...	100	100	100	100	100	100	100	100	100
1960/61 ...	109	114	108	116	125	114	119	130	119
1961/62 ...	101	103	106	101	105	111	101	106	115
1962/63 ...	99	101	94	99	102	89	98	102	84
1963/64 ...	108	107	111	114	111	123	117	113	137
1965	101	107	112	100	111	127	100	114	145
1966	105	111	115	108	119	137	109	123	171
1967	110	110	140	119	118	204	125	122	308
1968	98	98	123	91	92	155	87	89	209
1969	100	93	129	95	81	174	92	74	253

[1]) In the research region of South-Finland.

class VI it is clear, however, at least according to the figures given, that a rapidly rising trend is occurring. Thus, it also seems apparent that total net productivity and net productivity of labour have risen more on large farms than on small ones. This result is not surprising since it is quite compatible with prior expectations.

In comparing the development of output and inputs from 1967 to 1968 on bookkeeping farms with that of the aggregate series of AERI (which defines agriculture similarly), the following features can be recognized. Gross output dropped by 4 percent in the former series but remained rather stable in the latter one. External inputs rose by 12 percent in the former and by slightly more than 3 percent in the latter series, while the labour inputs rose by less than 2 percent and about 0.5 percent, respectively. Capital input increased by 6.5 percent in bookkeeping farms, but remained stable in the AERI-series. (Bookkeeping figures on external and capital inputs above are reduced, of course, see p. 32 and 44). Thus, the development of each category indicated above has been less advantageous in bookkeeping farms than in the agricultural sector as a whole. The differences of change in gross outputand labour input are real. However, only an ostensible difference between the figures of capital input and external inputs appears plausible.

As was mentioned earlier, (p. 43) a reappraisal of various capital items was made in 1968 to eliminate the influence of inflation. The effect of this reappraisal of capital inputs was not taken into consideration in present study because of obvious risks of error. Had it been considered, the capital input prior to 1968 would have been somewhat higher than the values presented. Through detailed comparison of the capital stock of all bookkeeping farms (as weighted averages) in 1967 with that of 1968, it can be concluded that the capital stock at constant prices would be approximately the same for both years if the effect of reappraisal were taken into consideration.

The sharp rise in external inputs from 1967 to 1968 indicated by the weighted average of all bookkeeping farms may also be partially ostensible. It might be, for example, that the influence of each factor which was affected by the change in the bookkeeping accounts system in 1968 was not reduced or otherwise accounted for in the present study. On the other hand, farmers may have consciously used more purchased inputs than previously knowing that they can count these inputs as deductable expenses in taxation which was not possible under the previous tax system.

If it is assumed that the capital input remained constant from 1967 to 1968, and, somewhat uncertainly, that the volume of external inputs rose only by as much as in the AERI-series, or by 3 percent, the following index numbers for the years 1968 and 1969 are obtained. The initial numbers for 1966 and 1967 as well as AERI-figures for each of the above mentioned four years are also presented for comparison.

Measure and source of data	Index number (1959/60 = 100) in			
	1966	1967	1968	1969
Total gross productivity:				
— All bookkeeping farms	105	110	104	107
— AERI-aggregates	112	115	115	121
Total net productivity:				
— All bookkeeping farms	108	119	108	113
— AERI-aggregates	114	119	118	128
Net productivity of labour:				
— All bookkeeping farms	109	125	109	117
— AERI-aggregates	116	122	121	134

If the year 1967 is ignored the development of each productivity measure from the bookkeeping farms corresponds rather well to that of AERI-aggregates although the trends of the bookkeeping estimates seem to rise at slower pace than those of AERI in each case. The fact that the rise from 1966 to 1967 was relatively higher on the bookkeeping farms than in the AERI-series, however, leads one to wonder if perhaps some reflections of the change in taxation system were already reflected in the bookkeeping results of 1967, (in other words if perhaps the 1967-figures were inflated at the expence of those of 1968). At any rate, remembering that the assumption regarding the rate of growth of external inputs on bookkeeping farms is probably underestimated, it seems evident that the increase of productivity on those farms has been slower than in the agricultural sector as a whole. Due to the uncertainty in numbers since 1968 caused by the change in bookkeeping accounts system, any accurate difference in growth cannot be estimated. Thus, the bookkeeping series do not provide any significant contribution to estimating the share of internal changes in the total growth of productivity in the agricultural sector.

4. OUTPUT AS A FUNCTION OF INPUTS

The purpose of the preceding chapter was to present a description of variations in output in ratio to inputs, and in section 3.3 gross and net output were thus expressed in ratio to corresponding inputs. In this chapter the purpose is to explain the variations in output by changes in the use of inputs. In other words, aggregate production functions for Finnish agricultural sector will be estimated. In addition to the inputs treated earlier a few other independent variables will be taken into consideration as well.

A great number of aggregate production functions for various industries and national economies as a whole has been estimated during the last fifteen years. Problems included in estimation have been largely discussed as well. Of interest in these respects are the studies of e.g. Solow (1957), Niitamo (1958 and 1969), Arrow et.al. (1961), Lave (1962), Nelson (1964) etc. Aggregate production functions estimated for the agricultural sector apparently are few in number, while no such studies have been previously made in Finland. Kettunen & Torvela (1970) and Ryynänen (1970), have estimated whole farm production functions for selected farm groups, however.

In the following subchapters 4.1 and 4.2 gross and net output will be explained as functions of corresponding inputs. In the latter subchapter a labour productivity function will be estimated as well.

4.1. Production functions for gross output

Gross output is produced by external inputs including purchased raw materials as well as depreciation, obsolescence and maintenance of capital goods and by internal inputs i.e. labour and capital. In addition, the skill and knowledge, especially of entrepreneurs, but of other labour force, too, as well as the general technological advance also affect gross output. Explicitly in agriculture gross output is also regulated by such entirely non-controllable external factors as weather conditions.

In the previous chapter gross output was expressed in ratio to all directly measurable inputs to obtain total gross productivity. Here it is attempted to explain variations in gross output by those inputs and by a few other constructed variables as well. Gross output functions are estimated by using the above mentioned data prepared by both Central Statistical Office (CSO) and the Agricultural Economics Research Institute (AERI). The below listed variables are used in each case.

Y_G = gross output
X_1 = external inputs
X_2 = labour input
X_3 = capital input
X_4 = input of human knowledge and skill
X_5 = technological factor (alternative to t)
t = time (year 0, 1, 2 . . .; alternative to X_5)

When using the CSO-statistics only the above variables are included. In the case where the analysis is based on the AERI-statistics two additional independent variables expressing the effects of weather are also considered. External inputs are divided into subgroups as well. These variables are treated later on in more detail.

The functions estimated from the CSO-statistics are presented and analyzed at first. The dependent variable (gross output) is represented by the corresponding CSO-series in Table 2 (p. 28). External inputs are represented by the CSO-series in Table 4 and capital input by the series of Table 8, accordingly. The variable of labour input is obtained by multiplying the number of work-days indicated by the constructed CSO-series in Table 6 by the average wage per work-day [1]) in the base year of the series in question. Thus, the labour input variable in this case expresses the computed total labour cost of agriculture in each year at constant prices.

In several earlier studies (e.g. Solow 1957 and Arrow 1962) based on time series attempts are made to explain the residuals unexplained by production functions by constructed independent variables describing technological change. The influence of this technological change is reflected in the fact that a given combination of inputs (measured conventionally) is able to produce higher output than previously, or that it is possible to produce a given output with a lesser amount of inputs than previously. Thus, the inputs have improved with respect to their capacity to produce. This has taken place partly through innovations and partly through increased knowledge of entrepreneurs and workers which has made it possible to adapt available methods more efficiently than previously.

The measurement of the mentioned technological factor is, of course, a difficult and diversified problem. Two alternative groups of methods are

[1]) 13,20 marks per work-day in calendar year 1964.

used by economists to resolve the problem: 1) The traditional measurement methods and 2) the so-called service-flow-methods (NIITAMO 1969, p. 3—4).

The use of the former methods postulates the measurement of inputs ignoring changes in their quality. This equals the assumption on homogeneity of inputs in the general theory of production functions. Thus, the whole residual of an estimated function is considered to be influenced by technological change. When analyzing the residual one should remember that it consists not only of the effect of technological change but also of possible errors in methods of estimation, in hypotheses regarding the type of function, and so on.

Service-flow-methods assume that the output is always functionally proportionate to the sum of inputs and that the residual includes only the error factors mentioned above. According to this assumption the inputs should be measured so as to take into consideration the changes in their quality, i.e. changes in efficiency of machinery, in skill and knowledge of workers etc. These methods will only allow the principle of constant returns to scale, while in the traditional methods increasing or decreasing returns to scale are also logical. The greatest problem in adaptation of service-flow-methods is to meet the requirement about the reliable measurement of the quality of inputs.

In choosing between the two methods outlined above, economists have most often tried to apply the traditional ones. Among the numerous efforts to measure the effect of technological change, the following methods are of special interest.

SOLOW (1962) proposed as a solution that technological change is embodied in each year's investments. According to his ideas investments in a given year include the improvements in technology developed in earlier years. Thus, the technological advance can be measured indirectly by accumulated investments. NELSON (1964) also considered that technological change is largely reflected by improvements in the quality of capital. SHESHINSKI (ref. NIITAMO 1969, p. 39) attempted to explain technological change by both accumulated investments and accumulated output occurring in a given period. ARROW (1962) developed a theory called the »Learning by doing»-hypothesis. It is based on an assumption that through the increasing age of a given production process the machinery is becoming more specialized for that production, the labour input is correspondingly becoming more skillful, etc. Thus, the accumulated experience and specialization reflects technological advance which ARROW considers as an internal factor within firms or industries rather than a general external one. NIITAMO (1958) also looked at the question primarily from internal point of view, constructing a variable that indicates the number of live persons educated at least up to the level of junior high school [1]). In spite of the many possibilities available like the ones referred to above, the solution in many studies has been to measure technological change indirectly by time (by a systematic variable e^{ct}, for instance). This idea indicates that technological change is correlated with the passage of time. Actually this method is only a substitute for those mentioned above and has been applied because of difficulties involved in the measurement of technology variables.

In the present study it will be attempted to explain the residual by two separate independent variables. One describes the current general state of technology including the production techniques available in each year as well as the current knowledge about input-output relationships, etc. In other words it expresses the general possibilities and facilities which the agricultural industry can utilize in each year. This variable is at least partially external because the innovations available for agriculture are not only of agricultural origin but also — and obviously even primarily — due to the general increase in the stock of human knowledge. The other variable will express the prerequisites that must exist within agriculture in order to but available technological innovations and knowledge into practice. Thus, this variable, indicating farmers'current skills and knowledge, is a factor reflecting internal development in agriculture. These two variables have been constructed as follows.

For the first technology variable the simple time factor (t = years, 1950 = 0, 1951 = 1, 1952 = 2 etc.) is used as a proxy for technological change as has been done in other previous studies. The other technological change variable is based partially on the above theory of accumulated investments. In the present study the investments are limited, however, to cover only those capital items which most clearly reflect technological advance. Land improvements, buildings and machinery and equipment have been considered to represent such items. Furthermore, technological change is taken as being reflected by the amount of manual labour saved by the investments in question. To estimate this, the real stock of accumulated investments in each year is expressed in ratio to current labour input in agriculture. Thus, for 1950 the real capital stock (accumulated real net investments up to this year) in various capital groups [1]) is divided by the corresponding labour input. This process is repeated to obtain estimates for the subsequent years. The annual values of this variable (X_5) are presented as index numbers below.

---

[1]) Keskikoulu

[1]) Based on the study of IHAMUOTILA & STANTON (1970).

Year	Variable X_5	Year	Variable X_5
1950	100.0	1960	173.8
1951	111.4	1961	186.2
1952	119.0	1962	195.6
1953	132.7	1963	215.3
1954	141.8	1964	225.0
1955	148.7	1965	237.9
1956	160.2	1966	257.6
1957	162.6	1967	273.0
1958	165.8	1968	274.7
1959	171.5	1969	294.0

The variable (X_4) describing the knowledge and skill of farmers is constructed of two parts as follows. One part is based on information from the censuses of agriculture in 1950, 1959 and 1969 concerning the number of farmers on farms of two or more hectares of arable land having professional training in agriculture and/or forestry. These numbers are presented below.

Classification	1950		1959		1969	
	Number of farmers (1 000's)	Percent of total	Number of farmers (1 000's)	Percent of total	Number of farmers (1 000's)	Percent of total
Professional training	6.4	15.0	17.3	6.9	19.8	9.7
No training	93.6	219.4	234.1	93.1	184.9	90.3
Altogether	100.0	234.4	251.4	100.0	204.7	100.0

An index series is built up based on the percentage shares of trained farmers. Since this share has increased from 1959 to 1969 much faster than from 1950 to 1959, the annual indices are derived from a quadratic function $Y = aX + bX^2$. The constructed series is presented in Table 15.

The construction of the other part of the variable X_4 is based on the hypothesis that farmers are more skillful than their family members and hired workers with respect to agricultural work and thus the relative skill of agricultural labour force increases in ratio to farmers' share of total labour input. Information about this share has been taken directly from bookkeeping data for the years since 1966 and from the author's study (Ihamuotila 1968, p. 74—75) for the fiscal years 1956/57—1965 [1]). Because of the clear and even rise of this share through time, a linear trend was estimated and it was extrapolated backwards to obtain estimates for fiscal years 1950/51—1955/56. When comparing the values from the estimated trend line to those indicating the farm families' share of total labour input, the former values seemed very logical. Based on the farmers' shares of labour input derived from the estimated trend line, an index series on the relative skill of the labour force is built up with the share in 1950/51 as 100. The formation of this series is presented in Table 15.

---

[1]) All are expressed as weighted averages.

Table 15: Formation of the index of farmers' share of total labour input, the index of trained farmers' share of total and the joint index of knowledge and skill (variable X_4)

Year	Whole farm family's share of total labour input, percent	Farmers' share, percent		Former column as an index (1950 = 100)	Index of trained farmers (1950 = 100)	Variable X_4 Index of knowledge and skill (1950 = 100)
		Actual observations	Derived from trend line			
1950	77.8	...	36.7	100.0	100.0	100.0
1951	80.1	...	37.1	101.1	100.1	100.7
1952	81.6	...	37.6	102.5	100.3	101.6
1953	82.5	...	38.1	103.9	100.6	102.6
1954	83.4	...	38.5	104.9	101.0	103.7
1955	84.7	...	39.0	106.3	101.6	104.9
1956	85.7	39.0	39.5	107.6	102.5	106.4
1957	85.6	39.7	40.0	109.0	103.8	108.5
1958	86.4	39.9	40.4	110.1	105.6	110.1
1959	86.9	41.1	40.9	111.4	107.8	113.9
1960	88.0	41.2	41.4	112.8	110.4	117.5
1961	89.0	43.1	41.8	113.9	113.4	121.3
1962	89.6	42.5	42.3	115.3	116.8	125.8
1963	91.8	43.3	42.8	116.6	120.7	130.8
1964	93.1	44.1	43.3	118.0	124.9	136.1
1965	92.4	43.6	43.7	119.2	129.5	141.9
1966	93.5	43.5	44.2	120.5	134.5	148.2
1967	93.9	44.0	44.7	121.8	139.8	155.0
1968	92.2	45.1	45.1	123.0	145.5	162.2
1969	92.4	45.4	45.6	124.3	151.6	170.1

To form a series for the joint variable of knowledge and skill (X_4) the annual values of the series indicating the change of the share of trained farmers (Table 15, column 5) are adjusted by half of the corresponding changes in the series of farmers' share of total labour input (column 4). Thus, less weight is given to the influence of the latter series because it is evident that training is a more important factor than the improved skill of labour force due to the rise of farmers' share of total labour input.

The influence of inputs upon gross output are studied by two different types of functions, i.e. linear- and Cobb-Douglas functions. The linear function, though generally somewhat illogical to describe input—output relationships, has been chosen for this analysis because it is probable that observations about inputs are available only from a comparatively short segment of the complete production function range. In this segment the presumable curvilinearity often is obscurred by the chance variation in observations which is especially common in agricultural data.

The Cobb-Douglas function is employed both in its traditional form ($Y = aX_1^{b_1} \cdot X_2^{b_2} \ldots X_n^{bn}$), and in the form ($Y = aX_1^{b_1} \cdot X_2^{b_2} \ldots X_n^{bn} \cdot e^{ct}$) in which the time-variable is also included, that is in a form where other independent variables are the same as in the usual Cobb-Douglas function, but the time-variable t is included as an exponent to the base of natural logarithms. It should be emphasized again that this time-variable is an

Table 16. Linear gross output functions estimated from CSO-statistics. Multiple correlation coefficients (R), Durbin-Watson test-values for serial correlation (d) [1]), regression coefficients [2]) and their standard errors (in parentheses below coefficients)

Function	R	d	External inputs X_1	Labour input X_2	Capital input X_3	Knowledge and skill factor X_4	Techno-logical factor X_5	Time-variable t
(1)	0.981	1.44°	0.657 (0.455)	0.203 (0.187)	5.51** (1.79)			
(2)	0.992	1.96−	0.227 (0.496)	0.479° (0.238)	7.01** (1.90)	4.49° (2.60)		
(3)	0.992	1.96−	0.224 (0.530)	0.478° (0.248)	6.94 (4.19)	4.43 (4.13)		0.681 (0.361)
(4)	0.993	2.03−	—0.070 (0.310)	—0.530 (0.456)	13.03*** (1.91)	22.81*** (4.51)	—11.76* (3.97)	

[1]) The signs following d-values indicate (at 5 percent probability level):
— no significant positive serial correlation
° test inconclusive
+ positive serial correlation exists

[2]) The signs following regression coefficients express their probability levels according to t-test as follows:
°P > 90.0 percent
*P > 95.0 percent
**P > 99.0 percent
***P > 99.9 percent

Table 17. Cobb-Douglas gross output functions

Function	R	d	External inputs $\ln X_1$	Labour input $\ln X_2$	Capital input $\ln X_3$	Knowledge and skill factor $\ln X_4$	Time-variable ln t	Time-variable t
(5)	0.991	2.06−	0.038 (0.134)	0.546* (0.242)	1.25** (0.407)	0.513* (0.200)		
(6)	0.992	2.02−	0.047 (0.140)	0.474 (0.315)	1.46° (0.709)	0.419 (0.327)	—0.022 (0.061)	
(7)	0.992	2.02−	—0.095 (0.144)	0.524° (0.273)	1.21° (0.640)	0.588° (0.315)		0.010 (0.016)

alternative to the constructed variable X_5 described above and thus these two variables are not used simultaneously in the same function.

The most relevant indicators of the functions estimated to explain variations in gross output are presented in Tables 16 and 17. Multiple correlation coefficients (R) and standard errors of regression coefficients are derived in the usual manner. The probability levels of regression coefficients based on t-test are also expressed as well as the so-called Durbin-Watson test-values for serial correlation.

Multiple correlation coefficients derived from each function are quite high. The standard errors of the estimates (not presented in the tables) are correspondingly low. Analysis of variance for the regression was made regarding all functions. According to F-test, a very significant difference, at the probability level of more than 99.9 percent, prevailed between the mean square attributable to regression and the error mean square in each case. If presenting multiple correlation coefficients squared (R^2) it can be recognized that even function (1), where only the conventional input items are represented, was able to explain 96.3 percent of the variation of gross output. When adding the constructed input on farmers' knowledge and skill (X_4) into the function, R^2 rises to 98.4 percent. Through comparison of the error mean squares of the two functions (1 and 2) with each other, an almost significant difference at a level of slightly below 95 percent between them was found. Thus, there is a statistical evidence about improvement in function through inclusion of this variable.

On the other hand, function (2) was not substantially improved by either the constructed technological change factor (X_5) or the time-variable (t). Nor was any increase in multiple correlation coefficient attained in replacing the linear type of function with the Cobb-Douglas function.

Figure 6 illustrates the development of gross output estimated by function (3) compared with actually observed values. The fairly good consistency is readily noticeable. The function explains the changes in gross output occurred in early 1950's quite well, for example, and also its relatively rapid rise at the beginning of the 1960's. The differences of estimates from actual observations in a few single years refer to a possible need, of some kind weather variable to explain chance variations in output, however. Such variations occurred, for instance, in 1955, a drought year, 1962, a year of widespread crop failure due to excess rainfall and coolness and 1964, in which weather conditions were particularly favourable for production.

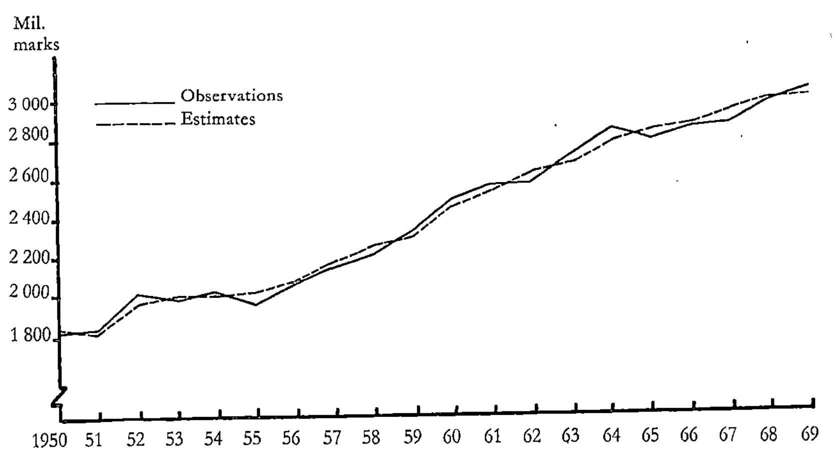

Figure 6. The observed values of gross output (CSO) and corresponding values estimated by function (3)

Capital and farmers' knowledge and skill have been the individual inputs indicated by the functions as having had the highest regression coefficients. The regression coefficients of capital input indicated by functions (1), (2) and (5) are significant at probability levels of greater than 99 percent. In comparison, the significance of regression coefficients in other functions, (ignoring function (4) which seems somewhat illogical), is deteriorated by their rather high standard errors. This also holds true regarding the regression coefficients of the knowledge and skill factor in each function. According to function (2) an addition of capital input e.g. by one million marks would appear to increase gross output by 7 million marks which sounds unrealistic. One has to remember, however, that capital input is represented here by four percent interest charge on total real capital stock. Thus, more realistically an addition of real capital stock by one million marks would actually increase gross output by 0.28 millions. According to the Cobb-Douglas function (5) where the variables are the same than in the function (2), though in logarithmic form, the corresponding increase in gross output would approximate 0.24 million marks. Each Cobb-Douglas function indicates increasing marginal productivity of capital, however, which appears somewhat illogical. The effect of the knowledge and skill factor on gross output according to function (2), for example, implies that a rise of one percentage point in the number of trained farmers would increase gross output by more than 4 percent or — at the mean level of observed gross output — by approximately 80 million marks.

The labour input was of somewhat lesser relevance with respect to its effect on gross output than the two factors above. Only in function (5) the corresponding regression coefficient was significant at the probability level of above 95 percent. According to this function — adjusting the labour input into work-days — an addition of one million work-days would increase gross output by approximately 5.9 million marks (calculated at 1964 prices). The functions (2) and (3) would correspondingly allow an increase of slightly above 6 millions.

All linear and Cobb-Douglas functions express rather low (and in two cases even negative) regression coefficients for external inputs and coefficients do not differ significantly from zero in any case. These results are rather surprising. It might be possible, however, that the single input items included in this group of inputs would have mutually opposite regression coefficients. At any rate, it would have been desirable to divide this group of inputs into subgroups before analysis. It may be mentioned, however, that in a Cobb-Douglas function (not presented in Table 17) corresponding function (1) external inputs did have positive and almost significant ($P > 90$ percent) regression coefficient. Adding the knowledge and skill factor into that function, the regression coefficient of external inputs as well as the contents of the whole function changed remarkably.

Addition of the time-variable (t) into the functions had no practical effect at all. The technological factor, constructed to proxy for the time-variable, has behaved quite illogically. Some evidence will be presented later on regarding the apparent fact that this variable is at least partially substituted for by the knowledge and skill factor.

Some additional information about the effects of single input factors upon gross output are presented below, where the numbers represent the partial correlation coefficients, (r), for the respective variables and functions.

Function	X_1	X_2	X_3	X_4	t
(1)	0.34	0.26	0.61	•	•
(2)	0.11	0.46	0.68	0.41	•
(3)	0.11	0.46	0.40	0.28	0.01
(5)	0.07	0.50	0.62	0.55	•
(6)	0.09	0.37	0.48	0.32	—0.09

In the gross output function analysis based on AERI-statistics the corresponding independent variables like used above are included at the first stage. Thus, external inputs and labour input represent the AERI-series in Tables 4 and 6 while capital input, knowledge and skill factor as well as technological factor (Tables 8 and 15 and the set of numbers on page 58) are just the same that were used in the analysis based on CSO-statistics. Labour input is expressed differently than in CSO-analysis, however, and is indicated as million work days rather than as total labour cost at constant prices.

At a further stage of analysis two alternative weather variables are also included. One (variable X_6) represents June rainfall. This kind of factor has been selected because in high latitudes favourable moisture conditions of early summer are of utmost importance for the development of crops. In Finland, especially in southwestern parts, the precipitation in June is often insufficient, however. In the study of ROUHIAINEN (1972) variations in crop production were largely explained by June rainfall.

In the present study June rainfall in each year has been expressed as an average calculated from more than 100 weather stations scattered all over the country. (Before the year 1955 only around 70 stations were included, however, because the total number of stations was lesser at that time than since 1956). Since agricultural production in Finland has been largely concentrated into southwestern parts of country, the number of weather stations included in this study has been relatively highest in Southwest-Finland decreasing rather strongly when shifting northeastwards. The map of the stations in 1969 is presented in Appendix 1. The calculated June rainfall numbers are presented in Table 18.

A so-called *Stallings weather index* developed by STALLINGS (1960) is the other alternative weather variable (variable X_7) used in the present study. The formation of this index is based on an idea that in yields per acre there is a long term trend affected by current technology and inputs used and the residuals unexplained by this linear regression are caused by influences of weather. STALLINGS (1960, p. 182) has constructed mentioned indices for various crops ever since 1900 up to 1957. In the present study a linear trend is fitted to the data regarding average yield (expressed in crop-units) per hectare in the whole country from 1948 to 1970. The unexplained residuals are considered to be affected by weather. Indices for various years are constructed by designating the computed yield of each year as 100.0 while the ratio of actual to computed yield expresses the weather index of each year. These indices are presented in Table 18.

The Stallings method is open to criticism in some respects, however. First, there is the illogicallity that in construction of independent variable (= Stallings index) variations at least in a part of dependent variable (= output) are used as an explanator. Secondly, the influence of weather as measured by mentioned index includes not only effects of direct components of weather but also indirect influences like insects, disease etc. Anyway, if the effects of all measurable inputs to yield are known, it can be stated that unexplained residuals reflect the influence of weather and thus they can be considered as some kind of substitutes for »real weather variable». Such »real weather variables» have been constructed by e.g. SHAW (1964) and OURY (1965) but those variables are not attempted to build up in the present study because of complexity of such a task.

At the second stage of the analysis also the external inputs (X_1) are divided into two components: Fertilizer input (X_{1a}) and other external inputs (X_{1b}). An argument for this solution is the fact, that the use of fertilizers has more than quadrupled during the time span of this study and that there are some evidence (ROUHIAINEN, 1972) supporting the idea that the fertilizer use has strongly affected to crop production. Fertilizer input as well as the rest of external inputs are presented in Table 18.

The most relevant indicators of the gross output functions estimated from AERI-statistics are presented in Table 19. Like in Tables 16 and 17 multiple correlation coefficients derived from each function are high indicating that from 95.3 to 98.0 percent of the variation in gross output has been explained by the functions. All functions presented in Table 19 are linear. The corresponding Cobb-Douglas-functions are not presented because of somewhat lower multiple correlation coefficients resulted.

The indicators of functions (8) and (9) relate closely to those of corresponding CSO-functions (1) and (2) in Table 16. The regression coefficients of external inputs are not significant in any of the mentioned functions and

Table 18. Additional independent variables in the analysis based on AERI-statistics: Fertilizer input (X_{1a}), other external inputs (X_{1b}), June rainfall (X_6) and Stallings weather index (X_7) in 1950—1969

Year	Fertilizer input [1] X_{a1}	Other external inputs [1] X_{1b}	June rainfall [1] X_6	Stallings index X_7
1950..............	63.0	247.0	41.4	105.7
1951..............	74.0	274.1	42.6	99.8
1952..............	75.7	268.3	65.7	103.5
1953..............	85.9	287.8	58.3	108.9
1954..............	85.6	333.1	57.2	98.2
1955..............	92.8	392.4	29.3	87.4
1956..............	109.5	395.8	46.4	89.5
1957..............	109.7	350.6	61.5	94.0
1958..............	117.8	362.2	37.6	96.6
1959..............	141.7	411.2	26.6	86.2
1960..............	146.1	423.0	70.5	113.5
1961..............	143.4	447.7	85.7	103.6
1962..............	143.3	560.1	51.5	86.5
1963..............	178.1	510.1	33.6	97.3
1964..............	204.2	508.3	27.3	103.4
1965..............	202.1	517.0	41.5	88.4
1966..............	198.4	544.4	35.2	95.4
1967..............	225.2	553.8	41.6	101.5
1968..............	244.3	562.5	40.5	102.6
1969..............	276.8	571.8	19.0	104.9

1) In million marks at crop year 1961/62 prices
2) In millimeters

neither do the regression coefficients of labour input in functions (1) and (8). (When considering the last mentioned regression coefficients in Table 19, it must be noted that labour input is represented not by the value of this input at constant prices as it was in Tables 16 and 17 but by million work days. Thus, due to the wage per work-day of 10,— marks in AERI-series, the corresponding regression coefficients should be divided by 10 to make them comparable with those of Tables 16 and 17). Both in CSO- and AERI-functions the regression coefficients of capital input are significant at a level of above 99 percent. The mentioned coefficient of knowledge and skill factor is significant in function (9) but only at a level of a little above 90 percent like was the case in function (2) as well. Technological factor (X_5) and time-variable (t) are not included in the functions of Table 19 because of illogical or non-significant regression coefficients indicated by those variables.

When considering June rainfall (X_6) as an independent variable in function (10), the regression coefficient resulted acts somewhat illogically while the mentioned coefficients of other variables included have remained rather constant compared with those of function (9). When replacing June rainfall by Stallings index (X_7), the regression coefficients of other variables — especially knowledge and skill factor — change while the regression

Table 19. Linear gross output functions estimated from AERI-statistics. Multiple correlation coefficients (R), Durbin-Watson test-values for serial correlation (d), regression coefficients and their standard errors (in parentheses below coefficients) [1])

Function	R	d	External inputs X_1	Fertilizers X_{1a}	Other external inputs X_{1b}	Labour input X_2	Capital input X_3	Knowledge and skill factor X_4	June rainfall X_6	Stallings index X_7
(8)	0.976	1.48°	0.651 (0.445)			2.98 (2.65)	5.77** (1.83)			
(9)	0.980	2.00-	0.199 (0.499)			6.61° (3.30)	7.53** (2.02)	4.30° (2.54)		
(10)	0.981	2.01-	0.135 (0.584)			6.89° (3.62)	7.86** (2.54)	4.45° (2.70)	—0.251 (1.09)	
(11)	0.986	2.25-	0.806 (0.512)			4.57 (3.04)	5.88** (1.92)	0.306 (2.83)		4.45* (1.92)
(12)	0.989	2.26-		3.20*** (0.704)	0.000 (0.356)	9.49** (2.48)	7.30*** (1.47)			
(13)	0.989	2.05-		3.88** (1.14)	0.097 (0.383)	8.95** (2.62)	6.73*** (1.56)	—2.05 (2.69)		
(14)	0.989	2.33-		3.29*** (0.749)	0.067 (0.392)	9.31** (2.58)	6.89*** (1.64)		0.380 (0.797)	
(15)	0.990	2.25-		2.65** (0.807)	0.250 (0.399)	8.51** (2.55)	6.91*** (1.36)			2.11 (1.63)

[1]) The explanation of the signs following d-values and regression coefficients is given in the footnotes of Tables 16 and 17.

coefficient of the added variable indicates significance at a level of above 95 percent.

Functions (12) to (15) indicate the second phase of analysis when external inputs are divided into two separate components, fertilizer input (X_{1a}) and other external inputs (X_{1b}). The regression coefficients of fertilizers are very significant (in functions 12 and 14 at a level of above 99.9 percent) expressing that one mark (at 1961/62 prices) in fertilizer input adds gross output by 2,7 to 3,9 marks. The effect of fertilizer input was not able to make the regression coefficient of all external inputs significant, however, when treating these inputs as one aggregate like was done in functions (8) to (11). No significant regression coefficients are resulted for external inputs other than fertilizers.

The inclusion of fertilizer input has added the significance of the regression coefficients of both labour and capital inputs, the former up to a level of above 99 and the latter up to above 99.9 percent in each function. The regression coefficient of labour input has also risen whereas that of capital input has remained rather stable compared with functions (8) and (11).

The most conspicuous change caused by the consideration of external inputs as two separate variables is the fact that the regression coefficient of the knowledge and skill factor has turned to illogical, though the coefficient is not significant. This phenomenon might be explained by a theory that the growth in fertilizer use has been affected by the increased knowledge about the influences of fertilizers. Thus, farmer's knowledge might have been indirectly reflected by the use of fertilizers.

June rainfall and Stallings index indicate logical but not significant regression coefficients in functions (14) and (15). Evidently the chance variation in crop production caused by weather is at least partially eliminated in gross output by the use of external inputs.

In further examination of the indicators of the most important internal inputs, i.e. labour and capital, it is noticeable that the regression coefficients of mentioned inputs in the functions (8) to (10) relate closely to those of CSO-functions (1) to (3). The regression coefficients of capital input are directly comparable with each other while the labour input variable in CSO-analysis must be adjusted to million work days before comparison. After this adjustment it can be realized that an addition of labour input by 1 million work days would add gross output e.g. in functions (9) and (10) by 6.61 and 6.89 million marks, respectively, compared with 6.30 and 6.32 millions according to the nearest corresponding CSO-functions (2) and (3).

The functions (14) and (15) are analyzed in more detail by dividing the time period of study into sub-periods. The selection of sub-periods was made rather arbitrarily based on features in the development in input use. The sub-periods do not represent exactly successive spells but cover somewhat each other. The results of this analysis are presented in Table 20.

The multiple correlation coefficients derived from the gross output functions fitted into sub-period data are high though not just so high as the figures derived from the whole period data. Some interesting features appear

Table 20. Gross output functions (14) and (15) estimated from various sub-periods. Multiple correlation coefficients (R), Durbin-Watson test-values (d), regression coefficients and their standard errors (in parentheses below coefficients) [1])

Function	Sub-period	R	d	Fertilizers X_{1a}	Other external inputs X_{1b}	Labour input X_2	Capital input X_3	June rainfall X_6	Stallings index X_7
(14) ..	1950—1962	0.987	2.60−	5.83** (1.51)	0.476 (0.390)	4.62 (3.33)	0.585 (3.14)	1.87° (0.869)	
(14) ..	1954—1966	0.987	2.81−	4.31° (2.04)	0.335 (0.556)	9.68* (3.62)	5.40 (4.35)	0.805 (1.11)	
(14) ..	1957—1969	0.977	2.67−	3.40* (1.15)	—0.138 (0.516)	12.77* (4.23)	10.18* (2.99)	—0.184) (0.929)	
(15) ..	1950—1962	0.985	2.39−	4.60* (1.50)	0.568 (0.473)	2.72 (4.19)	1.53 (3.25)		3.66 (2.13)
(15) ..	1957—1969	0.979	2.80−	3.13* (1.21)	0.040 (0.548)	11.74* (4.26)	9.34* (2.85)		1.27 (2.00)

[1]) The explanation of the signs following d-values and regression coefficients is given in the footnotes of Tables 16 and 17.

regarding regression coefficients. The regression coefficients are generally less significant than those derived from whole period data because of lesser number of degrees of freedom in the former case. Some interesting features appear regarding regression coefficients. In the case of fertilizers, the later is the period in question and thus, the greater is fertilizer use, the lower is coefficient. This refers clearly to the existence of the so-called principle of diminishing returns. The regression coefficients of labour input indicate an opposite development. The more scarce is labour force, the higher is coefficient. This is also quite logical. In the case of capital input the coefficient has also risen through time, although the real capital stock has increased. It is probable, however, that the quality of capital has also increased and led to higher productivity. Both June rainfall and Stallings index indicate higher coefficients in the earlier than in the later periods of study. This phenomenon can be also explained logically. In the earlier periods when the fertilizer use was rather scarce and the technology of production was relatively poor, crop production was more susceptible to influences of weather than during the later parts of study period.

The most relevant problems which often may exist in studies based on time series are autocorrelation and multicollinearity. Autocorrelation means that the residuals unexplained by a function are serially correlated. Autocorrelation may be either positive or negative. In the former case several successive values estimated by a function differ from the observed values in the same given direction and following successive values in the opposite direction. If significant negative autocorrelation exists, the estimated values deviate from the observed values alternately to both directions. Negative autocorrelation may occur if the functions used are not able to explain e.g. seasonal variation in observed values which often is a problem in short term analyses. In studies, like the present one, which are based on annual observations during long periods seasonal variation does not usually raise any problems as a source of error, especially if the industry in question is not susceptible to business cycles. That is why the Durbin-Watson test is made in the present study against positive autocorrelation only. The test-value d is computed as follows (see DURBIN & WATSON 1951):

$$d = \frac{\sum_{t=2}^{N} (d_t - d_{t-1})^2}{\sum_{t=1}^{N} d_t^2}$$

In the formula d_t is the unexplained residual for observation t and N is the number of observations.

Table 21. Correlation coefficient matrix of the variables. AERI-functions

Variable	Gross output Y	Fertilizers X_{1a}	Other external inputs X_{1b}	Labour input X_2	Capital input X_3	Knowledge and skill factor X_4	June rainfall X_6	Stallings index X_7
Y	1.000	0.946	0.941	—0.926	0.973	0.904	—0.278	0.032
X_{1a}		1.000	0.914	—0.974	0.937	0.982	—0.424	0.060
X_{1b}			1.000	—0.934	0.967	0.898	—0.352	—0.186
X_2				1.000	—0.958	—0.960	0.393	0.044
X_3					1.000	0.903	—0.274	—0.085
X_4						1.000	—0.407	0.080
X_6							1.000	
X_7								1.000

As indicated by Tables 16 and 17 no significant positive autocorrelation appears in the cases of six CSO-functions and in the seventh (1) the test was inconclusive which means that more observations would have been needed in that case to ascertain the results of test. In AERI-functions test-values indicate no significant positive autocorrelation either though the test regarding the function (8) was inconclusive like in the corresponding CSO-function (1). With regard to negative autocorrelation the test is inconclusive in functions (11), (12), (14) and (15), however, as well as in each function based on sub-period data (Table 20). At any rate, the estimated functions seem to be quite succesful as to autocorrelation.

Multicollinearity, or correlation between independent variables, causes a somewhat disturbing problem in this study. The degree of multicollinearity is expressed by the correlation coefficient matrix of linear variables of AERI-functions in Table 21. The simple correlations of gross output to each single input are also presented (in row 1).

Thus, the problem is seen to exist here as it has in several other studies (e.g. NIITAMO 1958, p. 88—89) based on time series. A main reason for multicollinearity in the present study (as it was in NIITAMO's) seems to be the strong correlation of each dependent input variable with time. This indicates how the technological change is indirectly reflected by time.

To eliminate some of the influence of multicollinearity the functions of Table 19 are fitted into the first difference data of the variables. The results obtained [1]) indicate that fertilizers and in most cases also capital had significant regression coefficients (at 95 percent level) but those of labour input were insignificant. These results give some additional evidence about the reliability of the indicators of initial functions. The functions fitted into first difference data have low multiple correlation coefficients which seems quite natural, however, because of elimination of trends of gross output and inputs.

[1]) The results, not presented here, are obtainable from the author.

4.2. Production functions for net output and partial net productivity of labour

In the section on functional relationships between net output and corresponding inputs, all inputs except the external ones are taken into consideration as independent variables. It would be illogical to explain the variations in net output by external inputs, since net output was obtained by deducting just these inputs from gross output. Thus, although this operation is based on the unsure assumption that the average productivity of external inputs equals 1, it is clear that these inputs can no longer be considered because their estimated contribution has already been excluded from the output side.

Linear and Cobb-Douglas functions are fitted regarding net output, too. Since the Cobb-Douglas function is based on a hypothesis that inputs are completely substitutable for each other (HEADY & DILLON 1966, p. 84—85) which is not always logical, the original intent had been to use a so-called CES-production function in the present study, also. The CES (constant elasticity of substitution)-function developed by ARROW et.al. (1961, p. 228—231) has the form

$$Y_N = a\,[b \cdot L^{-\alpha} + (1 - b)\,C^{-\alpha}]^{-\frac{v}{\alpha}}, \quad \text{where } Y_N = \text{net output}$$

$$L = \text{labour input}$$

$$C = \text{capital input}$$

$$a,\ b,\ \alpha \text{ and } v = \text{constants } (0 < b < 1)$$

$$\alpha = \frac{1}{\delta} - 1, \quad \text{where } \alpha = \text{substitution parameter and}$$

$$\delta = \text{elasticity of substitution}$$

Unfortunately, the computer programs which could handle this type of function were not available and, therefore, it had to be ignored.

Table 22. Linear production functions for net output. Multiple correlation coefficients (R), Durbin-Watson test-values (d) [1]), regression coefficients [2]) and their standard errors (in parentheses below coefficients). CSO-statistics

Function	R	d	Labour input X_2	Capital input X_3	Knowledge and skill factor X_4	Time-variable t
(16)	0.848	1.66-	0.282° (0.154)	4.51** (1.19)		
(17)	0.859	2.03-	0.486° (0.248)	4.65** (1.20)	2.45 (2.35)	
(18)	0.860	2.05-	0.494° (0.256)	6.07 (4.30)	3.65 (4.24)	—0.125 (0.362)

[1]) and [2]) See footnotes in Tables 16 and 17.

Table 23. Cobb-Douglas production functions for net output. CSO-statistics

Function	R	d	$\ln X_2$	$\ln X_3$	$\ln X_4$	ln t	t
(19)	0.833	1.39°	0.256 (0.198)	1.08** (0.301)			
(20)	0.861	2.04⁻	0.794* (0.369)	0.979** (0.292)	0.518 (0.306)		
(21)	0.864	1.97⁻	0.623 (0.482)	1.25 (0.998)	0.302 (0.489)	—0.052 (0.091)	
(22)	0.862	2.01⁻	0.801* (0.370)	0.974** (0.289)	0.520 (0.309)		—0.000 (0.031)

The results obtained by the two types of functions fitted into CSO-data are presented in Tables 22 and 23. Multiple correlation coefficients obtained are clearly lower than those derived from functions for gross output. This is partially due to the fact that, after deducting external inputs, the chance variation of gross output was accumulated into net output. Actually, such variation in net output has been relatively wider than in gross output which is readily noticeable through comparison of Figure 7 with Figure 6. In the former figure the observed values of net output are presented compared with those estimated by function (21).

The F-test-values derived from analyses of variance for the multiple regression indicate a confidence level of above 99.9 percent for each function, however. When adding independent variables to functions (16) and (19) no significant difference in fit could be discussed. Thus, the error mean square derived from function (21), for example, differs from that of function (19) at a probability level of only about 65 percent.

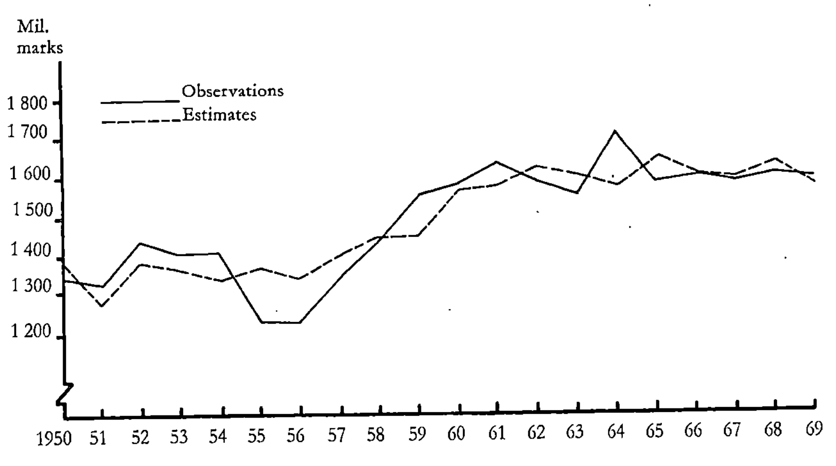

Figure 7. The observed values of net output (CSO) and corresponding values estimated by function (13)

In the case of linear functions, the capital and knowledge and skill factor are the inputs with highest regression coefficients. These coefficients of the latter factor are nct significant, however. This holds true regarding Cobb-Douglas functions as well. Regression coefficients of labour input are more significant than those indicated by the functions for gross output. The effect of the time-variable is quite insignificant as was the case in the gross output functions. The constructed technological factor (X_5) is not included in the functions in Tables 22 and 23 because of illogical regression coefficients which resulted when it was applied. A function (not presented in the tables either) where the knowledge and skill factor (X_4) were replaced by technological factor (X_5), indicated a positive and even otherwise logical regression coefficient for the latter factor but the multiple correlation coefficient for the function was rather low (0.808). At any rate, it seems evident that the knowledge and skill factor also reflects technological change and as such serves in degree as a substitute for variable X_5 and for the time-variable as well. To add the information about the separate effects of individual inputs the partial correlation coefficients (r) derived from selected functions are presented below.

Function	X_2	X_3	X_4	t
(8)	0.41	0.68	.	.
(9)	0.44	0.70	0.25	.
(11)	0.30	0.66	.	.
(12)	0.47	0.64	0.39	.
(13)	0.31	0.38	0.16	—0.14

Through a more detailed study on the regression coefficients of single inputs the corresponding marginal rates of substitution can be derived. The Cobb-Douglas type function (20), where the most significant regression coefficients appeared, indicates — after conversion of labour input to work-days and capital input to real capital stock — that the marginal rate of substitution of capital for labour at their mean levels is 50.76. This ratio implies that an investment of approximately 50 million marks (1964 currency) would substitute 1 million work-days which ratio seems very favourable for investments. Within the limits determined by the standard errors of the regression coefficients in question the amount of investment required may vary from 20.5 to 104 million marks. Thus, the limited information available about labour and capital inputs as well as the relatively low multiple correlation coefficients obtained dictate a cautions attitude when evaluating the results above.

The Durbin-Watson test-values (d) indicate that no significant positive autocorrelation appears in the cases of functions other than (19) where the test-value obtained (1.39) was only slightly below limit-value ($d = 1.41$) for no significant autocorrelation. Thus, autocorrelation appears to present no

Table 24. Production functions for partial net productivity of labour. Multiple correlation coefficients (R), Durbin-Watson test-values (d), regression coefficients and their standard errors. Linear and Cobb-Douglas functions

Function	R	d	Capital input X_3	Knowledge and skill factor X_4	Time-variable t
(23)	0.955	2.06-	0.00127**	0.00198*	
			(0.00043)	(0.00069)	
(24)	0.956	2.06-	0.00207	0.00264	—0.00719
			(0.00197)	(0.00173)	(0.0172)
			$\ln X_3$	$\ln X_4$	ln t
(25)	0.954	1.96-	1.09*	0.563*	
			(0.391)	(0.218)	
(26)	0.956	2.06-	1.90	0.433	—0.073
			(1.17)	(0.283)	(0.099)

problem here. Multicollinearity, however, disturbs the analysis even more than was the case with the gross output functions. The correlation between independent variables, omitting external inputs, relates closely to those of the matrix on page 81.

When comparing the functions above with the corresponding ones estimated from AERI-series no practical differences in fit are found. A few unimportant differences exist in regression coefficients, however.

Production functions for partial net productivity of labour also are estimated but only in an experimental sense. The variation in partial net productivity of labour are explained by capital input, knowledge and skill factor and time-variable. Labour input would be illogical as an explanator in this case bacause labour input is included in dependent variable as denominator of net output. The results obtained using linear and Cobb-Douglas functions are presented in Table 24.

Multiple correlation coefficients are clearly higher than those derived from functions explaining changes in net output. This is obviously due to the fact that the chance variation in net output is partially levelled by the division by labour input and that the trend line of partial net productivity of labour rises more in parallel with trends of independent variables than did the trend of net output.

With only two independent variables, i.e. capital input and knowledge and skill factor, the regression coefficients of these variables are statistically significant for both types of function. Including the time-variable in the functions, caused the above coefficients to become less significant while the regression coefficients of the added variable acted illogically. No significant autocorrelation can be recognized in the cases of the functions in question.

Initially it was also intended as a part of this study, (following the example of Niittamo, 1958, p. 98—108) to formulate a Cobb-Douglas type function for net output, designated simply as $Y_N = a\ L^{\alpha}\ C^{\beta}$, to meet the requirement that the sum of exponents $(\alpha + \beta)$ would equal 1. The function can then be written also as $Y_N = a\ L^{1-\beta}\ C^{\beta}$. In this case the labour productivity function could be constructed simply in the form

$$\frac{Y_N}{L} = a \left(\frac{C}{L}\right)^{\beta}$$

The knowledge and skill variable as well as time-variable could also be included in this function. This function would then relate closely to the corresponding function for net output. If designating the latter function as $Y_N = a\ L^{1-\beta}\ C^{\beta}\ K^{\gamma}\ e^{\sigma t}$ (where K = knowledge and skill factor) the labour productivity function would be resulted as

$$\frac{Y_N}{L} = a \left(\frac{C}{L}\right)^{\beta} K^{\gamma}\ e^{\sigma t}$$

where the constant »a» as well as each exponent would equal those of the net output function. Again, unfortunately, the restriction that $\alpha + \beta = 1$ could not be met by available computer programs.

5. SUMMARY AND CONCLUSIONS

The purpose of this study was to make the definitions of some productivity concepts clearer, to discuss the problems in measurement of productivity, especially from macroeconomic point of view, and investigate the development of productivity in the Finnish agricultural sector in 1950—1969. In addition, aggregate production functions were estimated to explain variations in gross and net output and in labour productivity.

The most relevant concepts defined and used in this study were total gross productivity, total net productivity, net productivity of labour, net productivity of capital and partial net productivity of labour. The first one expresses gross output in ratio to all inputs and total net productivity indicates net output in ratio to the sum of labour and capital inputs. Net productivity of labour expresses net output reduced by capital input in ratio to labour input and net productivity of capital was defined correspondingly. Partial net productivity of labour, which probably is the most commonly used concept, expresses net output in ratio to labour input exclusively. A new concept of efficiency was also defined in the present study.

The problems involved in measuring outputs or inputs as volume indices were treated in detail. Possibilities in measuring separately the influences of structural and internal changes in productivity were taken into consideration. In addition, a few problems included in the measurement of labour and capital inputs were handled.

The empirical data of this study is based, for the part of gross output and external inputs, on the national income statistics of Central Statistical Office (CSO) on one hand and on the so-called total accounts of agriculture prepared by the Agricultural Economics Research Institute (AERI) on the other. A few other separate statistics and studies were utilized to construct labour and capital input series. The results derived from bookkeeping farm accounts were also used for comparison. The weighted average of all farms as well as size classes I—II (less than 10 hectares of arable land) and VI (above 50 hectares) were selected into detailed analysis. This analysis was limited to cover only 1960's, however.

The linear trends estimated from CSO-series indicated an increase of 2.8 percent per year in gross output compared with 2.3 percent derived from

AERI-series. The average growth in net output was slower approximating 1 percent per year in both cases.

The volume of external inputs rose rapidly and according to CSO-series more than tripled compared with an increase of above 2.7 times in AERI-series. The new series on labour input constructed in the present study indicated an average annual decline of slightly more than 2 percent. The real capital input of agriculture rose around 35 percent during the whole period of study.

The development of total gross productivity derived from estimated linear trends indicated an average increase of 2.7 percent per year in CSO-series and 2.5 percent in AERI-series. The growth was a little faster in 1950's than during the latter half of the study period. In a more detailed examination a spell of rather slow development was found in the early 1950's followed by a period of rapid rise round the year 1960 and a span of slackening growth in late 1960's. Features being rather equal to those of total gross productivity also appeared in the development of other productivity measures though their trends were more sharply rising and annual variations in their observed values were somewhat wider than those of total gross productivity. The average rise of total net productivity derived from trend line approximated 3 percent per year in both series. The rate of growth in both net productivity of labour and partial net productivity of labour varied from 3.7 to 3.8 percent per year in each of the two series.

Problems arose when attempting to derive productivity estimates from bookkeeping accounts comparable with the aggregate figures. A main reason for the problems was the difficulty to eliminate the effect of the 1968 change in bookkeeping system. Anyway, it seemed evident that rate of productivity growth indicated by bookkeeping results was somewhat slower than that of the whole agricultural sector. This implies the influence of structural change upon the sectoral productivity increase.

An interesting additional information about the relative productivity growth in Finnish agricultural sector can be obtained through comparison with the corresponding situation in Sweden. The figures about Sweden are based on the study of GULBRANDSEN & LINDBECK (1969, p. 180) and they indicate development in a measure that expresses agriculture's contribution to real gross domestic product in ratio to labour input. To make the figures about Finland comparable with the preceding ones net output is added by depreciation and the sum is expressed in ratio to labour input. Because of this addition the series of the new measure differs somewhat upwards from that of partial net productivity of labour presented in Table 13. The comparison, where the AERI-figures are used, is presented below.

Crop year	Finland	Sweden	Crop year	Finland	Sweden
1950/51	100	100	1959/60	144	140
1951/52	107	103	1960/61	148	141
1952/53	117	111	1961/62 ..	159	160
1953/54	118	117	1962/63	156	165
1954/55	122	117	1963/64	165	161
1955/56	111	110	1964/65	188	182
1956/57	116	129	1965/66	178	198
1957/58	125	133	1966/67	191	194
1958/59	132	129	1967/68	198	251

The figures indicate quite a parallel development up to crop year 1967/68 when a dramatic rise [1]) took place in labour productivity of Swedish agriculture. This consistent development appears somewhat surprising because the structural change in Swedish agriculture probably was already in 1950's at least at the same stage as in Finland in 1960's. One has to consider, however, that the development of productivity in Swedish agriculture in 1940's evidently was clearly faster than that in Finland. According to GULBRANDSEN & LINDBECK the index of labour productivity in 1950/51 approximated 157 if designating 1940/41 as 100. The study of SUOMELA (1958, p. 96) indicates remarkably slower, if any, rate of growth in Finnish agriculture. Although his concept (= partial net productivity of labour) differs a little from that of GULBRANDSEN & LINDBECK and although his study, based on bookkeeping accounts, primarily reflects changes in productivity within individual farms, the figures plausibly are rather comparable, however, since no structural advance occurred in Finnish agriculture in 1940's.

A spell of rather rapid productivity growth took place in Finnish agricultural sector round the year 1960 as was already mentioned. Without any accurate examination it can be recognized that, besides a few favourable growing seasons at that time, the price ratio of bread grain to most other products was made rather favourable through the official price regulations in 1958 and 1962. This increased the acreage of bread grain remarkably. Since this production line was relatively easy to rationalize, the shift to bread grain production obviously was at least partially responsible for the rapid rise in productivity.

In the last chapter of this study aggregate production functions were estimated to explain variation in gross output, net output and partial net productivity of labour. Linear and Cobb-Douglas functions were used in analyses. Multiple correlation coefficients derived from the gross output functions were quite high varying from 0.993 to 0.976. Capital input, knowledge and skill factor and labour input had the highest regression coefficients

---

[1]) Obviously it was a real rise rather than misprint since a marked increase took place in gross domestic product of agriculture while the labour input declined clearly.

in the first phase of analysis. Capital input was the only one, however, having significant coefficients. At the later stage of analysis external inputs were divided into two components: fertilizers and other external inputs and two weather variables, June rainfall and so-called Stallings weather index, were included as well. This procedure changed some of the indicators of functions markedly. Fertilizers indicated regression coefficients being significant from 99 up to above 99.9 percent level. The regression coefficients of capital input exceeded the significance level of 99.9 percent in each function and labour input exceeded 99 percent level, accordingly. The inclusion of fertilizer input as a separate variable changed the regression coefficient of knowledge and skill factor to negative. Evidently, farmers' increased knowledge was reflected in higher fertilizer intensity. The weather variables has mostly insignificant regression coefficients the effect of Stallings index on output being somewhat stronger than that of June rainfall.

Multiple correlation coefficients derived from the net output functions were clearly lower than above or from 0.864 to 0.833. In these functions especially capital but also the knowledge and skill of farmers as well as labour input had rather strong effects on output. In one (20) of the net output functions, having the most significant regression coefficients, the marginal rate of substitution of capital for labour indicated that an increment of 50 million marks in real capital stock would substitute 1 million work-days. This ratio implies advantages of sensible investment.

Of the problems generally involved in studies based on time series the autocorrelation did not raise any questions in the present study. Instead, rather strong multicollinearity disturbed the analyses. Some additional more detailed analyses with functions fitted into first differences data of variables ascertained the reliability of the results obtained, however.

REFERENCES

Arrow, K. J. 1962. The economic implications of learning by doing. Rev. of Ec. Studies. Vol. 29: 154—174.

—»— & Schenery, H. B. & Minhas, B. S. & Solow, R. M. 1961. Capital labour substitution and economic efficiency. The Rev. of Ec. and Stat. Vol. 43, 3: 225—250.

Austad, K. 1957. Produktiviteten i jordbruket. Mål og midler. Vinterlandbr. skolen og Landbr. akad. småskrifter 10, 95 p.

Böker, R. 1952. Die Produktivität in der Landwirtschaft. Ber. ü. Landw. Vol. 30: 161—166.

Clark, C. 1951. The conditions of economic progress. XIII + 584 p.

Durbin, J. & Watson, G. S. 1950 and 1951. Testing for serial correlation in least squares regression. Parts I and II. Biometrika. Vol. 37: 409—428 and Vol. 38: 159—178.

Geuting, H. 1954. Masstäbe der Produktivität und Rentabilität. Handb. der Landw. 2. Aufl. Bd. 5: 463—490.

Griliches, Z. 1957. Specification bias in estimates of production functions. J. of Farm Ec. Vol. 39, 1: 8—20.

Gulbrandsen, O. & Lindbeck, A. 1969. Jordbruksnäringens ekonomi. 280 p. Stockhoml.

Heady, E. O. 1952. Economics of agricultural production and resource use. 850 p. New York.

—»— & Dillon, J. L. 1966. Agricultural production functions. VIII + 667 p. Ames.

Ihamuotila, R. 1968. Viljelijöiden työtulojen taso kirjanpitotiloilla 1956—1965. (Summary: Labour income level of farmers on Finnish bookkeeping farms in 1956—1965). Maat.tal. tutk.lait. julk. 10: 1—172.

—»— 1971. Pääoman merkityksestä tuotannontekijänä Suomen maataloudessa vuosina 1948—1970. Erip. Osuuspankkijärj. tal. kats. 2. 8. p.

—»— & Stanton, B. F. 1970. A balance sheet of agriculture for Finland 1948—1967. Publ. of the Agr. Ec. Res. Inst. 20: 1—122.

Kaarlehto, P. & Stanton, B. F. 1966. Productivity in Finnish agriculture 1956—57 to 1965—66. Bank of Finland Monthly Bull. Vol. 40, 12: 18—23.

Kaitila, E. 1964. Taseoppi. 182 p. Porvoo.

Kendrick, J. 1961 a. Productivity trends in the United States. LII + 630 p. Princeton.

—»— 1961 b. Some theoretical aspects of capital measurement. Am. Ec. Review. Vol. 51, 2: 102—111.

Kettunen, L. & Torvela, M. 1970. The intensity and interdependence of gross return and factors of production in agriculture. Publ. of the Agr. Ec. Res. Inst. 19: 1—92 + 2 app.

Klauder, G. 1953. Zur Systematik der Produktivität. Ber. ü. Landw. Vol. 31, 4: 508—512.

Kuznets, S. 1946. National product since 1869. 430 p. New York.

Ladd, G. W. 1957. Biases in certain production indexes. J. of Farm. Ec. Vol. 39, 1: 75—85.

LAVE, L. B. 1962. Empirical estimates of technological change in United States agriculture 1850—1958. J. of Farm Ec. Vol. 44, 4: 941—952.

LOOMIS, R. A. & BARTON, G. T. 1961. Productivity of agriculture, United States 1870—1958. USDA Techn. Bull. 1 238: 1—63.

Maa- ja metsätalousministeriön asettaman työryhmän selvitys maatalouden tulotason kehityksestä 1968—1971. 1971. II + 72 p.

MARJOMAA, P. 1968. Maataloutta vuosina 1948—1965 koskeva kansantulotilasto (Summary: National income statistics for agriculture 1948—1965). Erip. Til. kats. 9: 43—66.

NELSON, R. R. 1964. Aggregate production functions. Am. Ec. Rev. Vol. 54, 5: 575—606.

NIITAMO, O. 1954. Tuottavuus mitattuna tuotannon tuloksen ja työpanoksen suhteena ja sovellutus Suomen teollisuuteen. Kans. tal. aikak. Vol. 50, 3: 175—192.

—»— 1958. Tuottavuuden kehitys Suomen teollisuudessa vuosina 1925—1952. Kans. tal. tutkimuksia 20: 1—192.

—»— 1969. Tuotantofunktio, sen jäännöstermi ja teknillinen kehitys. Til. päätoim. Monist. tutk. 9: 1—49.

NOU, J. & NILSSON, O. 1955. Produktivitet och produktivitetsberäkningar inom jordbruket. Kungl. lantbr. akad. tidskr. 94: 159—209.

OURY, B. 1965. Allowing for weather in crop production model building. J. of Farm Ec. Vol. 47, 2: 270—283.

PRIEBE, H. 1952. Arbeitsproduktivität in der Landwirtschaft. Ber. ü. Landw. Vol. 30, 2: 167—178.

ROUHIAINEN, J. 1972. Aggregate crop production functions in Finnish agriculture in 1956/57—1968/69. An unpublished Master's thesis. Univ. of Minnesota. 76 p.

RUSTEMEYER, F. C. 1964. Die Produktivität der Landwirtschaft — Begriff, Messung und Anwendung. 149 p. Göttingen.

RUTTAN, V. W. 1964. Technological progress in the meat packing industry. USDA Marketing Res. Report 59.

RYYNÄNEN, V. 1970. Tutkimuksia maatalouden tuotantofunktioista Sisä-Suomen kirjanpitoviljelmillä vuosina 1960—1966. (Summary: Production function analyses of farm management survey data in Central Finland in 1960—1966). Acta Agralia Fennica 120: 1—66.

SHAW, L. H. 1964. The effect of weather on agricultural output: A look of methodology. J. of Farm Ec. Vol. 46, 1: 218—230.

SOLOW, R. M. 1957. Technical change and aggregate production function. Rev. of Ec. and Stat. Vol. 39, 3.

—»— R. M. 1962. Substitution and fixed proportions in the theory of capital. The Rev. of Ec. Studies 6.

STALLINGS, J. 1960. Weather indexes. J. of Farm Ec. Vol. 42, 1: 180—186.

SUOMELA, S. 1958. Tuottavuuden kehityksestä Suomen maataloudessa. (Summary: Development of producticity in Finnish agriculture). Maat. tal. tutk. lait. julk. 1: 1—128.

—»— 1968. On the concept of productivity. J. of the Sci. Agr. Soc. of Finland. Vol. 40, 2: 96—105.

SVT (Suomen virallinen tilasto) III: 45, 1. Yleinen maatalouslaskenta v. 1950. 1954.

SVT III: 53, 1. Yleinen maatalouslaskenta v. 1959. 1962.

SVT III: 67, 2. Yleinen maatalouslaskenta v. 1969. 1970.

TAYLOR, H. C. 1949. Outlines of agricultural economics. 614 p. New York.

Tutkimuksia Suomen maatalouden kannattavuudesta, tilivuodet 1950/51—1969.

WESTERMARCK, N. 1956. Jordbruksproduktionens lokalisering och utformning. Lantbrukets driftsekonomi, p. 317—404.

SELOSTUS

TUOTTAVUUDESTA JA TUOTANTOFUNKTIOISTA SUOMEN MAATALOUDESSA VUOSINA 1950—1969

Makrotaloudellinen tutkimus

RISTO IHAMUOTILA

Tämän tutkimuksen tarkoituksena on ollut selventää eri tuottavuuskäsitteiden sisältöä ja tarkastella tuottavuuden mittaamiseen liittyviä ongelmia erityisesti makrotalouden kannalta sekä selvittää tuottavuuden kehitystä Suomen maataloussektorissa vuosina 1950—1969. Tutkimukseen sisältyy myös aggregaattituotantofunktiotarkastelu, jossa kokonaistuotoksen, nettotuotoksen ja työn tuottavuuden muutoksia on selitetty eri panostekijöiden avulla.

Tutkimuksessa käytetyt tuottavuuskäsitteet ovat kokonaistuottavuus, nettotuottavuus, »traditionaalinen» työn tuottavuus ja »varsinainen» työn tuottavuus. Täydellinen eli *kokonaistuottavuus* ilmaisee kokonaistuotoksen (kokonaistuoton volyymin) suhteessa kaikkien tuotantopanosten kokonaismäärään (tuotantokustannuksen volyymiin) eli kaavan muodossa:

$$P_{GT} = \frac{Q}{I}, \text{ jossa } P_{GT} = \text{kokonaistuottavuus}$$

Q = kokonaistuotos

I = panosten yhteismäärä

Kokonaistuottavuus on käsitteenä erittäin looginen, mutta on ollut suhteellisen vähän käytetty. Kenties vieläkin harvinaisempi käsite on *nettotuottavuus*, jolla tässä tutkimuksessa on tarkoitettu nettotuotoksen suhdetta työ- ja pääomapanoksen summaan. Nettotuotos saadaan vähentämällä kokonaistuotoksesta elinkeinon (tai yrityksen) ulkopuolelta ostetut panoserät (vastaavien kustannusten volyymi) poistot ja kunnossapito mukaanluettuna. Nettotuotos osoittaa siten sen osan kokonaistuotoksesta, mikä on tuotettu elinkeinon (tai yrityksen) sisäisillä panostekijöillä, työpanoksella ja pääomalla. Nettotuotoksen laskeminen perustuu kuitenkin siihen nimenomaiseen olettamukseen, että ulkoisten panostekijöiden keskimääräinen tuottavuus = 1. Tällainen oletukseen perustuvuus on kaikkien muiden tuottavuuskäsitteiden paitsi kokonaistuottavuuden heikkoutena. Nettotuottavuus voidaan ilmaista seuraavassa muodossa:

$$P_{NT} = \frac{Q - G}{L + C}, \text{ jossa } P_{NT} = \text{nettotuottavuus}$$

G = ulkoiset panokset

Q—G = nettotuotos

L = työpanos (työpanoksen arvo kiintein hinnoin)

C = pääomapanos (pääoman korkovaatimus kiintein hinnoin)

Laskettaessa nettotuotos pelkästään työpanosta kohden on kysymyksessä yleisimmin käytetty tuottavuuskäsite, jota tässä tutkimuksessa on kutsuttu *»traditionaaliseksi» työn tuottavuudeksi.* Se voidaan ilmaista seuraavasti:

$$P_{L(P)} = \frac{Q - G}{L}$$

Käsite on kuitenkin teoreettisesti erheellinen sentähden, että pääoman lisäyksestä aiheutuva nettotuotoksen lisäys heijastuu työn tuottavuuden kohoamisena, vaikkei työpanoksen määrässä tai laadussa olisi tapahtunut minkäänlaisia muutoksia. Tämän epäkohdan poistamiseksi tässä tutkimuksessa on muodostettu uusi, *»varsinaiseksi» työn tuottavuudeksi* nimitetty käsite, jonka sisältö ilmenee oheisesta kaavasta:

$$P_L = \frac{Q - G - C}{L}$$

»Varsinaista» työn tuottavuutta laskettaessa on nettotuotoksesta siis vähennetty pääomapanos ja vasta jäännös jaettu työpanosta kohti. »Varsinainen» pääoman tuottavuus voidaan määrittää vastaavalla tavalla. On kuitenkin huomattava, että kummassakin viimeksi mainitussa tapauksessa muiden kuin tutkittavana olevien panosten keskimääräiseksi tuottavuudeksi on jälleen oletettu 1. »Oikea» työn tuottavuus saataisiinkin selvitetyksi vasta silloin, kun luotettavan tuotantofunktion pohjalta on estimoitavissa työpanoksella aikaansaatu osuus kokonaistuotoksesta, joka sitten ilmaistaan työpanosta kohden.

Tutkimuksessa on käsitelty mm. tuottavuuden ja kannattavuuden välistä eroavuutta ja kiinnitetty huomiota eräisiin muihin tuottavuutta lähellä oleviin käsitteisiin. Siinä yhteydessä on myös muodostettu sektori- ja yrityskohtaisiin analyyseihin soveltuva uusi *tehokkuuskäsite,* mikä voidaan ilmaista seuraavassa muodossa:

$E = \frac{B_{Min}}{B}$, jossa E = tehokkuus

B_{Min} = pienin mahdollinen panosmäärä, jolla tietty tuotos voidaan tuottaa

B = tämän tuotoksen aikaansaamiseen todellisuudessa käytetty panosmäärä

Kaavasta näkyy, että tehokkuus voi teoriassa saada arvoja välillä 0—1 viimeksi mainitun suhdeluvun osoittaessa optimaalista tehokkuuden astetta.

Teoreettiselta kannalta katsottuna tuottavuus on luonteeltaan teknillinen käsite. Koska eri tuotosten ja varsinkin tuotantopanosten saattaminen yhteismitallisiksi joitain teknillisiä mittayksiköitä käyttäen on mahdotonta, on mittaaminen tehtävä rahayksiköissä, toisin sanoen käyttämällä tietyn kauden kiinteitä hintoja koko tutkittavalle ajanjaksolle. Tähän menettelyyn on sovellettavissa useitakin eri volyymi-indeksikaavoja, jotka kuitenkin antavat helposti toisistaan poikkeavia tuloksia erityisesti pitkien aikavälien ollessa kysymyksessä. Näin on siksi, että tuotteiden ja toisaalta tuotantopanosten keskinäisissä hintasuhteissa tapahtuu yleensä ajan mittaan muutoksia. Esimerkki näistä poikkeavista tuloksista on esitetty asetelmassa sivulla 20, jossa väkilannoitteiden, koneiden ja kaluston sekä palkatun työn yhdistetty panosindeksi on laskettu eräille vuosille neljää yleistä indeksikaavaa käyttäen.

Edelleen on käsitelty niitä mittausongelmia, joita esiintyy pyrittäessä selvittämään, mikä osuus esim. tietyllä sektorilla tapahtuneesta tuottavuuden kohoamisesta on ollut seurausta sektorin sisällä yrityksissä tapahtuneesta tuottavuuden noususta, mikä taas rakenteellisista muutoksista. Tutkimuksessa on myös kiinnitetty huomiota työ- tai pääomapanosten mittaamiseen tuottavuusanalyyseissä, ottaen nimenomaan huomioon näiden panosten laadussa inhimillisen tiedon tason kohoamisen ja teknologian kehityksen kautta tapahtuneen paranemisen.

Tutkimusaineisto perustuu pääosaltaan ns. kokonaistilaistoihin. Kokonaistuotoksen ja maatalousektorin ulkopuolelta ostettujen panosten osalta tutkimus perustuu toisaalta Tilastokeskuksen kansantulotietoihin ja -lukusarjoihin (tutkimuksessa käytetty lyhennettä CSO) toisaalta taas Maatalouden taloudellisen tutkimuslaitoksen kokonaislaskelmaan (lyhennetty AERI). Näistä kummastakin lähteestä johdetut sarjat on esitetty rinnakkain tuotosten, panosten ja tuottavuuden kehitystä tutkittaessa. Työ- ja pääomapanoksen selvittämiseksi on nojauduttu myös muihin kokonaistilastoihin sekä eräisiin tutkimuksiin. Myös kirjanpitotilojen aineistoa on käytetty tutkimuksessa apuna, lähinnä sentähden, että voitaisiin saada jonkinlainen kuva siitä, mikä osuus maatalousektorissa tapahtuneesta tuottavuuden kokonaismuutoksesta on aiheutunut kehityksestä yksittäisten tilojen sisällä. Tutkimus on kuitenkin tältä osin rajoittunut tilivuosiin 1959/60—1969 käsittäen maan kaikki kirjanpitotilat painotettuna keskiarvona sekä tilasuuruusluokat I—II (alle 10 peltohehtaarin tilat) ja VI (yli 50 peltohehtaarin tilat) Etelä-Suomen tutkimusalueella.

Tuotokset ja panokset on ilmaistu sekä kiinteähintaisina lukusarjoina että volyymi-indekseinä. CSO-sarjojen osalta kunkin vuoden määrät on painotettu kalenterivuoden 1964 hinnoilla. AERI-sarjoissa on puolestaan käytetty satovuoden 1961/62 hintapainoja. Kirjanpitotilojen osalta on täytynyt tyytyä puuttellisempaan ratkaisuun, jossa eri vuosien tuotto- ja kustannuserät on deflatoitu vastaavia, Maatalouden taloudellisen tutkimuslaitoksen hintaindeksejä käyttäen satovuoden 1961/62 tasoon.

Maatalouden kokonaistuotoksen ja nettotuotoksen kehitys on esitetty koko sektoria kuvaavien CSO- ja AERI-sarjojen osalta taulukossa 2 (s. 28). Kokonaistuotos nousi AERI-sarjasta estimoidun lineaarisen trendin mukaan 2.3 % vuodessa koko tutkimuskauden aikana keskimäärin. Vastaava kasvunopeus CSO-sarjasta laskettuna oli 2.8 % vuodessa. Kokonaistuotos kohosi kummankin sarjan mukaan suunnilleen yhtä paljon 1950-luvulla, mutta tutkimusajanjakson jälkimmäisellä puoliskolla CSO-sarja osoitti selvästi nopeampaa nousua kuin AERI-sarja. Tämä johtuu ilmeisesti siitä, että kun jälkimmäinen sarja koskee pelkästään ns. varsinaista maataloutta, niin edellinen puolestaan käsittää maatalousektorin laajempana sisällyttäen siihen myös kauppapuutarhat, turkistarhat jne., joissa tuotoksen nousu on todennäköisesti ollut nopeampaa kuin varsinaisessa maataloudessa. Eroon on lisäksi vaikuttanut se, että CSO-sarjoissa otetaan maatalousektorin sisällä tapahtuneet, esim. rehuviljan, myynnit ja ostot huomioon tuotoissa ja kustannuksissa mitä AERI-sarjoissa ei tehdä.

Nettotuotos [1]) eli toisin sanoen kansantaloudellinen tulo (= nettokansantuote) kiintein hinnoin kohosi tutkimuskauden aikana huomattavasti hitaammin kuin kokonaistuotos eli kummastakin sarjasta laskettujen lineaaristen trendien mukaan noin 1 prosentin vuotta kohden. Nettotuotos pysyi 1960-luvulla jokseenkin muuttumattomana.

Maatalousektorin kansantalouden muilta sektoreilta ostamien panosten reaaliarvo kasvoi tutkimuskauden aikana CSO-sarjan mukaan lähes 3.2- ja AERI-sarjan mukaan yli 2.7-kertaiseksi (taulukko 4). Keskinäinen ero aiheutuu todennäköisesti samoista syistä kuin kokonaistuotoksessa.

Koska maataloutta koskevat työpanostiedot ovat varsinkin tutkimusajanjakson alkupuolen osalta puutteellisia, on tässä tutkimuksessa konstruoitu uudet työpanos-

---

[1]) Nettotuotos = kokonaistuotos — muut panoserät paitsi koko työpanos ja koko pääomapanos.

sarjat. Työpanoksen on yksittäisillä tiloilla oletettu muuttuneen samassa suhteessa kuin ihmistyötuntien lukua hehtaaria kohti osoittava kaikkien kirjanpitotilojen painotettu keskiarvo on muuttunut. Maatalouden rakennemuutoksesta johtuvan työpanoksen vähenemisen huomioon ottamiseksi mainittu sarja on redusoitu maan kaikkien yli 2 ha:n tilojen lukumäärää ilmaisevalla indeksillä. Näin saadun sarjan osoittama työpanoksen kehityssuunta on 1960-luvulla varsin yhdenmukainen Maatilahallituksen ja työvoimatilaston sarjojen kanssa, mutta vuotuiset vaihtelut ovat vähäisemmät ja loogisemmat kuin näissä sarjoissa. Uutta sarjaa on käytetty sellaisenaan vastaamaan AERI-tilastojen mukaisia tuotossarjoja. Työpanossarja CSO-tilastoille on saatu muuttamalla yllä konstruoitua sarjaa ainoastaan siten, että siihen on lisätty CSO- ja AERI-tilastojen osoittamien palkkakustannusten ero työpäiviksi laskettuna. Uudet työpanossarjat poikkeavat siten toisistaan ainoastaan palkatun työn panoksen osalta, joka CSO-sarjassa on suurempi.

Uusien työpanossarjojen muodostuminen on esitetty taulukossa 6 (s. 39). Estimoitujen lineaaristen trendien mukaan työpanos supistui koko tutkimuskaudella CSO-sarjassa 2.1 ja AERI-sarjassa 2.3 prosenttia vuotta kohden. Supistuminen oli 1960-luvulla 1 %-yksikön verran nopeampaa vuotta kohti kuin tutkimuskauden alkupuoliskolla.

Pääomapanos (taulukko 8) on saatu suoraan erillisestä tutkimuksesta (Ihamuotila & Stanton 1970) laskemalla 4 %:n korko kiintein hinnoin määritetylle pääomakannalle. Näin saatua pääomapanossarjaa on käytetty vastaamaan sekä CSO- että AERI-tuotossarjoja.

Kokonaistuottavuuden ja nettotuottavuuden kehitys on esitetty taulukossa 12 (s. 46) sekä AERI-sarjojen osalta myös kuvioissa 4 ja 5, joihin on myös piirretty estimoidut lineaariset trendit. Kokonaistuottavuus on kehittynyt sekä CSO- että AERI-sarjojen pohjalta laskettuna varsin yhdenmukaisesti, joskin yksittäisten vuosien osalla esiintyy toisistaan poikkeavuutta. Tämä on kuitenkin sangen luonnollista jo siitäkin syystä, että CSO-sarjat perustuvat kalenterivuosi-, AERI-sarjat taas satovuosipohjalle. Edellisestä sarjasta estimoidun trendin mukaan kokonaistuottavuus kohosi 2.7 ja AERI-sarjasta estimoidun mukaan 2.5 prosenttia vuodessa. Peräkkäisten havaintoarvojen mukaan laskien kehitys oli tutkimuskauden alkupuoliskolla hieman nopeampaa kuin 1960-luvulla. Yksityiskohtaisemmassa tarkastelussa voidaan todeta suhteellisen hitaan kasvun kausi 1950-luvun alkupuoliskolla, varsin nopea nousu vuosikymmenen vaihteen kummankin puolen ja kasvutahdin hidastuminen 1960-luvun puolivälistä lähtien. Nettotuottavuuden kehitys osoitti varsin samankaltaisia piirteitä kuin kokonaistuottavuudenkin, paitsi että vuosittaiset vaihtelut olivat hieman jyrkempiä ja keskimääräinen kasvu hiukan nopeampaa. Estimoitujen lineaaristen trendien mukaan nettotuottavuus kohosi CSO-sarjoista laskettuna 3.1 ja AERI-sarjoista laskettuna 2.9 prosenttia vuotta kohden.

»Traditionaalisen» ja »varsinaisen» työn tuottavuuden kehitys on esitetty taulukossa 13 ja AERI-sarjojen osalta myös kuvioissa 4 ja 5. Näiden suureiden kehitys on ollut nopeampaa, mutta myös vuosittaiset vaihtelut ovat olleet suurempia kuin kokonais- ja nettotuottavuudessa. Tämä on luonnollisesti johtunut siitä, että työn tuottavuuksia laskettaessa huomioon ottamatta jätettyjen tuotantopanosten (sektorin ulkopuolelta ostetut panokset ja pääomapanos) keskimääräiseksi tuottavuudeksi on oletettu 1, minkä vuoksi niidenkin panosten aiheuttama tuottavuuden lisäys kumuloituu työn tuottavuudessa. Estimoitujen lineaaristen trendien mukaan »traditionaalisen» työn tuottavuuden nousu oli CSO-sarjoista laskettuna 3.8 ja AERI-sarjoista laskettuna 3.7 prosenttia vuodessa ja »varsinaisen» työn tuottavuuden kummassakin tapauksessa 3.7 prosenttia vuodessa.

Kirjanpitotilojen eri ryhmien osalta kokonais- ja nettotuotos on esitetty taulukossa 3, ostettujen panosten määrä asetelmassa sivulla 34, työpanos taulukossa 7 ja pääomapanos taulukossa 9. Tuottavuuden kehitys kaikilla kirjanpitotiloilla keskimäärin (taulukko 14) on ollut samantapaista kuin aggregaattisarjoissakin, mutta jonkin verran hitaampaa kunnes tilivuonna 1968 tapahtui selvä lasku. Tämä johtuu ainakin osaksi siitä, ettei vuonna 1968 kirjanpitosysteemiin tehtyjen muutosten [1]) vaikutuksia tilivuosien 1968 ja 1969 tuloksiin liene saatu tässä tutkimuksessa kokonaan poistettua. Tekemällä eräitä, mainittuja vuosia koskevia lisäoletuksia näyttää siltä, että eri tuottavuussuureiden kehitys kirjanpitotiloilla olisi koko 1960-luvulla ollut jonkin verran hitaampaa kuin kaiken kaikkiaan koko maataloussektorissa. Kirjanpitotulosten nojalla ei mainituista syistä johtuen voida kuitenkaan tehdä täsmällisiä johtopäätöksiä siitä, mikä osuus maataloussektorin tuottavuuden noususta on aiheutunut yksittäisten tilojen sisäisestä tuottavuuden kohoamisesta ja mikä puolestaan jäisi rakennemuutoksista johtuvaksi. Päätelmien tekemistä tuottavuuden kehityksestä kirjanpitotilojen tilasuuruusluokissa I—II ja VI on suuresti vaikeuttanut tilojen huomattava vaihtuminen näissä ryhmissä, johon suuruusluokassa I—II on lisäksi liittynyt tilojen lukumäärän selvä väheneminen. On kuitenkin ilmeistä, että tuottavuuden nousu on ollut suurilla kirjanpitotiloilla nopeampaa kuin pienillä.

Tutkimuksessa on estimoitu kokonaistuotoksen, nettotuotoksen ja työn tuottavuuden muutoksia selittävät aggregaattituotantofunktiot. Funktiotyyppeinä käytettiin lineaarista ja Cobb-Douglas funktiota sekä CSO- että AERI-aineistolle. Kokonaistuotosta selittävinä muuttujina olivat:

X_1 = sektorin ulkopuolelta ostetut panokset
X_2 = työpanos
X_3 = pääomapanos
X_4 = yrittäjien tiedon ja taidon taso
X_5 = teknologian kehitysfaktori. Vaihtoehtona t:lle
t = aika (vuodet 0, 1, 2 . . .). Vaihtoehtona X_5:lle

Teknologian kehitysfaktorin on ajateltu kuvaavan kulloinkin käytettävissä olevia mahdollisuuksia tuotantotekniikassa. Yrittäjien tiedon ja taidon taso taas ilmaisee ne edellytykset, joita viljelijöillä kulloinkin on soveltaa näitä mahdollisuuksia käytäntöön. Muuttuja (X_4) on konstruoitu kahdesta erillisestä tekijästä. Toinen on saatu interpoloimalla vuosien 1950, 1959 ja 1969 maatalouslaskentojen ilmoittamien, koulutettujen viljelijöiden lukumäärien perusteella neliöfunktiota käyttäen viljelijöiden koulutustasoa osoittava indeksisarja. Toinen puolestaan ilmaisee viljelijöiden työpanoksen osuuden maatalouden koko työpanoksesta. Tämän suhdeluvun on ajalteltu kuvaavan työvoiman suhteellista taitotasoa, jonka on oletettu lisääntyvän viljelijöiden työpanoksen osuuden kasvaessa. Sarjat on liitetty yhteen antamalla jälkimmäiselle kuitenkin vain puolet edellisen painosta. Muuttujan konstruointi näkyy taulukosta 15.

Teknologian kehitysfaktori (X_5) on muodostettu niiden teorioiden (Solow 1962, Nelson 1964) perusteella, että teknologian kehitys heijastuisi kumuloituneissa investoinneissa. Tässä tutkimuksessa tätä faktoria kuvaa indeksisarja, joka ilmaisee koneisiin ja kalustoon, perusparannuksiin sekä rakennuksiin kohdistuneiden kumuloituneiden nettoinvestointien määrän työpanosta kohti. Teknologian kehityksen on siten oletettu näkyvän nimenomaan näihin omaisuusesineisiin sijoitettujen investoin-

[1]) Tilivuonna 1968 tehtiin muutos kirjanpitosysteemissä, jolloin siirryttiin käyttämään mm. uuden maatalousverotuksen mukaisia poistoprosentteja ja jolloin myös eri omaisuusosien kirjanpitoarvoja selvästi korotettiin.

tien työtä säästävänä vaikutuksena. Eräissä funktioissa muuttuja (X_5) on korvattu aikavariaabelilla (t), joka Cobb-Douglas-malleissa esiintyy myös muodossa e^{ct}. Aikavariaabelin käyttö perustuu siihen usein esitettyyn ajatukseen, että teknogian kehitys on korreloitunut aikatekijään, jonka avulla sitä voidaan välillisesti mitata.

Kokonaistuotosfunktioiden tulokset on esitetty CSO-aineiston osalta taulukoissa 16 ja 17. Funktioiden yhteiskorrelaatiokertoimet ovat erittäin korkeat vaihdellen 0.993:sta 0.981:een, mikä tarkoittaa, että funktiot pystyivät funktiotyypistä ja selittävien muuttujien lukumäärästä riippuen selvittämään 98.4—96.3 prosenttia kokonaistuoton vaihtelusta. Merkitsevää yhteiskorrelaatiokertoimen paranemista ei tapahtunut siirryttäessä lineaarisista Cobb-Douglas funktioihin. Hyvästä selvityskyvystä antaa havainnollisen kuvan kuvio 6, joka osoittaa kokonaistuotoksen (CSO) havaittujen arvojen suhdetta funktion (3) estimoimiin vastaaviin arvoihin.

Yksittäisistä selittävistä muuttujista pääomapanos sekä tiedon ja taidon taso vaikuttivat voimakkaimmin kokonaistuotokseen. Kuitenkin vain pääomapanoksen osalla esiintyi merkitseviä regressiokertoimia yli 95 %:n luotettavuustasolla. Työpanoksen vaikutus oli jonkin verran vähäisempi kuin edellä mainittujen panosten. Ostettujen panosten vaikutus oli yllättävän vähäinen. Aikatekijällä ei ollut käytännöllisesti katsoen minkäänlaista vaikutusta kokonaistuotokseen. Teknologian kehitysfaktorille saatiin negatiivinen regressiokerroin muuttujan ollessa siten epälooginen. On ilmeistä, että tiedon ja taidon taso-muuttuja on selittänyt myös teknologian kehitystä ja peittänyt muuttujien X_5 ja t vaikutusta.

AERI-aineistosta estimoidut, sisällöltään edellä mainittuja vastaavat funktiot antoivat myös varsin samansuuntaisia tuloksia (taulukko 19, funktiot 8 ja 9). Analyysiä jatkettiin tältä osin jakamalla ulkoiset panokset kahteen ryhmään, väkilannoitteisiin ja muihin panoksiin ja ottamalla mukaan myös kaksi säämuuttujaa. Toinen näistä oli kasvukauden alkupuolen niukkasateista ajanjaksoa edustavan kesäkuun sademäärä, toinen taas ns. Stallingsin sääindeksi (Taulukko 18). Väkilannoitteiden huomioon ottaminen omana muuttujanaan sai aikaan joitakin muutoksia muiden muuttujien regressiokertoimissa. Väkilannoitepanokselle saadut regressiokertoimet olivat merkitsevyydeltään korkeita vaihdellen 99—99.9 %:n luotettavuustasoilla. Pääomapanoksen regressiokertoimien luotettavuusaste kohosi tällöin kaikissa ko. vaiheen funktioissa (funktiot 12—15, taulukko 19) yli 99.9 %:n ja työpanoksenkin yli 99 %:n. Sen sijaan tiedon taso-muuttujan kerroin muuttui negatiiviseksi, mikä lienee tulkittava siten, että tiedon tason nousu heijastui välillisesti jo väkilannoitepanoksessa. Kumpikaan säämuuttuja ei saanut merkitseviä (yli 90 %:n luotettavuustasolla olevia) regressiokertoimia.

Analyysiä jatkettiin edelleen katkaisemalla tutkimusajanjakso kolmeen lyhyempään kauteen ja estimoimalla kokonaistuotosfunktiot niitä koskevista aineistoista (taulukko 20). Tällöin voitiin mm. todeta väkilannoitteiden regressiokertoimen alentuvan siirryttäessä eteenpäin ajassa (ja samalla suurempiin lannoitemääriin), mikä viittaa selvästi vähenevän tuoton lain olemassaoloon. Työ- ja pääomapanoksen regressiokertoimet sen sijaan kohosivat, mikä myös vaikuttaa loogiselta. Kesäkuun sademäärän ja Stallingsin sääindeksin regressiokertoimet olivat sitä korkeammat mitä aikaisempi ajanjakso oli kysymyksessä. Tämä viittaa siihen, että silloin, kun väkilannoitteiden käyttö oli vähäistä ja tuotantotekniikka nykyistä kehittymättömämpi, myös säätekijöiden vaikutus kokonaistuotokseen oli suurempi.

Nettotuotosfunktioiden tulokset on esitetty taulukoissa 22 ja 23. Funktioiden selvityskyky oli selvästi heikompi kuin kokonaistuotosfunktioiden yhteiskorrelaatiokerrointen vaihdellessa 0.833:sta 0.864:än. Heikohko selvityskyky näkyy kuviosta 7, jossa nettotuotoksen (CSO) havaitut arvot on esitetty verrattuna funktion (21) estimoimiin arvoihin. Myös nettotuotosfunktioissa pääoma on ollut voimakkaimmin vaikuttava yksittäinen muuttuja. Työpanoksen regressiokertoimet ovat olleet jonkin verran luotettavammat kuin kokonaistuotosfunktioissa. Laskettaessa pääoman ja työn rajakorvaussuhde voitiin todeta, että esim. 50 miljoonan markan pääoman lisäyksellä oli nettotuotokseen yhtä suuri vaikutus kuin 1 miljoonalla miestyöpäivällä. Tämä viittaisi investointien huomattavaan edullisuuteen työpanoksen korvaajana.

Taulukossa 24 on esitetty työn tuottavuusfunktiot, joita ei ehkä voida pitää sisällöltään yhtä loogisina kuin edellä käsiteltyjä funktioita. Yhteiskorrelaatiokertoimet olivat niissä kuitenkin korkeammat (0.956—0.954) kuin nettotuotosfunktioissa. Pääoma oli jälleen voimakkaimmin vaikuttava yksittäinen panostekijä.

Funktioiden jäännöstermien mahdollista autokorrelaatiota tutkittiin Durbin-Watson testillä. Merkittävää autokorrelaatiota ei esiintynyt. Sen sijaan suhteellisen voimakas multikollineaarisuus on ollut kaikissa funktioissa häiritsevänä tekijänä.

Appendix 1. The location of weather stations used in the calculation of June rainfall (variable X_6).