

THE UNIVERSITY OF MANITOBA

REGIONAL OUTPUT AND FACTOR USE
IN CANADIAN AGRICULTURE, 1950-1974

by

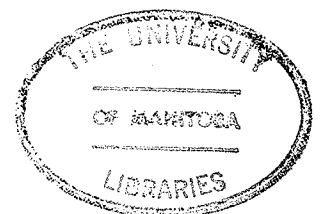
Francis Alabi Bortey

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ABSTRACT

A knowledge of the gains in agricultural productivity is of importance because it has implications for farmers in terms of income effects, for farm administrators in terms of policy measures, for suppliers of farm inputs in terms of demand, and for the general public in terms of food costs. The present study is concerned with regional productivity performance in Canadian agriculture.

A review of relevant statistics reveals that Canadian agriculture has made dramatic gains in productivity since World War II. It is hypothesized that these gains have been brought about mainly by adjustments in the farm labor force, increased capital inputs, and other technological progress.

The study attempts to demonstrate the extent to which adjustments in the farm labor force, increased use of capital inputs, and other technological progress, have contributed to gains in agricultural labor productivity in Canada and the five different statistical regions of the Atlantic, Quebec, Ontario, the Prairies and British Columbia during the period of 1950-1974. Agricultural labor productivity has been defined as either gross value of output per worker or net value of output per worker, in constant dollars.

Many studies have been conducted to measure productivity in Canadian agriculture. The majority of these works were national in scope, and relied mainly on the use of an index number technique to measure growth in productivity.

The primary objective of this study is to measure and to compare regional labor productivity growth rates, and the contributions of the major sources of productivity gains in the different regions using methods other than the traditional index technique.

The index number approach, which does not involve the use of formal mathematical functions, makes it difficult to incorporate technological progress explicitly, and even more difficult to conceptualize and to accommodate contributions of interactions among resource inputs to growth in productivity.

In terms of methods, therefore, the current study departs from the traditional index technique, and employs a production function framework in which technological progress is explicitly incorporated and interactions among resource inputs are accommodated. A Cobb-Douglas-type production function is specified and fitted to data to estimate output per worker for each region. Using these estimates, which compare quite favourably with actual output per worker, annual growth rates for Canada and the regions are computed. To estimate the contribution each resource input makes to this annual overall growth rate in labor productivity, the study assumes that farmers attempt to maximize their return and allocate resources so that the marginal cost of each resource input is equal to its marginal return. This assumption combined with data on farmers' operating expenditures, investment in land and buildings, machinery, and labor use, provide the basis for computing the contribution these resources make to gains in labor productivity. Growth in output

per worker is attributed to growth in expenditures on inputs per worker, each weighted by its factor share in gross value of output. To illustrate this procedure, let us assume, for example, that the share of machinery costs is one-tenth of the current value of farm production, and that machinery operating costs change at an annual rate of, say, 6 percent. Then the annual gain in labor productivity attributed to the annual change in machinery is estimated at .6 percent. Assuming an annual labor productivity growth rate of, say, 3 percent, it implies that one-fifth of the overall growth in labor productivity is imputed to growth in machinery expenditures. In general, the same procedure is applicable to all resource inputs which are identified as sources of improvements in labor productivity. The sources are categorized as labor input (effect of outmigration), land and buildings, mechanization, crop yield inputs, livestock yield inputs, and miscellaneous operating expenses. Land and buildings, crop yield inputs, and livestock yield inputs, are further broken down into specific items or categories. For changes in the labor input, however, a reduction in the farm labor force with less than proportionate reduction in output makes a positive contribution to growth in output per worker. Some indirect inputs which are difficult to quantify, such as increased education, skill of the labor force, and agricultural research, all of which bring about quality improvements in resource inputs, are estimated in a residual of "all other changes" as the contribution of technological progress to growth in labor productivity. To take account of interactions

among resource inputs, Taylor's expansion is employed to estimate the contribution each resource makes to overall growth in labor productivity.

The results of the study indicated that labor productivity in regional agriculture performed quite well, and that in general, different regions owe their gains in productivity to different input categories. According to the estimates, labor productivity in Canadian agriculture increased at an annual rate of about 6 percent at the national level, and ranged between 5.5 percent in Quebec to about 9 percent in British Columbia during 1950-1974. The results reveal some interesting regional differences in terms of the major components of growth in agricultural labor productivity. While in the Atlantic region, the effect of labor outmigration, and other technological progress, were dominant contributors to gains in labor productivity, in Quebec it was growth in livestock technology and to a lesser extent outmigration and crop yield technology, which contributed the bulk of the growth in labor productivity. Ontario achieved superior performance in livestock yield technology, as well as in land and buildings, and at the same time performed well in outmigration and crop yield technology. Although the effect of outmigration was lowest in the Prairie region, growth in labor productivity performed creditably well as a result of the remarkable performance recorded in land and buildings, mechanization and to a lesser extent, crop yield technology. In the British Columbia region, the much superior performance in land and buildings, coupled with reasonably high

growth rates in livestock technology, and the effect of out-migration, were responsible for the achievement of the highest overall growth in labor productivity in this region.

Compared with the Atlantic and Quebec regions, the three regions of Ontario, the Prairies, and British Columbia achieved superior performance in labor productivity during the period under consideration. The estimates demonstrate the importance of capital formation as a necessary source of growth. The Quebec and Atlantic regions appear to have lagged behind the rest of Canada in expenditures per worker in capital inputs related to land and buildings, and mechanization. In Canada as a whole, as well as in Ontario, the Prairies, and British Columbia, capital and material inputs contributed nearly half of the overall growth in labor productivity. However this dominant role of capital and material inputs in contributing to growth in productivity was apparently absent in the Atlantic and Quebec regions, where technological progress and the effect of outmigration were the dominant contributors to growth in productivity.

The estimates also indicated, in general, that at both the national and regional levels, the contribution of crop yield technology was the lowest in comparison to the contributions of mechanization, and livestock yield technology to a lesser extent.

If the results of this study are any guide then the analysis has isolated sources for achieving continued gains in Canadian agricultural productivity, namely the improvements in

yield technology in all regions, increased developments in land and buildings, especially in the Atlantic and Quebec regions, and increased outmigration of labor from farms, especially in the Prairies where the developments of more farm processing industries will help to speed up movement of labor from farms.

It must be stated, however, that increased gains in agricultural productivity must be matched by effective market development, and market organization for farm products, to ensure that such gains in productivity serve to provide the necessary conditions for improvements in farm incomes rather than the depressant of farm incomes.

In conclusion, a few remarks about the major limitations of this study is in order. The procedure employed in this study, although conceptually attractive, has its share of drawbacks.

The principal shortcoming of the approach is the assumption of equilibrium conditions, which enables the substitution of factor shares for production elasticities. Such an assumption ignores the more realistic gradual adjustment lags in resource allocation. The use of factor shares as production elasticities in a Cobb-Douglas production function framework, means that returns to scale are freely determined statistically. Greater factor shares, therefore, implies greater returns to scale, greater contribution is imputed to individual resource inputs, and consequently a smaller residual is imputed to "all other changes", as the contribution of other technological progress.

The second major problem, although by no means unique to this approach, is the problem of the existence of non-market transactions in agriculture. These non-market transactions pose data problems when it comes to estimating the factor income share of farm labor and capital inputs directly from labor earnings and capital expenditures. Indirect methods adopted to circumvent this data problem are at best approximations.

Throughout the analysis gross output per worker has been employed to measure labor productivity. The use of net output per worker as a measure of labor productivity would provide results different from those of the current study.

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CHAPTER 1

INTRODUCTIONA. Historic Trends in Labor Productivity:

Canadian agriculture has achieved dramatic gains in agricultural productivity¹ since World War II. There has been dramatic change in resource use, in technology and in labor productivity over the period 1950-1974. Historic labor productivity ratios² reveal that the average value of gross output per worker in Canadian agriculture, measured in 1961 dollars, was greater than \$3000 during the five year period 1950-1954. This annual average figure rose to over \$4000 during the period 1960-1964, and during the period 1970-1974 it stood at nearly three times its 1950-1954 level. Changes in real net³ labor productivity values followed a similar pattern as the gross measure discussed above (Table I).

Annual comparisons of regional agricultural labor productivity show the existence of significant regional differences in labor productivity regardless of whether labor productivity is

¹Agricultural productivity as used in this context is defined as output per unit of total farm input measured in constant dollars. See I-F Furniss "Productivity Trends in Canadian Agriculture, 1935 to 1964," Canadian Farm Economics; Vol. 1, No. 1; April 1966; p. 18.

²Labor productivity ratios measure labor productivity in terms of output per worker either as: a) the gross value of production per worker, or b) the net value of production per worker.

³Labor productivity is real and net in the sense that it is estimated in 1961 dollars and net of purchases from non-agricultural sectors, which are used in the process of production.

TABLE I

LABOR PRODUCTIVITIES, SELECTED PERIODS, FIVE
YEAR ANNUAL AVERAGES: CANADA & REGIONS, 1950-1974
(1961 DOLLARS)*

	<u>CANADA</u>	<u>ATLANTIC</u>	<u>QUEBEC</u>	<u>ONTARIO</u>	<u>PRAIRIES</u>	<u>B.C.</u>
<u>PERIOD</u>	<u>GROSS OUTPUT PER WORKER</u>					
1950-1954	3164	2212	1914	3460	3785	4897
1960-1964	4352	2350	3894	6257	5870	6973
1970-1974	8789	6138	5943	10188	9312	10538
	<u>NET OUTPUT PER WORKER</u>					
1950-1954	1729	1127	999	1647	2270	2606
1960-1964	1902	960	1298	2168	3160	3470
1970-1974	3293	1969	1973	3348	4306	3815

Source: Based on data from Statistics Canada (See Appendix, Tables 8 (A-F)).

measured as gross, or net, value of production per worker. The estimates showed that there have been substantial gains in agricultural labor productivity in all regions during the period 1950-1974.

In terms of gross output per worker, British Columbia consistently achieved the highest labor productivity values in all three selected periods. The Prairie region had the second largest productivity value during the period 1950-1954, followed by Ontario, the Atlantic region, and Quebec, in descending order of magnitude. This ranking was slightly altered during the sub-period of 1960-1964, when the second highest productivity value was recorded by Ontario, the Prairie region ranking third, followed by Quebec, with the Atlantic region achieving the lowest labor productivity. The ranking of the labor productivity values for the sub-period 1970-1974 was the same as that of the sub-period 1960-1964, with the Atlantic region once again achieving the lowest agricultural labor productivity value. The estimates also revealed that the labor productivity values of British Columbia, the Prairie region, and the Ontario region, were always above the national average in all selected periods, while those of the Quebec and Atlantic regions were below the national average for Canada.

Measured in terms of net value of production per worker, the British Columbia region topped the labor productivity rankings for the sub-period 1950-1954, the Prairie region was second, followed by Ontario, the Atlantic region, and Quebec, in that order. This ordering of magnitude was similar to that

of the sub-period 1960-1964, with the exception that the lowest labor productivity value was recorded in the Atlantic region. However, during the sub-period 1970-1974, the highest labor productivity estimate was achieved by the Prairie region, with the rest of the regions achieving the same ranking position as for the sub-period 1960-1964. In all the selected periods the net productivity values for the Prairie and British Columbia regions were constantly above the national average, while those of Quebec and the Atlantic were below the national average, with those of Ontario more or less at par with the national average values. Regional average growth rate in labor productivity ranged from a low of about 5.5 percent per annum in Quebec to a high of about 9 percent in British Columbia. There is some evidence from the above review that part of the productivity differences among regions can be explained by the fact that farmers in some regions purchase and utilize more inputs from the non-agricultural sector than their counterparts in other regions. One may therefore be tempted to hypothesize that agriculture in some regions is more efficient than agriculture in other regions because it is more highly mechanized. Estimates of resource inputs per worker in agriculture in the various regions may throw some light on the validity of such a hypothesis. But before then an analysis of changes in the agricultural labor force will be attempted.

B. Labor Inputs and Labor Productivity:

An important observation to be made concerning employment in agriculture during the period under study is the rapid

decline in the farm labor force in all regions of Canada. During the period, the Atlantic region experienced the highest annual rate of decline in agricultural employment, about 3.5 percent. The lowest annual rate of decline occurred in the Prairie region, about 1.5 percent. The rates of decline in the agricultural labor force for the other regions fell within this range. The significant decline of the farm labor force in the majority of the regions may be explained by the availability of non-farm job opportunities, such as logging and fishing in the Atlantic region, trade, finance and manufacturing in Ontario and Quebec and industrial development and tourism in British Columbia. Lack of non-farm job opportunities might have been the major contributory factor to the slow rate of decline in the Prairie region. These rapid rates of decline in agricultural employment are related to the significant changes in labor productivity in the various regions which were discussed earlier.

C. Resource Inputs Per Worker:

Given the considerable achievements in absolute labor productivity levels, which were most significant in the British Columbia, the Prairie, and Ontario regions, one may be tempted to hypothesize that the productivity gains in these regions are the result of efficiency from a more highly mechanized agriculture than that present in the rest of Canada. A comparison of resource inputs per worker partially explains the major differences in the intensity of input utilization among regions during the period 1950-1974, (Table II).

TABLE II
 RESOURCE INPUTS PER WORKER: CANADA & REGIONS,
 1950-1974 (1961 CONSTANT DOLLARS)

<u>Resource Description*</u>	<u>Canada</u>	<u>Atlantic</u>	<u>Quebec</u>	<u>Ontario</u>	<u>Prairie</u>	<u>B.C.</u>
Land and buildings	1437	750	1043	1730	1608	1920
Labor
Capital Inputs Related to:	2850	2089	1932	3506	2879	3188
Mechanization	1483	825	457	1308	2061	1195
Crop yield technology	305	389	221	455	252	334
Livestock yield technology	882	757	1060	1474	411	1438
Miscellaneous operating expenses	180	118	194	269	155	221

Source: Based on data from Dominion Bureau of Statistics, (See Appendix, Tables 5 (A-F)).

* These categories of resource inputs will be defined later in the study.

Resource inputs have been stratified by type of input into land and buildings, capital inputs related to mechanization, crop yield inputs, livestock yield inputs, and miscellaneous operating expenses. The results show that more significant differences exist among regions in capital inputs related to mechanization, and livestock yield technology, than is the case in land and buildings (except the Atlantic region), and crop yield technology. Table II shows that in British Columbia, expenditure per capita of labor employed in agriculture was highest in land and buildings, followed by livestock yield inputs, and mechanization. In the Prairie region, however, expenditure per worker in mechanization was highest, followed by land and buildings, with expenditure per worker in crop-yield technology being comparatively low. Ontario's expenditure per capita pattern was similar to that of British Columbia with land and buildings being the highest, followed by livestock-yield technology, before mechanization. In the Quebec region expenditure per worker in livestock-yield technology predominated slightly over land and buildings, with mechanization, and crop-yield technology being relatively low. Expenditures per worker on resource inputs in the Atlantic region were comparatively low in all cases, although one of the highest values of expenditure per worker on crop-yield technology occurred there.

On the basis of this preliminary analysis alone, a partial explanation of the higher labor productivity values achieved by British Columbia, the Prairie region, and Ontario, can be attempted. British Columbia's higher productivity values may be

due primarily to more intensive capital inputs related to land and buildings, livestock-yield technology, and mechanization. The Prairie region achieved higher productivity in agriculture mainly due to capital inputs related to mechanization, land and buildings, while labor productivity increases in Ontario may be attributed mainly to capital inputs related to land and buildings, livestock-yield technology, and mechanization. In the Quebec region expenditure per worker in livestock-yield technology, and land and buildings may be the major contributors to increases in labor productivity. Mechanization, livestock-yield technology, and land and buildings might have contributed to growth in labor productivity. At the national level, expenditure per worker was more intensive in mechanization and land and buildings. The similarity between the national estimates and the Prairie region show the predominant position occupied by the Prairie economy in Canadian agriculture.

The analysis so far has attempted to demonstrate that increases in farm labor productivity were not only affected by the rate of growth in total farm capital, but also by changes in the composition and most probably the quality of farm capital inputs during the period. Apart from the capital inputs other non-readily quantifiable changes might have contributed very significantly to labor productivity. Such factors may include crop variety and livestock improvements achieved through research; they may cover farm management practices, regional specialization, farm size distribution, farmer education, and other items which are difficult to measure quantitatively. Given the state

of technology, the fact that fewer farmers today produce more than was produced twenty-five years ago shows that by far the most significant contribution to growth in labor productivity has come through adjustments of the farm labor force itself. Even if a constant volume of production is assumed, the mere fact that fewer farmers are able to produce that volume of output reflects increased productivity, *ceteris paribus*. It can be hypothesized, therefore, that the fast growth, and changes in Canadian agricultural labor productivity were influenced not only by various types of variations in farm capital inputs, but also to a considerable extent by changes in, and the efficiency of resource utilization, commonly referred to as technological change.

D. Statement of the Problem:

The above analytical review clearly demonstrates that significant regional differences exist in Canadian agricultural labor productivity, and that productivity in Canadian agriculture is influenced not only by changes in farm capital but even more so by technological progress.

Although considerable research and discussion has been conducted on the topic of agricultural labor productivity, the majority of these works and discussions were limited to the national level.⁴ Agricultural labor productivity has not received ample attention at the regional level. Little research has been conducted on labor productivity associated with both

⁴This observation will be substantiated in the next chapter.

physical inputs and technological change in the past, probably due to the lack of a suitable conceptual framework for the quantitative measurement of technological change and the components of agricultural labor productivity. Some of these conceptual problems have been removed, at least partially, with the recent development of a conceptual framework for the empirical analysis of agricultural labor productivity and technological change by Ludwig Auer.⁵ The present study will employ the techniques and one of the concepts developed by Auer for the quantitative analysis of Canadian agricultural labor productivity and technological change at the regional level.⁶

Quantitative estimates of the contributions to gains in agricultural labor productivity by adjustments in the farm labor force, increased capital inputs, and technological change, will serve as a lead to indicate how further gains in labor productivity may be achieved. As in other sectors of the economy, high productivity gains in agriculture are essential to the achievement of higher levels of income in the longer run. They serve as a necessary, although not sufficient, condition for improved farm incomes. It is therefore important to explore and evaluate all possible avenues for potential further improvements in agricultural productivity, and especially those that contribute to farm income. It must be emphasized, however, that the

⁵See, L. Auer, "Canadian Agricultural Productivity," Economic Council of Canada, Staff Study No. 24, Queens Printer, Ottawa, 1970.

⁶Ibid.

present study focuses on regional productivity performance issues rather than farm income and cost-price relationships.

E. Objectives of the Study:

There has been remarkable growth in Canadian agricultural labor productivity. Compared to 1950-1954 productivity levels, the productivity values in 1970-1974 were two to three times higher in Canada and Canada's regions. This study is designed to investigate the nature of agricultural labor productivity and technological change in Canada, and the five statistical reporting regions of Canada, during the period 1950-1974. The study attempts to demonstrate the extent to which adjustments of the agricultural labor force, increased capital inputs, and other technological progress have contributed to gains in agricultural productivity. The major objective of the study is to carry out a comparison of regional productivity performance and to measure the major components of productivity in each region during the period, using data stratified by type of inputs. Specifically, the study attempts to achieve the following objectives:

- 1) to determine the annual growth rates in agricultural labor productivity and technological change in different regions,
- 2) to determine the contribution of individual resources, and technological change to growth in agricultural labor productivity, and
- 3) to examine how further gains in agricultural labor productivity may be achieved in different regions.

As a secondary objective, the study will also examine to what extent, using the methodology and data employed, a Cobb-Douglas-type 'labor productivity' production function approximates actual agricultural production per worker.

F. Organization of the Study:

The geographical scope of the study is Canada and the five statistical reporting regions of British Columbia, the Prairies (Alberta, Saskatchewan, Manitoba), Ontario, Quebec, and the Maritimes* (Prince Edward Island, Nova Scotia, New Brunswick).

Chapter II deals with a review of some previous related studies and further attempts to justify the present study. Various basic theoretical concepts which are pertinent to the measurement of technological change and agricultural labor productivity are discussed in Chapter III. The model for the empirical analysis of labor productivity and technological change is specified and developed in Chapter IV, followed by a presentation and discussion of the empirical results of the study and their implications for resource allocation at the regional level, in Chapter V. Finally, a discussion of the limitations of the study, summary and conclusions, is presented.

* Newfoundland is not included.

CHAPTER II

REVIEW OF RELATED STUDIES

Agricultural productivity analysis has been the subject of considerable interest to several Canadian economists for some time. This is demonstrated by the sizeable number of studies which have been conducted on it and other related topics, especially since World War II. Some of these studies have attempted to identify the major sources of productivity while others focused on depicting the role of technology in Canadian agriculture. This chapter of the present study provides a review of studies related to Canadian agricultural productivity. The emphasis here is on the techniques used for measuring agricultural productivity, the period, and geographical scope covered by each study.

A comparative study of the productivity of labor in Canadian agriculture within regions and between the agricultural and non-agricultural sectors of the economy, covering the period 1945-1953, was undertaken by Anderson.¹ The measure of productivity used was the net product² per unit of labor, in dollar and index forms, based on an approach he called the "residual method". This method which does not require the use

¹W. J. Anderson, "Productivity of Labor in Canadian Agriculture," The Canadian Journal of Economics and Political Science, Vol. 21, No. 2, (May 195), pp. 228-236.

²Net product in this case refers to the residual of farm income after accounting for the value of land and other farm capital, as well as purchased inputs from the non-agricultural sector, used in the production process. It refers to labor's share in total outputs.

of formal mathematical functions, derives its name from the manner in which the return to labor is computed. The return to labor is the remainder from net farm income after deducting the contribution of land and other capital inputs. Farm production was also adjusted for changes in inventories held by the Canadian Wheat Board. The agricultural labor force was then adjusted for differences in sex and composition and length of the working year to make it more comparable to the non-agricultural labor force. After obtaining the "residual" (return to labor input) it was divided by the adjusted labor force to obtain an annual value of labor productivity in dollar or absolute terms. This type of productivity measure is sometimes referred to as a 'partial' productivity measure. Each productivity value was then converted into a form of index number by taking the national productivity figure as a normalization base. There are two basic assumptions underlying the use of the "residual" method. Firstly, it assumes that market prices correctly reflect the productivity of some of the factors. This implies that all inputs, with the exception of labor, are valued at market prices. Secondly, the method also must assume that the sum of the marginal productivities of the factors multiplied by their prices equals the total value of the product. If this second assumption, that returns to factors account for the total product, is wrong, then the residual return to labor will be higher than the true value of the marginal production of labor, and the labor productivity estimate would be biased upwards.

Anderson's analysis showed wide regional variations in Canadian agricultural labor productivity. Eastern Canada (especially the Maritimes and Quebec) achieved lower productivity in comparison to the Western regions of British Columbia and the Prairies. Compared with the non-agricultural sector, the author indicated that variability between regions in productivity was much greater in agriculture than in other occupations, and that agricultural productivity was considerably lower than non-agricultural productivity during the period.

The partial productivity measure was also used by Hood and Scott in their productivity analysis covering the period 1926-1955.³ Gross domestic product (G.D.P.) in agriculture was estimated in constant 1949 dollars. The agricultural labor force was measured in man-hours. The productivity of agricultural labor was then measured in terms of dollars of output per man-hour. The rate of growth in productivity for selected periods ranged from a low of .60 percent in 1926-1947 to a high of over 11 percent in 1959-1953. The authors noted that figures of productivity in agriculture are extremely sensitive to variations in crop yields. They observed that part, at least, of the phenomenal rate of increase in the G.D.P. per man-hour achieved in Canadian agriculture during the post-war period must be attributed to good crop yields, coupled with increased mechanization, which progressed at a rapid rate during the period.

³W. C. Hood and A. Scott, "Output, Labor and Capital in the Canadian Economy," (Ottawa, Royal Commission on Canada's Economic Prospects, 1955), pp. 214-215.

In subsequent research, MacEachern and MacFarlane up-dated the earlier work of Hood and Scott for the 1960-1964 period.⁴ This latter work also employed labor productivity measured in terms of gross domestic product (in 1949 dollars) per man-hour, with the results showing continued but less dramatic gains in productivity. Like its predecessor, the second study was also national in scope.

A study was undertaken by Lok to test the hypothesis that rising productivity in the farm sector has been detrimental to farm income.⁵ The author chose a constant dollar method to measure input and output and decided to use the Laspeyres formula with four different weight periods along with the Paasche formula and a chain index formula (i.e.: he created six index number time series of productivity, of output, of gross income and of real net income).

The actual procedure of calculating the four constant weight series was as follows. The current outlay on each input taken from Statistics Canada farm income statistics was divided by its own price for each of the four weight periods selected.

⁴G. A. MacEachern and D. L. MacFarlane, "The Relative Position of Canadian Agriculture in World Trade," Report on the Conference on International Trade and Canadian Agriculture, Banff, 1966, (Ottawa, Economic Council of Canada and Agricultural Economics Research Council of Canada, 1966).

⁵S. H. Lok, "An Enquiry into the Relationships Between Changes in Over-all Productivity and Real Net Return per Farm, and Between Changes in Total Output and Real Gross Return, Canadian Agriculture 1926-1957." Technical Publications, (Ottawa, Economics Division, Dept. of Agriculture, 1961).

The values so derived for individual inputs were then added to give total input. This aggregate was then converted into an index number series based on the first year (1926 = 100). The method, therefore, produced a quantity index of aggregate input weighted by relative prices of the selected periods.

The same procedure was followed to obtain indices of gross physical output which, when divided by the indices of total inputs, gave the overall productivity indices required in the study.

Using the annual percentage changes in overall productivity and real net return per farm, the working hypothesis was tested by a simple linear regression. On the basis of the data and method used, the hypothesis was not substantiated and no evidence was found for the belief that Canadian agricultural productivity and real net return per farm are inversely related. Instead, as far as Canadian agriculture is concerned, the evidence suggested that with every percentage increase (decrease) in overall productivity, net return per farm increased (decreased) by about 1.5 to 2 percent.

As the author did not intend to describe and interpret fully the changes in the overall productive capacity of inputs, the productivity indices included weather and other extraneous but important effects. He did not separate resource saving technology from the exogenous sources of changes in overall productivity. Therefore, the results do not provide a quantitative measure of the contribution of technological progress to rising productivity.

In 1961, MacKenzie, as a means of examining the net productivity of agriculture for the period 1926-1958, measured the physical productivity per person employed in agriculture using three base periods, 1926, 1935-39 and 1946, for selected periods.⁶ The net productivity during each period was calculated by estimating the constant dollar gross volume of agricultural production and subtracting from it the constant dollar volume of purchased inputs. This was done with valuations of both gross output and purchased inputs in 1926, 1935-39 and 1946 prices. Net agricultural productivity was measured as net value added per man, and taking the value of each base period, the results were then converted to index form. The results of the study indicated that agricultural productivity relatively lost ground during the period 1944-48, but recovered effectively by 1949-53 and continued to improve during 1954-58. The author attributed the low relative position of productivity in the 1944-48 period to possibly the effects of shortages of men and materials (particularly machines) coupled with the effects of output fluctuations due to poor crop yields. However, the author concluded that agricultural productivity improved considerably in the post-1949 period.

Later in 1962, in an attempt to measure the impact of technological change in Canadian agriculture as a whole and by regions, MacKenzie determined an index of net output per unit

⁶W. MacKenzie, "The Terms of Trade, Productivity and Income of Canadian Agriculture," Canadian Journal of Agricultural Economics, Vol. IX, No. 2, (1961), pp. 1-13.

of factor input as an indicator of technological change within agriculture.⁷ The basic theoretical assumption underlying the approach adopted in this study is that purchased inputs are paid for at prices equated with their marginal productivity and that a rise in net output comes about as a result of internal productive efficiency.⁸ The study which covered the period 1944-1958, used 1944-1948 as a base period for constructing the index of net output and total inputs. Output and inputs were valued at 1926 and 1946 price levels.

The constant dollar gross volume of agricultural production was estimated first, by deflating the total gross income of agriculture by the official index of farm product prices on a 1935-39 base. It was then revalued at 1926 and 1946 prices. The purchased inputs were individually deflated by the relevant indices and then added to represent a constant dollar total of purchased inputs. The constant dollar totals were subtracted from the constant dollar totals of gross output to yield a constant dollar measure of net output. This was done at each of the three price levels for each of the regions of Canada. Then the five year average value of net output for the period 1944-1948, was used as a base period to construct an index of net output up to 1958. Productive efficiency was then measured as net output per unit of factor input.

⁷W. MacKenzie, "The Impact of Technological Change and the Efficiency of Production in Canadian Agriculture," Canadian Journal of Agricultural Economics, Vol. X, No. 1, (1962), pp. 41-53

⁸The term productive (or physical) efficiency has the same meaning as overall productivity in agriculture. It is expressed as the ratio of net output to weighted sum of total factor inputs, all measured in constant dollars.

The author indicated that productive efficiency increased in Canadian agriculture in all regions. However, the Maritime region showed the largest rate of gain followed by the Prairie region. The lowest rise occurred in the British Columbia region and Ontario was substantially behind the other regions in the rate of rise. In both the Maritimes and Quebec the rise in the second five year period was more or less as high as the first five years, whereas in British Columbia, the rate of gain was greater in the last five years than the first five. In Ontario the rate of change between periods was more gradual.

Analyzing these increases in efficiency, the author noted that the most striking relationship was between the rate of gain in efficiency and the rate of decline in the labor force. In the Maritimes and Quebec, where the largest relative gains occurred, labor had left agriculture relatively faster than elsewhere in Canada. On the other hand, he indicated that the replacement of man with machine, land with fertilizer and weed sprays, better cultivation practices, all partially contributed to the rise in net product per unit of factor input.

In yet another productivity study covering the period 1944-1958, MacKenzie employed the index technique as described above to measure changes in overall productivity (i.e. productivity per unit of factor input) and productivity per man.⁹

⁹W. MacKenzie, "Regional Changes in Income, Terms of Trade and Productivity Within Canadian Agriculture," Canadian Journal of Agricultural Economics, Vol. XI, No. 2, (1963), pp. 41-51.

In this third study, which was regional in nature, the author indicated his preference for the total productivity measure (i.e. output per unit of factor inputs), with the explanation that net value added per man in constant dollars has the disadvantage of measuring physical productivity per unit of only one factor of production. However, he indicated that it is worthwhile to bring out the differences in rates of change when productivity is measured by the partial ratio of net value added per man and the more complete ratio of net value added per unit of factor input. His results revealed that the former measure of productivity has a tendency to be biased upwards, compared with the latter. Thus, on a per man unit basis, all regions showed a much more substantial rate of gain than on an output per unit of factor input basis.

Productivity was measured as the total output/total input ratio using the constant dollar method to measure both output and inputs by Furniss.¹⁰ The study analyzed the changes in total output, total inputs and productivity in Canadian agriculture for the period 1935 to 1960. Furniss defined productivity as the ratio of the index of the volume of output to the index of the volume of all relative tangible inputs, with both indices based on 1935-39 constant dollars. Laspeyres' weighted aggregative formula is used to calculate index numbers of inputs and outputs. The procedure involves weighting the inputs and outputs in the time series by their prices for a particular base period. Annual

¹⁰I. F. Furniss, "Productivity of Canadian Agriculture, 1935 to 1960: a Quarter Century of Change." Canadian Journal of Agricultural Economics, Vol. Xii, No. 2, (1964), pp. 41-53.

total input and total output measures are obtained by adding the resultant constant dollar values, for all items for each year. The constant dollar values are then taken as a measure of the changes in physical quantities during the period. The annual total output per unit of total input measures changes in overall productivity of the inputs.

The author estimated that the productivity of Canadian agriculture increased at an average annual rate of 2.6 percent during the period. He attributed this increase in productivity to an average increase in farm output of 2.3 percent annually and a corresponding decline in total inputs of 0.3 percent. A breakdown of the total input mix indicated a decreasing proportion of labor, little change in real estate, and a substantial increase in capital. Labor on farms decreased at an annual rate of 2.4 percent; the increase of capital inputs, especially machinery and fertilizer, was 3.7 percent annually; farm real estate showed a fractional decrease (of less than 0.1 percent) each year of the period considered.

Later, in a second study using the same procedures, Furniss extended his period of observation to 1964 and used 1949 as a new price weight.¹¹ The author's estimates showed that agricultural productivity in Canada increased at an annual rate of about 2.2 percent from 1935 to 1964. This was the result of 1.9 percent increase in output coupled with a fractional decline

¹¹I. F. Furniss, "Productivity Trends in Canadian Agriculture, 1935 to 1964," Canadian Farm Economics, (Ottawa, Canada Department of Agriculture Economics Branch), Vol. 1, No. 1, April, 1966.

in total inputs. Furniss also measured the gross domestic product per man in agriculture, which showed an increase of about 4.3 percent annually during the period 1935 to 1964.

These earlier studies by Furniss were concerned with productivity measures at the national level. Therefore, in a third study Furniss applied the same index techniques and method to measure regional agricultural productivity.¹² This regional study covered the period 1946 to 1965. The results showed that agricultural productivity growth rates ranged from a high of 3.6 percent in Quebec to a low of 1.7 percent in B.C. In Quebec, the increase in productivity was the result of an annual increase of 1.9 percent in farm output coupled with a decline of 1.7 percent in total inputs. Although the Maritime region showed a fractional decrease of 0.1 percent in output, the rate of decrease in inputs was 2.4 percent per year, with the result that productivity increased by 2.6 percent per annum.

On the Prairies, farm output rose from 1946 at a rate of 1.8 percent a year while inputs declined fractionally. Consequently, agricultural productivity in the region increased at 2.0 percent per year. The heavy weight which Prairie agriculture carries in the all-Canada indices is reflected in the close correspondence between the growth rate for the region and for Canadian agriculture as a whole, 2.3 percent per year since 1946.

¹²I. F. Furniss, "Trends in Agricultural Productivity," Canadian Farm Economics, Vol. 2, No. 1, (April, 1967).

British Columbia agriculture showed the highest rate of growth in farm output, 2.6 percent per year. However, production inputs also rose by almost 1 percent annually, with the result that the rate of productivity growth was comparatively lower than in other regions, 1.7 percent per annum.

The author attempted to explain the regional differences in terms of the shifts which have occurred in the composition of farm inputs since 1946. Contrasted with the Maritime region where real estate inputs declined by 1.5 percent per year, British Columbia achieved an estimated 2.2 percent per year increase in farm real estate. Labor inputs declined in all regions, with the highest rate of decrease, 4.7 percent, being in Quebec, followed by the Maritimes with a decrease of 4.2 percent per year. Furniss indicated that the high rate of decline in the Quebec farm labor force was the main contributory factor to the overall productivity growth rate in that region.

The annual rate of growth in capital inputs in Quebec was higher than that in Ontario, but below the rates for the Prairies and British Columbia. British Columbia had the highest rate of growth in capital inputs, 2.5 percent per year. This was the principal factor which contributed to the productivity growth rate shown by that region.

In terms of the three main input categories of production discussed above, the decline in the farm labor force appears to have been the most important single factor contributing to productivity since 1946.

The latest study on productivity by Furniss dealt with productivity at the national level.¹³ The study covered the period 1950-1969. Once again the productivity measure was computed from an index of farm output and an index of total farm inputs. During the period under consideration the rate of growth in agricultural productivity is estimated to have been almost 2.0 percent. The increase was the net effect of a rise of more than two percent a year in farm output and an annual growth in the volume of farm inputs of less than half a percent a year.

Furniss indicated that since 1960, the rate of growth in farm productivity increased because of an increased rate of growth in output which more than offset an increase of one percent in farm inputs, with the result that productivity improved at a rate of 2.5 percent annually. The study also went on to isolate the major factors in the input mix contributing to the growth in productivity. It was observed that farm real estate inputs in Canadian agriculture were relatively stable during the period both in terms of volume and share of total inputs. Labor employed in agriculture showed a continually declining trend throughout the 1950's and 1960's, averaging about 3 percent per year rate of decline during the period. Regarding capital inputs, which the author broke down into machinery and equipment, purchased feed, fertilizer and lime, and other capital, the results

¹³I. F. Furniss, "Agricultural Productivity in Canada: Two Decades of Gains," Canadian Farm Economics, (Ottawa, Canada Department of Agriculture, Economics Branch), Vol. 5, No. 5, 1970.

indicated minimal increases in the total capital input category, although high rates of growth were recorded by individual capital inputs, during the period studied. For example, feed and seed purchased by farmers from the non-farm sector rose by almost 5 percent per year; fertilizer and limestone by almost 9 percent a year; other capital inputs by about 35 percent, while machinery and equipment increased by almost 2.0 percent per year.

With regard to farm labor productivity, which was measured by real gross domestic product (value added) per man in agriculture, Furniss observed an annual growth rate of more than 5 percent for the period 1950-1969, and an even faster rate of 6 percent a year for the decade 1960-1969. The author indicated that these rates of growth in agricultural labor productivity exceeded by a considerable margin the growth rates in labor productivity in the rest of the economy.

The 1950-1969 study by Furniss has been up-dated in a recent study by Shute.¹⁴ Applying the same index number technique as Furniss, the author analyzed total productivity in agriculture at the national level, for the period 1961 to 1973. In a follow up study Shute extended the period of analysis to 1974 and the geographical scope to include the regions. According to this second study by Shute,¹⁵ the growth rate of Canadian

¹⁴D. M. Shute, "Input Substitution and Productivity of Canadian Agriculture, 1961 to 1973," Canadian Farm Economics, (Ottawa, Canada Department of Agriculture, Economics Branch), Vol. 10, No. 1, Feb., 1975.

¹⁵D. M. Shute, "National and Regional Productivity of Canadian Agriculture, 1971 to 1974," Canadian Farm Economics, Ottawa, (Canadian Department of Agriculture, Economics Branch), Vol. 10, No. 6, December, 1975.

agricultural productivity was in the order of about 0.9 percent a year. Annual productivity growth rates at the regional level indicated that the Maritimes, Quebec and Ontario recorded increases of less than 1 percent while the Prairies and British Columbia experienced decreases in agricultural productivity. The negative agricultural productivity growth rates in western Canada are attributed to lower growth rates in farm outputs which were not enough to offset the higher growth rates of farm inputs. Shute also disaggregated the farm input mix and analyzed the annual growth rates of the various input items in an effort to try and explain regional productivity performance.

Farm real estate at the national level increased about 1.78 percent a year from 1962 to 1974. At the regional level, British Columbia achieved the highest rate of growth in farm real estate (over 6 percent per year), followed by the Prairies with a little over 2 percent per year; Ontario and Quebec recorded annual growth rates of 0.24 percent and 0.09 percent respectively. The Maritimes region showed an annual rate of decline in farm real estate of 0.84 percent per year.

Labor in Canadian agriculture decreased at about 3 percent per year from 1962 to 1974. The rate of decline was highest in the Maritimes region, some 6 percent annually. Quebec showed a decrease in the farm labor force of 3 percent per year, while in Ontario and the Prairie region the annual rate of decline was about 2.7 percent. British Columbia had a decline of less than 1 percent per year in the labor force during the period.

The highest growth rate in capital inputs, about 5 percent a year, occurred in British Columbia, while the lowest rate of 2.4 percent in capital inputs occurred in the Maritimes region. These estimates obtained by Shute appear to lend some support to the earlier observation by Furniss who indicated that the rate of decline in the labor force appears to be the single most important contributory factor to growth in agricultural productivity.¹⁶

In general Shute concluded that there appears to be a trend towards increasing agricultural productivity in eastern areas of the country, while the trend in the west has been towards decreasing agricultural productivity. In this connection Shute carried out yet another study which focused on changes in agricultural productivity for eastern Canada, namely Quebec, Ontario and the Maritimes.¹⁷ As usual, the technique of indices was the tool applied to measure agricultural productivity. The results showed that agriculture in the Atlantic region achieved the highest rate of growth in productivity, about 1 percent per annum, between 1962 to 1974, while in Ontario and Quebec the corresponding rates were 0.7 percent and 0.4 percent per annum, respectively. Once again the author concluded that the high rate of decline in the labor force appears to be the major force behind the comparatively higher growth in agricultural productivity achieved in the Maritime region.

¹⁶I. F. Furniss, op. cit.

¹⁷D. M. Shute, "Agricultural Productivity in Eastern Canada," Canadian Farm Economics, (Ottawa, Canada Department of Agriculture, Economics Branch), Vol. 11, No. 5, Oct. 1976.

Yeh and Li, in a study on supply and demand for farm labor in Canada, also applied the index technique to measure agricultural labor productivity for Canada and the regions.¹⁸ The index was derived from the ratio of total output to all associated inputs in real terms, using 1935-39 as a base period. This study covered the period 1946-1962.

The estimates of the above study indicated that the average change in productivity in Canadian agriculture was 2.5 percent per year during the period 1946-1962. During the same period, the highest average increase in productivity was 2.6 percent per year in the Prairie region. The other regions experienced slight changes in productivity over the period but as these were low and offsetting in sign, the Prairie increase proved to be the major single influence in Canadian aggregate average productivity increase.

In a second study by the same authors which was concerned with an analysis of technological change in Canadian agriculture for the period 1946-1965, they attempted not only to measure increases in labor productivity, but also to attribute the increases in labor productivity to increases in capital intensity or to technological change.

¹⁸M. H. Yeh and L. K. Li, "A Regional Analysis of the Supply and Demand for Farm Labor in Canada," Canadian Journal of Agricultural Economics, Vol. XIV, No. 2, (1966), pp. 15-31.

¹⁹M. H. Yeg and L. K. Li, "Technological Change in Canadian Agriculture," Research Report No. 15, Winnipeg, Department of Agricultural Economics, University of Manitoba, 1968.

Net output of farm production was computed as the difference between gross output and total inputs purchased from the non-agricultural sector, all measured in 1935-39 prices. This net value added was then divided by the labor force measured in man-equivalents.²⁰ Thus, productivity is measured as value added per man equivalent of the labor force employed in agriculture.

Solow's model was applied to Statistics Canada data to measure the geometric growth of net technological change in regional agriculture.²¹ The results indicated that Canadian agriculture experienced considerable technological change during the period 1946-1965. Regional differences in the annual rate of growth were even more dramatic. The highest growth rate of 4.4 percent was registered in the Atlantic region; Ontario ranked second with 3.7 percent, and the Prairies achieved a growth rate of 3.5 percent. British Columbia and Quebec recorded growth rates of 2.8 percent and 2.0 percent respectively.

With respect to total increases in labor productivity over the period, the results ranged from a high of almost 200 percent in Ontario and the Atlantic regions, to a low of about 100 percent in Quebec and British Columbia. The authors divided this total increase in net productivity measure into two parts, one

²⁰Man-equivalent is a measure of the labor force in adult male units, by a special adjustment procedure which takes into account age, and sex composition of the labor force. For details of the procedure see Yeh and Li (Ibid.), page 17.

²¹Yeh and Li, Ibid., page 12.

period of economic recession. In the second and fourth sub-periods (1950-1955, and 1960-1965) the authors indicated that the Korean War and the economic boom at the time called for great demand for farm products on both domestic and foreign markets. The above reason, accompanied by a rapid outmigration of farm labor, and increased farm capital use were the probable factors which made possible the significant increases in labor productivity in these two sub-periods.

The studies reviewed so far have almost invariably applied the index number technique for the measurement and analysis of productivity in agriculture (see Table III). In general, the technique involves the construction of indices -- an index number for total inputs, and an output index. The output index is then divided by the input index to obtain a measure of annual change in overall productivity.

To obtain the input index each input component is deflated by the appropriate price index based on a particular year's weights. Thus the input components are converted into constant "dollar values", which are aggregated into total inputs. These aggregated values are then expressed as a percentage of the first year of the series. A similar procedure is followed to obtain the output index. This is the procedure used by Lok and in fact most of the analysts who employed the technique.²²

²²S. H. Lok, op. cit.

TABLE III

SUMMARY OF PREVIOUS PRODUCTIVITY STUDIES, SHOWING PERIOD OF STUDY,
GEOGRAPHICAL SCOPE, AND TECHNIQUE USED

<u>AUTHOR</u>	<u>PERIOD</u>	<u>GEOGRAPHICAL SCOPE</u>	<u>TECHNIQUE</u>
Anderson	1945-1953	Canada	Index method
Hood & Scott	1926-1955	Canada	Index method
MacEachern & MacFarlane	1960-1964	Canada	Index method
Lok	1926-1957	Canada	Index method
MacKenzie	1926-1958	Canada	Index method
MacKenzie	1944-1958	Canada & Regions	Index method
Furniss	1935-1960	Canada	Index method
Furniss	1935-1964	Canada	Index method
Furniss	1946-1965	Canada & Regions	Index method
Furniss	1950-1969	Canada	Index method
Shute	1961-1973	Canada	Index method
Shute	1962-1974	Eastern Canada	Index method
Yeh & Li	1946-1962	Canada & Regions	C-D Production Function
Auer	1947-1965	Canada	Production Function Framework Labor Produc- tivity Function

Perkins carried out a review of Lok's productivity indices to evaluate their economic meaning.²³ He expressed the procedure for constructing Lok's inputs index number (I) as described above in the following mathematical formula:

$$I = \frac{\sum_j \left[\frac{\sum P_n Q_n \cdot \sum P_o Q_o}{\sum P_n Q_o} \right]_j}{\sum_j \left[\frac{\sum P_1 Q_1 \cdot \sum P_o Q_o}{P_1 Q_o} \right]_j}$$

where,

n = given year

o = the base year for the price indexes used

1 = the first year of the series, and

P and Q are price and quantity, respectively.

Perkins indicated that the inputs index expressed in the above formula is a "weighted sum of Paasche indices of input components divided by a similarly weighted sum of (the first year) Paasche index values,"²⁴ and is therefore not based on constant weights. He observed that the "measurement of changes in productivity by comparison of ratios of output index numbers to input index numbers necessitates the use of fixed weight indices, otherwise such measurements will not separate changes in productivity from changes in relative price." Perkins concluded that little economic meaning can be attached to both the input and output indices computed as above as well as their quotient used as a measure of changes in overall productivity.

²³B. B. Perkins, "What Do Lok's Productivity Indices Measure?", Canadian Journal of Agricultural Economics, Vol. XII, No. 2, (1964), pp. 70-71.

²⁴Ibid.

Added to the illusive fixed weights problem involved in computing such indices was one of aggregation. The method of aggregation employed in the index approach assumes a linear and homogenous production function, which enables an arithmetic (addition) aggregation of weighted inputs and output.²⁵ The index technique also attributes changes in productivity entirely to tangible inputs only. This is probably so because the technique does not require formal mathematical functions which express the functional relationships between output and resource inputs. It is, therefore, not easy to conceptualize changes in productivity brought about by technological progress, let alone incorporate such progress explicitly in that kind of framework.

Auer has developed a conceptual frame work which enables the formulation and measurement of productivity using formal mathematical functions.²⁶ The author used production function analysis as a conceptual framework for an analysis of labor productivity in Canadian agriculture. After formulating the general relation between the value of production of a particular industry and the resource inputs employed, he demonstrated that a change in output can be attributed to changes in each of the tangible resource inputs and technological progress. He then derived a labor productivity function from the formulated

²⁵This is an assumption which economists have debated for some time now. See Paul A. Samuelson, Foundations of Economic Analysis, Cambridge, Mass., (1947), pp. 83-89.

²⁶L. Auer, "Canadian Agricultural Productivity," (Ottawa, Economic Council of Canada, Staff Study No. 24, 1969).

production function and attributed changes in labor productivity to changes in resource and technological progress.

Auer's study attempted to identify the sources of growth in agricultural productivity at the national level, and to demonstrate to what extent adjustments of the agricultural labor force, increased capital inputs, and technological progress have contributed to gains in agricultural labor productivity. The approach assumed that farmers attempt to maximize their return. This assumption combined with data on farmers operating expenditures, investment in real estate, machinery, and labor use, provided the basis for computing the contribution these resource inputs made to overall growth in labor productivity. In other words, growth in output per worker is attributed to growth in expenditures on inputs per worker. For changes in labor inputs, however, a reduction in the labor force makes a positive contribution to growth in output per worker. Some indirect inputs, such as increased education, skill of the labor force, agricultural research, etc. were estimated summarily in a residual of "all other changes". The analysis is, therefore, restricted to growth in labor productivity measured in terms of growth in volume of production per worker.²⁷

The results of the analysis showed that Canadian agricultural labor productivity advanced at nearly 6 percent per year during the period 1947-1965. The movement of workers out of

²⁷The concepts, assumptions, and technical details underlying the approach are given further treatment in Chapter IV.

agriculture accounted for over one-third of this gain. Another third is attributable to increased capital and material inputs, and the balance to "all other changes" which contributed the residual to the growth in labor productivity.

The method employed by Auer for measuring productivity has a number of important advantages over the index approach. These advantages can be summarized as follows:

(i) the technique derives from a production function analytical framework which has a clear theoretical basis,

(ii) it allows the use of formal mathematical function to express a functional relation between labor productivity and resource inputs per unit of labor,

(iii) it does not attribute growth in productivity to tangible resource inputs only,

(iv) technological progress can be explicitly incorporated in this conceptual framework as a contributory factor to growth in productivity,

(v) the measure of changes in productivity obtained has a definite economic meaning, in terms of growth in overall labor productivity and in terms of the factors which contribute to that growth,

(vi) the technique neither assumes nor limits itself to a linear production function as does the index technique, and

(vii) the procedure is suitable for a disaggregated analysis.

It is in view of the above that this concept of a labor productivity function is preferable to the index number approach as

the technique to be used in the present study. Auer used the technique for national agricultural productivity analysis. In the present study the technique will be applied to regional data to analyze regional labor productivity performance during the period 1950-1974.

The next chapter develops a conceptual analysis of labor productivity with particular reference to agriculture, and the theoretical relationship between gains in labor productivity and resource use. Leading from this conceptual framework, the analytical model is specified, and developed for the empirical measurement of annual changes in labor productivity and its components in Chapter IV.

CHAPTER III

BASIC CONCEPTS IN AGRICULTURAL LABOR PRODUCTIVITY ANALYSIS

The major concern of this chapter is to present a theoretical discussion of the basic concepts which are relevant to the analysis of labor productivity, with particular reference to agriculture. The relation between gains in labor productivity, resource use and technological change are the focus of this conceptual analysis.

A. Concepts of Labor Productivity:

The term 'labor productivity' may be used to mean one of several things.¹ Firstly, labor productivity may be used to refer to the gross value of output obtained from a given combination of labor with other factors, divided by the units of labor employed.² This is the concept of labor productivity employed in the current study. Secondly, the term may be used with an abstract meaning to refer to the inherent ability or willingness on the part of a person to contribute to his or her efforts. In a more technical sense, labor productivity may refer to the value of the incremental product resulting from the addition of one unit of labor to a fixed quantity of other factors, given the demand for the product, the inherent ability of the worker and the nature of the available technology. This third concept is what is generally referred to in economic theory as the marginal

¹Anderson, op. cit.

²Units of labor in this case, may be expressed in terms of number of workers employed, or as total number of man-hours utilized.

product of labor, which measures the marginal increment to the value of total output. It is this last concept which has meaning and implications to the problem of optimal resource allocation within an industry or among industries.

The first concept, rather than the third, is employed to measure labor productivity in this study because the kind of data required in order to obtain an estimate of productivity using the third concept is not available. For the purposes of the current study, the first concept will be used.

B. Contribution of Resource Inputs:

Output at any date depends on many determinants, and it is changes in these determinants that cause output to change. An analysis of the sources of growth in output over any time span identifies the determinants that have changed and the contribution that changes in each have made to the change in output. The size of the contribution of a determinant depends upon its importance and the amount by which it has changed.³ The importance of each factor input is estimated by its marginal product at a particular point in time. Then its contribution to growth is measured by its rate of growth weighted by its marginal product. This procedure can be applied to analyze the contribution of the various resource inputs to growth in labor productivity.

³E. F. Denison, "Accounting for United States Economic Growth, 1929-1969," The Brookings Institution, Washington, D.C., 1974.

Under certain conditions the importance of each factor input can be estimated by its factor share. The factor shares approach derives from marginal productivity analysis which requires that the value of output be divided among the earnings of the various factors of production. The factor shares provide accurate estimates of the importance of the inputs if the earnings (prices) of the various factors of production are proportional to their marginal products. The proportionality of factor earnings and marginal products is achieved if it is assumed that enterprises combine factors in such a way as to obtain minimum factor cost combinations. Production at minimum cost to an enterprise implies that given the price at which factors can be obtained, factors are combined in that proportion which makes the marginal product of each factor proportional to the cost of obtaining it.⁴ This means that under such conditions there is a tendency in a particular industry toward an equilibrium position of the most efficient combination of factors. This tendency, although by no means a stable one, can nevertheless be a strong one especially in a competitive industry such as agriculture, if not in the short-run, at least over a number of years.

In the light of the above theory the basic assumption underlying the analysis of labor productivity in agriculture which is made in this study is that farmers attempt to allocate their expenditures rationally by investing their money so that

⁴See E. F. Denison, "Why Growth Rates Differ," The Brookings Institution, Washington, D.C., 1967.

each extra dollar yields the highest return. In other words farmers attempt to maximize profits by using least cost factor combinations. Given this assumption and coupled with data on farmer's operating expenses, investment in land and buildings, machinery, and labor use, the contribution these resources have made to overall growth in labor productivity, during the period under consideration, can be computed.

C. Labor Productivity and Resource Use:

As indicated above the relative importance of the various changes in resource use is estimated by weighting each of the changes by the cost share of that resource in total farm production. To illustrate this procedure let us assume, for example, the share of land and buildings is one-tenth of the current value of farm production, and that land and building operating costs (in constant dollars) change at an annual rate of, say, 5 percent. Then, the annual gain in labor productivity attributed to these changes in farm real estate is estimated at 0.5 (.10 x 5) percent. Assuming an annual rate of growth in labor productivity of, say, 5 percent, this implies that one-tenth of the total growth is imputed to land and buildings. In general, the same procedure is applicable to all other resource inputs which are identified as sources of improvement in labor productivity. However, in the case of the labor input, a reduction in labor inputs with less than proportionate reductions in output will raise the level of labor productivity in terms of output per worker. The lower the level and/or the greater the



reductions in labor inputs, the greater will be the imputed gains in labor productivity.

D. Identifying Sources of Growth in Labor Productivity:

Sources are defined to be the changes that are capable of causing labor productivity to increase from one year to the next year. Changes in output per worker can be attributed to a number of factors. For the purposes of this analysis, growth in output per worker is attributed to growth in expenditures on inputs per worker, which are used in production. For changes in labor inputs, a decline in the farm labor force makes a positive contribution to labor productivity. There are certain indirect inputs, such as increased education and skills of the agricultural labor force or agricultural research, which also contribute to growth in output per worker, but which are difficult to quantify. The analysis does not provide explicit estimates of the contribution to growth of these inputs. Instead this contribution is estimated in a residual of "all other changes", sometimes referred to as "factor productivity" or other technological change.⁵ Thus, changes in agricultural productivity are attributed to changes in resource use and productivity improvements.

The basis for attributing changes in agricultural labor productivity to changes in resource (including labor) use and productivity improvements is exemplified by Auer.⁶ The following three possible situations under which changes in labor productivity

⁵Factor productivity measures improvements in the overall level of resource use due to technology.

⁶Auer, op. cit.

can occur are examined:

- 1) Labor inputs in agriculture remain constant while capital and factor productivity change,
- 2) Labor inputs in agriculture change while capital inputs and factor productivity remain constant, or
- 3) Labor inputs, capital inputs and factor productivity change simultaneously.

Under the first set of conditions there is no change in labor inputs, and all gains in labor productivity are attributed to changes in capital inputs and factor productivity. Such a situation can occur if, for example, a farmer expands his present cropland acreage by purchasing and clearing additional land, probably land used as wild pasture, and partly in bush and trees. The farmer intends to plant this newly developed land in grains and, to cope with the larger acreage, he replaces his small tractor-pulled combine harvester by a self-propelled combine with greater harvesting capacity. According to the estimation procedures applied later in this study, part of the gains in annual output per worker is imputed to greater capital inputs in land and machinery, and part of it is imputed to productivity improvements. Gains in labor productivity are imputed to capital inputs because purchases of new land and machinery enable the farmer to produce more output without change in his annual labor inputs.⁷ The purchase of the self-propelled combine may also

⁷The assumption here is that the clearing of the newly acquired land was "contracted out" and did not require hiring of additional labor on the farmer's part.

enable him to cut down his harvesting losses by greater timeliness of operations and add to his productivity. Such further productivity improvements are captured in residual factor productivity.

The second set of conditions assumes that labor productivity varies with changes in labor inputs while the levels of capital inputs and factor productivity remain constant. This situation can be illustrated with the case of two neighboring farmers. Let us assume for one reason or another the first farmer decided to cease farming and sells his land, machinery and equipment to the second farmer. With the exit of the first farmer labor inputs are cut in half, capital inputs remain unchanged and labor productivity of the second farmer is doubled, assuming he succeeds in doubling his annual output. This situation implies that after consolidation -- without change in machinery and equipment -- one farmer alone cultivates as much land as two farmers. In such a situation the estimation procedures impute all of the gains in labor productivity to labor adjustments. This is possibly a somewhat unrealistic outcome, since it suggests that before consolidation both farmers were grossly underemployed.

More realistically, changes in agricultural labor productivity are more likely to occur under the third set of conditions, where changes in labor inputs, capital inputs, and factor productivity occur simultaneously. This situation can be illustrated with a retiring farmer who sells land, livestock, machinery, and equipment. This may change resource use and

cause changes in labor productivity in a number of ways. First, there is a positive effect on labor productivity if, after consolidation, total labor inputs are reduced. Secondly, there may be a slightly negative effect if some of the farm buildings go unused and abandoned. Thirdly, there is a positive effect if some of the small-scale depreciated machinery and equipment is placed by more efficient and more costly equipment. Fourthly, there are some additional gains in labor productivity if there are returns to scale from better use of farm machinery and equipment. And, finally, there could be some further productivity improvements due to better farm management. Thus labor productivity changes as a result of changes in both magnitude and proportion of both capital and labor inputs in the wake of technological progress. The analytical procedures adopted in this study, therefore, attribute changes in output per worker to changes in the magnitude and proportion of the labor force, capital inputs, and factor productivity or technological change.

Technological change and capital intensity are important concepts in the analysis of labor productivity. It is for this reason that a discussion of the various concepts of technological change, and their relation to labor productivity and capital inputs, is presented here.

E. Concepts of Technological Change:

Technological change has been defined by Solow as "any kind of shift in the production function".⁸ Such a shift may

⁸R. V. Solow, "Technical Change and the Aggregate Production Function," Review of Economics and Statistics, Vol. 39, p. 312, 1957.

originate from the adoption of improved seed varieties, regional specialization, acquisition of better skills and knowledge by the labor force, all of which make for better management of resources and result in more efficient production techniques. It is this change in the efficiency of resource use that is often referred to as technological change.

A simplified concept of technological change is to think of it in terms of increasing the level of output while holding the level of factor inputs constant. However, a more realistic concept of technological change postulates that the level of resource inputs does vary in both magnitude and proportion with advances in technology. This latter concept will be further elaborated later in a detailed discussion. Here a brief discussion of the types of technological change is presented.

F. Classification of Technological Change:

A number of conventions have been employed by economists to classify technological change. One such convention introduced by Hicks⁹ has been to classify technological advances into:

- 1) 'labor-saving' changes (which facilitate the use of other labor substituting inputs), and
- 2) 'capital-saving' changes (which facilitate the use of other capital substituting inputs). According to this classification a shift in the production function can be either "neutral" or "non-neutral",¹⁰ The technological change is said

⁹ J. R. Hicks, "Distribution and Economic Progress," Review of Economic Studies, Vol. 4.

¹⁰ J. R. Hicks, The Theory of Wages, McMillan and Company, (2nd ed.), 1963.

to be neutral if the marginal productivity¹¹ of capital and labor increased in the same proportion. Put differently, a neutral change is said to have occurred when the marginal rate of substitution of capital for labor remains unchanged. A non-neutral type of technological change, on the other hand, is one which alters the marginal rate of substitution of capital for labor at each point on the production function. If the marginal productivity of capital increases more than the marginal productivity of labor, a non-neutral shift is said to be 'labor-saving' (or 'capital-using'), and 'capital-saving' (or 'labor-using') if the marginal productivity of labor increases more than the marginal productivity of capital.

The concept of neutrality is important in the evaluation of the relative contribution of capital intensity and technological change to labor productivity. This is because whether or not all or part of the increase in labor productivity is attributed to technological change depends on whether or not the change is neutral. In the case of a neutral production function shift, all of the increase in labor productivity could be attributed to technological change because the capital per unit of labor remained unchanged. However, if the shift was non-neutral, some of the increase in the labor productivity might be due to the interaction between capital or labor and technological change. In other words, if the shift was non-neutral, for example, as a

¹¹The marginal productivity of a factor input is the rate of change in total productivity with respect to a variation in quantity of that input.

result of interaction of an increase in capital per unit of labor and technological change then capital might have made a substantial contribution to the resulting increase in labor productivity.

A second convention for types of technological change was introduced by Solow, who classified it as either "embodied", or "disembodied" technological change.¹² Disembodied technological change is defined as an increase in productivity resulting from the use of productive techniques, such as improvements in seed varieties and crop rotations, innovations in mechanization, increased use of fertilizer and herbicides for weed control, better management and superior knowledge. This type of technical change applies equally to all factor items of capital and labor employed in the production process. Embodied technological change is the increase in productivity due to improvements in quality of productive factors over time. Thus the utilization of the latest capital and its respective labor force leads to an embodied technological change. The embodied technological change concept implies that capital "produced" at different time periods have different quality contents and cannot therefore be treated as being homogeneous. Disembodied technological change upholds the homogeneity assumption for both labor and capital and allows their aggregation without a consideration of age differences.¹³

¹²Solow, op. cit.

¹³R. G. D. Allen, "Macro-Economic Theory", MacMillan & Co., New York, 1968.

In this study, assumptions relating to technological change will be made in the next chapter, when the research methodology is presented.

CHAPTER IV

RESEARCH METHODOLOGY

A great deal of research has been done using production function techniques for description and analysis of resource allocation in agriculture.¹ The production function approach is employed in this study for the analysis of labor productivity trends in agriculture. A discussion of some of the underlying assumptions and related concepts are presented here.

The general assumption underlying a production function is that there is a functional relationship between output (or value of production) of a particular industry and resource inputs. This concept can be expressed in a simplified mathematical form as in (1) below:

$$Y_t = f(X_{1t}, X_{2t}, \dots, X_{nt}) \quad (1)$$

where

Y_t is output expressed as a function of resource inputs X_1, X_2, \dots, X_n at time period (t).

To estimate the quantitative contribution of changes in resource use to output, the dynamic elements of production are taken into account by dating all changes in resource use. As

¹See E. O. Heady and J. L. Dillon, "Agricultural Production Functions," Ames, Iowa; Iowa State University Press, 1961. The approach adopted here follows that of Fred H. Tyner and Luther G. Tweeten, "A Methodology for Estimating Production Parameters," Journal of Farm Economics, Vol. 47, No. 5, December, 1965; p. 1462.

well, technological change is explicitly incorporated. No assumptions are made regarding returns to scale, neutral or non-neutral technological changes at this point. The only assumption made here is that the variables of function (1) have "finite and continuous derivatives of all orders which converge upon expansion".² Such changes in aggregate production can be described as shown in the following equation (2).

$$Y_{t+1} - Y_t = f(X_1, t+1, \dots, X_n, t+1) - f(X_1t, \dots, X_nt) \quad (2)$$

Changes in annual output can be computed by the techniques of calculus. The conventional technique of imputing growth to particular resources is to differentiate the production function with respect to time. An alternative method for achieving the same goal is Taylor's expansion. Using this technique changes in output can be attributed to changes in resource use, their marginal productivities, and a series of interaction effects among resources. The principal advantage of using Taylor's expansion instead of time derivatives is that it is more accurate because the result of using time derivatives is equivalent to a first-term Taylor expansion. In this study a third-term Taylor expansion will be used to minimize further the error of estimation. The Taylor expansion technique has the added advantage of being programmable, thus enabling the use of computer software. The result of applying Taylor's expansion to function (2) is as expressed in equation (3) following:

²L. Auer, "Comparative Analysis of Canadian and United States Productivity," A North American Common Market, Iowa State University Press, Ames, Iowa; U.S.A. 1969, p. 109.

$$\Delta Y = \sum_i^n \Delta X_i \left(\frac{\partial Y}{\partial X_i} \right)_t + \frac{1}{2!} \sum_i^n \sum_j^n \Delta X_i \Delta X_j \left(\frac{\partial^2 Y}{\partial X_i \partial X_j} \right)_t + \dots + R \quad (3)$$

A rearrangement of terms in (3) yields (4):

$$\begin{aligned} \Delta Y = & \Delta X_1 \left[\left(\frac{\partial Y}{\partial X_1} \right)_t + \frac{1}{2!} \sum_j^n \Delta X_j \left(\frac{\partial^2 Y}{\partial X_1 \partial X_j} \right)_t + \dots \right] \\ & \Delta X_2 \left[\left(\frac{\partial Y}{\partial X_2} \right)_t + \frac{1}{2!} \sum_j^n \Delta X_j \left(\frac{\partial^2 Y}{\partial X_2 \partial X_j} \right)_t + \dots \right] \\ & \vdots \\ & \Delta X_n \left[\left(\frac{\partial Y}{\partial X_n} \right)_t + \frac{1}{2!} \sum_j^n \Delta X_j \left(\frac{\partial^2 Y}{\partial X_n \partial X_j} \right)_t + \dots \right] + R \quad (4) \end{aligned}$$

where

$$\Delta Y = Y_{t+1} - Y_t$$

$$\Delta X_i = X_{i,t+1} - X_{i,t}$$

$$\Delta X_j = X_{jt,t+1} - X_{jt}$$

R = remainder term

Function (4) indicates that a change in output, ΔY , is attributed to a change in each of the n-factor inputs ΔX_i , marginal productivities $\partial Y / \partial X_i$, interaction effects among resources, and a remainder term R.

The above approach is applicable to different types of production functions.³ For the purposes of this study, however, a Cobb-Douglas type production function is chosen because it is simple to use and equally applicable to the type of empirical

³See A. A. Walters, "Production and Cost Functions: An Econometric Survey," *Econometrica*, Vol. 31, No. 1-2, Jan.-April, 1963, pp. 1-66.

analysis applied here. The Cobb-Douglas production function can be expressed in its general form as follows:

$$Y_t = a(t) \prod_{i=1}^n X_i^{b_i(t)}$$

where

$$\prod_{i=1}^n X_i^{b_i} = X_1^{b_1} X_2^{b_2} \dots X_n^{b_n}$$

Y is the level of output

X_i is the level of the i th resource input

b_i is the i th production elasticity

$a(t)$ measures factor productivity or technological change

In this study a neutral technological change is assumed, and therefore the Cobb-Douglas production function can be expressed as in (5) below:

$$Y = a(t) \prod_{i=1}^n X_i^{b_i} \quad (5)$$

This means that resource inputs are allowed to vary, but production elasticities (b_i) are assumed to remain constant. This implies that technological change shifts marginal and average productivities equi-proportionately. Neutral technological change in this formulation can be represented by an exponential shift variable for the term $a(t)$ in function (5) after Tinbergen's proposition⁵, i.e., $a(t)$ can be represented by $A_0 e^{vt}$.

⁴Factor productivity which measures improvements in the overall level of resource use due to technology is treated here in the same way as other variables.

⁵M. Brown, "On the Theory and Measurement of Technological Change," Cambridge University Press, 1966, p. 111.

Taylor's expansion can be applied to function (5) to express changes in output due to changes in resource inputs as in ^{equation} equation (6).

$$\begin{aligned} \Delta Y = \Delta \frac{aY}{a} & \left(1 + \frac{1}{2!} \sum_i^n b_i \left(\frac{\Delta X_i}{X_i} \right)_t + \dots \right) \\ & + b_1 \Delta X_1 \frac{Y}{X_1} \left(1 + \frac{1}{2!} \sum_i^n b_i \left(\frac{\Delta X_i}{X_i} \right)_t + \dots \right) \\ & \vdots \\ & + b_n \Delta X_n \frac{Y}{X_n} \left(1 + \frac{1}{2!} \sum_i^n b_i \left(\frac{\Delta X_i}{X_i} \right)_t + \dots \right) + R \end{aligned} \quad (6)$$

A. Growth Rates in Output and Resource Inputs:

The changes in output and resource inputs can be converted to growth rates r_i . This is achieved by dividing expression (6) by Y to obtain (7).

$$\begin{aligned} r_Y = r_a & \left(1 + \frac{1}{2} \sum_i^n b_i r_i + \dots \right) \\ & + b_1 r_1 \left(1 + \frac{1}{2} \sum_i^n b_i r_i + \dots \right) \\ & \vdots \\ & + b_n r_n \left(1 + \frac{1}{2} \sum_i^n b_i r_i + \dots \right) + R \end{aligned} \quad (7)$$

$$\text{if } i = j, b_i = b_j - 1.0$$

According to (7) growth in output r_Y , is the sum of the growth rates in each resource input r_i , each weighted by its production elasticity, and the set of interaction terms of the different resource inputs.

B. Estimation Procedure for Production Elasticities:

The conventional method of estimating production elasticities is to use the ordinary least squares technique on function (5).

However, since the current study is interested in a disaggregate analysis the OLS procedure would result in problems of multicollinearity. Production elasticities (b_i), can be shown to be proportionate or equal to factor shares of individual resources under a set of assumptions. These assumptions are that, resources in agriculture are allocated with the objective of maximizing net revenue and that quality and costs of resources use are constrained by the state of technology, risk, uncertainty, market demand and other restrictions. When all these restraints are combined, overall restriction on capital use can be derived as in (8).

$$R = \left(a \prod_i^n X_i^{b_i} \right) P_y - \sum_i^n X_i P_i + \mu \left(C - \sum_i^n X_i P_i \right) \quad (8)$$

where μ is a Lagrange multiplier;

R is net revenue or value of output Y at price P_y ;

X_i are resource input at price P_i ; and

C is capital resource constraining resource use.

The necessary⁶ conditions for maximizing net revenue R , subject to capital constraint C is expressed in (9),

$$\frac{\partial R}{\partial X_i} = P_y \frac{\partial Y}{\partial X_i} - (1 + \mu) P_i = 0 \quad (9)$$

$$\therefore P_y \frac{\partial Y}{\partial X_i} = (1 + \mu) P_i$$

⁶See Clopper Almon, Jr., "Matrix Methods in Economics," Reading, Mass., Addison-Wesley Publishing Company, 1967. Chapter 5, for a description of "necessary" conditions of a constrained maximum.

which implies that all resources are allocated in proportion to their marginal productivities.

In terms of production elasticities, function (9) can be expressed as in (10),

$$\frac{\partial R}{\partial X_i} = P_y^{b_i} \frac{Y}{X_i} - (1 + \mu)P_i = 0 \quad (10)$$

$$\therefore b_i = (1 + \mu) \frac{P_i X_i}{P_y Y}$$

where

b_i is production elasticity, and

$\frac{P_i X_i}{P_y Y}$ measures factor share of individual resources.

From (10) it follows that if capital is restricted, all resources are paid in proportion $1 + \mu > 1$ of their marginal productivities. However, if capital is unrestricted, $\mu = 0$, and all resources are paid exactly their marginal value productivities. This is what is assumed here in this study; that is, capital is unrestricted in Canadian agriculture and therefore production elasticities of resource inputs can be approximated by their factor shares, or in this case, "expenditure shares".

The contribution of each factor input to growth in output can therefore be estimated as its growth rate (r_i) weighted by its factor share (b_i). When the sum of their contributions is subtracted from growth in output, the residual is a measure of gains in factor productivity. The growth in output to resource use and factor improvements over a number of years can then be estimated as an average of this annual contribution of each resource input.

C. Labor Productivity Function:

Labor productivity has earlier been defined as output per worker. In terms of function (5), a labor productivity function can be derived as in (11),

$$\frac{Y}{X_1} = a \frac{X_1^{b_1}}{X_1} \prod_{i=2}^n X_i^{b_i} \quad (11)$$

where

X_1 is the labor input variable.

Labor productivity then is a function of factor productivity and other resource inputs. As in (7) above, growth in labor productivity can be imputed to changes in resource inputs and factor productivity as expressed in (12).

$$\begin{aligned} r_y^* &= r_a \left[1 + \frac{1}{2} \sum_{i=1}^n b_i r_i + \dots \right] \\ &+ b_1^* r_1 \left[1 + \frac{1}{2} \sum_{i=1}^n b_i r_i + \dots \right] \\ &\vdots \\ &+ b_n r_n \left[1 + \frac{1}{2} \sum_{i=1}^n b_i r_i + \dots \right] + R \end{aligned} \quad (12)$$

where

$$r_y^* = \frac{\Delta Y}{\Delta X_1} \div \frac{Y}{X_1}$$

$$b_i^* = b_i - 1.0$$

The production elasticity, b_i^* , of the labor input will be negative because the b_i exponent obtained earlier is less than 1.0. This negative value of b_i^* implies that a reduction in labor inputs would result in greater labor productivity. If increased capital inputs, and other productivity improvements

combine with reductions in labor inputs to bring about greater labor productivity, then additional gains must be imputed to factor productivity and other factor inputs used in conjunction with labor. For example, if capital stocks in machinery and equipment, real estate, and livestock and poultry (breeding stock) have changed, additional contributions to labor productivity improvements are imputed to changes in depreciation and capital cost or interest charges.

The analysis will be carried out with capital and material inputs which are disaggregated as follows:

- 1) Labor Input.....(X₁)
- 2) Capital and Material Inputs
 - a) Land and Buildings
 - Interest on real estate.....(X₂)
 - Depreciation on buildings.....(X₃)
 - Taxes on real estate.....(X₄)
 - Building repairs.....(X₅)
 - b) Machinery and Equipment
 - Interest on capital stock.....(X₆)
 - Depreciation on machinery.....(X₇)
 - Machinery operating expenses.....(X₈)
 - c) Crop Yield Inputs
 - Fertilizer and lime.....(X₉)
 - Other crop expenses (includes seed purchased).....(X₁₀)

d) Livestock Yield InputsInterest on capital stock.....(X_{11})Feed purchased.....(X_{12})Other livestock expenses.....(X_{13})e) Miscellaneous operating expenses(X_{14})D. The Data Used in the Study:

The procedures applied in this study for the analysis of growth in agricultural labor productivity require time series data on gross value of production, labor employed in agriculture and wages paid to farm labor, as well as data on the aggregated series of land and buildings, mechanization, crop yield inputs, livestock yield inputs, and other miscellaneous operating expenses. While some of these series were obtained from publications of Statistics Canada, other series had to be derived and adjusted by procedures to be explained shortly. The series are shown in Appendix Tables 4 and 7. The constant dollar values of the series found in Appendix Table 5 and 8, were measured in 1961 constant dollars by deflating each series by an appropriate price index using 1961 as the base year.

Gross Farm Production Series

Estimates of Gross Farm Income⁷ include cash receipts from farm marketings of crop and livestock production, the value of farm products consumed by the farm household, the rental value of

⁷Dominion Bureau of Statistics Handbook of Agricultural Statistics Part II, Farm Income Catalogue No. 21-511, Ottawa, Queens Printer, 1967.

farm dwellings, as well as different types of government payments. Since 1940 farmers in Canada have received various supplementary and deficiency payments for abnormal losses or low returns in production of wheat, potatoes, sugar beets, wool and dairy products.⁸ The gross farm income series were therefore adjusted for government payments and inventory changes to arrive at gross farm production.⁹

Weather variations in Canada have significant influence on agricultural production, particularly with respect to crop yields. For this reason, the annual estimates of gross farm production were adjusted in order to eliminate the effects of weather from output. For this adjustment, linear yield trends were fitted to yields per acre of selected principal crops for each region:

Alberta: wheat, oats, barley, rye, flaxseed.

Saskatchewan: wheat, oats for grain, barley, rye, flaxseed, rapeseed.

Manitoba: wheat, oats, barley, flaxseed, rapeseed.

Quebec: oats, fodder, corn, wheat, barley.

Ontario: wheat, oats for grain, barley, sorghum, corn for grain.

Prince Edward Island: oats for grain, potatoes, tame hay.

Nova Scotia: oats for grain, potatoes, tame hay.

New Brunswick: oats, potatoes, tame hay.

British Columbia: wheat, oats, barley.

⁸Ibid.

⁹This series could not be adjusted for the rental value of farm dwellings because of lack of information about the series on dwellings. The adjustment procedure for British Columbia is shown in Appendix .

The estimated trend was then subtracted from the observed yield. The differences between the observed and the estimated yields of individual crops were then weighted by their respective acreages and average prices per unit. These trend values were summed across crops and the sum was added to (if negative) or subtracted from (if positive) the observed values of farm production. This had the effect of lowering or raising the value of farm production during crop yield years of above (positive value) or below (negative values) "normal" production as shown in Appendix 6 for the British Columbia region.

Farm Labor Input Series

The series data on agricultural labor employed was measured in terms of number of workers. This series, obtained directly from Statistics Canada data, is comprised of unpaid family labor, hired farm labor, and farm operators, of fourteen years of age and older. The series was not adjusted for age or sex composition because it is assumed that each worker is paid the estimated market wage for agricultural labor. In any case, the measure of labor productivity employed in this study is output per worker. It would have been necessary to adjust the series for age and sex composition and for length of year worked if productivity were measured in man-equivalents or man-hours.

Land and Buildings

The land and buildings category consists of data series on interest on real estate, depreciation on buildings, taxes on real estate, and building repairs. The series on depreciation on buildings, taxes, and building repairs were extracted directly

from Statistics Canada publications. The capital cost on real estate was however estimated by an indirect method. Land, for example, has two market values. Firstly, the net rent paid per acre is the short term rate which should reflect current net productivity of land. Secondly, the mortgage rate charged by lending institutions reflects the amount that capital will earn over a longer period. Since no series on rental rates on land and buildings could be found for the period of the study, and since it was observed that mortgage rates during the period varied from one lending institution to another for agricultural production, it was finally decided to apply the average yield on Government of Canada bonds for ten years and over, to estimate interest charges on land and buildings. The series of average bond yields were applied to the capital stock on land and buildings series shown in Appendix 9. However, rental rates on real estate are likely to be more sensitive to change than average bond yields. Therefore, the estimate obtained for this series as explained here may be lower than actual interest charges on rural real estate during the period.

Machinery and Equipment

This consists of interest on investment in machinery and equipment, machinery depreciation, and machinery operating expenses. The series on machinery depreciation, and machinery operating expenses, were obtained from Statistics Canada data. Machinery operating expenses include expenditure on spare parts, gas, oil, and other lubricants. As in the case of land and buildings, government average annual bond yield rates were

applied to capital stock on machinery and equipment series to measure the interest charges on these items. Government of Canada average bond yield rates for three to five years were used.

Crop Yield Inputs

The crop yield inputs include expenditures on fertilizer and limestone, purchased seed, as well as expenses on insecticides and pesticides. The series on fertilizer and lime, and other crop expenses were derived from Statistics Canada publications as shown in the relevant appendix.

Livestock Yield Inputs

This group of inputs consists of the series of data on interest on capital investment in livestock and poultry, expenses on purchased feed, and other livestock expenses. Expenditures on feed, and other livestock items, are as published by Statistics Canada. The series on other livestock expenses cover such items as drugs, veterinary expenses, and artificial insemination. Interest charges on livestock investments were estimated by applying average bond yield rates between one to three years, to the capital stock series on livestock and poultry (see Appendix Tables 9 (A-F)). These rates were chosen because they reflect approximately the returns to capital on short-term investments and because livestock production is a short-term venture.

Miscellaneous Operating Expenses Series

This series, which covers other expenditures not covered by the various categories discussed above, is taken directly from

Statistics Canada publications. The series covers such items as fencing, custom work, insurance, and other expenses on supplies and services not previously specified.

CHAPTER V

EMPIRICAL RESULTSA. Estimates of Factor Shares:

In the last chapter it was indicated that if the production elasticities of all variables in function (5) were estimated simultaneously by application of the conventional technique of ordinary least squares, problems of multicollinearity would arise and result in unreliable parameter estimates. In a disaggregate analysis, such as the one attempted in this study, these multicollinearity problems could be quite serious. The short-cut method employed in the study assumes that employment of resources tends toward equilibrium levels where marginal costs are equal or proportionate to marginal returns. Marginal costs can be equated to marginal revenue in perfect equilibrium conditions and therefore production elasticities of individual resource inputs are equated to their factor shares as presented in the previous Chapter (IV).

As a working hypothesis, it is assumed that equilibrium factor shares remain unchanged over the period and therefore estimates for the elasticity parameters are obtained by averaging the annual values of the factor shares of individual resource inputs.¹

¹This hypothesis was statistically tested and the findings are presented in the Appendix of the study.

The factor shares of labor and capital inputs are estimated as the ratio of input cost to output returns, and the results for Canada and the regions are presented in Table IV. The results are based on five year "range estimates", and can be interpreted as the contribution to growth of both changes in resource use and advances in technology.

TABLE IV
 FACTOR SHARES (OR PRODUCTION ELASTICITIES) OF RESOURCE
 INPUTS IN AGRICULTURAL OUTPUT, ANNUAL AVERAGES,
 CANADA AND REGIONS, 1950 - 1974.

Resource Description:*	Canada	Atlantic	Quebec	Ontario	Prairie	B.C.
Land and buildings	.248	.192	.263	.257	.282	.279
Labor	.338	.496	.492	.299	.325	.275
Capital Inputs Related to:	.426	.476	.454	.497	.427	.408
Mechanization	.224	.180	.102	.178	.304	.145
Crop yield technology	.046	.093	.050	.064	.037	.045
Livestock yield technology	.124	.174	.257	.211	.061	.189
Miscellaneous operating expenses	.032	.029	.045	.044	.025	.029
Total	1.012	1.164	1.209	1.053	1.034	.962

Source: Based on data from Statistics Canada (See Appendix Tables 4 (A-F).
 and Appendix Tables 7 (A-H)).

* This table presents a summary of average annual factor shares. A detailed breakdown of resource inputs and their average annual production elasticities are presented in Appendix Tables 1 - A to F. Also, the composition and description of land and buildings, mechanization, crop yield technology, and livestock yield technology are given in the present chapter.

The factor shares estimates above closely resemble the earlier analysis of resource inputs per worker (see Table II). With the exception of the Atlantic region, no significant differences are observed in the share of land and buildings in agricultural output among regions. However, Table IV shows significant regional differences in the share of mechanization, livestock yield inputs, and to a lesser degree, labor inputs. The share of mechanization ranges from a high of 0.30 in the Prairie region, to a low of 0.10 in the Quebec region. The Quebec region, however, had the highest share in output in the area of livestock yield inputs, about 0.25, while the corresponding estimate for the Prairie region was only 0.06. The share of crop yield inputs was observed to be comparatively lower in all regions.

B. Estimated Production Functions and Labor Productivity Trends:

In the last chapter, a Cobb-Douglas-type production function describing output per worker in terms of resource inputs was formulated. In its general form, this function can be expressed using log to base ten as follows:

$$Y = X_1^{b_1} X_2^{b_2} \dots \dots \dots X_n^{b_n} 10^{a + b_i t}$$

where,

Y is output per worker, $b_1 \dots b_n$ are factor shares, $X_1 \dots X_n$ are resource inputs, and an exponential time - trend variable inserted to capture "all other changes" leading to improvements in productivity. The

time - trend variable is estimated as shown in the regression equation below:

$$\log_{10} \left(Y / \prod_{i=1}^n X_i^{b_i} \right) = a_0 + b_1 t + e$$

The estimated production functions for Canada and the regions are as presented in the following equations:²

Canada:

$$Y = X_1^{.338} X_2^{.138} \dots X_{14}^{.032} 10^{-.110} + .012t$$

Atlantic Region:

$$Y = X_1^{.496} X_2^{.092} \dots X_{14}^{.029} 10^{.731} + .017t$$

Quebec Region:

$$Y = X_1^{.492} X_2^{.030} \dots X_{14}^{.045} 10^{1.645} + .025t$$

Ontario Region:

$$Y = X_1^{.299} X_2^{.142} \dots X_{14}^{.044} 10^{-.001} + .011t$$

Prairie Region:

$$Y = X_1^{.325} X_2^{.164} \dots X_{14}^{.025} 10^{.060} + .008t$$

British Columbia Region:

$$Y = X_1^{.275} X_2^{.184} \dots X_{14}^{.029} 10^{1.027} + .003t$$

²Resource inputs $X_1 \dots X_{14}$ denote labor and capital inputs as specified in Appendix Tables 1 - A to F.

The estimated production functions above, describe agricultural production as proposed by Tinbergen, in which capital and labor inputs are disaggregated and the exponents of capital and labor inputs are estimated from factor shares.³

From these functions trends in agricultural labor productivity for Canada and the five regions are derived by dividing each function by the labor input variable X_1 , as shown below:

Canada:

$$Y/X_1 = X_1^{.338-1.00} X_2^{.138} \dots X_{14}^{.032} 10^{-.110} + .012t$$

Atlantic Region:

$$Y/X_1 = X_1^{.496-1.00} X_2^{.092} \dots X_{14}^{.029} 10^{.731} + .017t$$

Quebec Region:

$$Y/X_1 = X_1^{.492-1.00} X_2^{.030} \dots X_{14}^{.045} 10^{1.645} + .025t$$

Ontario Region:

$$Y/X_1 = X_1^{.299-1.00} X_2^{.142} \dots X_{14}^{.044} 10^{-.001} + .011t$$

Prairie Region:

$$Y/X_1 = X_1^{.325-1.00} X_2^{.164} \dots X_{14}^{.025} 10^{.060} + .008t$$

British Columbia Region:

$$Y/X_1 = X_1^{.275-1.00} X_2^{.184} \dots X_{14}^{.029} 10^{1.027} + .0035$$

³See M. Brown, op. cit. and also, Fred H. Tyner and Luther G. Tweeten, "A Methodology for Estimating Producing Function Parameters," Journal of Farm Economics, Vol. 47, No. 5, Dec. 1965, p. 1462.

These production function estimates of trends in labor productivity and the actual production per worker are as drawn in Figure 1 (a-f) and shown in Appendix Tables 5 (A-F), for Canada and the regions. Figures 1 (a-f) demonstrate that the specified Cobb-Douglas-type production function closely approximates the actual output per worker.

C. Estimates of Components of Growth in Labor Productivity:

Taylor's expansion is then applied to these labor productivity "trend functions" to obtain estimates of "components of growth" in labor productivity. The expansion technique is illustrated below using estimates for Canada as a whole.

$$\begin{aligned}
 r_y/x_1 = & r_1(0.338 - 1.00)(1.0 + \frac{1}{2}(.338 - 2.00)r_1 + \frac{1}{2}(.030)r_2 + \dots) \\
 & + r_2(.030)(1.0 + \frac{1}{2}(.338 - 1)r_1 + \frac{1}{2}(.030 - 1.00)r_2 + \dots) \\
 & + \dots \\
 & + r_{14}(0.32)(1.0 + \frac{1}{2}(.338 - 1.00)r_1 + \frac{1}{2}(.030)r_2 + \dots) \\
 & + r_a(1.00)(1.0 + \frac{1}{2}(.338 - 1.00)r_1 + \frac{1}{2}(0.30) r_2 + \dots)
 \end{aligned}$$

where

r_y/x_1 is the annual growth rate of gross output per worker;

$r_1 \dots r_{14}$ refer to annual growth rates of individual resource inputs, (see Appendix Table 2);

r_a describes productivity improvements due to "all other changes".

Each line in the expansion represents the annual average growth in labor productivity imputed to a particular resource.

Thus, the contribution of changes in resource use and technology to growth in labor productivity is measured in terms

OUTPUT PER
WORKER

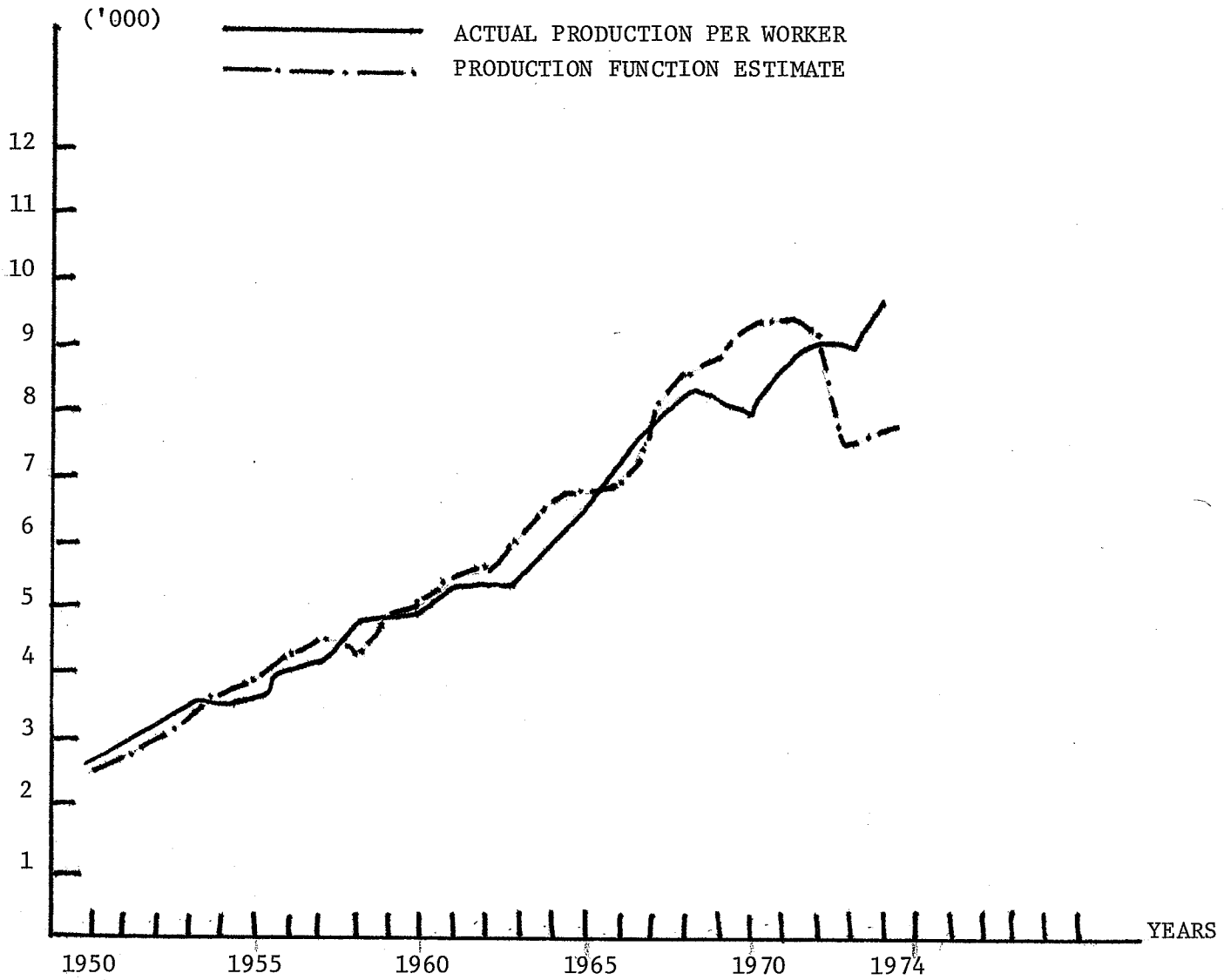


FIGURE 1 (a) - Gross value of production per worker in agriculture, Canada - constant dollars in thousands.
Source: See Appendix Table 5 - A.

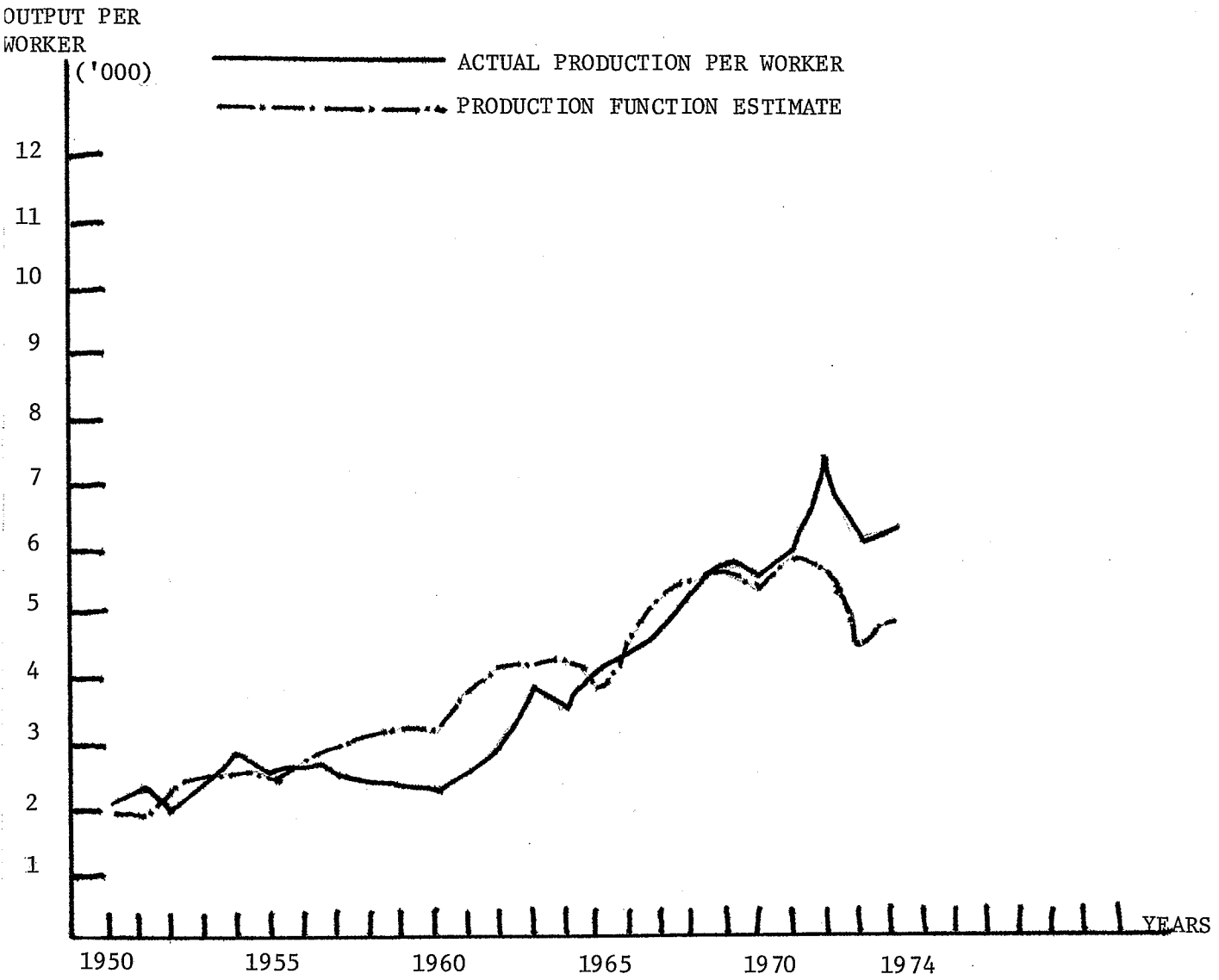


FIGURE 1 (b) - Gross value of production per worker in agriculture, Atlantic Region - constant dollars in thousands.
Source: See Appendix Table 5 - B.

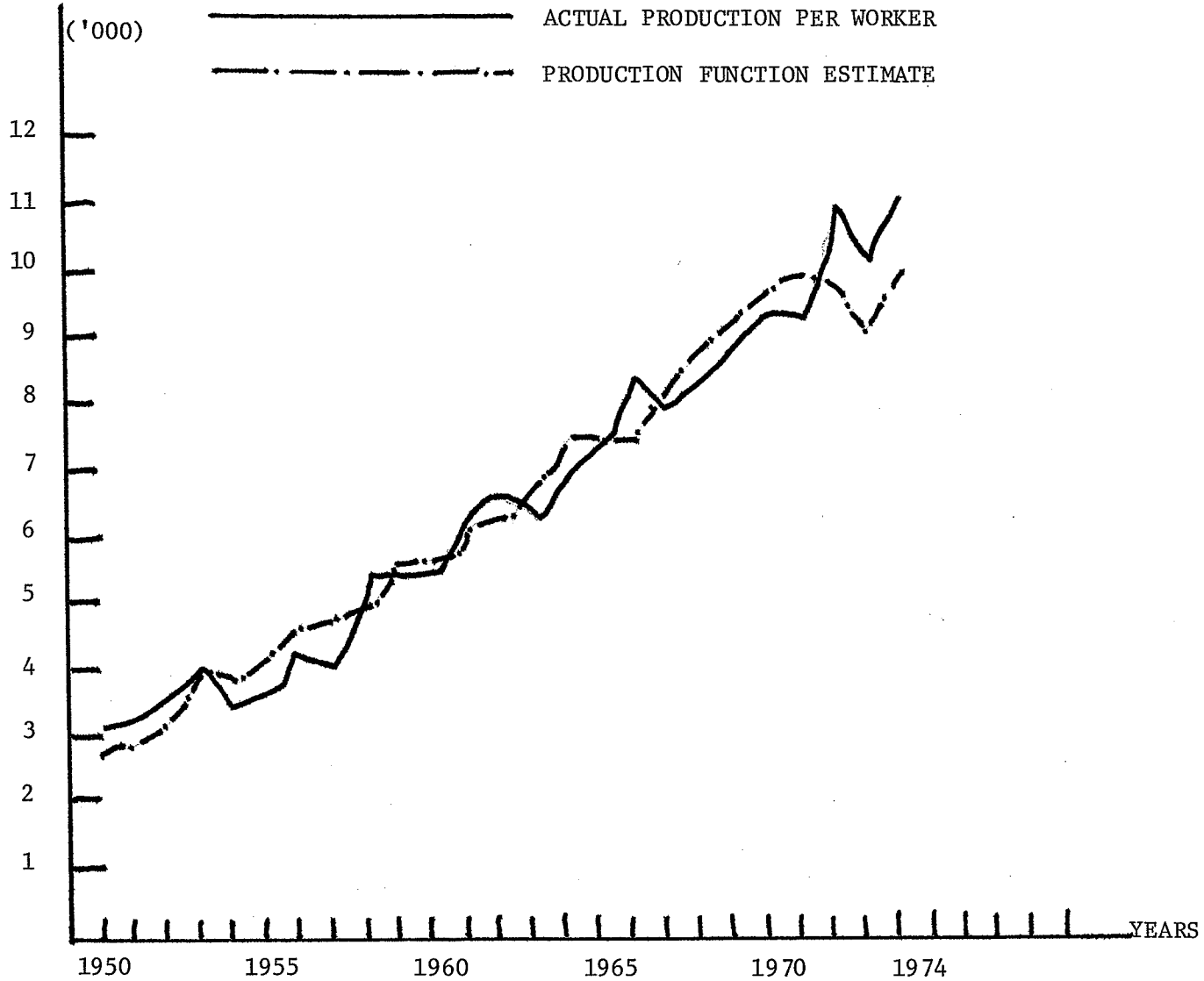
OUTPUT PER
WORKER

FIGURE 1 (d) - Gross value of production per worker in agriculture, Ontario Region - constant dollars in thousands.
Source: See Appendix Table 5 - D.

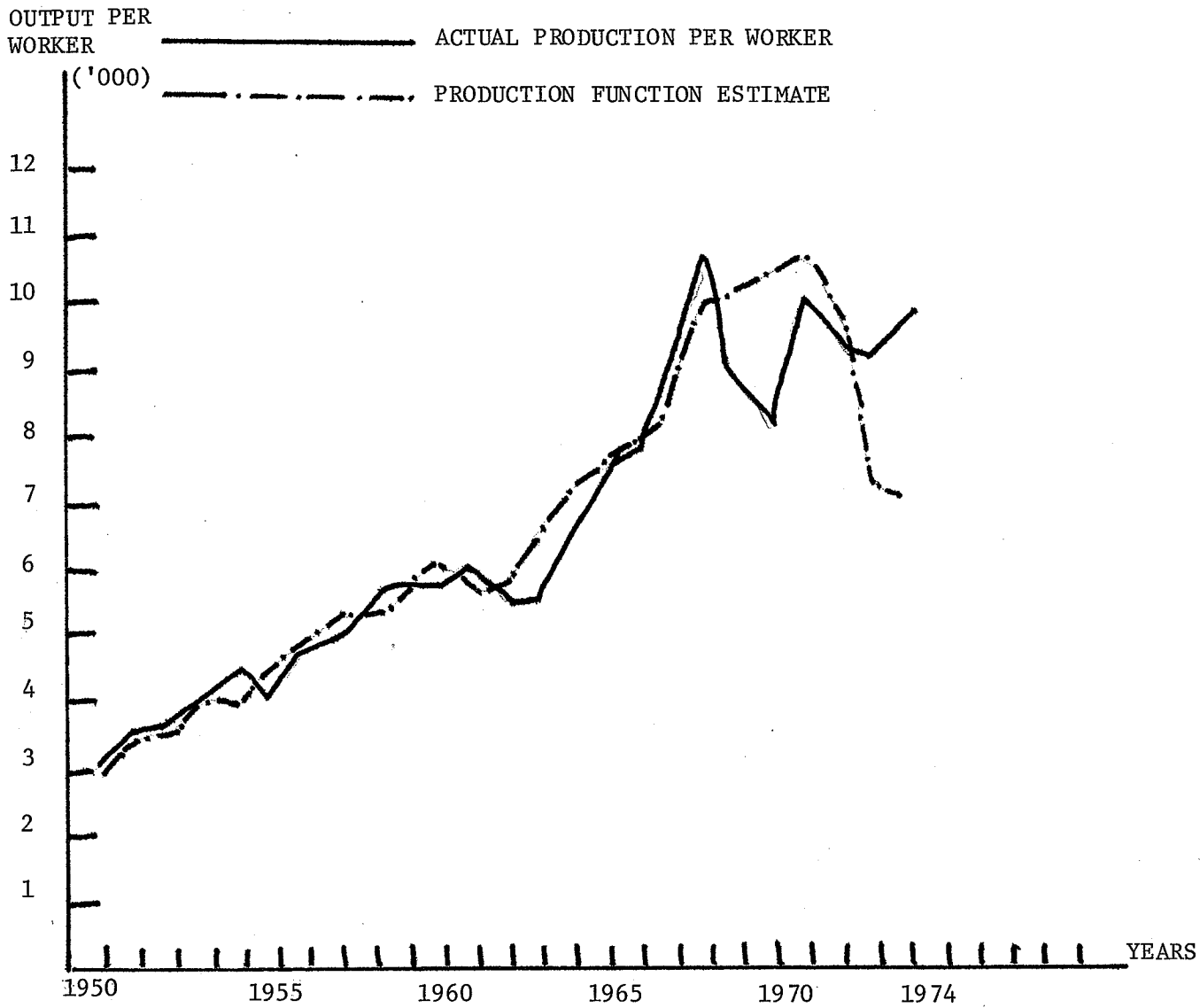


FIGURE 1 (e) - Gross value of production per worker in agriculture, Prairie Region - constant dollars in thousands.
Source: See Appendix Table 5 - E.

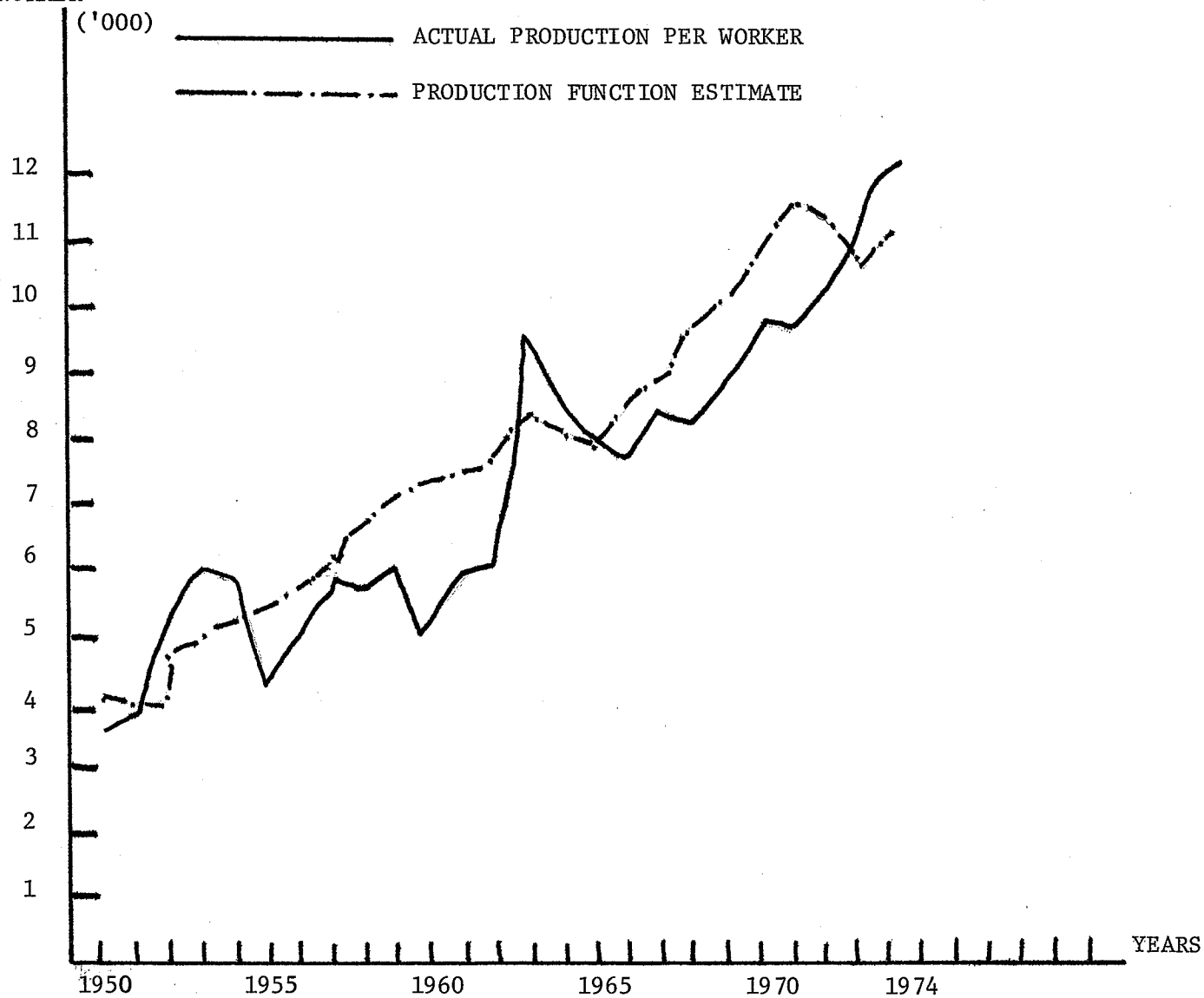
OUTPUT PER
WORKER

FIGURE 1 (f) - Gross value of production per worker in agriculture, British Columbia Region, constant dollars in thousands.

Source: See Appendix Table 5 - F.

of their average annual growth rates weighted by their elasticities. Overall growth rates in gross real output (r_y/x_1), per worker, weighted annual growth rates of individual resource inputs and technology ($r_i b_i$) are computed as described above, and summarized in Tables V to X for Canada and the regions.⁵

For Canada as a whole the overall growth rate in labor productivity is over 6 percent per annum. This result is slightly higher than that obtained by Auer in an earlier work.⁶ The major contribution to overall growth in labor productivity came from capital and material inputs including land and buildings. Of the three principal capital input categories, namely mechanization, crop yield inputs, and livestock yield inputs, mechanization ranked highest in contributing to overall growth in labor productivity in Canadian agriculture, with crop yield technology making the smallest contribution to productivity growth.

The overall growth rate per annum of labor productivity in the Atlantic region during the period is more or less of the same magnitude as the national average of 6 percent. However, unlike Canada as a whole, the estimates for the Atlantic region show that other technological changes contributed the major proportion in overall growth -- roughly about 50 percent. The labor input was next with over 25 percent and the remaining contribution was made by the capital and material inputs category (see Table VI).

⁵See Appendix Table 3 for detailed breakdown for Canada and the regions.

⁶Auer, op. cit.

TABLE V
 COMPONENTS OF GROWTH IN AGRICULTURAL LABOR PRODUCTIVITY,
 CANADA, 1950-1974

	<u>Average Annual Percentage Change</u>	<u>Percent</u>
Growth in Labor Productivity	6.21	100
Components:		
Labor Input (effect of outmigration)	1.46	23
Capital and Material Inputs	2.71	44
Land & Buildings	1.07	
Mechanization	.64	
Crop Yield Technology	.40	
Livestock Yield Technology	.49	
Miscellaneous	.11	
All other changes*	2.04	33

Source: Based on Statistics Canada data (see Appendix Table 1-A and Appendix Table 2).

* These changes are specified and discussed later on in this section of the study.

TABLE VI

COMPONENTS OF GROWTH IN AGRICULTURAL PRODUCTIVITY,
ATLANTIC REGION, 1950-1974

	<u>Average Annual Percentage Change</u>	<u>Percent</u>
Growth in Labor Productivity	6.01	100
Components:		
Labor Input (effect of outmigration)	1.74	29
Capital & Material Inputs	1.40	23
Land and Buildings	.40	
Mechanization	.38	
Crop Yield Technology	.19	
Livestock Yield Technology	.34	
Miscellaneous	.09	
All other changes	2.87	48

Source: Based on Statistics Canada (see Appendix Table 1-B, and Appendix Table 2).

Mechanization contributed 50 percent more to growth in productivity than crop yield inputs, and contributed about 5 percent more than livestock yield inputs.

Estimates of agricultural performance in the Quebec region are shown in Table VII. Agricultural labor productivity in the Quebec region grew at an annual rate of a little over 5.5 percent during the period under consideration. Nearly 40 percent of this growth in agricultural labor productivity came from "all other changes" or improvements in resource productivity. Capital and material inputs accounted for a third of the growth in overall labor productivity growth, with the labor input contributing the remaining 25 percent.

The estimates for the Ontario region bear a close resemblance to the national average growth rates. Table VIII shows that like Canada as a whole, the major contributor to the 6 percent per year rate of growth in agricultural labor productivity in the Ontario region is capital and material inputs. This resource input category accounted for more than 50 percent of the growth in agricultural labor productivity in that region. However, unlike the national estimates, the labor input contributed a little over 25 percent, with "all other changes" making up about 20 percent. Livestock yield inputs dominated mechanization, and crop yield inputs. Livestock yield technology contributed about 10 percent more than mechanization and about 25 percent more than crop yield technology in the Ontario region.

TABLE VII
 COMPONENTS OF GROWTH IN AGRICULTURAL LABOR PRODUCTIVITY,
 QUEBEC REGION, 1950-1974

	<u>Average Annual Percentage Change</u>	<u>Percent</u>
Growth in Labor Productivity	5.65	100
Components:		
Labor Input (effect of outmigration)	1.42	25
Capital and Material Inputs	1.92	34
Land & Buildings	.42	
Mechanization	.40	
Crop Yield Technology	.40	
Livestock Yield Technology	.56	
Miscellaneous	.14	
All other changes	2.21	39

Source: Based on data from Statistics Canada (See Appendix Table 1-C, and Appendix Table 2).

TABLE VIII
 COMPONENTS OF GROWTH IN AGRICULTURAL LABOR PRODUCTIVITY,
 ONTARIO REGION, 1950-1974

	<u>Average Annual Percentage Change</u>	<u>Percent</u>
Growth in Labor Productivity	6.05	100
Components:		
Labor Input (effect of outmigration)	1.57	26
Capital and Material Inputs	3.21	53
Land & Buildings	1.46	
Mechanization	.54	
Crop Yield Technology	.40	
Livestock Yield Technology	.64	
Miscellaneous	.17	
All other changes	1.27	21

Source: Based on data from Statistics Canada (see Appendix Table 1-D, and Appendix Table 2).

The major role which capital and material inputs play in contributing to growth is again shown by the estimates for the Prairie, and the British Columbia regions. As in the Ontario region, capital and material inputs made the dominant contribution to growth in agricultural productivity. Prairie agricultural labor productivity increased at an annual rate of over 6.5 percent. This is made up of some 47 percent from capital and material inputs, 37 percent from "all other changes", and some 16 percent by adjustments in the farm labor force, as shown in Table IX. Here again, mechanization predominates over livestock yield, and crop yield technologies.

The pattern in the British Columbia region is similar to the Prairie region, except for the fact that adjustments in the farm labor force, and other technological changes contributed about equal proportions to the overall growth rate in labor productivity in British Columbia, a little over 9 percent per annum. Capital and material inputs contributed about half of this overall growth, with the other half shared more or less equally between the labor input adjustments and "all other changes". Table X shows these estimates.

The magnitude of the overall rate of growth in labor productivity ranged from a high of over 9 percent in the British Columbia region to a low of about 5.5 percent in the Quebec region. The earlier estimates of the absolute magnitude of labor productivity revealed that superior performance was achieved by the British Columbia, Ontario, and Prairie regions, compared with that achieved by Quebec and the Atlantic regions

TABLE IX
 COMPONENTS OF GROWTH IN AGRICULTURAL LABOR PRODUCTIVITY,
 PRAIRIE REGION, 1950-1974

	<u>Average Annual Percentage Growth</u>	<u>Percent</u>
Growth in Labor Productivity	6.62	100
Components:		
Labor Inputs (effect of outmigration)	1.05	16
Capital and Material Inputs	3.13	47
Land & Buildings	1.32	
Mechanization	.75	
Crop Yield Technology	.49	
Livestock Yield Technology	.51	
Miscellaneous	.06	
All other changes	2.44	37

Source: Based on Statistics Canada (see Appendix Table 1-E and Appendix Table 2).

TABLE X
 COMPONENTS OF GROWTH IN AGRICULTURAL PRODUCTIVITY,
 BRITISH COLUMBIA REGION, 1950-1975

	<u>Average Annual Percentage Change</u>	<u>Percent</u>
Growth in Labor Productivity	9.17	100
Components:		
Labor Inputs (effect of outmigration)	2.45	27
Capital and Material Inputs	4.37	48
Land & Buildings	2.46	
Mechanization	.63	
Crop Yield Technology	.22	
Livestock Yield Technology	.93	
Miscellaneous	.13	
All other changes	2.35	25

Source: Based on data from Statistics Canada (see Appendix Table 1-F and Appendix Table 2).

(see Table 1). On the basis of the estimates presented in Tables V to X, a plausible explanation can now be attempted in terms of the specified 'components' of labor productivity as summarized in these tables, namely labor inputs, land and buildings, mechanization, crop yield inputs, livestock yield inputs, and "all other changes".

Labor Input: The labor input made a significant contribution to overall growth in labor productivity in all five regions studied. This has come through adjustments in the farm labor force. Canadian agriculture has experienced dramatic structural changes since World War II. Whereas farm employment has declined remarkably, farm output, on the other hand, has increased substantially. The non-agricultural sector in each region has played a useful role in providing employment for those of the farm labor force, especially the young, who preferred to leave the agricultural sector. The trend has been towards larger farm units, probably due to farm consolidation. The operation of these larger farm units has been made possible by increased mechanization without employing additional farm labor. Gains in agricultural labor productivity, therefore, have been achieved as a result of adjustments in the farm labor force, and partly from increased mechanization. Outmigration has been growing between the high annual rate of about 3 percent in British Columbia to a low of 1.5 percent in the Prairie region during the period 1950-1974. The effect of outmigration, contributed a high of about 2.5 percent per annum in the British Columbia region, to a low

of about 1 percent in the Prairie region, with the other regions falling inbetween that range.

Capital and Material Inputs: The regions of British Columbia, Ontario, and the Prairies derived the most significant contribution to growth in labor productivity from total capital and material inputs. About half of the overall growth in labor productivity in these regions has come from capital and material inputs. Although labor productivity gains from capital inputs (in aggregate) are similar in British Columbia, Ontario, and the Prairies, significant differences exist in the contribution of individual capital input categories, namely capital inputs related to mechanization, crop yield inputs, and livestock yield inputs as discussed below.

Mechanization: Apart from land and buildings, capital inputs related to mechanization contributed more significantly to overall growth in labor productivity than crop yield inputs, and livestock yield inputs, in the Prairie and Atlantic regions, as well as for Canada as a whole. These machinery items represent greater use of tractors, combine harvesters, trucks, pick-up balers, electric motors, and other equipment on farms, together with machinery operating expenses, such as machinery repairs and maintenance, diesel fuel, gasoline and lubricants.

Crop Yield Inputs: These inputs made the smallest contribution to overall growth in agricultural labor productivity. The estimates showed this to be the case for Canada as a whole, as well as all five regions. They represent purchases of fertilizer, lime, seed, and other crop expenses such as insecticides, and herbicides.

Livestock Yield Inputs: Compared to mechanization, and crop yield inputs, this input category made the most significant contribution to the overall growth in productivity, in British Columbia, Ontario, and Quebec, although its contribution to productivity in the Prairie and Atlantic regions was not as high compared with other input categories. These input items represent interest on livestock purchases, purchased feed, and other livestock expenses such as sprays, drugs, artificial insemination, and veterinary expenses.

"All Other Changes": In addition to capital and material inputs, other changes which could not be quantified in this conceptual framework also made a significant contribution to gains in labor productivity. These changes represent gains in labor productivity which can be attributed to research by various agencies (both public and private), better farm organization and management, increasing farm size, regional specialization in farm products, scale of operation, increased knowledge, skills and education of farmers and farm operators, and numerous other factors.⁷

The summaries of the components of growth in agricultural labor productivity presented in Tables V to X reveal some interesting differences among the five regions. In the Atlantic region the effect of outmigration and other technological changes

⁷"The Challenge and Growth of Change," Economic Council of Canada, Fifth Annual Review, September 1968, p. 86.