TECHNOLOGICAL CHANGE IN CANADIAN AGRICULTURE

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by

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ABSTRACT

TECHNOLOGICAL CHANGE IN CANADIAN AGRICULTURE

by

Lew-king Li

Over the period of 1946-1965, Canadian agriculture has experienced a spectacular increase in labor productivity. Increases in labor productivity are comprised of two parts: increases in capital intensity, and more efficient utilization of resources, i.e. technological change. The primary purpose of this study was to segregate the variations in labor productivity due to technological change from those due to capital intensity. More specifically, the objectives were to examine the nature of technological change, to investigate the elasticity of substitution between capital and labor, to estimate the returns to scale, to measure annual rates of technological change, and to segregate the components of increased labor productivity into those attributable to technological change and those due to capital intensity.

The analysis was made on a regional basis as well as for Canada as a whole. Five regions were formulated according to the existing production pattern and the geographic delimitation, viz., the Atlantic region including Nova Scotia, New Brunswick, and Prince Edward Island; the Quebec region; the Ontario region; the Prairie region including Manitoba, Saskatchewan, and Alberta; and the British Columbia region.

Solow's model was employed to measure technological change based on the concept of net (value-added) output. The assumptions of Hicks-neutral shifts of the production function and constant returns to scale underlying the model were examined. While the examination of neutral technological change involved testing the equality of the elasticities of substitution between labor and capital in two subperiods, 1946-1955 and 1956-1965, the examination of constant returns to scale involved performing a "F" test ($F = (Q_2-Q_1)(N-P-1)/Q_1$) where Q_2 and Q_1 are the residual sum of squares for the restricted and the unrestricted Cobb-Douglas function, respectively; N is the number of observations; and P is the number of independent variables). The CES production function was used in estimating the elasticity of substitution between labor and capital.

Data used in this study were mainly derived from publications of the Dominion Bureau of Statistics and of the Canada Department of Agriculture. Labor was measured in terms of man-equivalent. The series of output, capital, and farm wage rate were valued at 1935-39 prices. A six per cent return on capital was assumed.

The results of the statistical test show that during the period studied, technological change was neutral and returns to scale were constant in all regions. The elasticities of substitution between labor and capital were unitary in all regions, with a single exception of British Columbia in which it was less than one, being approximately 0.6 per cent.

It was found that Canadian agriculture has generally experienced a considerable technological change over the period 1946-1965. Regional differences in the annual rate of growth, however, were substantial. The highest growth rate was registered in the Atlantic region, being 4.4 per cent. Ontario was ranked as the second high, with an annual growth rate of 3.7 per cent. Following Ontario, the Prairies had a growth rate of 3.5 per cent. British Columbia lagged behind the other three regions, with a growth rate of 2.8 per cent higher than that in Quebec (2.0 per cent) only.

It was also found that the growth rates of farm technology were subject to a variety of change in all regions. The high rates of growth in the Atlantic and the Prairie regions appeared to have been concentrated in the Korean War period and in the years after 1960. In Quebec and British Columbia, the high growth rates occurred mostly in a single subperiod: while the former was in the Korean War period, the latter was in the years after 1960. Ontario was the only exceptional region in which the rates of technological advance appeared to have been relatively stable.

Over the period analysed, labor productivity (value added per man-equivalent) has increased by 176 per cent, of which technological change accounted for 75.18 per cent and capital 24.82 per cent. Among regions, the share of technological change in increased labor productivity varied from

84.39 per cent in the Atlantic to 62.22 per cent in Quebec. In the British Columbia, the Prairie, and the Ontario regions, it was 82.25, 78.37, and 74.97 per cent, respectively.

Finally, the results show that a large amount of surplus labor still existed in most of the regions even though there had been a considerable off-farm migration.

In the light of the above observations, it may be concluded that augmenting technological change was much more important than capital deepening in improving labor productivity. To raise the growth rates of labor productivity in Quebec and British Columbia to the national level, policies should be directed to developing such technological activities as research, education, and public health, and to accelerating migration from the farm, accompanied by an increase in the capital investment.

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CHAPTER I

INTRODUCTION

A. Historical Background

Over the last two decades, Canadian agriculture has surged forward at a virtually unprecedented rate of growth. Real net output[1], after being corrected for weather fluctuations,[2] has increased at an average annual rate of 1.9 per cent. This accompanied by a decline of farm labor employed of 2.7 per cent per year has brought about the increase in net output per man-equivalent,[3] conventionally termed as labor productivity, at an average annual rate of 9.3 per cent.[4]

Regional differences in the average growth rate of labor productivity were substantial, varying from 10.4 per cent in the Atlantic and Ontario to 5.3 per cent in Quebec. British Columbia was also low, only 5.4 per cent, as compared with other regions. The Atlantic and Ontario stood out with the highest rate of growth in labor productivity because there

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[1]Output is real and net in the sense that it was estimated in 1935-39 prices and net of purchases from non-agricultural sectors, which were consumed in the process of production.

[2]Weather indexes used were derived from M. H. Yeh and L. D. Black, "Weather Cycle and Crop Prediction," Technical Bulletin No. 8, Dept. of Agr. Econ., University of Manitoba, Winnipeg, Canada, November, 1964.

[3]Man-equivalent was obtained by modifying farm labor of various age and sex groups according to certain ratings which will be presented in Chapter III under the heading Derivation of the Data.

[4]See Appendix I.

had been a high rate of increase in net output and a high rate of decline in farm labor employed in these regions. Over the twenty-year period since 1946, labor employed on farms has decreased at an average annual rate of 3.3 per cent in the Atlantic, and 2.8 per cent in Ontario. The considerable decline in the agricultural labor force in these two regions was mainly due to the development of other types of activity such as logging and fishing in the Atlantic; trade, finance, and manufacturing in Ontario, which provided job opportunities attractive enough to pull labor out of the farms. In addition, the continuous development of land consolidation accompanied by an extensive use of machinery in the Atlantic, as shown in Appendix III, would seem to be an important factor resulting in a decline in agricultural labor force.

The low growth rates of labor productivity in Quebec and B. C. were caused by different factors. Whereas the former came from the negative rate of change in net output attributable to the relatively stable organization of production, the latter came from the low rate of decline in farm labor force due to the dominance of dairying, market gardening, and fruit growing activities, all of which require high labor inputs. The Prairie has enjoyed the highest rate of growth in net output among regions. But, because of the lack of non-farm job opportunities, the surplus of farm labor resulting from farm consolidation and mechanization has depressed the growth rate of labor productivity down to the third highest among regions.

With a constant capital-labor ratio, labor productivity and technological change are equivalent.[5] In other words, increases in labor productivity are entirely attributable to technological progress. However, farm capital per man-equivalent, in real terms, also has remarkably increased in Canadian agriculture and the differences in its growth rate among regions have been quite pronounced over the same time period. It follows that the growth of labor productivity was not only attributable to the advance in farm technology, but also due to the increased use of farm capital per man-equivalent, and that the effects of capital intensity on labor productivity were different in different regions. Table I presents a comparison

TABLE I

AVERAGE ANNUAL RATES OF CHANGE IN LABOR PRODUCTIVITY AND IN FARM CAPITAL PER MAN-EQUIVALENT CANADA AND REGIONS, 1946-1965*

	Canada	Atlantic	Quebec	Ontario	Prairie	B. C.
	....		Percentage		....	
Labor Productivity	9.3	10.4	5.3	10.4	8.0	5.4
Farm Capital/M.E.	7.3	3.1	4.5	7.9	7.4	4.3

*Source: Taken from Appendixes I and II.

[5]It is because technological change is defined as that part of increased labor productivity which is left over after increases in capital per man-equivalent are accounted for. Details will be discussed in Chapter II under the heading Concepts of Technological Change.

of average annual rates of change in labor productivity and in farm capital per man-equivalent for different regions.

The above table shows that growth rates of farm capital per man-equivalent fell in the same order as those of labor productivity among regions, with the only exception of the Atlantic in which farm capital was 3.1 per cent, the lowest among regions, whereas the labor productivity was 10.4 per cent, the highest among regions. This sharp contrast between the two reflected a significant improvement in the production techniques in this region. By breaking down the components of farm capital, it was found that the low rate of its growth came from a rapid decline in the values of livestock and poultry and, lands and buildings. The former has dropped from $33,146,000 in 1946 to $22,889,000 in 1965 while the latter, from $147,028,000 to $66,085,000, all were in 1935-39 prices.[6] The decline in the values of these two capital items was a result of changes in the organization of production on the one hand, and of shifts in the utilization of land from crop production to the forest growing on the other. The value of implements and machinery, however, has increased considerably. Its growth rate, in terms of per man-equivalent, was 10.3 per cent, the second highest among regions, as shown in Appendix II. This high rate was obviously the result of the coincidence of increased farm mechanization with a rapid off-farm migration.

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[6]For details, see the Quarterly Bulletin of Agricultural Statistics, 1967 Revision, Dominion Bureau of Statistics, Ottawa.

With high growth rates of farm capital per man-equivalent in the Prairie and Ontario where the production of grain crops and livestock dominated, the rates of growth of labor productivity were also high. Conversely, in B. C. and Quebec where there were low rates of increase in farm capital per man-equivalent, there were low growth rates of labor productivity. The rate of increase in capital-labor ratio was low in B. C. mainly because of its particular production patterns, as mentioned previously, which require high labor inputs and are less suitable for mechanization. It was low in Quebec, owing to the rapid decline in the real value of lands and buildings, from $500,393,000 in 1946 to $309,030,000 in 1965, as it accounted for a large percentage of farm capital. The growth rate of implements and machinery per man-equivalent was 11.2 per cent, the highest among regions, however. Thus, increases in labor productivity were not only affected by the rate of growth of total farm capital, but also by the change in its composition.

It is worth noting that labor productivity did not grow at an even rate, and farm capital per man-equivalent did not either. The growth rate of labor productivity was subject to a variety of changes. If the whole period is divided, according to the Canadian general economic situation, into four sub-periods: 1946-1950, 1950-1955, 1955-1960, and 1960-1965, a distinct change in trend appears. The growth rates of labor productivity were generally low (or even negative) in the first and third subperiods. The low or negative rates of increase in labor productivity resulted partly from a rapid decline in the total net output and partly because of the low off-farm migration due to lack of job opportunities in non-agricultural sectors during the period immediately following World War II and the period of economic recession. The decline in the total net output in the first subperiod was attributable to the readjustment of production from war to peace time conditions, while, in the third subperiod, it was due to the low demand for farm products in foreign markets. Additionally, the low rate of increase in farm capital was the reason for explaining the low or negative rates of growth of labor productivity, as they were highly associated.

In the second and fourth subperiods, the Korean War and the booming general economy called for a great demand for farm products in both domestic and foreign markets. This accompanied by a rapid out-migration of farm labor and a high rate of increase in farm capital have brought forth a tremendous surge in labor productivity in these two subperiods.

To the above generality, it should be added that Ontario was the only exceptional region in which growth of labor productivity averaged a high rate in the first subperiod and following it by a sharp drop, then advanced at moderate rates in the third and fourth subperiods. The growth rate in Ontario was high during the period immediately after World War II simply because non-agricultural sectors were already developed by that time. The development of non-agricultural sectors not only provides more job opportunities to accommodate the out-migration of farm labor, but demands more farm products for consumption and other purposes. As a consequence of the high rate of growth in the first subperiod, the rate of increase in the second subperiod was relatively low, as compared with other regions. The same reason would apply to the third subperiod during which the economic recession occurred. Table II contains the average annual rates of change in labor productivity in various subperiods.

Not only has the growth of labor productivity concentrated in certain subperiods, but it also fluctuated remarkably from year to year. Variability in the year-to-year rate of change in labor productivity was tremendously high. The standard deviations were more than three times higher than their respective means in all regions with a single exception of Ontario in which it was much lower, but still higher than the mean. For Canada as a whole, the relative dispersion[7] appeared to be lower than that in regions because the aggregation tended to offset the fluctuations. Table III exhibits the variability of year-to-year rates of change in labor productivity.

Like labor productivity, the growth of farm capital per man-equivalent also showed a high fluctuation. The relative dispersion of its year-to-year rates of change, as shown in Table IV, was not as high as that of labor productivity, but it

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[7]Relative dispersion is measured by the coefficient of variation which is defined as the sample standard deviation expressed as a percentage of the sample mean, i.e., $CV = 100s/\bar{x}$.

TABLE II

AVERAGE ANNUAL RATES OF CHANGE IN LABOR PRODUCTIVITY IN SUBPERIODS, CANADA AND REGIONS*

Subperiod	Canada	Atlantic	Quebec	Ontario	Prairie	B. C.
	....		Percentage	....		
1946-1950	3.35	- 5.64	.28	12.58	1.43	.90
1950-1955	11.77	22.21	22.07	1.10	14.38	2.31
1955-1960	1.80	- 1.38	- .14	7.49	.37	.38
1960-1965	8.11	19.03	- .99	7.32	7.30	14.26

*Computed from Appendix V.

TABLE III

MEANS, STANDARD DEVIATIONS, AND COEFFICIENTS OF VARIATION OF YEAR-TO-YEAR RATES OF CHANGE IN LABOR PRODUCTIVITY CANADA AND REGIONS, 1946-1965*

Canada & Region	Mean	Standard Deviation	Coefficient of Variation
	....	....Percentage....	....
Canada	6.9	17.6	255.1
Atlantic	8.9	29.4	330.3
Quebec	5.0	17.2	344.0
Ontario	6.4	10.2	159.4
Prairie	8.4	27.9	332.1
B. C.	5.8	22.0	379.3

*Source: Calculated from Appendix V.

TABLE IV

MEANS, STANDARD DEVIATIONS, AND COEFFICIENTS OF VARIATION OF YEAR-TO-YEAR RATES OF CHANGE IN CAPITAL-LABOR RATIO CANADA AND REGIONS, 1946-1965*

Canada & Region	Mean	Standard Deviation	Coefficient of Variation
	.....	Percentage	.....
Canada	4.7	3.2	67.5
Atlantic	3.0	11.3	372.9
Quebec	3.6	7.7	216.9
Ontario	5.2	7.6	146.2
Prairie	4.8	3.9	81.6
B. C.	4.6	18.5	400.4

*Source: Calculated from Appendix V.

was substantial. Moreover, regional differences in the relative dispersion were substantial, ranging from 81.6 per cent in the Prairie to 400.4 per cent in British Columbia. This was so probably because of the extreme difference in the patterns of farm enterprises in these two regions. While the former specialized in the production of grain crops and livestock which requires more steady increases in capital investment as farm mechanization continuously progresses, the latter dominated the dairying, market gardening, and fruit growing activities, all of which require high labor inputs rather than farm capital.

The analysis, so far, has led to a clear exposition of the fact that the growth of and the fluctuations in labor productivity were influenced by not only variations in the utilization of farm capital, but, even to a greater extent, by technological change. Although there have been a number of studies measuring labor productivity done in Canadian agriculture, little attention has been paid to the investigation of influences contributing to changes in labor productivity. In order to provide the agricultural policy-maker with some useful information for resource allocation, a comprehensive investigation and measurement of technological change is required.

B. Objectives of the Study

The primary purpose of this study is to segregate the variations in labor productivity due to technological change from those due to changes in the utilization of farm capital per man-equivalent. More specifically, the objectives are:

(1) to examine the nature of technological change;

(2) to investigate the elasticity of substitution between capital and labor;

(3) to estimate the returns to scale;

(4) to measure annual rates of technological change; and

(5) to segregate the components of increased labor productivity into those attributable to technological change and those to changes in capital intensity.

C. A Review of the Literature

For choosing an appropriate method for measuring the rate of technological change, a brief review of some relevant studies reported in the literature is necessary.

The study of technology has evolved through many stages with numerous approaches being used. It began with the measurement of disembodied technological change.[8] A technique for separating disembodied technological change was introduced by Solow in his study of the private non-farm sector of the United States.[9] Solow's method is not only capable of separating the influences contributing to changes in labor productivity,

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[8]Disembodied technological change is defined as an increase in productivity resulting from improved productive techniques, superior knowledge, better management, et cetra.

[9]R. M. Solow, "Technical Change and the Aggregate Production Function," Review of Economics and Statistics, Vol. 39, No. 3, August, 1957, pp. 312-20.

but also allows using variable income shares to factors over time as opposed to the constant income shares assumed by a Cobb-Douglas production function. This method has been widely used by economists to investigate the effect of technological change on output for different sectors of the economy. For example, Massell[10] has applied this method to United States manufacturing for the period 1919-55. His findings were similar to those of Solow, as were the findings of Chandler, who conducted a study using the same model to investigate productivity change in the farm and non-farm sectors of the United States.[11]

The derivation of Solow's model requires assumptions of (1) constant returns to scale, (2) homogeneity of factor inputs, and (3) competitive equilibrium in the economic system with factors being paid their marginal products. This model is designed to measure only disembodied technological change. If the assumption of factor homogeneity is violated, the measure of disembodied technological change becomes biased by an influence that should actually be recorded as embodied technological change.[12]

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[10]B. F. Massell, "Capital Formation and Technological Change in United States Manufacturing," Review of Economics and Statistics, Vol. 42, No. 2, May, 1960, pp. 182-8.

[11]C. A. Chandler, "The Relative Contribution of Capital Intensity and Productivity to Changes in Output and Income in the U. S. Economy, Farm and Nonfarm Sectors, 1946-58," Journal of Farm Economics, Vol. 44, No. 2, May, 1962, pp. 335-48.

[12]Embodied technological change is defined as an increase in productivity resulting from improvement of factor quality over time.

Salter introduced a model for measuring the extent of embodied technological change.[13] He argues that once an investment in fixed capital is made, the production function is no longer relevant, and factor substitution becomes important. Thus, he concluded that the quality of new capital available is the deciding factor in decisions regarding the adoption of best-practice techniques. Best-practice techniques are defined, according to Salter, as the techniques at each data which employ the most recent technical advances, and are economically appropriate to current factor prices.

Salter identifies four influences[14] that determine successive best-practice techniques. The first such influence is represented by the movement towards the origin of successive production functions. In other words, the extent of technical advance from one period to the next is defined and measured by "the relative change in total unit costs when the techniques in each period are those which would minimize unit costs when factor prices are constant".

The second influence is the bias towards uneven factor saving. Such biases are measured by the rate at which factor proportions change when factor prices are constant. The measure of biases is closely related to Hicks' definition of labor-and-capital-saving and implies the same definition of neutrality.

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[13] W. E. G. Salter, Productivity and Technical Change, Cambridge: Cambridge University Press, 1960.

[14] Ibid., pp. 30-45.

Salter's third factor in the determination of best-practice techniques is the elasticity of substitution between factors. This is important when businessmen equate factor proportions to relative prices.

The final influence is the changing relative factor prices.

Salter's model is based on several assumptions. Constant returns to scale is assumed. Technological advance must be embodied in new capital. Capital goods in place do not share in the productivity increase arising from the increasing efficiency that is embodied in new capital, i.e. no provision is made for disembodied technical change. The quality of labor is assumed to be homogeneous over time.

In 1959, Solow introduced a method of estimating capital embodied technical change.[15] Solow's measure is based on vintage production functions. For each vintage, v, of capital, there is assumed to be a Cobb-Douglas constant returns to scale production function. These functions show the relationship between output at time t produced by capital of vintage v, Q(v,t); the surviving capital of vintage v, K(v,t); and labor working with capital of vintage v, L(v,t). This function is of the form

$$Q(v,t) = Ae^{\lambda v}K(v,t)^{\alpha}L(v,t)^{1-\alpha},$$

[15] R. M. Solow, "Investment and Technical Progress", Mathematical Methods in the Social Sciences; 1959, ed. J. K. Arrow, S. Karlin, and P. Suppes, Stanford University Press, Stanford, 1960, pp. 89-104.

where λ represents the rate of capital embodied technical change, and α and $1-\alpha$ represent elasticities of production of capital and labor, respectively. Capital formed at time t is equal to gross investment, $I(v)$, and capital is assumed to depreciate exponentially at rate δ.[16] Thus, capital of vintage v is defined as

$$K(v,t) = I(v)e^{-\delta(t-v)}.$$

At any one time, the total capital stock will be the sum of capital of all vintages, which can be found by integrating over all vintages as

$$J_{\lambda}(t) = e^{-\delta t}\int_{-\infty}^{t} e^{v(\frac{\lambda}{\alpha}+\delta)} I(v)dv = \int_{-\infty}^{t} e^{(\frac{\lambda}{\alpha}v)} K(v,t)dv.$$

Solow calls $J_{\lambda}(t)$ the effective capital stock. Total output in year t would then be given by

$$Q(t) \equiv AJ_{\lambda}(t)^{\alpha} L(t)^{1-\alpha}.$$

Labor represented by $L(t)$ is assumed to be homogeneous and distributed efficiently over all vintages of capital such that labor's marginal productivity is equalized for all equipment. Solow indicates that capital embodied technical change, λ, can be estimated from

$$\frac{\lambda t}{\alpha} + \text{constant} = \log\left(\frac{\Delta R - \delta R}{I}\right)$$

where

$$R = \left(\frac{Q}{L^{1-\alpha}}\right)^{1/\alpha}.$$

This method requires an exogenous estimate for the elasticity of production of capital (α).

Numerous assumptions are involved with this model. Technical change is assumed to be neutral. Constant returns

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[16] According to Solow this implies that the average life of capital is $1/\delta$ years. *Ibid.*, p. 92.

to scale is assumed. Technical change must be embodied in new capital goods. The nature of technical change is such that at every point in time it affects only new capital goods, i.e., every capital good embodies the latest of known technology at the moment of its construction, but it does not participate in subsequent technical progress. Labor is assumed to be homogeneous over time and efficiently distributed across all vintages of capital. Shares of capital and labor are assumed to be constant throughout the period. Finally, it is assumed capital-embodied technical change is capital augmentive, i.e., it has the same effect as an increase in the capital stock.

In 1962, Solow added a new feature to his embodied technical change model.[17] He explicitly introduced cyclical factors into the production function through the unemployment rate. This permitted him to differentiate between potential output and actual observed output. Potential output, $P(t)$, was defined as a function of th effective stock of capital and the available supply of labor, $L(t)$, or $P(t) = F[J_\lambda(t), L(t)]$. No explicit mention of technical change is required, since it is already included in the effective stock of capital.

Observed output, $Q(t)$, is less than potential output because employment is less than the available supply of labor.

[17] R. M. Solow, "Technical Progress, Capital Formation, and Economic Growth", American Economic Review; Papers and Proceedings, Vol. 52, No. 2, May, 1962, pp. 76-92.

Actual output differs from potential output by a factor which is a function of the employment rate, E, or

$$Q(t) = f(E)F(J,L).$$

The function actually fitted was of the form

$$Q = AJ^{\alpha}L^{1-\alpha}10^{b+cE+dE^2}.$$

The unemployment function was $10^{b+cE+dE^2}$, and $AJ^{\alpha}L^{1-\alpha}$ was the production function of potential output.

Solow experimented with various improvement factors (λ) for capital and in this way derived alternative series for the effective capital stock.[18] These various capital stock series were then used in fitting the production function. The criteria for the best estimate for λ were the goodness of fit and low standard errors of the coefficients.

The foregoing models have considered the rate of either embodied or disembodied technical change exclusively but never simultaneously. Phelps made an effort to snythesize the two approaches in the form of a growth model.[19] The model employed by Phelps is based on a Cobb-Douglas type of production function which is a blend of Solow's embodied and disembodied technical change models. Phelps' model was of the form

$$Q = Ae^{ut}J^{\alpha}L^{1-\alpha},$$

where J represents Solow's effective capital stock which

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[18]This model does not require an exogenous estimate for α but rather requires alternative exogenous estimates for λ. In the previous model an exogenous estimate for α was required, and λ was estimated implicitly.

[19]E. S. Phelps, "The New View of Investment: A Neoclassical Analysis", Quarterly Journal of Economics, Vol. 76, No. 4, November, 1962, pp. 548-67.

implicitly includes embodied technical change; L represents labor which is distributed evenly over all vintages of capital; and e^{ut} allows for disembodied technical change.

Although Phelps combined Solow's two models into one containing both embodied and disembodied technical change, he made no effort to estimate both rates of technical change simultaneously. The Phelps model was extended by Intriligator in two ways.[20] First, the rate of embodied and disembodied technical progress were estimated simultaneously. Second, the rate of technical progress embodied in improved quality of labor, as well as that of capital, was estimated.

The model used by Intriligator involved a constant returns to scale Cobb-Douglas production function estimating potential output, which was related to actual output by Solow's unemployment function as

$$Q = Ae^{b+cE+dE^2}e^{ut}J^{\alpha}M^{1-\alpha} .$$

As before, J is the effective capital stock, e^{ut} is the time trend allowing for disembodied technical change, $e^{b+cE+dE^2}$ is the unemployment function, and M is the labor input index weighted by quality changes. The estimating procedure was identical to that used by Solow in his 1962 paper and outlined above.

The load of assumptions carried in Intriligator's model is also heavy. Disembodied technical change is assumed to be

[20] M. D. Intriligator, "Embodied Technical Change and Productivity in the United States 1929-1958", Review of Economics and Statistics, Vol. 47, No. 1, February, 1965, pp. 65-70.

neutral. Constant returns to scale is assumed. Labor is assumed to be effectively distributed over all vintages of capital such that labor's marginal productivity is equalized for all capital. Finally, capital embodied technical change is assumed to be capital augmentive.

So far, several important models used in the measurement of the rate of technical change have been reviewed. The largest contribution to methodology must be attributed to the Solow models. These models included methods of measuring the rate of embodied and disembodied technical change. The Intriligator model was simply an extension of the Phelps model, which in turn was a synthesis of two earlier Solow models. The models for measuring the rate of embodied technical change not only carry a heavy load of assumptions, but also require some data which are not usually available. Moreover, the assumption that technological change must be embodied in new capital has not yet been generally accepted by economists. For these reasons, Solow's method of measuring disembodied technological change is adopted in the present study. This method has the advantages of requiring fewer assumptions and allowing variable income shares to factors over time as opposed to the constant income shares assumed by a Cobb-Douglas production function.

D. Scope of the Study

In this study, an analysis is made on a regional basis as well as for Canada as a whole. Based on the existing production pattern and the geographic delimitation, five regions are formulated,[21] namely the Atlantic region, including Nova Scotia, New Brunswick, and Prince Edward Island; the Quebec region; the Ontario region; the Prairie region, including Manitoba, Saskatchewan and Alberta; and the British Columbia region, as shown in Figure 1. The time period of this study covers 20 years, from 1946 to 1965. It starts from 1946 partly because some data required in this study were available since that year and partly because most of technical innovations were introduced into Canadian agriculture after World War II.[22]

This dissertation consists of six chapters. The introductory chapter gives a brief historical background, the problematic situation, the objectives of the study, a review of several models for measuring technological change, and the scope of the study. Chapter II is concerned with a discussion of the theoretical background of the study. While the measurement of technological change and the interpretation of empirical results are presented in Chapter III, the fourth chapter

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[21] Technology in each region where the type of farming and the natural climate are similar is logically assumed to be homogeneous. Regional differences in adopting technology are reflected in the rate of technological change which contributes to the growth of la bor productivity.

[22] It is evidenced by rapid increase in the size of farm and in values of machinery, livestock and material inputs per farm. See Appendix III.

is devoted to the examination of assumptions underlying the measurement of technological change. The central theme in Chapter V is to explain implications of empirical results for resource allocation, prices and farm incomes, and income distribution. The final chapter provides the conclusions as well as a brief summary of the entire study.

FIGURE 1

MAP OF CANADA AND THE FIVE AGRICULTURAL REGIONS
UNDER STUDY OF TECHNOLOGICAL CHANGE

CHAPTER II

THEORETICAL FRAMEWORK

In this chapter an attempt is made to discuss the relevant theoretical considerations underlying the empirical investigation. The discussion proceeds from concepts of technological change, then to factors affecting technological change, and finally to aggregate production functions.

A. Concepts of Technological Change

The Meaning of Technological Change

Technological change is defined as a shift of the production function resulting from the adoption of improved production practices, the increased skill of the labor force, increased regional specialization, superior knowledge, better management, and all sorts of improvement.[23] Stated differently, it is a change in the efficiency of the use of resources. Assuming that factors of production are unchanged, technological progress takes place when inputs yield proportionally more output. The quantitative measure of technological change would then be the ratio of the increase in output to the previous output. Or algebraically,

$$\frac{\triangle A(t)}{A(t)} = \frac{A(t+1) - A(t)}{A(t)} = \frac{Y_{t+1} - Y_t}{Y_t}$$

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[23] R. M. Solow, "Technical Change and the Aggregate Production Function," Review of Economics and Statistics, Vol. 39, No. 3, August, 1957, p. 312.

where $\Delta A(t)/A(t)$ is the rate of technological change between time t + 1 and time t, and Y_{t+1} and Y_t are output at time t + 1 and time t, respectively.

In the real world, however, the factors of production would not remain unchanged in the presence of technological change. They vary both in magnitude and proportion. Additional capital investment in a farm rarely does not involve new and improved techniques. And even more rare is the case of the introduction of a new production practice that does not involve the expenditure of more capital of some kind. As a result, a reduction of farm labor employed becomes the inevitable concomitant of the substitution of capital for labor. Thus, in measuring technological change, changes in the utilization of farm capital and labor force should be taken into account.

This concept of technological change,[24] as used in the study, can be illustrated in Figure 2.[24a] Consider a two factor case where net output is expressed as a function of capital and labor, $Y = F(K,L)$, and this production function is assumed to be homogeneous of degree one, then $Y/L = F(K/L,1)$, i.e. labor productivity is a function of capital per man-equivalent. Assume that F and F_1 are two production functions representing before and after technological change respectively, then an increase in labor productivity is indicated

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[24] Refer to page 14 for another concept of technological change which was developed by Salter.

[24a] This figure was taken from L. B. Lane, Technological Change: Its Conception and Measurement, Prentice-Hall Inc., New Jersey, 1966, p. 49.

because of the shift in the production function from F to F_1. For taking the increase in capital per man-equivalent into consideration, assume further that at an initial time period, the economy is operating at point 1 or (k_1, y_1)[25] on the production function F, and at a later time period, the economy is operating at point 3 or (k_3, y_3) on the production function F_1. The movement from 1 to 3 is then a result of the increase in capital per man-equivalent $(k_3 - k_1)$ and of the shift of the production function $(F_1 - F)$.

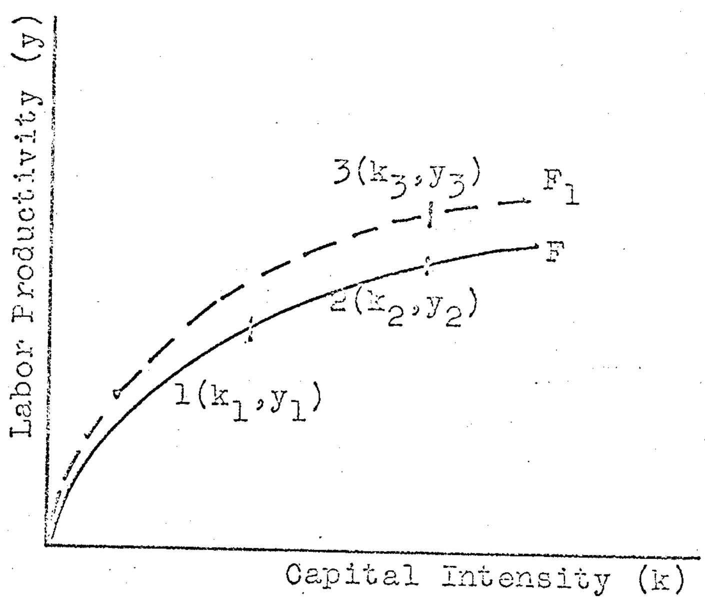

FIGURE 2. AN ILLUSTRATION OF THE INCREASE IN LABOR PRODUCTIVITY ATTRIBUTABLE TO CAPITAL INTENSITY AND TECHNOLOGICAL CHANGE

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[25] For convenience, Y/L, labor productivity, is represented by y and K/L, capital intensity, by k.

Types of Technological Change

A shift of the production function can be either neutral or non-neutral. The neutral type of technological change, as defined by Hicks, is one which alters the production function for each capital-labor combination but leaves unchanged the marginal rates of substitution of capital for labor, while the non-neutral type of technological change is viewed as one which alters the marginal rates of substitution of capital for labor at each capital-labor combination.[26] To put it differently, given a production function $Y = f(L, K)$ at time t and and another production function $Y = g(L, K)$ at time $t + \theta$, it can be said, for each level of capital-labor ratio, that between t and $t + \theta$, there has been a "neutral" improvement if marginal productivities of capital and labor have increased in the same proportions, that there has been a "capital-saving" improvement if the marginal productivity of labor has increased more than the marginal productivity of capital, and that there has been a "labor-saving" improvement if the marginal productivity of capital has increased more than the marginal productivity of labor.

The Hicksian neutral technological progress differs from the Harrodian. Sir Roy Harrod has defined a neutral technological progress as one in which the value of the capital

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[26] J. R. Hicks, The Theory of Wages, McMillan and Co., Ltd., London, 1935, p. 121.

coefficient does not change at a constant rate of interest.[27] These two concepts of neutrality are equivalent if and only if the elasticity of substitution of capital for labor is unitary. This can be illustrated with the aid of Figure 3. The initial equilibrium is at A with the ratio of wages to rents given by the slope of line (1) and the capital-labor ratio by the slope of line (3). Technological progress is represented by an inward shift of the unit isoquant. In the movement of isoquants from I to I_1, the capital-labor ratio increases to the slope of line (4), while the wage-rental ratio increases to the slope of line (2) which is tangent to the isoquant I_1 at E. The percentage change in the labor-capital ratio is AE/AC, and that in the rental-wage ratio is also AE/AC. By definition, the elasticity of substitution is the ratio of these two expressions which equals one. Harrod-neutral progress is indicated in the diagram because at a constant rate of interest (1/OD)[28], the capital-output ratio (OC) remains constant. Hicks neutrality is shown by a radical shrinking of the unit isoquant towards the origin with preserving the slope of the isoquant along any ray from the origin, as identical slopes at B and E exhibited in the diagram.

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[27] C. Kennedy, "Harrod on 'Neutrality'," Economic Journal, Vol. 72, No. 285, March 1962, pp. 249-50.

[28] At the initial equilibrium point A, the ratio of factor prices is w/r = DC/CA, or DC = w.CA/r = w.L/r. And OC = K represents the amount of capital required to produce a unit of output. Therefore, OD = DC + OC = (w.L + r.K)/r in a competitive situation, is the inverse of the rate of interest, since the price of output is given by (w.L + r.K). Similarly, for the equilibrium point at E.

constant. Hicks neutrality is shown by a radical shrinking of the unit isoquant towards the origin with preserving the slope of the isoquant along any ray from the origin, as identical slopes at B and E exhibited in the diagram.

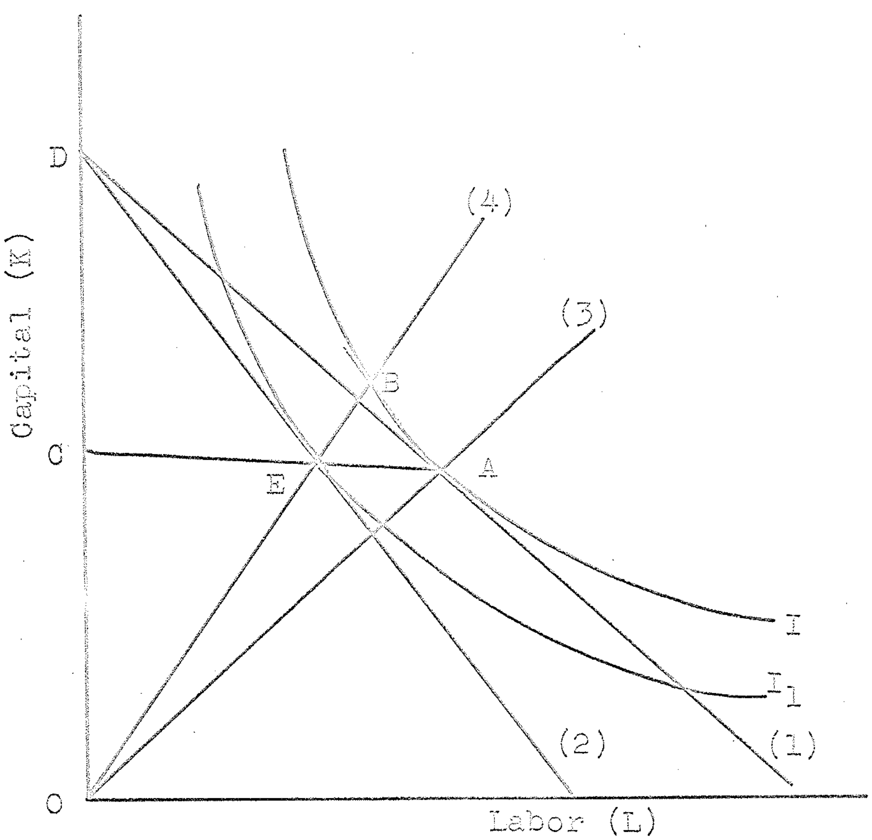

FIGURE 3. A UNIT ISOQUANT MAP SHOWING THE EQUIVALENT OF HARROD AND HICKSIAN NEUTRALITY OF TECHNOLOGICAL CHANGE

Neutrality of technological change is important in evaluating the relative causes of growth of labor productivity. If change were found to be non-neutral, some of the increase in labor productivity might be due to the interaction of capital or labor and technological change. For example, suppose the share of labor increases while capital per unit of labor remains unchanged, an increase in the labor force would cause an increase in output through the non-neutral shift in the production function. If technological changes were neutral, however, all the increase would be attributed to the residual since capital per unit of labor did not increase at all. On the other hand, a shift of the production function might have been caused by an increase in capital per unit of labor that has interacted with technological change to produce all of the increases in labor productivity. There would have been no increase in labor productivity without the capital formation; capital had a substantial share in the increase. Thus, to evaluate the relative contribution of capital intensity and technological change to the growth of labor productivity without examining neutrality would lead to a dubious interpretation.

B. Factors Affecting Technological Change

Technological change is measured as the residual of increased labor productivity after subtracting productivity increases which are due to changes in capital intensity.

General economic theory cannot explain why technology advances at different paces in various agricultural regions. Neither can it tell what factors bring about the increases. To understand the factors that make up technological change requires empirical investigation of the observations. Seven factors[29] which are commonly advanced as important in effecting technological change are: (1) type of farm, (2) the quality of soil in the farm, (3) regional differences in the levels of education of the farmers, (4) non-farm economic variables, (5) changes in the educational level of farmers and hired workers, (6) changes in the skill levels of operators not related to education, and (7) the rate of inventions and discoveries in agriculture.

Lave made a regression model for Appalachian agriculture in the United States and found that type of farm, type of soil, and state differences individually explain 49, 15, and 66 per cent of the variation in technological change respectively, and that the combination of these three variables explain 73 per cent of the variation in technological change.[29a] For non-farm economic variables, Garver pointed out that federal farm programs should be the stimuli to technological change. This is especially true of the acreage control programs. Finding

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[29] Lester B. Lave, Technological Change: Its Conception and Measurement, Prentice-Hall Inc., New Jersey, 1966, p. 163.

[29a] Ibid., p. 164.

themselves with directed acres, farmers have a land resource with a new margin. They try and adopt techniques to put this resource to a productive use.[30]

The education variable may be even more important in bringing about technological change. Basic literacy is almost a prerequisite to both learning of a new job and learning to do a new job. While a high level of education is essential to create technological change, a basic education is essential to permit farmers to adjust to it. For this point, Niitamo in his study of production of Finland, found that most of the increase in output was attributable to the human factor which includes the educational and skill levels of workers.[31]

With respect to the effect of inventions and discoveries in agriculture on output, a number of studies have been made.[32] All of them concluded that the level of public expenditures on agricultural research, education and extension affected output significantly and that their social rate of return was quite high.

Unfortunately, no similar data on Canadian agriculture are available for making those approaches in this study. In

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[30]Walter B. Garver, "Technical Change and the Problem of Manpower Adjustment," Journal of Farm Economics, Vol. 40, No. 5, December 1958, pp. 1441-50.

[31]O. Niitamo, "The Development of Productivity in Finnish Industry, 1925-52," Productivity Measurement Review, No. 15, November 1958, p. 30-41, published by the Productivity Measurement Advisory Service of the European Productivity Agency.

[32]For example, Z. Griliches, "Research Expenditures, Education, and the Aggregate Agricultural Production Function," American Economic Review, Vol. 54, No. 6, December 1964, pp. 961-974.

the light of their results, however, these factors would likely be also important in accelerating technological change in Canadian agriculture.

C. Aggregate Production Function

An aggregate production function for agriculture is the summation of all individual farm firm input-output relationships, under the assumptions of perfect competition, homogeneous factors, no errors of specification and measurement, and optimum allocation of factors. It is a very convenient tool for theoretically exploring some of the determinants of growth of productivity in agriculture. In an attempt to assess the growth prospects for agriculture, to identify the variables that are likely to determine the growth rate, and to examine the policies affecting growth, the explicit or implicit use of an aggregate production function is almost indispensable.

In recent years, economists have developed a variety of aggregate production functions. Two of them are discussed here which will be used in the following analysis.

The Cobb-Douglas Function

The most popular type of aggregate production function has been the generalized Cobb-Douglas type.[33] An aggregate production function of this type is exponential in natural

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[33] Since its introduction in 1928, no single form has enjoyed quite the same popularity. For this function, see C. S. Cobb and P. H. Douglas, "A Theory of Production," American Economic Review, Vol. 18, No. 1 Supplement, March 1928, pp. 139-165.

form and linear in logarithmic form. For a two factor case, the logarithmic form of this function is written as follows:

$$\log Y = \log a + b_1 \log L + b_2 \log K + \log e$$

where Y, L and K are aggregate variables representing, respectively, net output, labor and capital of all individual farm firms, and they are aggregated geometrically, i.e.,

$$\log Y = \sum_i \log Y_i,$$
$$\log L = \sum_i \log L_i,$$
and
$$\log K = \sum_i \log K_i, \quad i = 1, \ldots\ldots\ldots\ldots, N.$$

The regression coefficients b_1 and b_2 are also elasticities of production with respect to their corresponding independent variables, L and K. The elasticity of production measures the response of relative change in output to the relative change in input. The coefficient "a" is a constant which indicates the level of technology over the time period studied. These coefficients are easily estimated by standard regression techniques.

An aggregate production function of the Cobb-Douglas type permits increasing, constant or decreasing marginal productivity,[34] but does not allow both increasing and decreasing marginal productivity of a factor in the same function. Such characteristics of marginal productivity are, of course, dependent on the nature of aggregate production function. The

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[34] The marginal physical productivity of a particular input is defined as the quantity which an additional unit of this input adds to the total output. In this case, the marginal physical productivity of labor, MPP_L, is $b_1\hat{Y}/L$; and of capital, MPP_K, is $b_2\hat{Y}/K$, where $\hat{Y}$ represents the estimated total output.

sum of elasticities of production, b_1 and b_2, indicates the nature of the returns to scale[35] for the industry as a whole. The returns to scale are increasing if $b_1 + b_2 > 1$; decreasing if $b_1 + b_2 < 1$; and constant if $b_1 + b_2 = 1$.[36]

Other important characteristics a function of this type possesses are that of constant elasticity of production and that of unitary elasticity of substitution.[37] While the constant elasticity of production means that the relative shares of labor and capital remain unchanged over the time period under consideration, the unitary elasticity of substitution means that the relative change in the use of capital and labor proportionally responds to the relative change in their marginal productivity. These two implicit assumptions possibly make the use of this function restricted if they are incompatible with the actual situation. Thus, for the use of such a function, it is necessary to investigate whether there is strong *a priori* evidence against these assumptions implied in the function itself.

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[35]The returns to scale refer to the output response to a proportionate increase in all inputs.

[36]The returns to scale are said to be increasing if the output increases by a greater proportion than the inputs; decreasing if the output increases by a smaller proportion than the inputs; and constant if the output and inputs increase by the same proportion.

[37]$dL/dK = (b_2/b_1)(L/K)$. By definition,

$$e_s = - d(K/L)/(K/L)/d(dL/dK)/(dL/dK) = - d(K/L)/(K/L) \cdot (L/K)/d(L/K)$$

$$= - \frac{(LdK - KdL)/L^2}{K/L} \cdot \frac{L/K}{(KdL - LdK)/K^2} = -1.$$

The Constant Elasticity of Substitution Function

An aggregate production function may usefully be represented by a linearly homogeneous equation in which the elasticity of substitution, rather than relative factor shares, is constant. A general function with this characteristic has been suggested by Arrow, Chenery, Minhas, and Solow.[38] These authors call this production function the "Constant Elasticity of Substitution", or, more briefly, the CES, production function. The CES production function is written as follows:

$$Y = \gamma[\delta K^{-\rho} + (1 - \delta)L^{-\rho}]^{-\frac{1}{\rho}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.1)$$

where Y = net output (value added),

K = utilized capital,

L = labor input,

γ = efficiency parameter,

δ = distribution parameter,

and ρ = substitution parameter.

This function is derived from the logarithmic-regression equation

$$\log\left(\frac{Y}{L}\right) = \log a + b \log W + \log e \quad \ldots\ldots\ldots\ldots (2.2)$$

where W = the annual wage rate, and

b = the elasticity of substitution,

on the main assumptions that (1) perfect competition exists

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[38] K. J. Arrow, H. B. Chenery, B. S. Minhas, and R. M. Solow, "Capital-Labor Substitution and Economic Efficiency," Review of Economics and Statistics, Vol. 43, No. 3, August 1961, pp. 225-250.

both in the product and the factor markets; (2) the data represent situations in equilibrium; (3) constant returns to scale prevail; and (4) prices of products and material inputs do not vary systematically with the wage rate.[39] This "b" corresponds exactly to the elasticity of substitution for Equation (2.1) which is $1/1+\rho$.

An important attractive feature of the CES production function is that the elasticity of substitution can be any constant, not necessarily zero or unity. For this characteristic, Equation (2.2) is to be used to estimate the elasticity of substitution between capital and labor for regional agriculture and Canada as a whole. The realiability of the estimates is subject to the validity of the assumptions

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[39]The derivation procedures are as follows: Let Y/L by y and K/L be k. On those assumptions, $W = y - k\frac{dy}{dk}$, and then Equation (2.2) becomes $\log y = \log a + b \log (y - k\frac{dy}{dk})$. Take antilogarithms and solve for dy/dk,

$$\frac{dy}{dk} = \frac{a^{1/b}y - y^{1/b}}{a^{1/b}k} = \frac{y(1-\alpha y^{\rho})}{k}, \text{ or } \frac{dk}{k} \quad \frac{dy}{y(1-\alpha y^{\rho})}$$

where $\alpha = a^{-1/b}$, and $\rho = \frac{1}{b} - 1$.

Take a partial-fractions expansion, this gives $\frac{dk}{k} = \frac{dy}{y} + \frac{\alpha y^{\rho-1}dy}{1-\alpha y^{\rho}}$ which can be integrated to yield

$$\log k = \log y - \frac{1}{\rho}\log(1-\alpha y^{\rho}) + \frac{1}{\rho}\log\beta, \text{ or } k = \frac{\beta y^{\rho}}{1-\alpha y^{\rho}}$$

which in turn can be solved for y^{ρ}, and then y, to give

$$y = k(\beta + \alpha k^{\rho})^{\frac{-1}{\rho}} = (\beta k^{-\rho} + \alpha)^{\frac{-1}{\rho}}.$$

Written out in full, the production function is $Y = L(\beta K^{-\rho}L^{\rho} + \alpha)^{\frac{-1}{\rho}} = (\beta K^{-\rho} + \alpha L^{-\rho})^{\frac{-1}{\rho}}$. Set $\alpha + \beta = \gamma^{-\rho}$ and $\beta\gamma^{\rho} = \delta$, then the function becomes $Y = \gamma[\delta K^{-\rho} + (1-\delta)L^{-\rho}]^{-\frac{1}{\rho}}$.

underlying the function. Although agriculture is commonly classified as a perfectly competitive industry, the assumption of constant returns to scale should be empirically verified.

CHAPTER III

MEASUREMENT OF TECHNOLOGICAL CHANGE

A preliminary analysis made in Chapter 1 indicates that labor productivity has increased 176 per cent in Canadian agriculture over the last twenty year period since 1946. This increase can be viewed as an indicator of technological progress provided that the capital-labor ratio remains constant. A glance at Appendix II shows, however, that capital per man-equivilent has also had a substantial increase over the same time period. Thus, the rise in labor productivity has been achieved as a result of the increased use of capital and of the advances in farm technology. This chapter is devoted to measure annual and every five-year's technological change, based on different concepts of net (value added) and gross output.

A. The Models Measuring Technological Change

The principal model employed in this study to measure technological change is the Solow or geometric model. In order to make a comparison, however, technological change indices based on the arithmetic model are also calculated. While the arithmetic model is presented in Appendix IV, the derivation of the Solow model for measuring net and gross technological change are presented in sequence as follows:

Solow's model was based on a two factor production function of general form[40]

$$Y_N = F(K, L: t) \quad \text{.............................(3.1)}$$

where Y_N represents net output (value added), K and L are capital and labor inputs, respectively; and the variable t for time allows for technical change. Technical change (t) is a "catch all" expression for any kind of shift in the production function. On the assumption of neutral technical change, the production function takes the form

$$Y_N = A(t)_N f(K, L) \quad \text{...........................(3.2)}$$

where the multiplicative factor $A(t)_N$ is an index of the cumulative effects of shifts over time. By differentiating totally with respect to time and dividing by Y_N, Equation (3.2) becomes

$$\frac{\dot{Y}_N}{Y_N} = A(t)_N \frac{\partial f}{\partial K}\left(\frac{\dot{K}}{Y_N}\right) + A(t)_N \frac{\partial f}{\partial L}\left(\frac{\dot{L}}{Y_N}\right) + \frac{\dot{A}(t)_N}{A(t)_N} \quad \text{..........(3.3)}$$

where dots indicate time derivatives. Furthermore, by defining

$$W_{K,N} = \frac{\partial Y_N}{\partial K}\left(\frac{K}{Y_N}\right)$$

and $W_{L,N} = \frac{\partial Y_N}{\partial L}\left(\frac{L}{Y_N}\right)$

as the relative shares of capital and labor, respectively, and substituting these values into Equation (3.3), the result gives

$$\frac{\dot{Y}_N}{Y_N} = \frac{\dot{A}(t)_N}{A(t)_N} + W_{K,N}\,\frac{\dot{K}}{K} + W_{L,N}\,\frac{\dot{L}}{L} \quad \text{..................(3.4)}$$

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[40] R. M. Solow, "Technical Change and the Aggregate Production Function," pp. 312-20.

By assuming that the product is exhausted between capital and labor, and the production function is homogeneous of degree one, then

$$W_{L,N} = 1 - W_{K,N}$$

Let Y_N/L (the output-labor ratio or labor productivity) = y_N, and K/L (the capital-labor ratio) = k, then

$$\frac{\dot{y}_N}{y_N} = \frac{\dot{Y}_N}{Y_N} - \frac{\dot{L}}{L}$$

and

$$\frac{\dot{k}}{k} = \frac{\dot{K}}{K} - \frac{\dot{L}}{L}$$

Substituting these quantities into Equation (3.4) gives

$$\frac{\dot{y}_N}{y_N} = \frac{\dot{A}(t)_N}{A(t)_N} + W_{K,N}\frac{\dot{k}}{k}\text{, or}$$

$$\frac{\dot{A}(t)_N}{A(t)_N} = \frac{\dot{y}_N}{y_N} - W_{K,N}\frac{\dot{k}}{k} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.5)$$

This yields a series of annual measures of technical change that can be estimated from time series data of Y_N, K, L, and $W_{K,N}$ or $W_{L,N}$. In essence, this is to say that technical change in any year is measured as the difference between two ratios. The first ratio is the observed relative change in labor productivity, and the second is the relative change in labor productivity that is caused by the relative change in the capital-labor ratio. Successive multiplication of year-to-year measures of technical change and setting $A(t)_N = 1$ in the initial year gives an annual series of indexes of cumulative technical change.[41]

The Solow derivation is easily extended to the case where output is gross and material inputs are included in the production function. An aggregate production function incorporating three factors is generalized as the form

$$Y_G = H(K, M, L; t) \quad \text{......................} (3.6)$$

where Y_G represents gross output; K, M, and L stand for capital, material inputs, and labor, respectively; while t for time appears in H to allow for technical change. On the same assumptions and by the same procedures as above, Equation (3.6) can be developed into

$$\frac{\dot{A}(t)_G}{A(t)_G} = \frac{\dot{y}_G}{y_G} - W_{K,G}\frac{\dot{k}}{k} - W_M\frac{\dot{m}}{m} \quad \text{...............} (3.7)$$

where $W_M = \frac{\partial Y_G}{\partial M}(\frac{M}{Y_G})$ is the relative share of material inputs in income, and $m \equiv M/L$ is the material inputs per unit of labor.

Equation (3.7) differs from the value-added measure of technological change only by the last term: $W_M(\dot{m}/m)$. But this difference might result in the index of technological change substantially smaller than the A(t) defined by Equation (3.5).

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[41]For this study, set A(1946) = 1. Technological change indexes for successive years are calculated as follows:

$$A(1947) = A(1946)(1 + \dot{A}(1946)/A(1946)),$$

$$A(1948) = A(1947)(1 + \dot{A}(1947)/A(1947)),$$

and so on.

That is, material inputs might explain a large part of the residual. Griliches argues that the role of material inputs becomes important as the tendency to use material inputs from outside the agricultural sector has increased over time, and so the value of the value-added measure is strongly biased upward.[42] This is true in the case of Canadian agriculture. When interregional or sectorial comparisons are not the objective, the gross measure of technological change may provide a better understanding of the role of material inputs in the growth of total gross output, as compared with the value-added measure of technological change. For strict comparability with the basic factors of production originating in agriculture, however, output should be estimated net of material inputs consumed in the process of production. Moreover, the validity of the gross measure of technological change must be under the assumption that other sectors of the economy have received the benefit of quality changes in agriculture. But, such an assumption is hardly legitimate for policy purposes. Thus, the relevant measure in this study is the value-added measure of technological change on which a discussion of results for policy implications will be based. The gross measure of technological change is used for references only.

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[42]Z. Griliches, "The Sources of Measured Productivity Growth: U. S. Agriculture 1940-60," Journal of Political Economy, Vol. 71, No. 4, August 1963, pp. 331-346.

B. Derivation of the Data

The measurement of technological change by using Equation (3.5) and Equation (3.7) requires time series data on gross output (Y_G), material inputs (M), value added or net output (Y_N), farm labor (L), farm capital (K), capital's share in income (W_K), material's share in income (W_M), and labor's share in income (W_L). Most of these series were mainly derived from publications of the Dominion Bureau of Statistics and of the Canada Department of Agriculture. The series on output, material inputs, and farm capital stock were measured at 1935-39 constant prices. The period 1935-39 was chosen as a base because it represents the most stable period of Canadian economy. Furthermore, most official indexes contained in the publications were based on this period. This base, of course, can easily be changed to any other period by a single transformation of the data. The derivation and definitions of these series were briefly stated as follows:

Gross Output Series (Y_G): The value of gross output is the sum of values of two broad categories: field products and animal products, each of which includes cash income, income in kind, and net change in inventories. Before summation, these two categories were deflated by their respective price indexes in order to arrive at real values, and the category of field products was further deflated by weather indexes[43] for eliminating the influence of weather fluctuations on the output.

Material Inputs Series (M): The value of material inputs is the sum of current purchases of goods and services from outside the agricultural sector, which were consumed in the process of production. They include feed and seed; fertilizer and agricultural lime; electric power; miscellaneous, vegetables and supplies; shared expenses on tractor, truck, auto-engine, and combine; building and machine repairs; and so on, but exclude wages paid to hired labor. All items of inputs were individually deflated by their appropriate price indexes before addition.

Value Added or Net Output series (Y_N): The value added is the part of gross output which originates in agriculture. It was obtained simply by subtracting material inputs from the gross output.

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[43]Weather indexes, W_I, are a measure of the influence of weather on crop yields and were formulated by dividing the composite weather effect on crop yields, W, by the long run average yield, $\bar{Y}$, i.e. $W_I = [(\frac{W}{\bar{Y}}) \times 100] + 100$ where the composite weather effect is defined as the sum of the individual cycle's influence which might be super-imposed on one another in any given year. The equation of weather index shows that any index below 100% indicates a negative or unfavorable effect on crop yields due to bad weather influences while above 100% shows a positive or favorable effect on crop yields. See details in Yeh, M. H. and Black, L. D. "Weather cycles and crop predictions," Agricultural Economics Technical Bulletin No. 8, University of Manitoba, November, 1964.

Farm Labor Series (L): The series on farm labor employed was measured in terms of the man-equivalent.[44] The measurement of man-equivalents involves an adjustment of farm employment composed of all sex and age groups, on the basis of the following ratings:

TABLE V

AVERAGE MAN-EQUIVALENT RATINGS*

Sex	Age Group 14-19 (A)	20-54 (B)	55 and over (C)
Male	.756	1.000	.808
Female	.210	.345	.190
Female-Male ratio	.278	.345	.235

* Source: Taken from the Western Manitoba Farm Association.

The procedures of adjustment are formularized as follows:

$$\left[\begin{array}{l}.278 \text{ x No. of females in} \\ \text{group (A) + No. of males} \\ \text{in group (A)}\end{array} \text{ x } .756\right] + \left[\begin{array}{l}.345 \text{ x No. of females in} \\ \text{group (B) + No. of males} \\ \text{in group (B)}\end{array} \text{ x } 1.000\right]$$

$$+ \left[\begin{array}{l}.235 \text{ x No. of females in} \\ \text{group (C) + No. of males} \\ \text{in group (C)}\end{array} \text{ x } .808\right] = \text{Total man-equivalents.}$$

Farm Capital Series (K): Conceptually, the revelant measure of farm capital series is a measure of capital services, not total capital stock. However, the available data are not so satisfactory. A measure of utilized capital adopted by Solow is the application of the percentage of the labor force employed to the amount of actual capital stock under the

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[44] A man-equivalent is defined here as an adult male of average capacity, fully employed for a 12-month period. All other labor will be rated on the basis that 10 hours equal one day and 26 days equal one month, i.e.,

$$\text{man-equivalent} = \frac{\text{number of days worked}}{26} \times \frac{1}{12} = \frac{\text{number of months worked}}{12}.$$

assumption that capital stock will always be utilized to the same degree as available units of farm labor per year.[45] Such an assumption, however, is extremely tenuous since labor and already existing capital could be substitutable for each other. If this would be so, then, in principle, capital should never be idle unless its marginal value product has fallen to zero. Otherwise, it would pay to use more capital with the current input of labor; the extra product would provide at least some quasi-rent. In view of this point, capital stock was used in this study as an approximation. The value of capital stock in agriculture is composed of three items: livestock and poultry, lands and buildings, and implements and machinery; each of which was deflated by its appropriate price index. Furthermore, capital stock was measured in net value under the assumption that accrued depreciation is a rough measure of loss of productive efficiency.

<u>Capital's Share in Income Series</u> (W_K): There are two different methods to measure the series of capital's share in income. One of these is to calculate labor's share in total output by multiplying the total labor force employed by the market wage, and the capital's share in income is calculated as the difference between one and labor's share on the assumption of constant returns to scale. The use of this method to measure the series of capital's share in income, however, is subject to the restriction that labor is exactly paid its marginal product. If labor is paid more than its marginal

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[45] R. M. Solow, "Technical Change and the Aggregate Production Function," p. 316.

product, then it understates the share of capital and thus leads to overestimates of technological change. On the contrary, if labor is paid less than its marginal product, this method may overestimate capital's share in income; as a result, the measure of technological change will be biased downward.

Another method of measuring capital's share in income, which has gained more acceptance by economists,[46] involves the assumption that all of the capital in agriculture earns an annual return equal to the market rate of interest. This study uses the second method and it assumes that farm capital earns a 6 per cent return. Actually, this rate of interest did prevail in the capital market during the time period studied. Thus, the way of calculating capital's share in income merely involves finding a 6 per cent return on farm capital and dividing this by the total output. However, an 8 per cent rate of interest on farm capital is also taken into consideration for comparative purposes.

For making a comparison, technological change indices were also calculated on the basis of an 8 per cent return on farm capital and are presented in Appendix VI. These two series of technological change indices for all regions as well as for Canada as a whole, however, were not significantly different, as indicated by the results of statistical tests which are presented in Appendix VII.

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[46] Lester B. Lave, <u>op. cit.</u>, p. 89.

Material's Share in Income Series (W_M): On the assumption that material inputs are paid for at prices equated with their marginal productivities, the series of materials' share in income is simply calculated as the ratio of the value of material inputs to the value of total output.

Labor's Share in Income Series (W_L): On the basis of our assumption that returns to scale are constant, the series of labor's share in income is obtained by one minus capital's share in income for the value-added measure of output, and one minus capital's and materials' shares in income for the gross measure of output.

C. Empirical Measurement and Interpretation of Results

Geometric Growth of Net Technological Change

Annual geometric indices of net technological change derived by using Equation (3.5) for the five agricultural regions as well as for Canada as a whole are presented in Table VI.[47] A glance at the 1965 figures shows that increases in technological change were quite marked. For Canada as a whole, the technological change index rose from 1 in 1946 to 1.7975 in 1965, which implies a growth rate of 3.1 per cent per year. It was apparent that Canadian agriculture has gone through a revolution in the period 1946-1965. The technological revolution occurred partly due to the shortage of farm labor after World War II, and

[47] To examine whether the level of the technological change index for Canada as a whole is biased by the aggregation of the five regions, a Student's test was performed. The result shows that the mean of A(1965)'s for regions (1.8651) was not significantly different from A(1965) for Canada as a whole (1.7975).

TABLE VI

GEOMETRIC GROWTH OF NET TECHNOLOGICAL CHANGE[a]
CANADA AND REGIONS, 1946-1965[*]

Year	Canada	Atlantic	Quebec	Ontario	Prairie	B. C.
1946	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1947	.9401	.8042	.9182	1.0735	1.0195	.8941
1948	.9959	.8336	1.1673	1.1563	1.0219	.8468
1949	1.0404	.8457	1.1227	1.2559	1.1542	.8970
1950	.9937	.7118	1.0224	1.4074	.9575	.9963
1951	1.0778	.6996	.9958	1.2028	1.6325	.9990
1952	1.3880	1.1457	1.3243	1.4550	1.7071	1.2897
1953	1.4492	1.0609	1.4977	1.4661	1.8355	1.4456
1954	1.2134	1.2173	1.3407	1.2701	.9846	1.2516
1955	1.3687	1.1977	1.8000	1.3345	1.5205	1.0980
1956	1.3367	1.2194	1.4391	1.2934	1.5407	1.2134
1957	1.4247	1.2234	1.4866	1.3498	1.8287	1.3760
1958	1.2911	1.0363	1.3825	1.4919	1.3684	1.2714
1959	1.3320	1.0473	1.4186	1.4192	1.6749	1.2073
1960	1.3606	1.2824	1.5918	1.5384	1.4396	1.0700
1961	1.2632	1.0117	1.5729	1.6702	1.1327	1.1537
1962	1.4172	.9597	1.5940	1.7606	1.6404	1.3285
1963	1.6608	1.7441	1.3614	1.6618	1.8412	1.8773
1964	1.7307	1.9541	1.5619	1.8511	1.7460	1.6877
1965	1.7975	2.2728	1.4538	1.9918	1.8996	1.7076

[*]Source: Taken from Appendix V.

[a]Based on value added measure of output.

partly due to the substantial increase in the demand for farm products at this time.[48] While the shortage of farm labor resulted from the booming economy which provided abundant employment opportunities sufficiently attractive to draw labor from farms, it also stimulated and encouraged a widespread adoption of technological change. The increase in demand for farm products due to the general boom led to an increase in farm income which, in turn, made the purchase of farm equipment and facilities possible on a larger scale.

Among regions, the results of the statistical test show that there was a significant difference in the growth rates of technological change.[49] The cumulative indexes for 1965 varied from 2.2728 in the Atlantic to 1.4538 in Quebec; while the former rose at an annual rate of 4.4 per cent, the latter increased at a rate of approximately two per cent per year. Ontario was ranked as the second high, with an annual growth rate of 3.7 per cent; the Prairie fell just behind Ontario, with a rate, less than by only 0.2 per cent. B. C. was lagging behind the other three regions, with an annual growth rate of 2.8 per cent which was higher than that in Quebec only.

The high growth rates in the Atlantic and Ontario were likely because of the development of activities in non-agricultural sectors which drew a large number of labor out of farms.

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[48] G. V. Haythorne, "Discussion: Technological Change and Farm Manpower Adjustment," Journal of Farm Economics, Vol. 40, No. 5, December 1958, pp. 1451-54.

[49] A statistical test of the equality of growth rates among regions is given in Appendix VIII.

Over the last two decades, farm employment has declined approximately 63 per cent in the Atlantic and 54 per cent in Ontario.[50] The rapid decreases in farm labor in these two regions would stimulate the widespread adoption of farm technology. This, however, would not be the case for Quebec and B. C. While the low growth rate in Quebec might be attributable to the relatively stable organization of production, the less improvement in B. C. was likely due to the dominance of dairying, market gardening, and fruit growing activities, all of which are not suitable for application of mechanization.

Although all regions have experienced a considerable growth of technological change over the time period studied, the rates of growth were subject to a variety of changes. Figure 4 portrays year-to-year rates of technological change. Over the whole period since 1946, there have occurred four major troughs of rate of change: three of which were in 1950, 1954, and 1958 for all regions studied with the exception of 1954 in the Atlantic region and was resulted from economic recessions; and the other in 1961 was caused by natural hazards such as disease and insect infestations concurred along with the drought. In recessions, both education and research cannot be expected to progress at the same pace as in prosperity. Nor can innovations be expected to be pursued as

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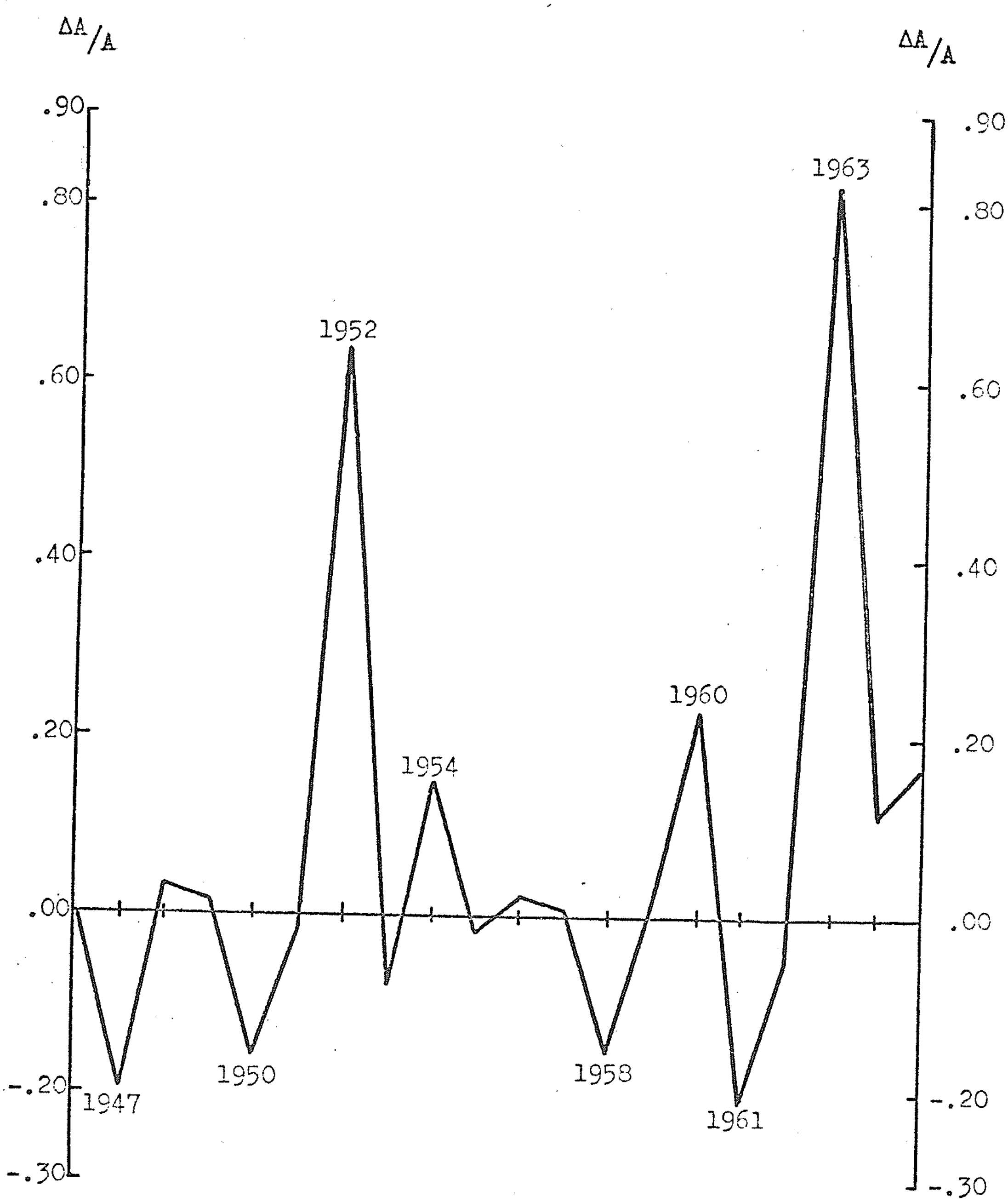
[50] Refer to Appendix V.

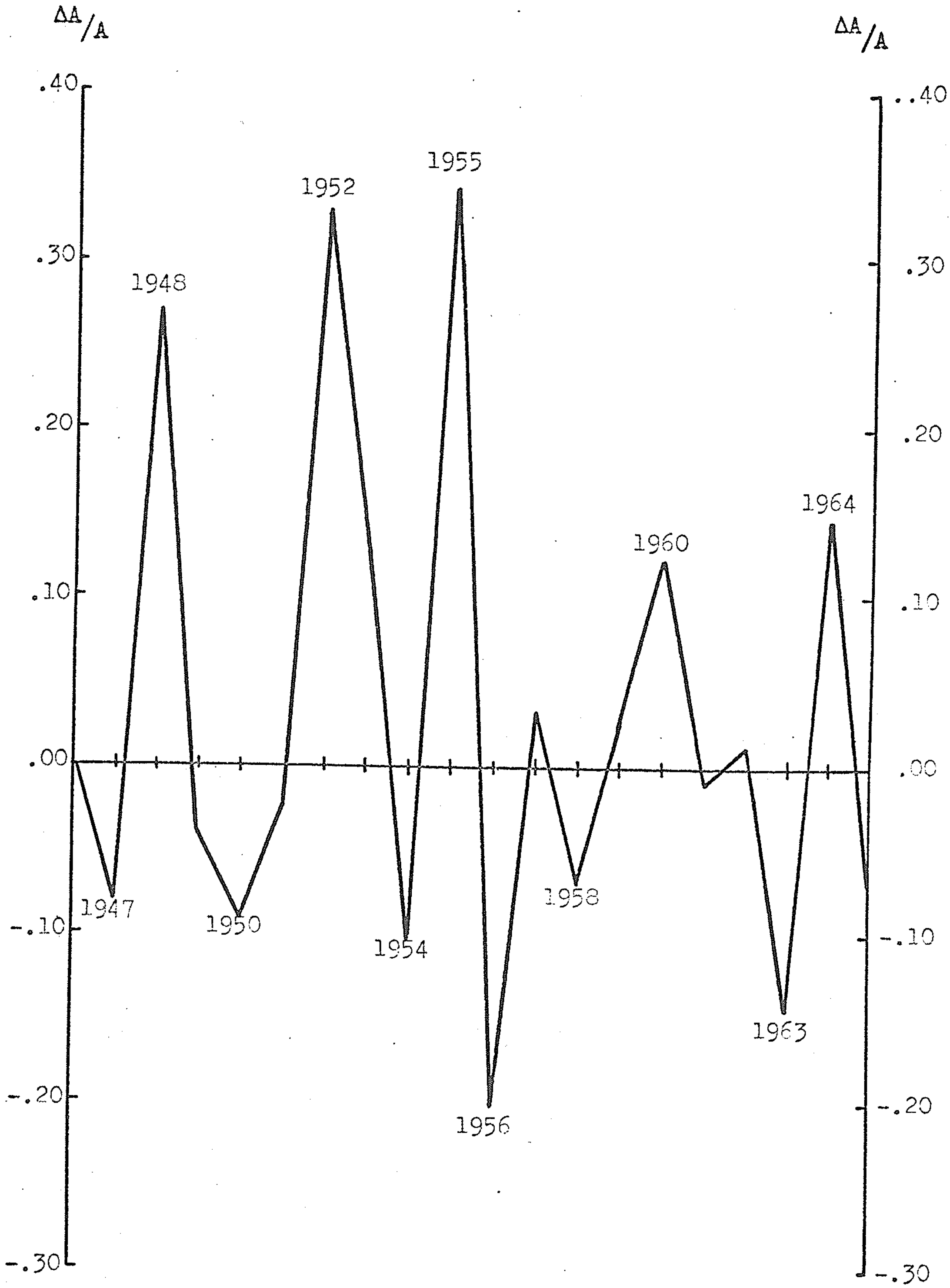
FIGURE 4-1. YEAR-TO-YEAR RATES OF CHANGE IN TECHNOLOGY[a] IN THE ATLANTIC REGION, 1946-1965*



Source: Appendix V-2; Col. 13.

[a]Based on value added measure of output.

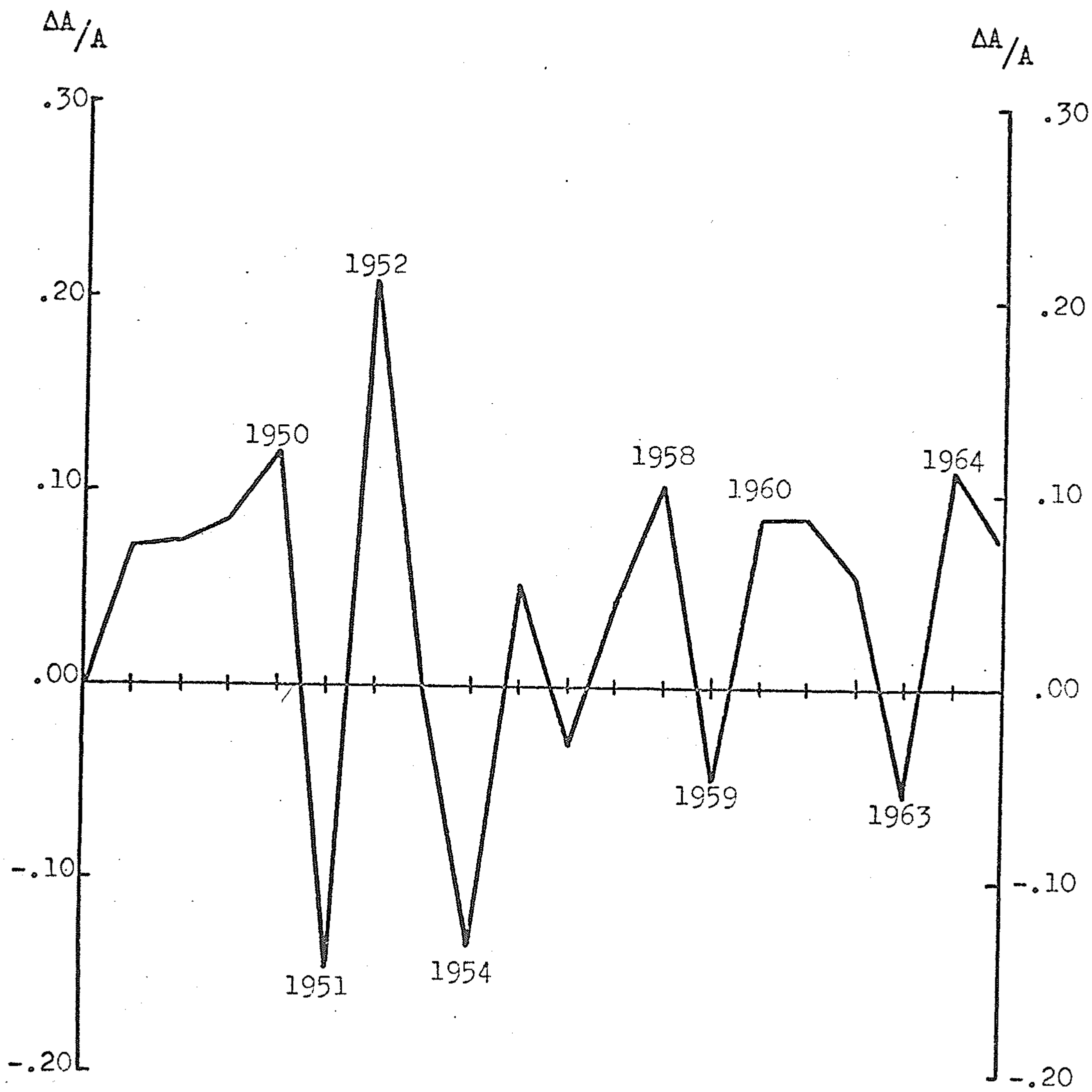
FIGURE 4-2. YEAR-TO-YEAR RATES OF CHANGE IN TECHNOLOGY[a] IN THE QUEBEC REGION, 1946-1965*



Source: Appendix V-3; Col. 13.

[a]Based on value added measure of output.

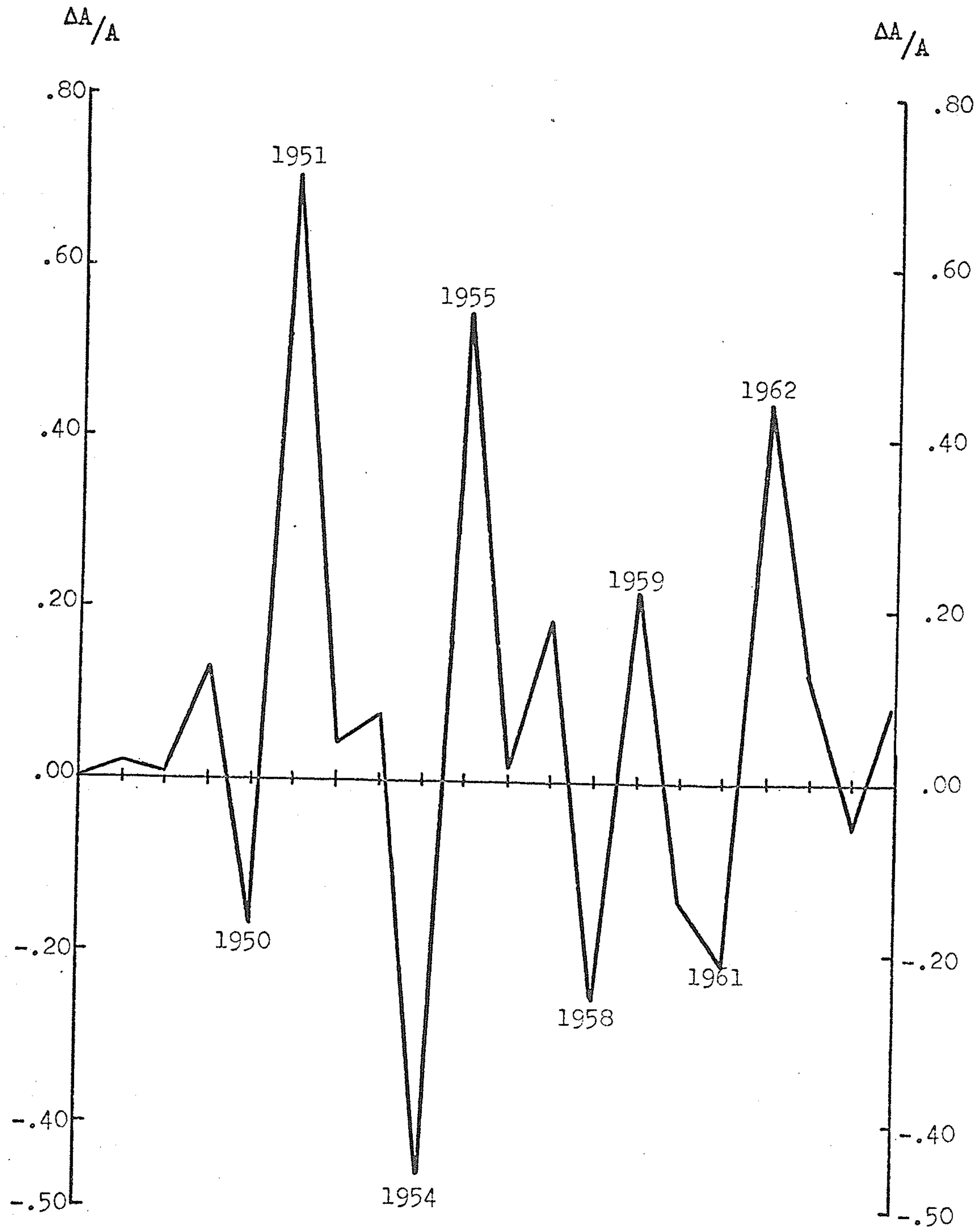
FIGURE 4-3. YEAR-TO-YEAR RATES OF CHANGE IN TECHNOLOGY[a] IN THE ONTARIO REGION, 1946-1965*



Source: Appendix V-4; Col. 13.

[a]Based on value added measure of output.

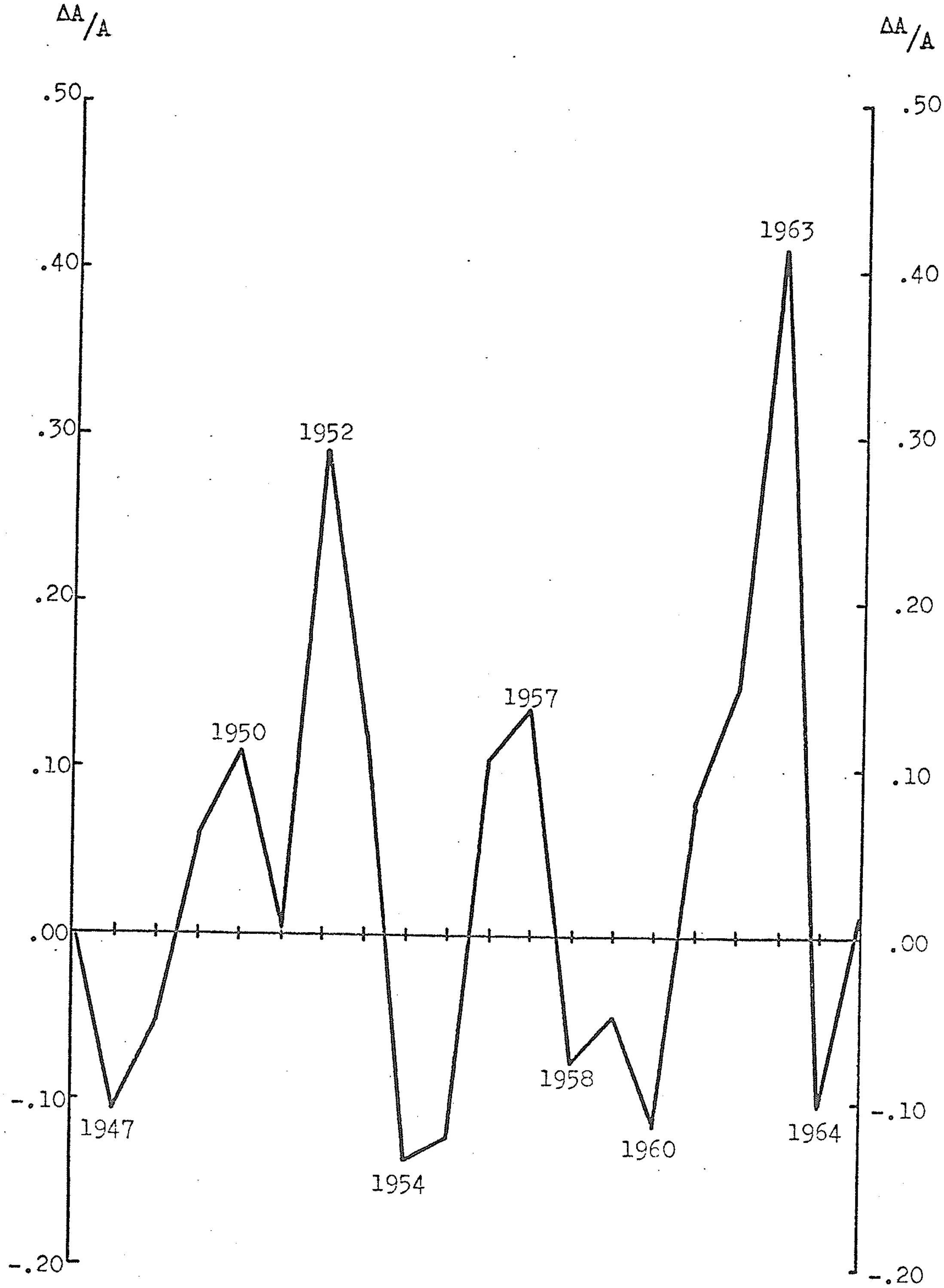
FIGURE 4-4. YEAR-TO-YEAR RATES OF CHANGE IN TECHNOLOGY[a] IN THE PRAIRIE REGION, 1946-1965*



Source: Appendix V-5; Col. 13.

[a]Based on value added measure of output.

FIGURE 4-5. YEAR-TO-YEAR RATES OF CHANGE IN TECHNOLOGY[a] IN THE B.C. REGION, 1946-1965*



Source: Appendix V-6; Col. 13.

[a]Based on value added measure of output.

vigorously in recessions as at other times for reasons of tight finances and reduced demand. Nor can workers be expected to have high morale and a proper attitude toward work when there is a widespread unemployment. Consequently, technological improvement pauses or even retrogresses.

Along with these troughs, there were peaks which occurred, as a rule, before the contractions and during the early stages of expansion.

Another interesting feature was the high concentration of technological progress. The high growth rate in the Atlantic and the Prairie regions appeared to have been concentrated in the Korean War period and in the years after 1960 when there was a great demand for farm products in both domestic and foreign markets. In Quebec and B. C. the high annual rates of technological change have occurred in a single subperiod: while the former was in the Korean War period, the latter was in the years after 1960. Ontario was the only exceptional region in which the rates of technological advance appeared to have been relatively stable. The following table contains the annual growth rates of technological change in different subperiods.

Table VII generally exhibits that high and low growth rates of technological change have occurred interchangeably among the subperiods. While the erratic decline in the growth rates immediately following the World War II to the end of the first recession could be attributed to the readjustment from war to peace time conditions, the low or even negative rates of growth in the subperiod from the mid-fifties to 1960 would likely be due to the low demand for farm products in the foreign market.

TABLE VII

ANNUAL GROWTH RATES OF TECHNOLOGICAL CHANGE IN VARIOUS SUBPERIODS, CANADA AND REGIONS*

Canada & Region	1946-1950	1950-1955	1955-1960	1960-1965
	.................Percentage.................			
Canada	- .15	6.60	- .12	5.70
Atlantic	-8.15	11.00	1.40	12.20
Quebec	.60	11.90	-2.43	- 1.80
Ontario	8.90	- 1.06	2.90	5.30
Prairie	-1.08	9.70	-1.09	5.70
B. C.	- .10	2.00	- .52	9.80

*Source: Implied in Table VI.

It may be argued that the technological change index will differ when A(t) is measured on a five-year basis rather than on a yearly basis, because of the time lag between the discovery and general application of new technical knowledge. In order to examine this argument, five-yearly estimates of technological change were also calculated by using the same data and the same model as were used for measuring the annual estimates. Both annual and five-yearly estimates are summarized in Table VIII.

TABLE VIII

COMPARISON OF ANNUAL AND FIVE-YEARLY MEASURES OF NET TECHNOLOGICAL CHANGE, CANADA AND REGIONS, 1946-1965*

A(1946)=1

Canada & Region	Annual Computation		Five-yearly Computation	
	A(1965)	% Growth	A(1965)	% Growth
Canada	1.7975	3.1	1.8327	3.2
Atlantic	2.2728	4.4	2.4286	4.8
Quebec	1.4538	2.0	1.5483	2.3
Ontario	1.9918	3.7	2.0661	3.9
Prairie	1.8996	3.5	1.8989	3.5
B. C.	1.7076	2.8	1.5670	2.4

*Source: Annual measure was taken from Table VI and Table VII; five-yearly measure was calculated from Appendix V.

The results revealed that it makes little difference whether the period taken is a year or a five-year for the Prairies and Ontario, and that the annual estimate is 14 per cent higher than the five-yearly estimate for B. C., and 8 and 13 per cent lower than the five-yearly estimate for the Atlantic and Quebec, respectively.[51] The difference in annual and five-yearly measures is due to the high concentration of technological progress.

[51]Calculated on the basis of annual growth rates.

Geometric Growth of Gross Technological Change

Another measure of technological change is the one where output is measured in gross terms. Table IX presents the derived annual geometric indices of gross technological change based on Equation (3.7). The cumulative indices for 1965 of this measure were generally much lower than those of the value-added measure. This is true because material inputs have explained a large part of the residual. Over the last two decades, material inputs from outside the agriculture per man-equivalent have increased nearly 240 per cent. Regional differences in the average percentage rate of growth were substantial, ranging from 16.3 per cent in Quebec to 7.1 per cent in B. C. Moreover, the ratios of value added to gross output were very low in all regions, especially in the Atlantic, only 38 per cent on the 1946-1965 average. That is to say that material inputs have constituted a large part of the gross output, and played an important role in the production of Canadian agriculture. The growth of material inputs and the ratios of value added to gross output are given in Table X and Table XI, respectively.

The differential magnitude of cumulative indices for 1965 between the value-added and gross measure of technological change is not only determined by the growth rate of material inputs, but also by the ratio of value added to gross output. The higher the growth rate of material inputs and the lower

TABLE IX

GEOMETRIC GROWTH OF GROSS TECHNOLOGICAL CHANGE[a]
CANADA AND REGIONS, 1946-1965[*]

Year	Canada	Atlantic	Quebec	Ontario	Prairie	B. C.
1946	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1947	.9756	.9023	.9458	1.0342	1.0132	.9356
1948	.9977	.9130	1.0329	1.0716	1.0500	.9065
1949	1.0232	.9159	1.0122	1.1188	1.1069	.9319
1950	.9984	.8596	.9680	1.1928	.9672	.9918
1951	1.0713	.8521	.9518	1.0946	1.4218	.9920
1952	1.2157	1.0305	1.0929	1.2094	1.4701	1.1599
1953	1.2502	.9977	1.1643	1.2150	1.5545	1.2434
1954	1.1109	1.0550	1.0953	1.1297	.9952	1.1407
1955	1.1984	1.0475	1.2793	1.1581	1.3373	1.0605
1956	1.1956	1.0535	1.1257	1.1289	1.3483	1.1210
1957	1.2336	1.0488	1.1205	1.1505	1.5240	1.2049
1958	1.1704	.9808	1.0972	1.2058	1.2433	1.1479
1959	1.1953	.9841	1.1083	1.1784	1.4292	1.1154
1960	1.1917	1.0592	1.1623	1.2202	1.2919	1.0494
1961	1.1531	.9675	1.1557	1.2699	1.1122	1.0911
1962	1.2397	.9508	1.1605	1.3022	1.4115	1.1761
1963	1.3450	1.1725	1.0904	1.2664	1.5240	1.4438
1964	1.3625	1.2261	1.1431	1.3338	1.4650	1.3642
1965	1.3923	1.3130	1.1135	1.3806	1.5511	1.3722

[*]Source: Taken from Appendix V.

[a]Based on gross measure of output.

TABLE X

GROWTH IN MATERIAL INPUTS[a] PER MAN-EQUIVALENT
CANADA AND REGIONS, 1946-1965*

Canada & Region	1946 level[b] ($)	1965 level[b] ($)	Incr. over period (%)	Av. annual % rate
Canada	369	1,254	239.8	12.6
Atlantic	312	975	212.5	11.2
Quebec	299	1,223	309.0	16.3
Ontario	479	1,691	253.0	13.3
Prairie	325	1,015	212.3	11.2
B. C.	682	1,600	134.6	7.1

*Source: Computed from Appendix V.

[a]For components of material inputs, see the context.

[b]Valued at 1935-39 prices.

TABLE XI

RATIOS OF VALUE ADDED TO GROSS MEASURE OF OUTPUT
CANADA AND REGIONS, 1946-1965*

Year	Canada	Atlantic	Quebec	Ontario	Prairie	B. C.
	....	.....	Percentage	.....	....	
1946	60.9	45.2	47.3	50.9	72.2	57.4
1947	57.9	37.2	40.4	48.9	70.5	52.7
1948	60.8	38.1	51.0	52.5	70.3	55.4
1949	62.5	39.4	49.3	54.8	71.6	59.4
1950	58.4	35.2	47.3	54.2	65.9	58.1
1951	63.5	32.1	43.9	49.3	75.4	56.9
1952	65.2	41.8	49.0	52.9	76.1	59.2
1953	65.9	39.2	52.2	52.6	76.4	61.4
1954	55.2	41.4	47.5	49.4	62.7	57.8
1955	60.8	39.4	51.0	49.5	71.3	57.2
1956	57.2	37.3	41.4	44.4	69.5	55.5
1957	60.4	40.6	43.1	45.8	72.4	58.4
1958	54.4	35.0	38.6	45.7	65.8	54.9
1959	55.9	34.2	38.6	43.9	68.5	52.9
1960	54.8	38.4	40.4	47.1	65.1	51.7
1961	50.9	30.9	38.8	47.0	59.3	51.0
1962	56.0	28.2	38.1	48.2	66.9	54.2
1963	57.8	39.7	32.6	46.4	70.6	55.3
1964	56.1	43.6	33.8	46.4	67.7	54.7
1965	55.8	43.9	30.6	46.6	67.7	53.7
1946-65 average	58.5	38.0	42.7	48.8	69.3	55.9

*Computed from Appendix V.

the ratio of value added to gross output, the greater is the difference of cumulative indices for 1965 between the value-added and gross measure of technological change. For this reason, the Atlantic region was no longer the leading region, and instead, the Prairies became the first high as far as the gross measure was concerned. Ontario and Quebec still maintained their respective positions as they were in the value-added measure. The following table summarizes all relevant figures for making a comparison between these two measures.

TABLE XII

COMPARISON OF VALUE-ADDED AND GROSS MEASUREMENTS OF TECHNOLOGICAL CHANGE CANADA AND REGIONS, 1946-1965*

A(1946)=1

Canada & Region	Value-Added Measure			Gross Measure		
	A(1965)	% Growth	Rank	A(1965)	% Growth	Rank
Canada	1.7975	3.1		1.3923	1.7	
Atlantic	2.2728	4.4	1	1.3130	1.4	4
Quebec	1.4538	2.0	5	1.1135	.6	5
Ontario	1.9918	3.7	2	1.3806	1.7	2
Prairie	1.8996	3.5	3	1.5511	2.3	1
B. C.	1.7076	2.8	4	1.3722	1.6	3

*Source: Value-added measure and gross measure were calculated from Table VI and Table IX, respectively.

With regards to the variation in the year-to-year growth rates, the gross measure showed a pattern similar to the value-added measure. However, the magnitude of variation for the former was much less than that for the latter. This situation was probably true because material inputs could be easily adjusted to the coincidence of economic conditions such as recession, boom, and so on.

The difference between annual and five-yearly estimates in the gross measure was also similar to that in the value-added measure. There was little difference between these two estimates in the Prairie, and a greater difference in Quebec and the Altantic. A comparison of annual and five-yearly estimates is given in the following table.

TABLE XIII

COMPARISON OF ANNUAL AND FIVE-YEARLY MEASURES OF GROSS TECHNOLOGICAL CHANGE, CANADA AND REGIONS, 1946-1965*

A(1946)=1

Canada & Region	Annual Computation		Five-yearly Computation	
	A(1965)	% Growth	A(1965)	% Growth
Canada	1.3923	1.7	1.4284	1.9
Atlantic	1.3130	1.4	1.4427	2.0
Quebec	1.1135	.6	1.2114	1.0
Ontario	1.3806	1.7	1.4157	1.8
Prairie	1.5511	2.3	1.5636	2.3
B. C.	1.3722	1.6	1.2966	1.4

*Source: Five-yearly estimates were computed from Appendix V; annual estimates were taken from Table XII.

Arithmetic Growth of Net and Gross Technological Change

For the sake of contrast, annual arithmetic indices of net and gross technological change were also calculated for all regions and Canada as a whole. While the net measure was derived from Equation (a), the gross measure was derived from Equation (b); all of which are given in Appendix IV. These two indices are presented in Table XIV and Table XV, respectively.

The results generally indicate that both net and gross technological change indices derived from arithmetic model were quite close to those derived from the geometric model in all regions. This was especially true in the Prairie and Ontario. The pairwise comparison of annual growth rates implied in geometric and arithmetic indices of net and gross technological change is contained in Table XVI.

Components of Increased Labor Productivity

From Table VI and Table IX, it is possible to divide the total increase in net labor productivity (value added per man-equivalent) and gross labor productivity (gross output per man-equivalent) into two parts: one part can be measured by the shift of the aggregate production function which results from technological change, and another is the movements along the production function attributable to the increased use of capital per man-equivalent. The calculation of these

TABLE XIV

ARITHMETIC GROWTH OF NET TECHNOLOGICAL CHANGE[a] CANADA AND REGIONS, 1946-1965[*]

Year	Canada	Atlantic	Quebec	Ontario	Prairie	B. C.
1946	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1947	1.0166	.8204	.9239	1.0707	1.0203	.8902
1948	1.0675	.8530	1.1907	1.1564	1.0230	.8413
1949	1.1624	.8622	1.1441	1.2528	1.1510	.8904
1950	1.0615	.7405	1.0398	1.3954	.9719	.9818
1951	1.4287	.7341	1.0218	1.2196	1.6357	.9854
1952	1.6056	1.1517	1.3168	1.4652	1.7093	1.2296
1953	1.7007	1.0660	1.4925	1.4774	1.8353	1.3737
1954	1.1175	1.2059	1.3313	1.2641	1.0037	1.1833
1955	1.4896	1.1884	1.7207	1.3269	1.5333	1.0224
1956	1.4750	1.2122	1.3826	1.2899	1.5540	1.1235
1957	1.6470	1.2174	1.3697	1.3447	1.8382	1.2615
1958	1.4054	1.0196	1.3382	1.4737	1.3963	1.1692
1959	1.5663	1.0303	1.3711	1.4061	1.7013	1.1149
1960	1.4914	1.2589	1.5233	1.5321	1.4718	.9716
1961	1.3256	.9740	1.5050	1.6553	1.1456	1.0425
1962	1.5494	.9370	1.5238	1.7424	1.6541	1.2539
1963	1.6885	1.5102	1.3254	1.6399	1.8528	1.7824
1964	1.6993	1.7233	1.5084	1.8188	1.7615	1.5940
1965	1.7818	1.9909	1.3980	1.9552	1.9098	1.6134

[*]Source: Calculated from the data in Appendix V, using Equation (a).

[a]Based on value added measure of output.

TABLE XV

ARITHMETIC GROWTH OF GROSS TECHNOLOGICAL CHANGE[a] CANADA AND REGIONS, 1946-1965*

Year	Canada	Atlantic	Quebec	Ontario	Prairie	B. C.
1946	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1947	1.0096	.9246	.9679	1.0333	1.0142	.9389
1948	1.0399	.9382	1.0929	1.0751	1.0161	.9097
1949	1.0957	.9420	1.0715	1.1224	1.1041	.9404
1950	1.0381	.8906	1.0230	1.1882	.9845	.9942
1951	1.2405	.8881	1.0152	1.1094	1.4182	.9964
1952	1.3365	1.0469	1.1403	1.2175	1.4661	1.1292
1953	1.3876	1.0151	1.2148	1.2229	1.5470	1.2070
1954	1.0773	1.0663	1.1488	1.1286	1.0179	1.1043
1955	1.2702	1.0602	1.2987	1.1557	1.3503	1.0131
1956	1.2632	1.0679	1.1793	1.1411	1.3630	1.0663
1957	1.3482	1.0698	1.1745	1.1627	1.5347	1.1391
1958	1.2328	1.0019	1.1639	1.2111	1.2703	1.0918
1959	1.3079	1.0055	1.1747	1.1859	1.4480	1.0644
1960	1.2730	1.0809	1.2240	1.2337	1.3146	.9889
1961	1.1969	.9914	1.2182	1.2784	1.1248	1.0244
1962	1.2983	.9805	1.2240	1.3100	1.4160	1.1036
1963	1.3632	1.1542	1.1670	1.2732	1.5320	1.3854
1964	1.3679	1.2198	1.2171	1.3341	1.4799	1.3010
1965	1.4126	1.2962	1.1884	1.3788	1.5620	1.3095

*Source: Calculated from the data in Appendix V, using Equation (b).

[a]Based on gross measure of output.

TABLE XVI

A PAIRWISE COMPARISON OF ANNUAL GROWTH RATES IMPLIED IN GEOMETRIC AND ARITHMETIC INDICES OF NET AND GROSS TECHNOLOGICAL CHANGE CANADA AND REGIONS, 1946-1965

Canada & Region	Net T. C.		Gross T. C.	
	Geometric	Arithmetic	Geometric	Arithmetic
	................Percentage................			
Canada	3.1	3.0	1.7	1.8
Atlantic	4.4	3.7	1.4	1.4
Quebec	2.0	1.8	.6	.9
Ontario	3.7	3.6	1.7	1.7
Prairie	3.5	3.5	2.3	2.3
B. C.	2.8	2.5	1.6	1.4

components has been made as follows:

1. The increase in net and gross labor productivity over the period 1946-1965 is calculated as

$$\Delta y_N = y_{N(1965)} - y_{N(1946)} \text{ and } \Delta y_G = y_{G(1965)} - y_{G(1946)},$$

respectively, where y_N is net labor productivity and y_G is gross labor productivity.

2. Net and gross labor productivities in 1965 (the ending year in this study) are deflated by their respective technological change indices, $A_N(1965)$ in Table VI and $A_G(1965)$ in Table IX, to obtain net and gross labor productivity after removing technological change; the excess of this over net and gross labor productivity in 1946 (the initial year of this

study) is the increase imputed to capital intensity, i.e.,

$$\Delta y_{N,k} = y_{N(1965)}/A_N(1965) - y_{N(1946)} \text{ and}$$

$$\Delta y_{G,k} = y_{G(1965)}/A_G(1965) - y_{G(1946)}.$$

3. The remainder of the increase is imputed to technological change, i.e.,

$$\Delta y_{N,T} = \Delta y_N - \Delta y_{N,k} \text{ and}$$

$$\Delta y_{G,T} = \Delta y_G - \Delta y_{G,k}.$$

Such a division of increased labor productivity into those due to technological change and those attributable to capital intensity, however, is on the assumptions of neutral shifts of the production function and constant returns to scale. If the shifts had not been neutral, the effects of increasing capital intensity would have reflected in non-neutral shifts and the excess of the deflated labor productivity over the 1946 figures would represent economies of scale.

Following above procedures, the calculated share of capital and of technological change in increased net and gross labor productivity are given in Table XVII and Table XVIII, respectively.

The results show that the increased net labor productivity was 176 per cent of which technological change accounted for 75.18 per cent and capital 24.82 per cent, over the last two decades for Canada as a whole. Capital has been assigned a relatively minor role because capital per man-equivalent did

TABLE XVII

PERCENTAGE SHARE OF CAPITAL INTENSITY AND OF TECHNOLOGICAL CHANGE IN INCREASED NET LABOR PRODUCTIVITY CANADA AND REGIONS, 1946-1965

Canada & Region	Increased in Labor Productivity	Percentage Share of	
		Cap. Intensity	Tech. Change
	..................Percentage..................		
Canada	176.0	24.82	75.18
Atlantic	196.9	15.61	84.39
Quebec	100.8	37.78	62.22
Ontario	197.8	25.03	74.97
Prairie	152.6	21.63	78.37
B. C.	101.6	17.75	82.25

TABLE XVIII

PERCENTAGE SHARE OF CAPITAL INTENSITY AND OF TECHNOLOGICAL CHANGE IN INCREASED GROSS LABOR PRODUCTIVITY CANADA AND REGIONS, 1946-1965

Canada & Region	Increased in Labor Productivity	Percentage Share of	
		Cap. Intensity	Tech. Change
	..................Percentage..................		
Canada	201.0	56.12	43.88
Atlantic	205.3	64.55	35.45
Quebec	210.6	84.92	15.08
Ontario	225.0	60.20	39.80
Prairie	169.4	43.49	56.51
B. C.	115.7	49.46	50.54

not grow so fast as net labor productivity,[52] as shown in Table I. Among regions, the share of technological change in increased net labor productivity varied from 84.39 per cent in the Atlantic to 62.22 per cent in Quebec, indicating a wide variation in the relative importance of capital formation.

The results also show that the share of technological change in gross labor productivity was much lower than that in net labor productivity. It was relatively low because a part of increased gross labor productivity has been attributed to the rising use of material inputs. The difference in the percentage share of technological change in net and gross labor productivities indicates that material inputs have played a role of different importance in different regions over the last two decades. A comparison of Tables XVII and XVIII is illustrated in Figure 5.

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[52]By Equation (3.5), $\mathring{A}(t)_N/A(t)_N = (1 - W_{K,N})\mathring{y}_N/y_N$, if $\mathring{y}_N/y_N = \mathring{k}/k$. That is, if both capital per man-equivalent and net labor productivity grow at the same rate, the share of technological change in increased net labor productivity is $(1 - W_{K,N})$ while that of capital is $W_{K,N}$, the share of capital in income. Since capital per man-equivalent increased about three-fourth as fast as net labor productivity, and the share of capital in income was approximately 40 per cent, this 24.82 per cent for the contribution of capital to increased net labor productivity seems reasonable.

CHAPTER IV

EXAMINATION OF ASSUMPTIONS UNDERLYING THE MEASUREMENT AND ESTIMATION OF MARGINAL PRODUCTIVITY OF RESOURCES

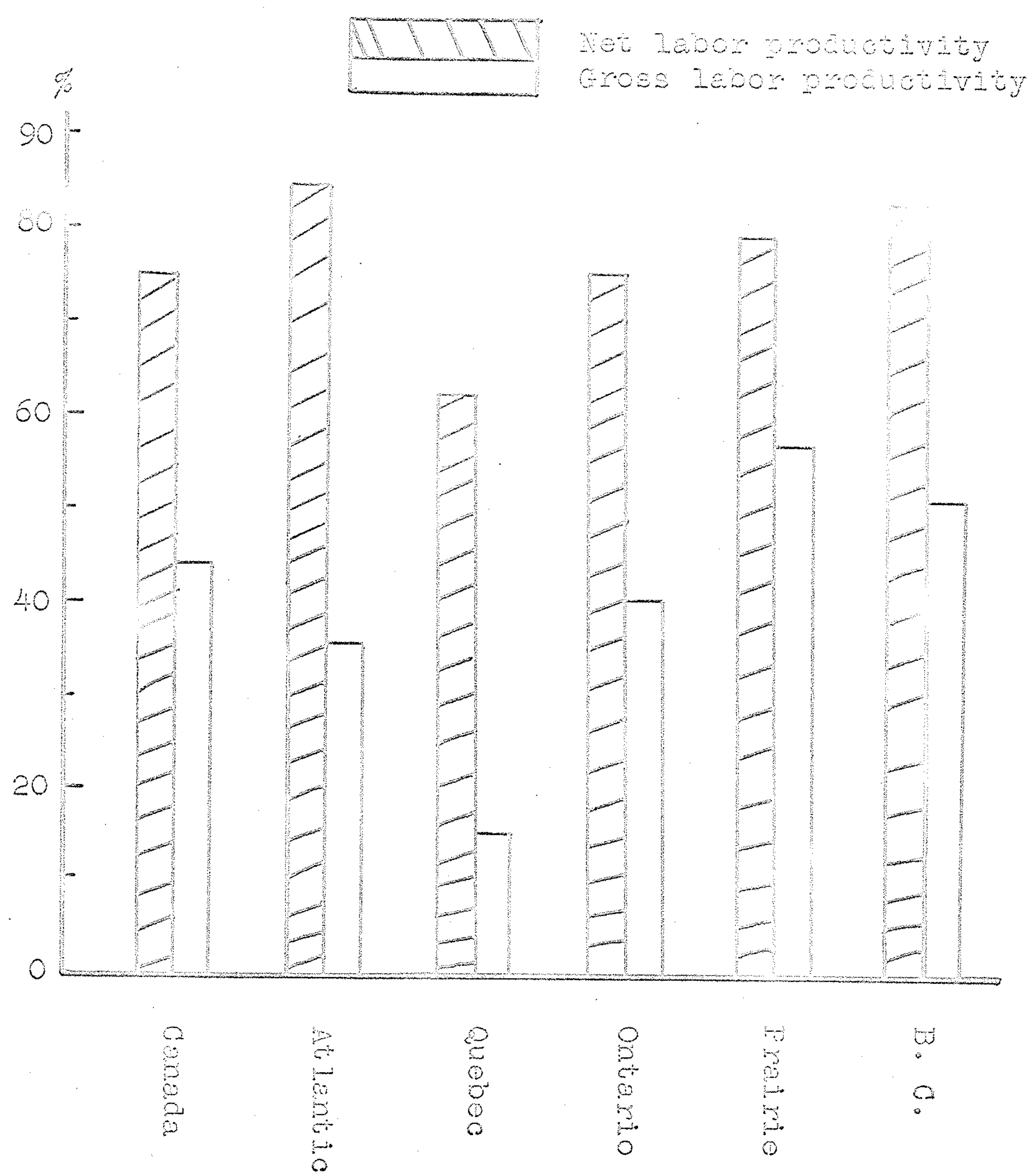
The foregoing analysis of growth of labor productivity was based upon the explicit assumption of Hicks-neutral technological change and of constant returns to scale. If the first assumption is violated, the measure of technological change becomes biased upward by an influence that should actually be recorded as the interaction between capital and technological change. If the second assumption is violated, the estimate of technological change also becomes biased: it is biased upward if the returns to scale are increasing; downward if the returns to scale are decreasing. In view of this point, the examination of these two assumptions seems necessary. The present chapter examines these assumptions as well as the estimates of marginal value productivity of labor and of capital.

A. Elasticity of Substitution - A Digression

The model used in this study is basically a production function of the Cobb-Douglas form.[53] An implicit assumption of

[53] Solow's model in our study turns out to be a Cobb-Douglas production function since the observed share of capital in income ($W_{K,N}$), presented in Appendix V, did not significantly change over the time period studied, in either individual or regions in Canada as a whole, which is shown by the results of the Chi-square test.

FIGURE 5. COMPARISON OF THE PERCENTAGE SHARE OF TECHNOLOGICAL CHANGE IN INCREASED NET AND GROSS LABOR PRODUCTIVITY, CANADA AND REGIONS, 1946-1965



the Cobb-Douglas production function is a unitary elasticity of substitution between labor and capital. Thus, before examining the assumptions on which the foregoing analysis was based, it is worthwhile to investigate whether there is a strong *a priori* evidence against the assumption implied in the model itself. This assumption can be investigated by fitting a log-linear relationship between net labor productivity (value added per man-equivalent) and the wage rate. The model, as developed in Chapter II, is written as follows:

$$\log \left(\frac{Y}{L}\right) = \log a + b \log W + \log e$$

where Y/L is the value added per man-equivalent which has been defined in the previous chapter; W is the yearly wage rate obtained by dividing the total hired wage income by the number of man-equivalent of hired farm labor, deflated by the implicit output deflator using 1935-39 as a base;[54] b is the elasticity of substitution between labor and capital; and e is a disturbance, log e is assumed to be normally and independently distributed with zero mean and common variance.

The results of fitting such a relationship are summarized in Table XIX. Standard errors are included in parentheses under the regression coefficients. The values of R^2, coefficient of determination, are presented in Column 4, while the values of s, standard error of residuals, are given in Column 5.

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[54]It is assumed that family labor and hired labor received the same yearly wage rate. The yearly real hired wage per man-equivalent is given in Appendix IX.

The statistical tests show that all the values of R^2 are significant at the one per cent level, although their values vary from .9200 in Ontario to .2654 in the Prairie. The high value of R^2 means that the wage rate explains a high percentage of the variation in labor productivity. And the reverse is also true. Generally speaking, all regression equations may express the relationship between labor productivity and the wage rate for their respective regions.

TABLE XIX

ESTIMATES OF THE ELASTICITY OF SUBSTITUTION
CANADA AND REGIONS, 1946-1965

Canada & Region	log a	b	R^2	s
Canada	.07138	.98747 (.10977)	.8257*	.0540
Atlantic	-.54379	1.13953 (.16996)	.7141*	.0904
Quebec	.45866	.80511 (.11815)	.7206*	.0681
Ontario	.30947	.90385 (.06279)	.9200*	.0398
Prairie	1.00082	.73441 (.28801)	.2654*	.1181
B. C.	1.32900	.59971 (.14350)	.4925*	.0979

Note: * stands for a one per cent level of significance.

The values of b, the elasticity of substitution between capital and labor, are not statistically different from unity at the conventional levels in all regions with a single exception of B. C., in which it is significantly different from unity at the five per cent level but not, at the one per cent level. Thus, there does not seem to be any strong *prima facie* evidence against the Cobb-Douglas form which was used in the previous analysis. The calculated Student's t for testing the hypothesis of unitary elasticity of substitution are given in the following table.[55]

TABLE XX

TESTING THE HYPOTHESIS OF UNITARY ELASTICITY OF SUBSTITUTION
CANADA AND REGIONS

	Canada	Atlantic	Quebec	Ontario	Prairie	B. C.
H_o: $b_o = 1$						
t	.114	.821	-1.650	-1.531	.922	-2.790

Note: For 18 degrees of freedom, the critical value of t = 2.878 at 1%; t = 2.101 at 5%.

The elasticity of substitution is used to measure the degree of substitution between production factors. While a high elasticity of substitution indicates that the region would be able to substitute capital for labor, a low elasticity of substitution indicates that it would be much more difficult for a region to make this substitution, in the case of a change in relative prices. In B. C., the elasticity of substitution has been low over the last two decades possibly

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[55]The value of t was computed as $b - b_o / s_b$, where s_b is the standard error of b.

because of the dominance of dairying, market gardening, and fruit growing activities; for all such enterprises, it is difficult to substitute capital for labor.

B. Examination of Neutrality of Technological Change

As Hicks-neutral technological change is defined as one which alters the production function for each capital-labor combination but leaves the marginal rates of substitution of capital for labor unchanged, the test would then be to relate the marginal rates of substitution with the capital-labor ratio. If these two variables are closely related, technological change is said to be neutral. If, on the other hand, the relationship shifts over time, the situation is not neutral.

With reference to this test, it was required to investigate the elasticity of substitution from period to period. Since the elasticity of substitution is defined as a ratio of the relative change in the capital-labor ratio to the relative change in the marginal rates of substitution of capital for labor, neutral technological change is indicated if it remains unchanged from period to period. This is done by fitting the above equation to the data of two subperiods, 1946-1955 and 1956-1965, separately.[56] The estimated regression coefficients, b_1 for 1946-1955 and b_2 for 1956-1965, are presented in Table XXI. The numbers in parentheses are the estimated standard errors of the respective coefficients.

[56]This study covers only 20 years. It is not suitable for being divided into more than two subperiods because of the degrees of freedom.

TABLE XXI

ESTIMATES OF THE ELASTICITY OF SUBSTITUTION IN TWO SUBPERIODS, 1946-1955 AND 1956-1965 CANADA AND REGIONS

Canada & Region	1946-1955 b_1	1956-1965 b_2
Canada	.87894 (.18226)	1.06498 (.15488)
Atlantic	.99277 (.36697)	1.24000 (.11922)
Quebec	.89657 (.15945)	.66818 (.19097)
Ontario	.85814 (.07529)	.96429 (.11100)
Prairie	.63358 (.46523)	.89722 (.36467)
B. C.	.65099 (.11020)	.44064 (.38497)

Under the null hypothesis of equality of regression coefficients ($b_1 = b_2$) and the general assumptions of normality and independence, the test criterion is a "t" statistic.[57] The calculated values of t are given in Table XXII.

[57] $t = b_1 - b_2 / \sqrt{s_p^2 \left(1/\Sigma W_{1j}^2 + 1/\Sigma W_{2j}^2 \right)}$, where b_1 and ΣW_{1j}^2 are the regression coefficient and sum of squares for W, the wage rate, from the sample 1946-1955; and similarly for the sample 1956-1965; and s_p^2 is the pooled variance.

TABLE XXII

TESTING THE HYPOTHESIS OF EQUALITY OF ELASTICITIES OF SUBSTITUTION IN TWO SUBPERIODS, 1946-1955 AND 1956-1965 CANADA AND REGIONS

	Canada	Atlantic	Quebec	Ontario	Prairie	B. C.
$H_0: b_1 = b_2$ t	.7404	.6834	.9161	.8047	.4219	.6000

Note: For 16 degrees of freedom, the critical value of t = 2.921 at 1%; t = 2.120 at 5%.

The results of the test show that elasticities of substitution for 1946-1955 were not significantly different from those for 1956-1965 in all regions and Canada as a whole. Thus, the shifts of production function do not appear to have departed from neutrality.

In order to confirm this result, another method of testing neutral technological change was also used. As mentioned in the previous chapter, technological change is neutral if the rate of change ($\frac{\dot{A}}{A}$) is independent of the capital-labor ratio (k), and only a function of time. Thus the test is simply to plot the computed $\frac{\dot{A}}{A}$ against the capital-labor ratio. If it shows no trace of a relation between these two variables, the shifts over the period are, on the average, approximately neutral.

Instead of plotting, the coefficients of rank correlation between $\frac{\dot{A}}{A}$ and k were calculated as given in the following table.

TABLE XXIII

COEFFICIENTS OF RANK CORRELATION[a] BETWEEN YEAR-TO-YEAR RATES OF TECHNOLOGICAL CHANGE AND CAPITAL-LABOR RATIOS CANADA AND REGIONS, 1947-1965*

Canada	Atlantic	Quebec	Ontario	Prairie	B. C.
.0298	.4982	.0649	-.0158	-.0070	.2579

*Source: Calculated from Appendix V.

[a]For 19 pairs of observation, the value of coefficient of rank correlation which is significant at the one per cent level is .55.

The estimated correlation coefficients show that no relation existed between these two variables in all regions and Canada as a whole. Hence, neutrality of technological change is concluded.

C. Examination of Constant Returns to Scale

Having obtained the technological change index as presented in Table VI, it is possible to derive a series of real value-added output, net of technological change. This was done by deflating the value-added series by their corresponding technological change indexes. The deflated series of real value added is, then, a function of labor and capital. As for fitting a curve to this relationship, an unrestricted Cobb-Douglas function was employed. One of the characteristics of the unrestricted Cobb-Douglas function, as discussed in Chapter II, is that it permits increasing, constant, or decreasing returns to scale depending upon the sum of exponents. The returns to scale are increasing if the sum of exponents is greater than one; constant if the sum of exponents is equal to one; and decreasing if the sum of exponents is less than one.

The statistical results of such a fitting are contained in Table XXIV. Standard errors are included in parentheses under their respective regression coefficients. While the values of R^2 and the residual standard errors are presented in Row 2 and Row 3 respectively, the Von Neumann Ratio which is used to examine autocorrelation in the residual is shown in the last row.

The values of R^2, the coefficient of determination, are extremely high and are significant at the one per cent level, indicating that all regression equations estimated in this study are a meaningful and useful expression of the relationship between output of value-added and inputs of labor and capital while abstracting the effects of technological change, for their respective regions. The value of R^2 equalling .9985 for Canada as a whole, for example, reveals that 99.85 per cent of the variation in the real value-added were explained by labor and capital.

TABLE XXIV

REGRESSION COEFFICIENTS AND OTHER STATISTICAL RESULTS OF THE ESTIMATED PRODUCTION FUNCTION, $\hat{Y} = aL^{b_1}K^{b_2}$, AFTER ELIMINATING THE EFFECTS OF TECHNOLOGICAL CHANGE CANADA AND REGIONS

	Canada	Atlantic	Quebec	Ontario	Prairie	B. C.
R^2	.9985*	.9777*	.9954*	.9969*	.9833*	.9804*
S	.00207	.01445	.00535	.00245	.00559	.00740
log a	.9911	.0896	1.3645	1.0424	2.1935	2.0536
b_1	.55657* (.00556)	.38484* (.05575)	.52910* (.01612)	.55254* (.01164)	.64831* (.03597)	.63156* (.02256)
b_2	.46172* (.04134)	.66139* (.10092)	.37513* (.07666)	.45496* (.02843)	.26346* (.07093)	.27421* (.04019)
$b_1 + b_2$	1.01829	1.04623	.90423	1.00750	.91177	.90577
V-N Ratio	2.3021	1.9013	1.1789	1.9628	1.7325	1.6004

Note: 1. Model is fitted with annual data from 1946 to 1965.

2. The symbol * stands for one per cent level of significance.

3. The V-N Ratio is computed as the ratio of the "mean-square successive difference" to the "variance of residuals", i.e.,

the ratio $K = \Delta e^2 / S_e^2$, where $\Delta e^2 = \sum_{t=1}^{n-1} (e_t - e_{t-1})^2 / n-1$, and $S_e^2 = \sum_{t=1}^{n} e_t^2 / n$; Δe^2 is a measure of autocorrelation and e_t is the residual at time t.

For samples of 20 observations, the critical value of K is greater than 3.1151 or less than 1.0954 at the one per cent level of significance; greater than 2.8425 or less than 1.3680 at the five per cent level of significance.

The regression coefficients of both labor and capital were highly significant in all regions and Canada as a whole. The V-N Ratio shows that no autocorrelation existed in the residuals. The absence of autocorrelation is an evidence of random data and unbiased regression coefficients of all variables.

The sum of b_1 and b_2, regression coefficients of labor and capital, ranged from 1.04623 in the Atlantic to .90423 in Quebec. Intuitively, it seemed to reflect increasing returns to scale in the Atlantic and Ontario; and decreasing returns to scale in the Prairie, Quebec, and B. C. Statistically, however, none of the sum of regression coefficients was significantly different from unity, as the results of test shown in Table XXV.[58] Thus, the assumption of constant returns to scale made in the previous analysis is justified.

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[58]Under the null hypothesis of constant returns to scale and the standard assumptions of normality and independence, the test criterion is a "F" statistic with 1 and N-P-1 degrees of freedom, where N is the number of observations; and p the number of independent variables. The value of F is calculated as

$$F = (Q_2 - Q_1)(N - P - 1)/Q_1$$

where Q_1 is the residual sum of squares for the unrestricted Cobb-Douglas function which can be found from Table XXV; and Q_2 the residual sum of squares for restricted Cobb-Douglas function which is computed as

$$Q_2 = S_{YY} - b_1'S_{YL} - b_2'S_{YK} - \lambda$$

where S_{YY} is the sum of squares of the value-added; S_{YL} and S_{YK} are the sums of cross products of the value-added and labor, and the value-added and capital, respectively; b_1' and b_2' are regression coefficients of L and K, respectively, under the restriction of constant returns to scale; and λ is the Lagrange multiplier.

TABLE XXV

TESTING HYPOTHESIS OF CONSTANT RETURNS TO SCALE FOR THE ESTIMATED PRODUCTION FUNCTION, $\hat{Y}/A(t)=aL^{b_1}K^{b_2}$ CANADA AND REGIONS

		Canada	Atlantic	Quebec	Ontario	Prairie	B. C.
Unrestricted							
	b_1	.55657	.38484	.52910	.55254	.64831	.63156
	b_2	.46172	.66139	.37513	.45496	.26346	.27421
Restricted							
	b'_1	.55529	.40978	.51243	.55044	.67721	.66145
	b'_2	.44471	.59022	.48757	.44956	.32279	.33855
Unrestricted SSE	Q_1	.00007	.00355	.00049	.00010	.00053	.00093
Restricted SSE	Q_2	.00007	.00367	.00055	.00011	.00055	.00109
Difference	$Q_2 - Q_1$	.....	.00012	.00006	.00001	.00002	.00016
Degrees of Freedom		1/17	1/17	1/17	1/17	1/17	1/17
Value of F		.00000	.0338	.1224	.1000	.0413	.1733

Note:. ..... denotes the value less than 1/100000.

2. For 1 and 17 degrees of freedom, the critical value of F is 8.4 at 1%; 4.45 at 5%.

For the case that output is gross and material inputs are incorporated into the production function, it is also possible to derive the regression equations of unrestricted Cobb-Douglas form, after eliminating the effects of technological change, and test for their constant returns to scale. The statistical results of fitting such a relation are summarized in Table XXVI. But, here no attempt was made to test constant returns to scale.

The values of R^2 were quite high and were significant at the one per cent level, indicating a good fitting of regression equations for all regions and for Canada as a whole. The sums of b_1, b_2, and b_3 ranging from 1.08732 in the Atlantic to .93728 in Quebec, were quite close to unity.

D. Estimation of Marginal Value Productivity of Labor and Capital

Having examined constant returns to scale, one can estimate marginal value productivity of labor and of capital in the absence of technological change by multiplying elasticities of production of labor (b_1') and capital (b_2') by their respective average productivity. Stated mathematically,

$$MVP_L = b_1' \frac{Y}{L}, \text{ and}$$

$$MVP_K = b_2' \frac{Y}{K} .$$

The estimated marginal value productivity of labor and of capital are presented in Table XXVII and Table XXVIII,

TABLE XXVI

REGRESSION COEFFICIENTS AND OTHER STATISTICAL RESULTS OF THE ESTIMATED PRODUCTION FUNCTION, $\hat{Y} = aL^{b_1}K^{b_2}M^{b_3}$, AFTER ELIMINATING THE EFFECTS OF TECHNOLOGICAL CHANGE CANADA AND REGIONS

	Canada	Atlantic	Quebec	Ontario	Prairie	B. C.
R^2	.9909*	.9697*	.9654*	.9846*	.9501*	.9881*
S	.00129	.00523	.00547	.00326	.00272	.00399
log a	1.37633	.09157	2.47894	.94880	1.76188	1.31257
b_1	.31938* (.00815)	.15489* (.02024)	.26215* (.04250)	.24767* (.02087)	.44200* (.02900)	.36445* (.01264)
b_2	.12195* (.02671)	.19531* (.03964)	.06115** (.02293)	.19455* (.04649)	.18578* (.05094)	.25899* (.03656)
b_3	.49347* (.01277)	.73712* (.04393)	.61398* (.04823)	.52742* (.03614)	.31171* (.04366)	.33841* (.02376)
$b_1+b_2+b_3$	.93480	1.08732	.93728	.96964	.93949	.96185
V-N Ratio	1.8002	1.3602	1.2738	1.8884	2.4062	2.0909

Note: 1. Model is fitted with annual data from 1946 to 1965.

2. Level of significance: * = 1 per cent; ** = 5 per cent.

3. For critical values of V-N Ratio, refer to the notes below Table XXIV

TABLE XXVII

MARGINAL VALUE PRODUCTIVITY OF LABOR IN SPECIFIC YEARS[a]
IN THE ABSENCE OF TECHNOLOGICAL CHANGE
CANADA AND REGIONS

Canada & Region	1946	1950	1955	1960	1965
	..................Dollars[b]...............				
Canada	269	285	320	340	365
Atlantic	111	115	143	121	144
Quebec	138	137	165	182	189
Ontario	271	294	328	384	408
Prairie	570	630	681	732	758
B. C.	608	633	640	669	718

[a]Based on the restricted Cobb-Douglas function.

[b]In 1935-39 constant dollars.

TABLE XXVIII

MARGINAL VALUE PRODUCTIVITY OF CAPITAL IN SPECIFIC YEARS[a] IN THE ABSENCE OF TECHNOLOGICAL CHANGE CANADA AND REGIONS

Canada & Region	1946	1950	1955	1960	1965
			Dollars[b]		
Canada	.05572	.05273	.04515	.04196	.03817
Atlantic	.06258	.06058	.05264	.05743	.05107
Quebec	.04593	.04780	.03858	.03466	.03404
Ontario	.05743	.05197	.04562	.03751	.03467
Prairie	.05799	.04990	.04102	.03640	.03219
B. C.	.04778	.04469	.04089	.03632	.03121

[a] Based on the restricted Cobb-Douglas function.

[b] In 1935-39 constant dollars.

respectively. The results show that in the absence of technological change, marginal value productivity of labor has continuously increased whereas marginal value productivity of capital has continuously declined. Apparently, it is due to the fact that continuous substitution of capital for labor calls the law of variable proportions into play.

Marginal value productivity of labor and of capital in the presence of technological change were also estimated and are given in Table XXIX and Table XXX, respectively. They are calculated simply by multiplying MVP_L and MVP_K in the absence of technological change by their corresponding A(t) given in Table VI.

A glance at Table XXIX shows that marginal value productivity has increased from year to year at a high rate in all regions, especially in the Atlantic and Ontario. This increase apparently resulted from technological change on the one hand, and from the rapid off-farm migration, on the other. Even though it has made so much progress in the last two decades, yet its level of 1965 was much lower than the real wage rate in three of the five regions.[59] This large gap existed between marginal value productivity and the real wage rate in the Atlantic, Quebec, and Ontario partly because the former was too low as compared with other regions, and partly because the

[59] Compare Table XXIX with Appendix IX.

TABLE XXIX

MARGINAL VALUE PRODUCTIVITY OF LABOR IN SPECIFIC YEARS[a]
IN THE PRESENCE OF TECHNOLOGICAL CHANGE
CANADA AND REGIONS

Canada & Region	1946	1950	1955	1960	1965
	....	.....	Dollars[b]	.....	....
Canada	269	283	438	463	656
Atlantic	111	82	171	155	327
Quebec	138	140	297	290	275
Ontario	271	414	438	591	813
Prairie	570	603	1,035	1,054	1,440
B. C.	608	631	703	716	1,226

[a]Based on the restricted Cobb-Douglas function.

[b]In 1935-39 constant dollars

TABLE XXX

MARGINAL VALUE PRODUCTIVITY OF CAPITAL IN SPECIFIC YEARS[a] IN THE PRESENCE OF TECHNOLOGICAL CHANGE CANADA AND REGIONS

Canada & Region	1946	1950	1955	1960	1965
	....	....	Dollars[b]	....	....
Canada	.05572	.05240	.06180	.05709	.06861
Atlantic	.06258	.04312	.06305	.07365	.11607
Quebec	.04593	.04887	.06944	.05517	.04949
Ontario	.05743	.07314	.06088	.05771	.06906
Prairie	.05799	.04778	.06237	.05240	.06115
B. C.	.04778	.04452	.04490	.03886	.05329

[a]Based on the restricted Cobb-Douglas function.

[b]In 1935-39 constant dollars.

latter increased rapidly as a consequence of keen competition between agricultural and non-agricultural labor markets. In the Prairies and B. C., the level of marginal labor productivity in 1965 exceeded that of real wage rate, indicating more efficient use of labor resources on the one hand, and the lack of attractive job opportunities in non-farm sectors, on the other. Even marginal value productivity was relatively high in these two regions, but not high enough as compared with that in non-agricultural sectors. Low marginal value productivity reflects that a large number of surplus labor still exists in Canadian agriculture.[60]

In reference to marginal value productivity of capital, the Table XXX shows that it has also much increased in most of the regions, especially in the Atlantic. With the exception of Quebec and B. C., the levels of marginal value productivity of capital in 1965 were higher than the market interest rate of 6 per cent. The excess of marginal value productivity over the market interest rate (marginal cost) suggests that it is profitable to increase investment in those regions. In Quebec and B. C., on the other hand, the increase in investment will suffer more loss at the present situation of technological progress. The increase in investment would be profitable in these two regions provided that they could expedite their technological progress.

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[60]Refer to L. K. Li, A Market Structure for Hired and Family Labor in Canadian Agriculture, an unpublished Master's Thesis, The University of Manitoba, Winnipeg, Manitoba, 1965.

CHAPTER V

IMPLICATIONS OF EMPIRICAL RESULTS

So far, technological change in the agricultural regions as well as in Canada as a whole has been measured and the assumptions on which the measurement of technological change was based have been verified. As the results indicated, Canadian agriculture has experienced a rapid growth rate of technological change over the last two decades, and this change proceeded at dramatically different rates in different regions. These results have some important implications for resource allocation, prices and farm incomes, and income distribution; all of which will, in sequence, be discussed in this chapter.

A. The Implication for Resource Allocation

Technological change permits the substitution of knowledge for resources. The continuous flow of new knowledge into agriculture has reached such proportions that substantial increases in the net farm output were being achieved with only moderate increase in capital inputs and with constantly declining labor inputs.[61] Of the measured increase in net labor productivity, capital intensity was responsible for less than one third and the most part was explained by technological change.

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[61] Refer to Appendixes I and II.

This is especially true in the Atlantic where the highest growth rate of technological change was registered with the lowest rate of the increase in farm capital among regions.[62] As Solow points out, "capital formation is not the only source of growth in productivity. Investment is at best a necessary condition for growth, surely not a sufficient condition. Recent study has indicated the importance of such activities as research, education, and public health."[63] Griliches in his study found that public expenditures on research and extension affect the level of agricultural output "significantly" and that their social rate of return is quite high.[64] For regional differences in the growth rate of technological change, those activities also play an important role. The regions in which research expenditures have been highest have also experienced the most rapid rates of technological change.[65] In recognizing the significance of those activities in the process of economic growth, this study is still unable to make any quantitative estimate of their

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[62]Compare Table XVII with Appendix II.

[63]R. M. Solow, "Technical Progress, Capital Formation, and Economic Growth," American Economic Review, Vol. 52, No. 2, May 1962, p. 86.

[64]Z. Griliches, "Research Expenditures, Education, and The Aggregate Agricultural Production Function," American Economic Review, Vol. 54, No. 6, December 1964, pp. 961-974.

[65]V. Ruttan and T. Stout, "Regional Differences of Technical Change in American Agriculture," Journal of Farm Economics, Vol. 40, No. 2, May 1958, pp. 196-207.

contribution to the measured increase in net labor productivity because of lack of the data. However, as Hendrix has suggested, if technological change and capital inputs can be viewed as substitutes, it becomes possible to get away from the question of the quantity of resources required for research if output requirements are to be met. Nevertheless, a certain amount of complementarity does exist between innovation and capital inputs. In many cases, both capital investment and purchase of material inputs are necessary if the advances in technology are actually to be introduced. This may be true even though the innovation results in a reduction in total capital inputs required to produce a given output.[66] Thus, in order to bring productivity in Quebec and B. C. up to the national level, the resource policy should emphasize an increase in the allocation of public funds for research and education designed to speed the rate of technological change, accompanied by a moderate increase in capital investment.

On the labor side, it is apparent that the acceleration of farm productivity advance since 1946, coupled with the increased rate of substitution of capital for labor, has been an important factor in the accelerated rate of decline in farm employment in both absolute terms and relative to non-farm

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[66] See W. E. Hendrix, "Availability of Capital and Production Innovations on Low-Income Farms," _Journal of Farm Economics_, Vol. 33, No. 1, February 1951, pp. 66-74.

employment. Gruen[67] explains the process by which agricultural labor transfers to the non-agricultural sector with the aid of the following Gruen's figure. Assume that there are two goods, agricultural (A) and non-agricultural (N), in the economy, that technical progress is taken place only in the production A, and that the economy is closed. Prior to the technical change, let the production possibility curve be LPV. Given the indifference curve I_1, the optimum output combination is at the point P, when On units of N and Oa units of A are produced, and the relative price of A in terms of N is given by the slope of the price line XM. With technical progress in the production of A, productivity of resources in the production A increases, so the production possibility curve shifts up to be BSRTV. The new production possibility curve possesses the following properties;

1. It coincides with the pre-improvement transformation curve LPV at point V, when all resources are devoted to the production of N.

2. The slope of point R on the new transformation curve is greater than the slope of the corresponding point P on the old transformation curve. This implies that, unless relative prices of product change, the production of N will decline after technical progress in A. In terms of transformation curve, the marginal rate of transformation of N for A,

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[67]F. H. Gruen, "Agriculture and Technical Change," Journal of Farm Economics, Vol. 43, No. 4, November, 1961, pp. 838-841.

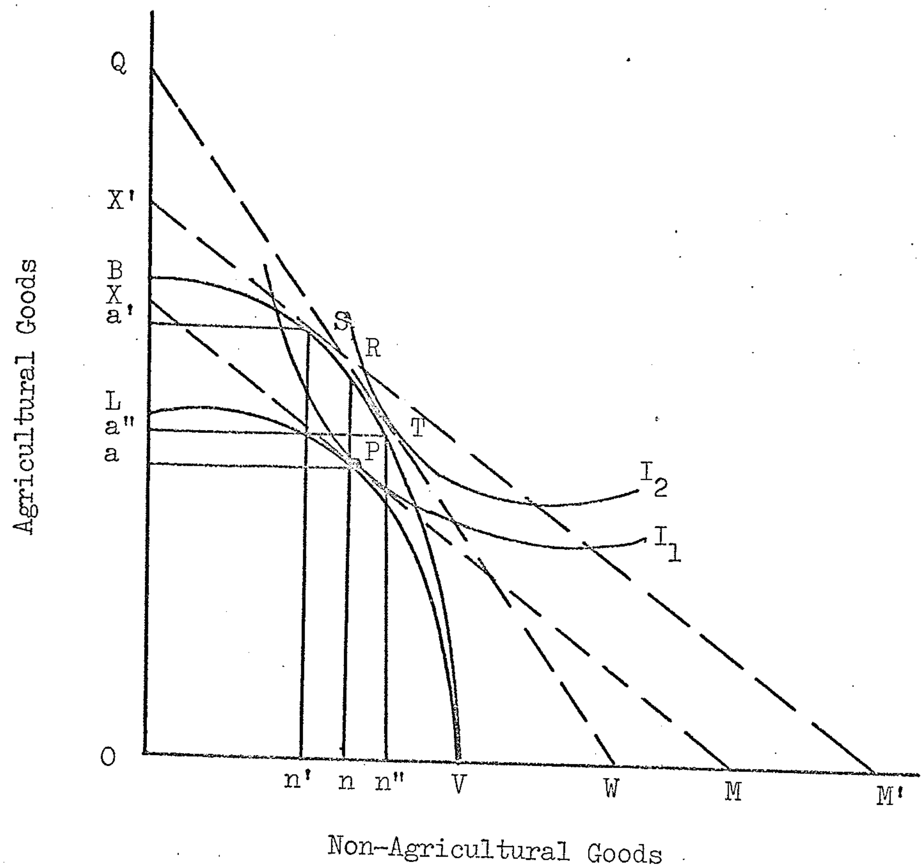

FIGURE 6. AN ILLUSTRATION OF THE PROCESS OF TRANSFERRING FARM LABOR TO NON-FARM SECTOR

i.e. dA/dN, will be increased by technical progress. Since the aggregate demand elasticity for farm products as a whole is less than unity, an increase in output brought forth by technical progress inevitably causes a decline in the price of farm products. As a result, consumers become better off and the price ratio of farm products to non-farm products drops. When the community is confronted with the new production possibility curve BSRTV, the optimum position moves from P to T where Oa" units of A and On" of N are produced. This movement can be divided into an expansion effect from P to S, and a substitution effect from S to T. The combination of these two effects leads to a reduction in the resources, particularly farm labor, devoted in agricultural production, since T lies to the right of R.

There was, of course, some interaction; insofar as increased opportunity for employment elsewhere during this period was part of the explanation of an increasing exodus from farms, this may have been a factor in accelerating technological advance. This seems plausible if the exodus were primarily from farms of less than average efficiency, or reduced disguised unemployment. But insofar as the acceleration was autonomous, then the accelerated technological progress has aggravated the farm problem as it related to the need for shifting labor resources.

Since technological advance in farming has been persistently ahead of resources adjustment, the surplus of farm labor may be one of the reasons for explaining the low rates of growth in productivity in Quebec and B. C. Denison has suggested that movement of labor from the farms to high-productivity jobs has played a relatively important role in economic growth.[68] Massel has estimated that shifts of the relative allocation of capital and labor between industries accounted for approximately one quarter of total-factor-productivity growth in the post-war era.[69] These suffice to indicate the importance of labor resources adjustment for the growth of agriculture as well as for the economy as a whole. Garver has suggested that "there are unfortunately a number of serious impediments. ....Acquiring the training and skill for the non-farm jobs where opportunities are greatest is in itself a herculean task for many. .... The sheer cost of moving home and family to a strange setting are insuperable for many. Severing home and community ties of long standing appears too tragic for many people. The insecurities and uncertainties about such a radical change is a forbidding prospect to many folks. Economic fluctuations, such as recession, are a major deterrent."[70] In order to obtain the optimum allocation

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[68] E. Denison, "How to Raise the High-Employment Growth Rate by One Percentage Point," American Economic Review, Vol. 52, No. 2, May 1962, pp. 67-75.

[69] B. F. Massell, "A Disaggregated View of Technical Change," Journal of Political Economy, Vol. 59, No. 6, December 1961. p. 555.

[70] W. B. Garver, "Technical Change and the Problem of Man-power Adjustment," Journal of Farm Economics, Vol. 40, No. 5, December 1958, p. 1450.

of labor resources, public policy should be directed to remove these obstacles of out-migration.

B. The Implication for Prices and Farm Incomes

Innovations designed to lower costs usually have a curious propensity to result in expanded output. It is difficult to conceive of an innovation that successfully lowers costs which does not also expand output under free market conditions. With an inelastic demand for agricultural products, the output increasing innovation will undoubtedly cause a decline in the prices of agricultural products, and hence reduce farm income below the levels which would otherwise prevail.[71] As Gruen pointed out, "producers get less for producing more. ...... An inelastic demand may be not only a necessary but also a sufficient condition for an absolute decline in farm incomes. In other words that, even if the supply elasticity is large and positive - say greater than unity - an inelastic demand may still lead to lower farm incomes after technical progress than before."[72]

To assess the general implications of a change in technology for prices, and hence for incomes, Figure 6 is employed again. Let the production model be

$$\frac{A^2}{y_A^2} + \frac{N^2}{y_N^2} = 1$$

[71] E. O. Heady, "Basic Economic and Welfare Aspects of Farm Technological Advance," Journal of Farm Economics, Vol. 31, No. 2, May 1949, pp. 293-316.

[72] F. H. Gruen, "Agriculture and Technical Change," Journal of Farm Economics, Vol. 43, No. 4, November 1961, p. 838.

where A is the per capita production of agricultural goods, and N is the per capita production of non-agricultural goods; y_A and y_N represent the per capita output if all resources are employed in agriculture and non-agriculture, respectively. Furthermore, let the consumption model be

$$U_A \cdot U_N = c$$

where U_A stands for the per capita consumption of agricultural products, while U_N stands for the per capita consumption of non-agricultural products; and c is the structual coefficient interpreted as income level. Assuming that what is produced is also consumed, then $U_A = A$ and $U_N = N$. The production model and the consumption model can now be put together to determine the ratio of exchange for agricultural and non-agricultural goods. One unique point of tangency of these two curves is P, before technological progress, where the slope of both curves is equal to y_A/y_N.[73] This is the exchange ratio of agricultural products to non-agricultural products at an equilibrium position of consumer preferences and production. A change in technology in agriculture increases y_A while a change in technology in the non-agricultural sector increases y_N. Thus, technological progress in the agricultural sector alone reduces the prices of agricultural products, and hence farm incomes, as compared with those in the non-agricultural sector. In order to move from the position Oa'Sn' to the new equilibrium

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[73]The slope of the production possibility curve is $dA/dN = - Ny^2/Ay_N^2$. The slope of the consumer preference curve is $dA/dN = - A/N$. Equating the slope of these two curves gives $A/N = y_A/y_N$.

position Oa"Tn" in Figure 6, it is necessary to shift resources from the agricultural to the non-agricultural sector. However, in arriving at the new equilibrium position T, the prices of agricultural products rise relative to those of non-agricultural products, but this price ratio at the new equilibrium position T is still lower than it was at the old equilibrium position P.[74] One of the more comprehensive studies of the relative incomes of agriculture and non-agriculture indicates that it is almost universally true that agricultural income is low relative to non-agricultural income.[75] In addition, this study indicates extreme variability in this income ratio among regions. The differences in the elsticity of demand for agricultural products, the growth rate of technological change, and the mobility of labor resources are, of course, the main reasons for explaining this variability. When technological change is relatively rapidly in a region faced by an elastic demand curve, it tends to increase labor as well as capital that should be allocated to that region. On the other hand, when technological change proceeds relatively rapidly in a region facing an inelastic demand curve, that region's optimum share of the economy's resources tends to decline.

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[74]M. A. MacGregor, "Implications of Changing Technology for Prices and Incomes in Agriculture," Journal of Farm Economics, Vol. 40, No. 5, December 1958, pp. 1582-1585.

[75]J. R. Bellerby, Agriculture and Industry Relative Income, MacMillan & Co. Ltd., London, 1956, Chapter 2, pp. 18-36, and Chapter 6, pp. 89-153.

C. The Implication for Income Distribution

Kendrick, in his discussion of the effects of technological change on income distribution, argues that "........ technological advance has increased the relative demand for more highly skilled and professional personnel, while its contribution to real income has made possible the increasing investments in education and training required to effectuate a gradual upgrading of the labor force. The increased relative supply of more highly trained and educated numbers of the labor force has, in turn, contributed to a narrower dispersion of wage and salary rates. This too has been an important force in reducing income inequality."[76]

Secondly, technological advance has brought about the lower agricultural prices. Since the income elasticity of demand for agricultural products in the low income groupsis greater than that in the high income group, the former may share the gains from technological progress much more than the latter. This, too, has contributed to greater equality of income distribution.

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[76] J. W. Kendirck, "Technological Change and Economic Progress," Journal of Farm Economics, Vol. 46, No. 5, December 1964, p. 1072.

E. O. Heady, Economics of Agricultural Production and Resource Use, Prentice-Hall, Inc., N. Y., 1952, Chapter 27,

CHAPTER VI

SUMMARY AND CONCLUSIONS

Over the period of 1946-1965, Canadian agriculture has been spectacularly successful in raising real net output per man-equivalent which is conventionally termed as labor productivity. Increases in labor productivity are compounded of two parts: movements along the production function resulting from the use of additional capital per man-equivalent, and shifts of the production function stemming from a change in the efficiency of the use of resources, i.e., technological change. The primary purpose of this study was to segregate the variations in labor productivity due to technological change from those due to changes in the utilization of farm capital per man-equivalent. More specifically, the objectives were:

(1) to examine the nature of technological change;

(2) to investigate the elasticity of substitution between capital and labor;

(3) to estimate the returns to scale;

(4) to measure annual rates of technological change; and

(5) to segregate the components of increased labor productivity into those attributable to technological change and those due to capital intensity.

The analysis was made on a regional basis as well as for Canada as a whole. Five regions were formulated according to the existing production pattern and the geographic delimitation, viz, the Atlantic region including Nova Scotia, New Brunswick, and Prince Edward Island; the Quebec region; the Ontario region; the Prairie region including Manitoba, Saskatchewan, and Alberta; and the British Columbia region.

Technological change was measured on the basis of different concepts of net (value added) and gross output. The net output differs from the gross output in that it does not include material inputs consumed in the process of production. For strict comparability with the basic factors of production, labor and capital, originating in the regions as well as in the agricultural sector as a whole, the relevant measure should be the value-added measure of technological change. The gross measure of technological change was used for reference only.

The principal method of measuring technological change used in this study was the Solow or geometric model. In order to make a comparison, however, the arithmetic index of technological change was also calculated. Solow's model derived from an aggregate production function incorporating two factors, under the assumptions of Hicks-neutral technological change and of constant returns to scale, is given by the equation

$$\frac{\dot{A}(t)_N}{A(t)_N} = \frac{\dot{y}_N}{y_N} - W_{K,N}\frac{\dot{k}}{k}$$

where dots indicate time derivatives; $A(t)_N$ is an index of the cumulative net technological change; y_N and k are net output (value added) and farm capital per man-equivalent, respectively; and $W_{K,N}$ denotes the relative share of farm capital in net income. This equation yields a series of annual measures of technological change. Successive multiplication of year-to-year measures of technological change and setting $A(t)_N$ in the initial year, 1946 in this case, gives an annual series of indexes of cumulative technological change.

In the case that output is measured in gross terms and material inputs are included in the production function, the derived model becomes

$$\frac{\dot{A}(t)_G}{A(t)_G} = \frac{\dot{y}_G}{y_G} - W_{K,G}\frac{\dot{k}}{k} - W_M\frac{\dot{m}}{m}$$

where W_M represents the relative share of material inputs in gross income, and m is the material inputs per man-equivalent.

Data required for measuring technological change were mainly derived from publications of the Dominion Bureau of Statistics and of the Canada Department of Agriculture. The time series of output, material inputs, and farm capital were valued at 1935-39 prices. Labor series were measured in terms of man-equivalent. While the share of capital in income was calculated as a 6 per cent return on farm capital divided by the total output, the share of material in income was estimated as the ratio of material inputs to the total output. Under the assumption of constant returns to scale, labor's share in income was obtained simply by one minus capital's share in income for the value-added measure of output, and one minus capital's and materials' shares in income for the gross measure of output.

Having measured technological change index, it is possible to segregate the components of increased labor productivity into those attributable to technological change and those due to capital intensity. The way of segregation involves calculating the increase in labor productivity over the period 1946-1965 in the presence of technological change and that in the absence of technological change. While the latter is imputed to capital intensity, the former after being accounted for the latter is imputed to technological change.

Such a segregation, however, is under the assumptions of Hicks-neutral shifts of the production function and constant returns to scale. In order to ascertain whether the estimated shares of capital intensity and technological change in increased labor productivity are biased, these two assumptions were examined accordingly. The assumption of Hicks-neutral technological change was examined by two different methods: one of which was to fit a CES production function to the data, value added per man-equivalent and the real wage rate, of two subperiods, 1946-1955 and 1956-1965, separately. If the regression coefficient, the elasticity of substitution between labor and capital, remains unchanged from one subperiod to another subperiod, neutral technological change is indicated.

The other method used to examine Hicks-neutral technological change was to calculate the coefficient of correlation between the rate of technological change ($\frac{\dot{A}}{A}$) and the capital-labor ratio (k). If no relation exists between these two variables, the shifts over the period are, on average, approximately neutral.

The examination of the assumption of constant returns to scale involves fitting an unrestricted and a restricted Cobb-Douglas production function, separately, to the data on value-added output net of technological change, labor, and capital. Under the null hypothesis of constant returns to scale and the standard normality and independence assumptions, the test criterion is a "F" statistic (= $(Q_2-Q_1)(N-P-1)/Q_1$ where Q_2 and Q_1 are the residual sum of squares for the restricted and unrestricted Cobb-Douglas function, respectively; N is the number of observations; and P is the number of independent variables) with 1 and 17 degrees of freedom. If the calculated F value does not exceed the tabular value at conventional levels of significance, the assumption of constant returns to scale is verified.

Furthermore, it was considered worthwhile to investigate if the model used in this study is appropriate. Since the observed share of capital in income was fairly constant, the model would turn out to be a Cobb-Douglas function. An implicit assumption of the Cobb-Douglas function is a unitary elasticity of substitution between labor and capital. Thus, to investigate whether the model used is appropriate or not is to investigate whether the elasticity of substitution between labor and capital is unitary or not. This investigation was done by fitting the CES production function to the relationship between value-added per man-equivalent and the wage rate over the period 1946-1965.

Finally, in order to determine the efficiency of resource use, marginal value productivity of labor and of capital had to be estimated.

The accuracy of the results obtained from foregoing analyses is subject to the validity of the untestable assumptions of perfectly competitive markets and equilibrium situations of production underlying the Cobb-Douglas and the CES production functions. If those assumptions conform with the actual situation, the results suggest the following conclusions.

1. Technological change during the period analysed was neutral in all regions.

2. The elasticities of substitution between labor and capital were unitary in all regions, with a single exception of B. C. in which it was less than one. While a unitary substitution coefficient implies that a relative change in the wage rate will not cause a change in the relative share of labor in income, an inelastic substitution coefficient implies that the relative share of labor in income varies with the wage rate. The elasticity of substitution in the B. C. region

has been low over the last two decades possibly because of the dominance of dairying, market gardening, and fruit growing activities; for all of those enterprises, labor is not easily substituted by capital in the case of change in relative prices.

3. Constant returns to scale did exist in all regions during the period studied.

4. Farm technology has progressed at an annual rate of 3.1 per cent in the agricultural sector as a whole. Regional differences in the annual rate of growth were substantial, varying from 4.4 per cent in the Atlantic to 2.0 per cent in Quebec. Ontario was ranked as the second highest, with an annual growth rate of 3.7 per cent; the Prairie fell just behind Ontario, with a rate, less than by only .2 per cent. British Columbia was lagging behind the other three regions, with an annual growth rate of 2.8 per cent greater than that in Quebec only.

The high growth rates in the Atlantic and Ontario were likely because of the development of activities in non-agricultural sectors which drew a large number of labor out of farm. Over the period studied, farm employment has declined approximately 63 per cent in the Atlantic and 54 per cent in Ontario. The rapid decreases in farm labor in these two regions would stimulate the widespread adoption of farm technology. This, however, would not be the case for Quebec and B. C. While the low growth rate in Quebec might be attributable to the relatively stable organization of production, the less improvement in B. C. was likely due to its special production pattern.

Although all regions have experienced considerable technological change, the rate of change was subject to a variety of fluctuations. The high growth rates in the Atlantic and the Prairie regions appeared to have been concentrated in the Korean War period and in the years after 1960 when there was a great demand for farm products in both domestic and foreign markets. In Quebec, the growth of technology mostly occurred during the Korean War and tended to retard onward. British Columbia enjoyed a high growth rate of technological change only in the years after 1960, but no significant retardation of change has ever happened. The exceptional region in which the rates of technological advance appeared to have been relatively stable was Ontario. Farm technology stably advanced in Ontario possibly because of the adjustment made by the development of non-agricultural sectors.

5. Over the period 1946-1965, net labor productivity increased by 176 per cent, of which technological change accounted for 75.18 per cent and capital 24.82 per cent. Capital has been assigned a relatively minor role because the capital-labor ratio did not grow so fast as net labor productivity. Among regions, the share of technological change in

increased net labor productivity varied from 84.39 per cent in the Atlantic to 62.22 per cent in Quebec. It was also considerably high in B. C., the prairie, and Ontario, being 82.25, 78.37, and 74.97, respectively. The different percentage shares of technological change indicate the relative importance of capital formation in different regions.

6. In the absence of technological change, marginal value productivity of labor continuously increased, whereas marginal value productivity of capital continuously declined. Obviously it was due to the fact that continuous substitution of capital for labor called the law of variable proportions into play.

In the presence of technological change, marginal value productivity of labor and of capital all increased remarkably in all regions. As compared with the real wage rate (marginal cost of labor), however, marginal value productivity of labor in 1965 was low in the Atlantic, Quebec, and Ontario. This suggests that a large number of surplus labor still existed in Canadian agriculture. The marginal value productivity of capital in 1965 was lower than the market interest rate of 6 per cent in Quebec and B. C. This suggests that the increase in investment will suffer more loss at the present situation of technological progress. The increase in investment would be profitable in these two regions provided that they could expedite their technological progress.

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A P P E N D I X

APPENDIX I

GROWTH IN REAL VALUE ADDED,[a] MAN-EQUIVALENTS OF FARM LABOR EMPLOYED,[b] AND REAL VALUE ADDED PER MAN-EQUIVALENT, CANADA AND REGIONS, 1946-1965[*]

	Canada	Atlantic	Quebec	Ontario	Prairie	B. C.
			Real Value Added			
1946 level ($1000)	628,259	21,606	68,198	146,594	366,100	25,761
1965 level ($1000)	855,424	23,639	56,478	201,999	538,054	35,254
Increase over period (%)[c]	36.2	9.4	- 17.2	37.8	47.0	36.9
Average annual rate of change (%)	1.9	.5	- .9	2.0	2.5	1.9
			Man-equivalents of Farm Labor Employed			
1946 level (1000)	1,095	84	254	296	435	28
1965 level (1000)	540	31	105	137	253	19
Increase over period (%)[d]	- 50.7	- 63.1	- 58.7	- 53.7	- 41.8	- 32.1
Average annual rate of change (%)	- 2.7	- 3.3	- 3.1	- 2.8	- 2.2	- 1.7
			Real Value Added Per Man-equivalent			
1946 level ($)	574	257	268	495	842	920
1965 level ($)	1,584	763	538	1,474	2,127	1,855
Increase over period (%)[e]	176.0	196.9	100.8	197.8	152.6	101.6
Average annual rate of change (%)	9.3	10.4	5.3	10.4	8.0	5.4
Compound annual rate of growth (%)[f]	5.4	5.9	3.7	5.9	5.0	3.8

[*]Source: Computed from Appendix V.

[a]Refer to foot note 1.

[b]Refer to foot note 3.

[c]Calculated as real value added (1965)/real value added (1946) - 1.

[d,e]Calculated similarly as[c].

[f]This rate would have brought the increase.

APPENDIX II

GROWTH IN FARM CAPITAL[a] PER MAN-EQUIVALENT EMPLOYED CANADA AND REGIONS, 1946-1965[*]

	Canada	Atlantic	Quebec	Ontario	Prairie	B. C.
			Livestock and Poultry/M.E.			
1946 level ($)	542	395	485	675	496	767
1965 level ($)	1,346	738	1,074	1,589	1,350	1,664
Increase over period (%)[b]	148.3	86.8	121.4	135.4	172.2	116.9
Average annual rate of change (%)	7.8	4.6	6.4	7.1	9.1	6.2
			Lands and Buildings/M.E.			
1946 level ($)	2,692	1,750	1,970	2,519	3,260	4,883
1965 level ($)	5,995	2,132	2,943	6,266	7,299	8,270
Increase over period (%)[b]	122.7	21.8	49.4	148.7	123.9	69.4
Average annual rate of change (%)	6.5	1.1	2.6	7.8	6.5	3.7
			Implements and Machinery/M.E.			
1946 level ($)	696	398	408	661	931	869
1965 level ($)	2,041	1,176	1,279	1,774	2,582	1,846
Increase over period (%)[b]	193.2	195.5	213.5	168.4	177.3	112.4
Average annual rate of change (%)	10.2	10.3	11.2	8.9	9.3	5.9
			Total Farm Capital /M.E.			
1946 level ($)	3,930	2,543	2,864	3,855	4,687	6,519
1965 level ($)	9,382	4,046	5,296	9,629	11,231	11,779
Increase over period (%)[b]	138.7	59.1	84.9	149.8	139.6	80.7
Average annual rate of change (%)	7.3	3.1	4.5	7.9	7.4	4.3
Compound annual rate of growth (%)[c]	4.7	2.4	3.3	4.9	4.7	3.1

[*]Source: Calculated from _Quarterly Bulletin of Agricultural Statistics_, 1967 Revision, Dominion Bureau of Statistics, Ottawa.

[a]Comprises livestock and poultry, lands and buildings, and implements and machinery, all of them are valued at 1935-39 prices.

[b]Calculated as $\frac{\text{value of 1965}}{\text{value of 1946}} - 1$.

[c]This rate would have brought the increase.

APPENDIX III

TRENDS IN THE SIZE OF FARM, VALUES OF MACHINERY, LIVESTOCK AND MATERIAL INPUTS PER FARM CANADA AND REGIONS, 1941-1961[x]

Year		Canada	Atlantic	Quebec	Ontario	Prairie	B. C.
				Size of Farm[a]			
1941	(Acre)	237	116	117	126	405	153
	(%)	100	100	100	100	100	100
1951	(Acre)	281	129	125	139	498	178
	(%)	119	111	107	110	123	116
1961	(Acre)	360	170	148	153	617	226
	(%)	152	147	127	121	152	148
				Value of Machinery Per Farm[b]			
1941	($)	746	328	505	773	982	525
	(%)	100	100	100	100	100	100
1951	($)	1,670	610	845	1,590	2,470	1,191
	(%)	224	186	167	206	252	227
1961	($)	2,048	1,074	1,203	1,826	2,744	1,660
	(%)	275	327	238	236	279	316
				Value of Livestock Per Farm[b]			
1941	($)	682	326	587	919	685	638
	(%)	100	100	100	100	100	100
1951	($)	961	436	749	1,351	985	812
	(%)	141	134	128	147	144	127
1961	($)	1,538	787	1,198	1,812	1,652	1,506
	(%)	226	241	204	197	241	236
				Value of Material Inputs Per Farm[b]			
1941	($)	328	197	242	478	315	356
	(%)	100	100	100	100	100	100
1951	($)	742	461	577	1,042	720	713
	(%)	226	234	238	218	229	200
1961	($)	1,264	1,057	1,143	1,720	1,073	1,405
	(%)	385	537	472	360	341	395

[x]Source: Census of Canada, 1951 and 1961; Quarterly Bulletin of Agricultural Statistics, 1967 Revision; and Handbook of Agricultural Statistics, Part II, Farm Income, 1926-1965; Dominion Bureau of Statistics, Ottawa.

[a]Occupied farm. [b]in 1935-39 prices.

APPENDIX IV

THE ARITHMETIC MODEL

The arithmetic index is the most common measure of technological change. It is simply the ratio of the index of value added to the index of labor and capital inputs, each input weighted by its share in the corresponding value added of output in the base year.[1] Mathematically, the arithmetic model is given by

$$C_{(t+1)-t} = \frac{Y_{t+1}}{Y_t} \frac{1}{W_t \frac{L_{t+1}}{L_t} + i_t \frac{K_{t+1}}{K_t}} \quad \ldots\ldots\ldots\ldots\ldots (a)$$

where C stands for year-to-year measures of arithmetic technological change; Y, L, and K are value added, labor, and capital, respectively; W and i represent the relative shares of labor and capital in the value added of output, respectively; and t denotes time equalling 1 to 20, or 1946 to 1965, in this study. Successive multiplication of year-to-year measures of change and setting $C(t) = 1$ in the initial year yields a series of indexes of cumulative arithmetic technological change.

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[1]This is the SAK method of expressing the Residual. See J. Schmookler, "The Change Efficiency of the American Economy: 1869-1938," Review of Economics and Statistics, Vol. 34, 1952, pp. 214-31; M. Abramovitz, "Resource and Output Trends in the U. S. since 1870," American Economic Review, Vol. 46, 1956, pp. 5-23; and J. W. Kendrick, "Productivity Trends: Capital and Labor," Review of Economics and Statistics, Vol. 38, 1956, pp. 247-57.

In the case that the measure of output is gross and materials are included among the inputs, the formulation entails an additional term to the denominator of the right hand side of Equation (a). That is, the model becomes

$$C_{(t+1)-t} = \frac{Y_{t+1}}{Y_t} \frac{1}{W_t \frac{L_{t+1}}{L_t} + i_t \frac{K_{t+1}}{K_t} + O_t \frac{M_{t+1}}{M_t}} \quad \text{........(b)}$$

where Y and M represent gross output and material inputs, respectively; and O is the relative share of material inputs in the gross output.

Like Solow's approach, the arithmetic index of technological change is also measured on the assumptions of constant returns to scale, and of neutrality. For the former, Barzel exhibits that:

> The output-per-unit-of-input method avoid the specification of a production function........the assumption underlying the production function is that of no economies of scale.[2]

and for the latter, Domar points out that:

> For the marginal products of the inputs are changed by the "other forces" and always in the same proportion, so that their ratios remain constant and independent of the ratio of the quantities of the inputs, however fast capital may grow relative to labor.[3]

Unlike Solow's approach, for the arithmetic measure factor changes are combined arithmetically rather than geometrically.

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[2]Y. Barzel, "Productivity in the Electric Power Industry 1929-55," Review of Economics and Statistics, Vol. 45, 1963, p. 396.

[3]E. D. Domar, "On Total Productivity and All That," Journal of Political Economy, 1962, p. 601.

APPENDIX V - 1

MEASUREMENTS OF GROSS AND NET GEOMETRIC GROWTH RATES OF TECHNOLOGICAL CHANGE IN CANADIAN AGRICULTURE, 1946-1965.

terial Inputs 1935-39 ices (Thous.) M (2)	Net Output in 1935-39 prices (Thous.) Y_N (3)	Capital Stock in 1935-39 prices (Thous.) K (4)	Employ't. (Thous.of Man-equi.) L (5)	Share of Capital in Gross Output $W_{K,G}$ (6)	Share of Capital in Net Output $W_{K,N}$ (7)	Share of Mat. Inputs in Output W_M (8)	Share of Labor in Gross Output $W_{L,G}$ (9)	Share of Labor in Net Output $W_{L,N}$ (10)	Year-to-Year Rates of Change in Tech. Gr.Meas. $\Delta A/A,G$ (11)	Year-to-Year Rates of Change in Tech. Val.Add.M. $\Delta A/A,N$ (12)	Cummulated Technological Change Gr.Meas. $A(t)_G$ (13)	Cummulated Technological Change Val.Add.Meas. $A(t)_N$ (14)
59,429	72,745	580,630	150	.2577	.4789	.4396	.3027	.5211			1.0000	1.0000
66,779	67,110	578,190	145	.2516	.5169	.4843	.2641	.4831	-.0244	-.0599	.9756	.9401
59,519	68,992	550,010	143	.2511	.4783	.4528	.2961	.5217	.0227	.0594	.9977	.9959
58,830	72,363	555,900	143	.2481	.4609	.4376	.3143	.5391	.0256	.0447	1.0232	1.0404
61,330	66,871	567,450	131	.2596	.5091	.4677	.2727	.4909	-.0242	-.0449	.9984	.9937
64,675	69,711	575,650	120	.2454	.4955	.4596	.2950	.5045	.0730	.0846	1.0713	1.0778
65,891	85,354	586,090	109	.2253	.4120	.4216	.3531	.5880	.1348	.2878	1.2157	1.3880
66,565	87,946	592,010	106	.2223	.4039	.4165	.3612	.5961	.0284	.0441	1.2502	1.4492
70,130	75,477	603,295	109	.2457	.4796	.4760	.2783	.5204	-.1114	-.1627	1.1109	1.2134
72,125	84,401	607,370	107	.2274	.4318	.4500	.3226	.5682	.0788	.1280	1.1984	1.3687
79,190	78,773	589,210	101	.2169	.4488	.4859	.2972	.5512	-.0023	-.0234	1.1956	1.3367
74,550	82,055	589,600	97	.2191	.4311	.4617	.3192	.5689	.0318	.0658	1.2336	1.4247
80,580	74,320	601,710	95	.2270	.4858	.5067	.2663	.5142	-.0512	-.0938	1.1704	1.2911
83,980	76,440	612,710	93	.2221	.4809	.5074	.2705	.5191	.0213	.0317	1.1953	1.3320
82,970	78,360	610,310	94	.2227	.4673	.5047	.2726	.5327	-.0030	.0215	1.1917	1.3606
86,480	71,294	598,570	92	.2231	.5037	.5371	.2398	.4963	-.0324	-.0716	1.1531	1.2632
87,570	77,327	594,300	87	.2082	.4611	.5113	.2805	.5389	.0751	.1219	1.2397	1.4172
85,429	82,103	589,580	74	.2034	.4309	.4913	.3053	.5691	.0849	.1719	1.3450	1.6608
89,335	87,173	581,690	77	.1919	.4004	.4912	.3169	.5996	.0130	.0421	1.3625	1.7307
93,160	87,453	566,830	74	.1824	.3889	.4997	.3179	.6111	.0219	.0386	1.3923	1.7975

of regional data on corresponding series.

7) are calculated as $.06 \times \frac{(4)}{(1)}$ and $.06 \times \frac{(4)}{(3)}$
ssuming a 6% interest
all capital.

1).

5) - (8).

(7)

/(1) - (6) $\frac{\Delta(4)}{(4)}$ - (8) $\frac{\Delta(2)}{(2)}$ - (9) $\frac{\Delta(5)}{(5)}$

/(3) - (7) $\frac{\Delta(4)}{(4)}$ - (10) $\frac{\Delta(5)}{(5)}$

(14) are calculated from (11) and (12)
th 1946 = 1.

Year	Gross Output in 1935-39 prices (Thous.)	Material Inputs in 1935-39 prices (Thous.)	Net Output in 1935-39 prices (Thous.)	Capital Stock in 1935-39 prices (Thous.)	Emp (Th Man
	Y_G (1)	M (2)	Y_N (3)	K (4)	(5
1946	135,180	59,429	72,745	580,630	1
1947	137,890	66,779	67,110	578,190	1
1948	131,450	59,519	68,992	550,010	1
1949	134,430	58,830	72,363	555,900	1
1950	131,130	61,330	66,871	567,450	1
1951	140,730	64,675	69,711	575,650	1
1952	156,100	65,891	85,354	586,090	1
1953	159,820	66,565	87,946	592,010	1
1954	147,320	70,130	75,477	603,295	1
1955	160,260	72,125	84,401	607,370	1
1956	162,980	79,190	78,773	589,210	1
1957	161,480	74,550	82,055	589,600	
1958	159,040	80,580	74,320	601,710	
1959	165,520	83,980	76,440	612,710	
1960	164,400	82,970	78,360	610,310	
1961	161,000	86,480	71,294	598,570	
1962	171,250	87,570	77,327	594,300	
1963	173,890	85,429	82,103	589,580	
1964	181,860	89,335	87,173	581,690	
1965	186,430	93,160	87,453	566,830	

Source: Geometric means of regional data on corresponding series.

Notes: Cols. (6) and (7) are calculated as $.06 \times \frac{(4)}{(1)}$ and $.06 \times \frac{(4)}{(3)}$ respectively, assuming a 6% interest rate return on all capital.

Col. (8) = $^{(2)}/(1)$.

Col. (9) = 1 - (6) - (8).

Col. (10) = 1 - (7)

Col. (11) = $^{\Delta(1)}/(1) - (6)\frac{\Delta(4)}{(4)} - (8)\frac{\Delta(2)}{(2)} - (9)\frac{\Delta(5)}{(5)}$

Col. (12) = $^{\Delta(3)}/(3) - (7)\frac{\Delta(4)}{(4)} - (10)\frac{\Delta(5)}{(5)}$

Col. (13) and (14) are calculated from (11) and (12) respectively, with 1946 = 1.

APPENDIX V - 2

MEASUREMENTS OF GROSS AND NET GEOMETRIC GROWTH RATES OF TECHNOLOGICAL CHANGE IN THE ATLANTIC AGRICULTURE, 1946-1965.

al Inputs 5-39 (Thous.)	Net Output in 1935-39 prices (Thous.)	Capital Stock in 1935-39 prices (Thous.)	Employ't. (Thous.of Man-equi.)	Share of Capital in Gross Output	Share of Capital in Net Output	Share of Mat. Inputs in Output	Share of Labor in Gross Output	Share of Labor in Net Output	Year-to-Year Rates of Change in Tech. Gr.Meas.	Year-to-Year Rates of Change in Tech. Va.Add.Meas.	Cummulated Technological Change Gr.Meas.	Cummulated Technological Change Val.Add.Meas.
M	Y_N	K	L	$W_{K,G}$	$W_{K,N}$	W_M	$W_{L,G}$	$W_{L,N}$	$\Delta A/A,G$	$\Delta A/A,N$	$A(t)_G$	$A(t)_N$
2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
,182	21,606	213,619	84	.2682	.5932	.5479	.1839	.4068			1.0000	1.0000
,179	17,258	212,864	79	.2750	.7401	.6284	.0966	.2599	-.0977	-.1958	.9023	.8042
,747	16,460	192,907	75	.2679	.7032	.6190	.1131	.2968	.0119	.0365	.9130	.8336
,483	16,544	191,377	75	.2732	.6941	.6064	.1204	.3059	.0032	.0145	.9159	.8457
,041	14,121	194,147	71	.2900	.8249	.6484	.0616	.1751	-.0615	-.1583	.8596	.7118
,693	13,121	186,940	58	.2748	.8548	.6785	.0467	.1452	-.0087	-.0172	.8521	.6996
,655	20,596	189,249	54	.2306	.5513	.5818	.1876	.4487	.2094	.6376	1.0305	1.1457
,538	18,367	182,414	52	.2333	.5959	.6084	.1583	.4041	-.0318	-.0740	.9977	1.0609
,337	20,046	183,537	47	.2276	.5493	.5857	.1867	.4507	.0574	.1474	1.0550	1.2173
,703	19,328	179,534	46	.2197	.5573	.6058	.1745	.4427	-.0071	-.0161	1.0475	1.1977
,221	19,145	170,242	46	.1989	.5335	.6273	.1738	.4665	.0057	.0181	1.0535	1.2194
,603	19,531	165,569	49	.2064	.5086	.5942	.1994	.4914	-.0044	.0033	1.0488	1.2234
,561	16,434	160,567	51	.2050	.5862	.6503	.1447	.4138	-.0648	-.1529	.9808	1.0363
,868	16,531	157,086	52	.1947	.5702	.6584	.1469	.4298	.0033	.0106	.9841	1.0473
,330	19,544	152,698	50	.1801	.4688	.6158	.2041	.5312	.0764	.2245	1.0592	1.2824
,442	14,936	145,190	51	.1801	.5832	.6913	.1286	.4168	-.0866	-.2111	.9675	1.0117
,373	13,134	140,098	43	.1807	.6400	.7176	.1017	.3600	-.0172	-.0514	.9508	.9597
285	18,607	135,613	31	.1735	.4373	.6032	.2233	.5627	.2331	.8173	1.1725	1.7441
180	22,519	131,896	35	.1531	.3514	.5644	.2825	.6486	.0457	.1204	1.2261	1.9541
127	23,639	125,433	31	.1397	.3184	.5611	.2992	.6816	.0709	.1631	1.3130	2.2728

ere derived from: Handbook of Agricultural
Farm Income, 1926-1965; Col. 4 from:
of Agricultural Statistics, 1967 Revision;
bor Force Survey; Dominion Bureau of

ted as the difference between Col. (1)

ned in the context.

Year	Gross Output in 1935-39 prices (Thous.)	Material Inputs in 1935-39 prices (Thous.)	Net Output in 1935-39 prices (Thous.)	Capital Stock in 1935-39 prices (Thous.)	Employ (Thous. Man-equ
	Y_G	M	Y_N	K	L
	(1)	(2)	(3)	(4)	(5)
1946	47,788	26,182	21,606	213,619	84
1947	46,437	29,179	17,258	212,864	79
1948	43,207	26,747	16,460	192,907	75
1949	42,027	25,483	16,544	191,377	75
1950	40,162	26,041	14,121	194,147	71
1951	40,814	27,693	13,121	186,940	58
1952	49,251	28,655	20,596	189,249	54
1953	46,905	28,538	18,367	182,414	52
1954	48,383	28,337	20,046	183,537	47
1955	49,031	29,703	19,328	179,534	46
1956	51,366	32,221	19,145	170,242	46
1957	48,134	28,603	19,531	165,569	49
1958	46,995	30,561	16,434	160,567	51
1959	48,399	31,868	16,531	157,086	52
1960	50,874	31,330	19,544	152,698	50
1961	48,378	33,442	14,936	145,190	51
1962	46,507	33,373	13,134	140,098	43
1963	46,892	28,285	18,607	135,613	31
1964	51,699	29,180	22,519	131,896	35
1965	53,856	30,127	23,639	125,433	31

Source: Cols. (1) and (2) were derived from: Handbook of Agricultural Statistics, Part II, Farm Income, 1926-1965; Col. 4 from: Quarterly Bulletin.of Agricultural Statistics, 1967 Revision; and Col. (5) from Labor Force Survey; Dominion Bureau of Statistics, Ottawa.

Col. (3) was calculated as the difference between Col. (1) and Col. (2).

Note: All Cols. were defined in the context.

APPENDIX V - 3

MEASUREMENTS OF GROSS AND NET GEOMETRIC GROWTH RATES OF TECHNOLOGICAL CHANGE IN QUEBEC AGRICULTURE, 1946-1965

Inputs 9 hous.)	Net Output in 1935-39 prices (Thous.)	Capital Stock in 1935-39 prices (Thous.)	Employ't. (Thous.of Man-equi.)	Share of Capital in Gross Output	Share of Capital in Net Output	Share of Mat. Inputs in Output	Share of Labor in Gross Output	Share of Labor in Net Output	Year-to-Year Rates of Change in Tech. Gr.Meas.	Year-to-Year Rates of Change in Tech. Val.Add.M.	Cummulated Technological Change Gr.Meas.	Cummulated Technological Change Val.Add.Meas.
	Y_N	K	L	$W_{K,G}$	$W_{K,N}$	W_M	$W_{L,G}$	$W_{L,N}$	$\Delta A/A,G$	$\Delta A/A,N$	$A(t)_G$	$A(t)_N$
	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	68,198	727,340	254	.3030	.6399	.5265	.1705	.3601			1.0000	1.0000
	59,490	699,303	232	.2852	.7053	.5957	.1191	.2947	-.0542	-.0818	.9458	.9182
	71,520	641,544	225	.2748	.5382	.4895	.2357	.4618	.0920	.2713	1.0329	1.1673
	66,584	611,765	222	.2717	.5513	.5072	.2211	.4487	-.0201	-.0382	1.0122	1.1227
	63,077	634,238	233	.2852	.6033	.5273	.1875	.3967	-.0437	-.0893	.9680	1.0224
	60,719	650,198	212	.2823	.6425	.5607	.1570	.3575	-.0167	-.0260	.9518	.9958
	77,374	669,660	194	.2543	.5193	.5102	.2355	.4807	.1482	.3299	1.0929	1.3243
	84,685	644,587	188	.2382	.4567	.4785	.2833	.5433	.0653	.1309	1.1643	1.4977
	78,633	661,480	198	.2397	.5047	.5251	.2352	.4953	-.0593	-.1048	1.0953	1.3407
	90,575	646,775	159	.2185	.4284	.4901	.2914	.5716	.1680	.3426	1.2793	1.8000
	70,650	635,160	153	.2233	.5394	.5861	.1906	.4606	-.1201	-.2005	1.1257	1.4391
	70,345	623,229	158	.2292	.5316	.5688	.2020	.4684	-.0047	.0330	1.1205	1.4866
	67,247	629,345	149	.2167	.5615	.6140	.1693	.4385	-.0208	-.0700	1.0972	1.3825
	67,453	628,919	142	.2162	.5594	.6136	.1702	.4406	.0101	.0261	1.1083	1.4186
	70,807	626,166	125	.2141	.5306	.5965	.1894	.4694	.0487	.1221	1.1623	1.5918
	69,390	607,782	127	.2039	.5255	.6121	.1840	.4745	-.0057	-.0119	1.1557	1.5729
	68,323	597,440	122	.1999	.5247	.6190	.1811	.4753	.0042	.0134	1.1605	1.5940
	57,058	596,450	112	.2047	.6272	.6736	.1217	.3728	-.0604	-.1459	1.0904	1.3614
	61,685	577,293	103	.1899	.5615	.6618	.1483	.4385	.0483	.1473	1.1431	1.5619
	56,478	556,114	105	.1805	.5908	.6945	.1250	.4092	-.0259	-.0692	1.1135	1.4538

Year	Gross Output in 1935-39 prices (Thous.)	Material Inputs in 1935-39 prices (Thous.)	Net Output in 1935-39 prices (Thous.)	Capital Stock in 1935-39 prices (Thous.)	Emplo (Thou Man-eq
	Y_G	M	Y_N	K	L
	(1)	(2)	(3)	(4)	(5)
1946	144,035	75,837	68,198	727,340	254
1947	147,125	87,635	59,490	699,303	232
1948	140,102	68,582	71,520	641,544	225
1949	135,109	68,525	66,584	611,765	222
1950	133,432	70,355	63,077	634,238	233
1951	138,217	77,498	60,719	650,198	212
1952	157,975	80,601	77,374	669,660	194
1953	162,374	77,689	84,685	644,587	188
1954	165,569	86,936	78,633	661,480	198
1955	177,618	87,043	90,575	646,775	159
1956	170,691	100,041	70,650	635,160	153
1957	163,150	92,805	70,345	623,229	158
1958	174,220	106,973	67,247	629,345	149
1959	174,571	107,118	67,453	628,919	142
1960	175,471	104,664	70,807	626,166	125
1961	178,893	109,503	69,390	607,782	127
1962	179,320	110,997	68,323	597,440	122
1963	174,826	117,768	57,058	596,450	112
1964	182,409	120,724	61,685	577,293	101
1965	184,863	128,385	56,478	556,114	105

APPENDIX V - 4

MEASUREMENT OF GROSS AND NET GEOMETRIC GROWTH RATES OF TECHNOLOGICAL CHANGE IN ONTARIO AGRICULTURE, 1946-65.

Material Inputs in 1935-39 prices (Thous.)	Net Output in 1935-39 prices (Thous.)	Capital Stock in 1935-39 prices (Thous.)	Employ't. (Thous.of Man-equi.)	Share of Capital in Gross Output	Share of Capital in Net Output	Share of Mat. Inputs in Output	Share of Labor in Gross Output	Share of Labor in Net Output	Year-to-Year Rates of Change in Tech. Gr.Meas.	Year-to-Year Rates of Change in Tech. Val.Add.M.	Cummulated Technological Change Gr.Meas.	Cummulated Technological Change Val.Add.Meas.
M	Y_N	K	L	$W_{K,G}$	$W_{K,N}$	W_M	$W_{L,G}$	$W_{L,N}$	$\Delta A/A,G$	$\Delta A/A,N$	$A(t)_G$	$A(t)_N$
(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
141,686	146,594	1,141,180	296	.2375	.4671	.4915	.2710	.5329			1.0000	1.0000
156,811	149,920	1,119,764	276	.2190	.4481	.5112	.2698	.5519	.0342	.0735	1.0342	1.0735
139,975	154,698	1,048,384	268	.2135	.4066	.4750	.3115	.5934	.0362	.0771	1.0716	1.1563
138,087	167,298	1,072,340	263	.2107	.3846	.4522	.3371	.6154	.0440	.0861	1.1188	1.2559
147,298	174,204	1,080,223	234	.2016	.3721	.4582	.3402	.6279	.0661	.1206	1.1928	1.4074
156,260	151,735	1,171,741	221	.2283	.4633	.5073	.2644	.5367	-.0823	-.1454	1.0946	1.2028
159,833	179,598	1,189,515	212	.2103	.3974	.4709	.3188	.6026	.1049	.2097	1.2094	1.4550
160,410	178,191	1,209,468	204	.2143	.4072	.4737	.3120	.5928	.0046	.0076	1.2150	1.4661
172,227	168,438	1,253,067	235	.2207	.4464	.5056	.2737	.5536	-.0702	-.1337	1.1297	1.2701
176,627	172,805	1,288,591	220	.2213	.4474	.5055	.2732	.5526	.0251	.0507	1.1581	1.3345
196,884	156,926	1,258,465	198	.2134	.4812	.5565	.2301	.5188	-.0252	-.0308	1.1289	1.2934
185,774	156,794	1,286,459	178	.2253	.4923	.5423	.2324	.5077	.0191	.0436	1.1504	1.3498
200,120	168,565	1,355,928	162	.2207	.4826	.5428	.2365	.5174	.0481	.1053	1.2058	1.4919
210,000	164,513	1,420,668	162	.2276	.5181	.5607	.2117	.4819	-.0227	-.0487	1.1784	1.4192
199,837	178,078	1,378,493	165	.2189	.4645	.5288	.2523	.5355	.0355	.0840	1.2202	1.5384
208,745	184,998	1,399,175	151	.2132	.4538	.5302	.2566	.5462	.0407	.0857	1.2699	1.6702
206,783	192,035	1,412,215	146	.2125	.4412	.5185	.2690	.5588	.0255	.0541	1.3022	1.7606
214,132	185,507	1,374,216	156	.2063	.4445	.5358	.2579	.5555	-.0275	-.0561	1.2664	1.6618
227,956	197,260	1,369,048	145	.1932	.4164	.5361	.2707	.5836	.0532	.1139	1.3338	1.8511
231,643	201,999	1,319,229	137	.1825	.3919	.5342	.2833	.6081	.0351	.0760	1.3805	1.9918

Year	Gross Output in 1935-39 prices (Thous.)	Material Inputs in 1935-39 prices (Thous.)	Net Output in 1935-39 prices (Thous.)	Capital Stock in 1935-39 prices (Thous.)	Emplo (Thou Man-e
	Y_G	M	Y_N	K	I
	(1)	(2)	(3)	(4)	(5)
1946	288,280	141,686	146,594	1,141,180	296
1947	306,731	156,811	149,920	1,119,764	276
1948	294,673	139,975	154,698	1,048,384	268
1949	305,385	138,087	167,298	1,072,340	263
1950	321,502	147,298	174,204	1,080,223	234
1951	307,995	156,260	151,735	1,171,741	221
1952	339,431	159,833	179,598	1,189,515	212
1953	338,601	160,410	178,191	1,209,468	204
1954	340,665	172,227	168,438	1,253,067	235
1955	349,432	176,627	172,805	1,288,591	220
1956	353,810	196,884	156,926	1,258,465	198
1957	342,568	185,774	156,794	1,286,459	178
1958	368,685	200,120	168,565	1,355,928	162
1959	374,513	210,000	164,513	1,420,668	162
1960	377,915	199,837	178,078	1,378,493	165
1961	393,743	208,745	184,998	1,399,175	151
1962	398,818	206,783	192,035	1,412,215	146
1963	399,639	214,132	185,507	1,374,216	156
1964	425,216	227,956	197,260	1,369,048	145
1965	433,642	231,643	201,999	1,319,229	137

APPENDIX V - 5

MEASUREMENTS OF GROSS AND NET GEOMETRIC GROWTH RATES OF TECHNOLOGICAL CHANGE IN THE PRAIRIE AGRICULTURE, 1946-1965

Inputs 39 Thous.)	Net Output in 1935-39 prices (Thous.) Y_N (3)	Capital Stock in 1935-39 prices (Thous.) K (4)	Employ't. (Thous.of Man-equi.) L (5)	Share of Capital in Gross Output $W_{K,G}$ (6)	Share of Capital in Net Output $W_{K,N}$ (7)	Share of Mat. Inputs in Output W_M (8)	Share of Labor in Gross Output $W_{L,G}$ (9)	Share of Labor in Net Output $W_{L,N}$ (10)	Year-to-Year Rates of Change in Tech. Gr.Meas. $\Delta A/A,G$ (11)	Year-to-Year Rates of Change in Tech. Val.Add.Meas. $\Delta A/A,N$ (12)	Cummulated Technological Change Gr.Meas. $A(t)_G$ (13)	Cummulated Technological Change Val.Add.Meas. $A(t)_N$ (14)
35	366,100	2,038,773	435	.2411	.3341	.2784	.4805	.6659			1.0000	1.0000
34	367,621	2,082,929	420	.2398	.3400	.2947	.4655	.6600	.0132	.0195	1.0132	1.0195
15	368,942	2,146,496	414	.2456	.3491	.2965	.4579	.6509	.0363	.0024	1.0500	1.0219
69	411,265	2,196,184	403	.2294	.3204	.2841	.4865	.6796	.0542	.1295	1.1069	1.1542
69	334,808	2,262,073	376	.2670	.4054	.3413	.3917	.5946	-.1262	-.1704	.9672	.9575
91	548,450	2,263,392	359	.1866	..2476	.2463	.5671	.7524	.4700	.7050	1.4218	1.6325
96	568,320	2,320,635	352	.1864	.2450	.2393	.5743	.7550	.0340	.0457	1.4702	1.7071
29	599,679	2,483,547	336	.1899	.2485	.2358	.5743	.7515	.0574	.0752	1.5546	1.8355
64	312,715	2,422,431	318	.2915	.4648	.3728	.3357	.5352	-.3598	-.4636	.9953	.9846
74	475,711	2,462,101	311	.2213	.3105	.2873	.4914	.6895	.3437	.5443	1.3374	1.5205
46	470,280	2,389,679	304	.2119	.3049	.3049	.4832	.6951	.0082	.0133	1.3483	1.5407
32	531,730	2,349,237	287	.1921	.2651	.2755	.5324	.7349	.1303	.1869	1.5240	1.8287
01	398,272	2,430,623	278	.2408	.3662	.3424	.4168	.6338	-.1842	-.2517	1.2433	1.3684
28	473,371	2,434,756	267	.2114	.3086	.3149	.4737	.6914	.1495	.2240	1.4292	1.6749
98	409,858	2,523,217	263	.2404	.3694	.3492	.4104	.6306	-.0961	-.1405	1.2919	1.4396
83	328,961	2,522,830	276	.2728	.4601	.4071	.3201	.5399	-.1391	-.2132	1.1122	1.1327
73	477,762	2,554,458	276	.2146	.3208	.3312	.4542	.6792	.2691	.4482	1.4115	1.6404
00	549,084	2,684,127	280	.2071	.2933	.2940	.4989	.7067	.0797	.1224	1.5240	1.8412
86	522,565	2,786,495	276	.2167	.3199	.3228	.4605	.6801	-.0387	-.0517	1.4650	1.7460
21	538,054	2,841,521	253	.2145	.3169	.3230	.4625	.6831	.0588	.0880	1.5511	1.8996

Year	Gross Output in 1935-39 prices (Thous.)	Material Inputs in 1935-39 prices (Thous.)	Net Output in 1935-39 prices (Thous.)	Capital Stock in 1935-39 prices (Thous.)	Emplo (Thou Man-e
	Y_G	M	Y_N	K	L
	(1)	(2)	(3)	(4)	(5)
1946	507,335	141,235	366,100	2,038,773	435
1947	521,255	153,634	367,621	2,082,929	420
1948	524,457	155,515	368,942	2,146,496	414
1949	574,434	163,169	411,265	2,196,184	403
1950	508,277	173,469	334,808	2,262,073	376
1951	727,641	179,191	548,450	2,263,392	359
1952	747,116	178,796	568,320	2,320,635	352
1953	784,708	185,029	599,679	2,483,547	336
1954	498,579	185,864	312,715	2,422,431	318
1955	667,485	191,774	475,711	2,462,101	311
1956	676,526	206,246	470,280	2,389,679	304
1957	733,962	202,232	531,730	2,349,237	287
1958	605,673	207,401	398,272	2,430,623	278
1959	690,899	217,528	473,371	2,434,756	267
1960	629,756	219,898	409,858	2,523,217	263
1961	554,844	225,883	328,961	2,522,830	276
1962	714,335	236,573	477,762	2,554,458	276
1963	777,684	228,600	549,084	2,684,127	280
1964	771,651	249,086	522,565	2,786,495	276
1965	794,775	256,721	538,054	2,841,521	253

APPENDIX V - 6

MEASUREMENTS OF GROSS AND NET GEOMETRIC GROWTH RATES OF TECHNOLOGICAL CHANGE IN B. C. AGRICULTURE, 1946-1965.

...ial Inputs ...35-39 ...s (Thous.)	Net Output in 1935-39 prices (Thous.)	Capital Stock in 1935-39 prices (Thous.)	Employ't. (Thous.of Man-equi.)	Share of Capital in Gross Output	Share of Capital in Net Output	Share of Mat. Inputs in Output	Share of Labor in Gross Output	Share of Labor in Net Output	Year-to-Year Rates of Change in Tech. Gr.Meas.	Year-to-Year Rates of Change in Tech. Val.Add. M.	Cummulated Technological Change Gr.Meas.	Cummulated Technological Change Val.Add.Meas.
M	Y_N	K	L	$W_{K,G}$	$W_{K,N}$	W_M	$W_{L,G}$	$W_{L,N}$	$\Delta A/A,G$	$\Delta A/A,N$	$A(t)_G$	$A(t)_N$
(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
,090	25,761	182,542	28	.2442	.4252	.4256	.3302	.5748			1.0000	1.0000
,557	24,064	186,127	30	.2448	.4641	.4725	.2827	.5359	-.0644	-.1059	.9356	.8941
,700	23,247	180,676	32	.2584	.4663	.4458	.2958	.5337	-.0311	-.0529	.9065	.8468
,905	26,180	192,544	34	.2621	.4413	.4062	.3317	.5587	.0282	.0593	.9319	.8970
,532	25,743	195,533	27	.2650	.4557	.4186	.3164	.5443	.0643	.1107	.9918	.9963
,830	24,832	196,077	25	.2695	.4738	.4313	.2992	.5262	.0002	.0027	.9920	.9990
,194	27,844	197,669	20	.2521	.4259	.4081	.3398	.5741	.1693	.2910	1.1599	1.2897
,863	31,658	205,896	20	.2398	.3902	.3855	.3747	.6098	.0720	.1209	1.2434	1.4456
,509	29,501	216,850	22	.2551	.4410	.4217	.3232	.5590	-.0826	-.1342	1.1407	1.2516
,290	29,763	224,364	28	.2586	.4523	.4282	.3132	.5477	-.0703	-.1227	1.0605	1.0980
,355	30,389	218,338	25	.2393	.4311	.4449	.3158	.5689	.0570	.1051	1.1210	1.2134
,088	32,473	228,472	22	.2467	.4221	.4155	.3378	.5779	.0748	.1340	1.2049	1.3760
,102	30,563	236,848	22	.2553	.4650	.4510	.2937	.5350	-.0473	-.0760	1.1479	1.2714
,791	30,054	252,687	22	.2667	.5045	.4713	.2620	.4955	-.0283	-.0504	1.1154	1.2073
,290	29,244	254,650	27	.2703	.5225	.4827	.2470	.4775	-.0592	-.1137	1.0494	1.0700
,012	29,198	246,659	24	.2587	.5069	.4896	.2517	.4931	.0397	.0782	1.0911	1.1537
,414	33,581	245,536	24	.2376	.4387	.4583	.3041	.5613	.0779	.1515	1.1761	1.3285
,904	34,499	238,781	15	.2296	.4153	.4472	.3232	.5847	.2276	.4131	1.4438	1.8773
,115	35,156	229,270	19	.2140	.3913	.4530	.3330	.6087	-.0551	-.1010	1.3642	1.6877
,405	35,254	223,806	19	.2045	.3809	.4631	.3324	.6191	.0059	.0118	1.3722	1.7076

Year	Gross Output in 1935-39 prices (Thous.)	Material Inputs in 1935-39 prices (Thous.)	Net Output in 1935-39 prices (Thous.)	Capital Stock in 1935-39 prices (Thous.)	Employ' (Thous. Man-equ
	Y_G (1)	M (2)	Y_N (3)	K (4)	L (5)
1946	44,851	19,090	25,761	182,542	28
1947	45,621	21,557	24,064	186,127	30
1948	41,947	18,700	23,247	180,676	32
1949	44,085	17,905	26,180	192,544	34
1950	44,275	18,532	25,743	195,533	27
1951	43,662	18,830	24,832	196,077	25
1952	47,038	19,194	27,844	197,669	20
1953	51,521	19,863	31,658	205,896	20
1954	51,010	21,509	29,501	216,850	22
1955	52,053	22,290	29,763	224,364	28
1956	54,744	24,355	30,389	218,338	25
1957	55,561	23,088	32,473	228,472	22
1958	55,665	25,102	30,563	236,848	22
1959	56,845	26,791	30,054	252,687	22
1960	56,534	27,290	29,244	254,650	27
1961	57,210	28,012	29,198	246,659	24
1962	61,995	28,414	33,581	245,536	24
1963	62,403	27,904	34,499	238,781	15
1964	64,271	29,115	35,156	229,270	19
1965	65,659	30,405	35,254	223,806	19

APPENDIX VI

GEOMETRIC GROWTH OF NET TECHNOLOGICAL CHANGE[a]
CANADA AND REGIONS, 1946-1965[*]

Year	Canada	Atlantic	Quebec	Ontario	Prairie	B. C.
1946	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1947	.9353	.7896	.9059	1.0657	1.0129	.9016
1948	.9966	.8268	1.1605	1.1531	1.0100	.8665
1949	1.0362	.8403	1.1232	1.2462	1.1353	.9175
1950	.9745	.6908	1.0257	1.3761	.9258	.9802
1951	1.0392	.6437	.9712	1.1444	1.5749	.9700
1952	1.3175	1.0438	1.2705	1.3756	1.6411	1.2165
1953	1.3685	.9664	1.4381	1.3755	1.7481	1.3571
1954	1.1475	1.0888	1.2936	1.2121	.9295	1.1835
1955	1.2897	1.0714	1.6966	1.2557	1.4317	1.0717
1956	1.2544	1.1006	1.3502	1.1998	1.4517	1.1705
1957	1.3292	1.1205	1.4068	1.2251	1.7177	1.2962
1958	1.1964	.9642	1.2896	1.3229	1.2711	1.1904
1959	1.2265	.9817	1.3115	1.2476	1.5502	1.1171
1960	1.2557	1.2004	1.4412	1.3615	1.3223	1.0248
1961	1.1654	.9628	1.4353	1.4557	1.0500	1.0895
1962	1.2977	.8837	1.4488	1.5251	1.5192	1.2552
1963	1.4877	1.5618	1.2109	1.4597	1.6998	1.6772
1964	1.5615	1.7753	1.3773	1.6114	1.6022	1.5606
1965	1.6188	2.0510	1.2969	1.7298	1.7241	1.5837

[*]Source: Calculated from data in Appendix V,

[a]Based on value added measure of output and an 8 per cent return on farm capital.

APPENDIX VII

TESTS FOR EQUALITY OF TWO SERIES OF A(t) CALCULATED ON THE BASIS OF 8% AND 6% RETURN ON CAPITAL CANADA AND REGIONS

Canada & Region	F value	t value
Canada	1.622	1.124
Atlantic	1.340	.713
Quebec	1.518	1.148
Ontario	2.034	1.640
Prairie	1.279	.809
B. C.	1.498	.723

Note: The F statistic is used to test the equality of variances. For 19/19 degrees of freedom, the value of F which is significant at 5% = 2.51; at 1% = 3.40.

The t statistic is used to test the equality of means. For 38 degrees of freedom, the value of t which is significant at 5% = 2.04; at 1% = 2.74.

APPENDIX VIII

TESTING THE EQUALITY OF GROWTH RATES AMONG REGIONS

A test for significance of differences in the growth rates of technological change among regions is an analysis of variance. As it has been known that considerable variations existed among years, a two way classification was employed accordingly. The performance of this test is based on the assumption of normality and of common variance. For the former, no attempt was made to test here since the F test is a hardy one, a little departure from normality tends to have small effects. For the latter, Bartlett's test was performed with results summarized in Table A.

TABLE A

TEST FOR HOMOGENEITY OF VARIANCE OF A(t) ACROSS REGIONS

Region	d.f.	s^2	log s^2	(n-1)log s^2	1/n-1
Atlantic	19	.163558	- .78622	-14.9382	.05263
Quebec	19	.058293	-1.23441	-23.4538	.05263
Ontario	19	.066331	-1,17829	-22.3875	.05263
Prairie	19	.113647	- .94462	-17.9478	.05263
B. C.	19	.080047	-1.09664	-20.8362	.05263
Totals	95			-99.5635	.26316
Pooling		.096375	-1.01601	-96.5210	

$$\chi^2 = 2.3026 \left[(-96.5210 - (-99.5635)\right] = 7.0057 \text{ with 4 d.f.}$$

The result of the test showed that there was no evidence to reject the hypothesis of the homogeneity of variance of A(t) across regions.[4]

After verifying the assumption, one can proceed to test the equality of growth rates among regions. In Table B the results of the two-way classification analysis of variance are presented.

TABLE B

ANOVA FOR TESTING THE EQUALITY OF GROWTH RATES AMONG REGIONS

Source of Variation	d.f.	SS	MS	F
Among regions	4	1.246122	.31153	8.3835*
Within years	19	6.331844	.33325	
Error	76	2.823814	.03716	
Total	99	10.401780		

Note: For 4 and 76 degrees of freedom, the critical value of F = 2.5 at 5%; F = 3.6 at 1%.

Since calculated F exceeds 1% tabular F, one rejects the hypothesis and conclude that there was a significant difference in the growth rates of technological change among regions.

[4]For 4 degrees of freedom, the critical value of χ^2 = 9.49 at 5%.

APPENDIX IX

YEARLY REAL HIRED WAGE[a] PER MAN-EQUIVALENT CANADA AND REGIONS, 1946-1965[*]

Year	Canada[b]	Atlantic	Quebec	Ontario	Prairie	B. C.
	....	....	.....Dollars.....	....	....	....
1946	456	450	289	435	704	496
1947	579	625	383	542	812	621
1948	407	332	300	505	532	418
1949	393	338	314	480	505	368
1950	520	356	370	670	646	673
1951	571	385	362	685	767	832
1952	626	486	411	721	733	913
1953	692	518	415	875	769	1,093
1954	666	502	444	650	787	1,149
1955	741	527	652	760	887	967
1956	810	566	624	903	903	1,214
1957	868	506	798	974	984	1,276
1958	831	486	618	1,033	1,005	1,272
1959	734	411	526	1,013	891	1,092
1960	755	499	560	975	917	983
1961	743	457	559	984	902	996
1962	731	484	545	1,107	833	859
1963	877	815	601	1,181	1,073	836
1964	967	866	694	1,289	1,060	1,029
1965	990	866	673	1,351	1,142	1,056

[*]Source: Derived from Appendix V and <u>Handbook of Agricultural Statistics, Part II, Farm Income</u>, Dominion Bureau of Statistics, Ottawa, 1926-1965.

[a]Using composite price index of farm product as a deflator and using 1935-39 as a base.

[b]Geometric mean of the regions' values.