Technological Innovation Studies Program

Research Report

INNOVATION IN FOREST HARVESTING
BY FOREST PRODUCTS INDUSTRIES

by

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University of Toronto.
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The forest products industries are major contributors to Canada's position in world trade. Forest harvesting is a primary component within these industries, not only in its own right but also as an input to Forest Products and Paper and Allied Products. To increase -- or at least maintain -- its competitiveness in international markets, the logging industry must continually improve its productivity. Efficiency in production involves the use of improved technology where the primary component is innovation (the application of a new invention).

To study innovation in the forest harvesting industry it is important to develop an adequate criterion of effective innovation. Such a criterion could be used to contrast the improvements in productivity among industries and to identify the most effective firms within an industry. This study was designed to compare productivity across industries using data from Statistics Canada and to contrast logging operations using company data. If the industry has had limited success in improving productivity, it would be important to spotlight those characteristics which enhance innovation and those which inhibit it.

TOTAL FACTOR PRODUCTIVITY

Most studies comparing industries and regions use only the labour factor as an input, but this is insufficient, omitting a major component of productivity, capital. To study the impact of innovation on productivity, total factor productivity, i.e. changes in productivity due to both capital and labour over time, has been used for the time period ending in 1971 which is the latest available. Because of missing data, alternative time periods terminated in 1968 and 1969 are used in places. A nine year time period, starting in 1963, was used to establish a stable estimate of productivity change over time.

Comparisons of total factor productivity were made among five Canadian industry groups, logging, paper and allied products, wood products, mining, and total manufacturing. During the target period, logging and wood products were well below the others in capital intensiveness, while mining was far above. However, the increase in capital intensiveness for logging was proportionately much greater than it was for the other comparison groups except mining.

The benchmark used for assessing the change in total factor productivity for the logging industry was total manufacturing for Canada. The relative positions for total factor productivity among the industries is shown in Summary Table IV-12. Since capital input data were not available in 1971, comparisons will have to be made for the periods ending in 1968 and 1969. The logging industry compares reasonably well with the other three industries and only slightly below all manufacturing. The industries which are in the poorest positions are Mining and Paper and Allied Products.

(1) Research sponsored by Science and Technology, Industry, Trade and Commerce.

Summary Table IV-12.

Average Annual Growth Rates, in percent, of various productivity indexes, gross value added basis.

Industry.	Productivity Measure.	Time Period 1963-71	1963-68	1963-69
All Manufacturing	Labour, weighted	2.27	2.12	2.37
	Capital	n.a.	-.53	-.40
	Total, weighted	n.a.	.77	.94
Logging	Labour, weighted	4.23	3.11	3.29
	Capital	-2.88	-3.68	-2.49
	Total, weighted	.82	.04	.69
Mining	Labour, weighted	2.40	3.24	3.37
	Capital	-3.87	-3.02	-3.62
	Total, weighted	-2.57	-1.62	-2.13
Wood Products	Labour, weighted	2.52	3.38	2.26
	Capital	-2.59	-.22	-1.52
	Total, weighted	.11	1.78	.59
Paper and Allied Products	Labour, weighted	1.49	.18	1.51
	Capital	n.a.	-3.00	-1.05
	Total, weighted	n.a.	-1.62	.07

Summary Table IV-12 shows that labour factor productivity for all manufacturing during the available periods is relatively constant varying from a 2.12 to a 2.37 per cent annual increase. Labour factor productivity for Logging was above All Manufacturing with a 3.11 to 4.23 per cent average annual increase. Mining and Wood Products industries were similar to Logging. Pulp and Allied Products were consistently well below All Manufacturing with a 0.18 to 1.51 per cent annual increase in labour productivity. Thus it initially appeared that the national logging industry has remained competitive with Canadian manufacturing by effectively managing its labour factor input, but further analysis of the capital productivity made such a conclusion questionable.

As capital intensiveness increases, it would be expected that non-production workers would be substituted for production workers, and the former would be more efficient. In logging non-production workers were more efficient but there was not a substitution of non-production for production workers as indicated by similar weighted and unweighted labour input indexes. Labour input in logging declined considerably during the entire period in contrast to an increase in all manufacturing.

The picture for capital productivity in Logging was not nearly as good as it was for labour. Except for Wood Products in the 1968 period, shortly after the 1967 recession, all four industries are below the All Manufacturing average. Throughout Canada capital has not been used effectively to contribute to increases in productivity. In fact it is a negative contribution in each time period and industry. For all three time periods the Logging Industry basically replaced labour with capital on approximately a one-to-one ratio so little productivity improvement has occurred. Neither capital nor labour have been used effectively to produce improved productivity.

CAPITAL INVESTMENT DECISION PROCESS

Using financial data, it was not feasible to study a third factor, managerial effectiveness, as an independent contributor to total factor productivity. It is imbedded within both the labour and capital factors. Although it was not the primary purpose of this initial study, some data on the processes used for managing technological change and innovation (new applications of technology) were collected from 14 companies. Total factor productivity data were not available from enough of the individual firms during the 1963-71 period for comparisons to be made between the firms with the highest increase in productivity and those with the lowest. Therefore the results from the interviews were only descriptive rather than comparative.

The capital investment decision process was tied to the operating budget process. The primary criterion for evaluating a capital investment proposal was to control maintenance costs as long as there was an acceptable, continuous flow of logs to the mills. It was expected that the more general criterion of improving capital productivity would have been used. The primary source of information for such decisions was maintenance records.

New equipment and innovations appeared to be provided with limited financial, technical, and management support during evaluation and start-up stages.

Typically field managers were assigned new equipment during either stages as part of their normal operations. They appeared to be held accountable primarily for the latter although effective implementation of the new equipment often required a significant portion of their current resources.

Individual firms did not appear to have basic research budgets although in some instances development project budgets were established to evaluate new equipment or systems. Most development activities involved equipment modifications which took place in field shops out of the expense budgets.

ORGANIZATION POLICY AND STRUCTURE

As capital intensiveness increases, specialized skills tend to develop to aid management to plan, evaluate, and implement new technology, equipment and systems. A wide range of specialization was found among the 14 firms, but their average (16.4) was relatively low since a maximum achievable score was 56.0. It appeared that the basic locus of specialization within Logging was in short-range, operating support such as operating records and maintenance in contrast to long-range innovation.

Another factor important in organization design is centralization, the level at which a final decision is made. There were significant differences among the 14 firms with the average decision made at the upper middle manager-lower executive level. Operating and manpower decisions are quite decentralized while financial and organization policy and structure decisions are centralized at executive levels.

LABOUR PRODUCTIVITY

To further analyze the problem of managing labour and capital inputs to improve productivity in Logging, an attempt was made to compare regions and firms of different sizes to see if one or the other might be an important consideration. Capital data were not available, but an analysis of labour productivity was made. The results are summarized in Table V-1.

Generally labour productivity tends to increase as the size of the firm increases. This occurred both nationally and in British Columbia. It was partially true for Ontario, but size did not appear to be a factor in Quebec.

This table also shows that the growth rate for labour productivity was much lower in British Columbia than in the other provinces. It is possible that logging conditions in British Columbia required greater capital intensiveness in an earlier period of time so the increase in labour productivity occurred then.

A comparison of changes in labour input shows that Quebec's decreased at a greater rate during the target period while Ontario was less and British Columbia's least, considerably below the national average. Thus Quebec substituted capital for labour at a greater rate than did the other provinces. Quebec (7.1%) also had the only annual labour productivity increases which were greater than the national average (5.61%), Ontario's was 4.3% and British Columbia's 3.1%.

R.F. Morrison : March 1975.

Table V-1.

Average Annual Logging Industry Labour Productivity Increase in Percent over the period 1963-1971 by Province and Size.

	Size in Value of Shipment	Quebec	Ontario	British Columbia	Canada
A.	≤ $99,999	6.89	2.59	0.07	2.90
B.	$100,000 - $999,999	5.36	4.39	1.54	4.08
C.	> $999,999	6.60	3.95	3.20	5.68
	Total	7.10	4.33	3.10	5.57

TOTAL FACTOR PRODUCTIVITY AS A MEASURE OF INNOVATION IN THE FOREST HARVESTING INDUSTRY

I. Introduction.

Technological change may be the most important contributor to a firm, industry or nation attempting to compete in world markets and thereby achieve economic growth. A change in technology can create an alteration in productivity (the production function) because of four elements: 1) Better equipment; 2) Improved material; 3) More effective management and organization; and 4) New products.[1] A primary component of technological change is innovation, the application of an invention for the first time, because it requires an effective combination of two or more of the four elements. To study the effectiveness of innovation in an industry -- or country --, it is possible to use total factor productivity since it combines managerial decisions involving labour and capital, and successful innovators appear to grow more rapidly than non-innovators.[2]

This report analyzes measures of the average annual rate of productivity change in the Logging industry from 1963 to 1971 inclusive and compares this rate of productivity change to other industries in Canada. The industries used for the comparisons are Wood Products, Paper and Allied Products, and Mining. In addition, the rate of productivity change for all Manufacturing industries combined was used as a benchmark. The choice of the first two industries for comparative purposes was made because they

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(1) Mansfield, E. The Economics of Technological Change. New York: W.W. Norton & Co., 1968.

(2) Mansfield, E. Industrial Research and Technological Innovation: An Econometric Analysis. New York: W.W. Norton & Co., 1968.

both use as inputs the output of the Logging industry, though they have very different technological characteristics, Mining was chosen, although it involves the "harvesting" of a non-renewable resource, because the capital intensity of this industry is much higher than the Logging industry and provides a useful contrast.

This report explains the general techniques used in measuring the variables included in constructing productivity indexes, presents the productivity indexes, and analyzes the trends in productivity over time. The technical Appendix to this report presents the basic data used for all industries and discusses some technical problems involved in the measurement of input and output variables.

The use of productivity analyses of the type presented in this report has been subject to some technical criticism by economists. An alternative that has been suggested is the use of econometric techniques to measure production functions for the various industries. The proposed techniques are much more involved and very difficult from a statistical point of view. To date, however, it has not been demonstrated that the more sophisticated measurement techniques will yield estimates of productivity change that are substantially superior to the estimates obtained using the simpler and more direct approach.

There have been some productivity studies performed on Canadian industry or total manufacturing data. Unfortunately the measures of productivity change estimated in this report are not directly comparable to estimates in other studies since the variables are measured differently and the base periods used are different.

Economists view the production process as the combination of a set of inputs in certain proportions to generate a set of outputs or a single output.

The proportions in which the inputs are used depends on the technology of the industry or firm and management decisions. The inputs usually considered are labour and capital. Land is ignored since it is assumed to be fixed or very small. A factor which cannot be measured but is present is managerial skill since management decisions determine the input mix and the use of new production techniques and technology.

With a given technology, a firm can maintain its output by altering its input mix. Conversely, output can be increased by increasing inputs. In neither case will there necessarily be an improvement in productivity, which is a measure of output per unit of input. If, however, labour becomes more efficient with the same amount of capital, or new capital is introduced which not only substitutes for labour but improves capital efficiency, then productivity will increase. Productivity is a measure of the efficiency with which inputs are converted to outputs. Productivity is an important concept since increasing productivity leads to increasing real per capita income in the economy and in its constituent units.

Productivity measures can be used to compare the changes in efficiency among different industries. At the level of the individual firm, such comparisons may highlight future problems in the firm's operations and point the way to remedial action before such problems become evident in the firm's financial results.

Application at the level of the firm is questionable and requires considerable judgment on the part of the decision maker, since the productivity measures are subject to unknown errors which cancel out at the level of the industry because the measures are aggregates of the individual firms within the industry. Even the industry figures must be used with some caution since small differences in productivity between different industries may not be statistically or operationally significant. Unfortunately there are no statistical tests to apply to these differences to aid the decision maker in distinguishing significant from random differences.

Other limitations beyond measurement error which must be kept in mind when interpreting productivity measures are: First, in considering changes in productivity over time, the analysis assumes that all that is changing is the aggregate amount of inputs and the resulting output. However, the quality of the output variable may be changing; thus one unit of output in the starting period may be of a better or poorer quality than a unit of output in a subsequent year. This problem is not dealt with directly in the productivity measures used here. Second, productivity measures based on only one input, for example, either labour or capital, do not give an accurate picture of the changes in the efficiency with which the inputs are combined. Such partial productivity measures may reflect either increasing efficiency in the use of the factor input in question or the impact of substitution among different factors.(1) Therefore, to obtain an indication of the increasing efficiency of the factors, the productivity index must be one which considers all factor inputs. Such an index is called a measure of total factor productivity. Third, total factor productivity measures provide a measure of efficiency in the use of resources but do not allow for changes in the degree of utilization of factors. For example, production efficiency may be increasing but if there is underutilization of factors, the increase in output potential is offset and no increase in output appears. The possibility of such an offset must be considered in interpreting productivity indexes. One example of this effect is the purchase of more

(1) This is discussed in more detail in Section II.

efficient capital equipment to meet anticipated increases in demand for a firm's output. Since the capital equipment is purchased for future use there is currently some underutilization. If the expected demand increases do not materialize then the excess capacity will be substantial. Cyclical movements in productivity measures can be related to the existence of excess capacity in capital equipment. Because individual units of capital are very large in the paper manufacturing portion of the paper and allied products industry, the problem of capacity may be important. Finally, a distinction must be drawn between economic efficiency and productive efficiency and the impact of each on economic welfare. Economic efficiency is concerned with the way in which resources are allocated between industries, rather than with their use within industries. Improving economic efficiency is important and will increase economic welfare. However, productive efficiency is concerned with the use of improved technology within industries to serve an existing set of markets. Changes in productivity efficiency are probably more important in increasing economic welfare than changes in economic efficiency.

In Section II of this report the concept and measurement of productivity change is discussed. Measures of the input and output variables needed for the productivity analysis are presented in Section III. Section IV presents the indexes for labour, capital and total factor productivity for all industries examined in the study. The annual average growth rates in productivity are estimated for three time periods and differences among industries in these growth rates are identified and analyzed. Finally, Section V calculates provincial labour productivity growth rates in the logging industry for firms of different size classes.

An attempt was made to gather the data essential to developing total factor productivity indices for individual logging activities so that contrasts among firms could be made. However, sufficient productivity data, especially capital series, was available for only one firm so this analysis had to be dropped.

II. General Measurement of Productivity Change.

Productivity is the relationship of the physical volume of output produced to the physical volume of inputs used for a given firm, industry or the economy as a whole. To perform a productivity analysis, a productivity index is constructed starting from a pre-determined base period; in our analysis, the base period in 1963. The productivity index is equal to an output index divided by an input index, i.e. if Y_t and I_t are the values of the output and input indexes in period t, then the productivity index at time t, i.e. P_t is defined as

$P_t = \frac{Y_t}{I_t}$ In the base period $Y_o = I_o = 1.00$. The average annual change in productivity between the base period and period t is defined as (1)

$$\text{Average annual change in productivity} = \frac{1}{t} \ln\left(\frac{P_t}{P_o}\right)$$

where t is number of years between the base period and period t. This is the continuously compounded annual percentage growth in productivity over the period in question.

In order to construct indices for outputs and inputs we face problems of measurement for the physical volumes of the inputs and outputs. There are also problems in the comparability of these physical volume measures among different firms and/or industries.

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(1) Assume that $P_t = P_o e^{gt}$ i.e. productivity index begins at P_o and grows at an average annual rate of g%. Therefore $P_t/P_o = e^{gt}$ and $\ln(P_t/P_o) = gt$. Thus $g = \frac{1}{t} \ln(P_t/P_o)$.

First, if a firm produces different products how can the outputs in each product be aggregated into a total physical volume of output? It is impossible, for example, to aggregate the physical volumes of different products to obtain a sensible total output measure unless the products are homogeneous. This aggregation problem becomes even more serious when firm outputs are aggregated into an industry output.

The comparison of physical output measures between industries which produce completely different products is impossible. How can one compare the output of the logging industry -- i.e. cunits of wood, to gallons of milk or tons of steel?

A similar aggregation problem is also present when we consider the physical volume of inputs. For example, on the labour input side, it is impossible to add up physical units of labour with different skills and compare the resulting total to labour input in another firm or industry where different skill mixes may exist.

In order to circumvent the problems involved in using physical volumes,we define inputs and outputs in terms of their dollar values. Once these categories are in terms of dollars aggregate comparisons are possible.

However, we cannot consider all changes in the dollar value of inputs or outputs as reflecting the real changes in amounts produced or used. For example if output is measured in current dollars, an increase in output can result from an increase in price with physical output remaining constant, or an increase in physical output with price constant, or a combination of the two. In order to remove the price change effect and identify changes in value due exclusively to physical output increases, the dollar value of output is deflated by a price index specific to the product being investigated. The resulting real value of output is then used in the productivity analyses. Using the time series for the real value of output an output index is constructed which has a value in the base year (i.e. 1963) equal to 1.00.

For inputs there is an analagous problem and the real value of the inputs used in the production process must be calculated. The actual construction of the real value of inputs is presented in detail in section III but may be summarized as follows. Consider the labour input first. The real physical volume of labour input in each year is man-hours paid or man-hours worked.[1] To obtain real dollar value of this input, the physical input in every period is multiplied by the actual rate of return for the input measured at a base period. In the case of labour, the rate of return is equal to the wage rate paid at the base period; this wage rate reflects the efficiency of the labour input at the base period. In every subsequent period the real value of labour input is calculated as the product of the base period wage rate and the physical labour input, i.e. man-hours paid (or worked). The real value of labour input in any year is not necessarily equal to the real value of the wage bill in the same year but reflects the actual input of labour as if it were of the same efficiency as the base period. A labour input index is constructed from the real value of labour input series with a value of 1.00 in the base period.

The resulting productivity measure with labour used as an input compares the actual real value of output in successive time periods to real outputs that would have been produced had the labour input efficiency not

(1) As discussed in section III the two will be different.

changed. Therefore, increases in the efficiency of the labour input are translated into productivity increases.

A similar technique is used for the capital input. Capital provides services in the production process. To remove the impact of price changes on the capital used, the actual dollar value of the capital stock in any year is deflated by an appropriate capital stock price index to obtain the real-value of capital stock. To obtain the value of the capital input services in any period, the real dollar value of capital stock in a given period is multiplied by the base period rate of return on capital. This rate of return is a percentage figure, for example 15%, and the services of the capital stock reflect the real value of capital input services in any period as if the efficiency of capital were the same as in the base period. After constructing a capital services input index, the resulting productivity measure reflects the increases in real output resulting from changes in efficiency for the capital services input.

Productivity measures are of two general types, partial factor productivity and total factor productivity. Partial factor productivity measures are the most common and measure the productivity of only one input, usually labour. If we define the value of the labour input index in period t as L_t, then the partial productivity measure in period t is Y_t/L_t and is called labour productivity. Similarly if capital is the only factor considered, then capital productivity is measured as Y_t/K_t where K_t is the value of the capital input index in period t.

The use and interpretation of partial factor productivity indexes is open to serious question. In order to produce a given output with a given technology a firm can choose one of many possible combinations of labour and capital. In fact, the firm will choose that combination which minimizes its factor input costs. However, as factor prices change the optimal combination of capital and labour will change even though the output remains constant. Consider the case where the price of labour increases relative to the price of capital and there is a substitution of capital for labour without an increase in output.(1) If we were to measure labour productivity we would find that it has increased, i.e. Y_t is constant but L_t is falling. However, it would be incorrect to say that the increasing labour productivity is an increase in the efficiency of labour per se. In fact, labour has become more efficient only because of the use of additional capital inputs.

If capital productivity were measured in the above example, it would show a decrease. The decrease should not be interpreted as a reduction in the efficiency of capital inputs, since they are used to substitute for labour.

In order to measure the correct productivity changes for a firm or industry, it is essential to adjust for the changing input mixes. Once this has been accomplished, changes in productivity will reflect increases in the efficiency with which inputs are used and changes in technology.

The partial productivity measure for labour will reflect true efficiency changes in labour only if the other factors remain constant, or are small relative to the labour input, or if all factors are used in fixed proportions.

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(1) Output can increase if the firm decides to increase its scale of operations but the technology does not change and there is a pure substitution of capital for labour.

In table II-1 we present the capital-labour ratios for the industries analysed in this study as well as for total manufacturing. As can be seen all industries had increasing capital-labour ratios over time. In addition, we will show in a later section that the value of the capital input series did not remain constant, nor was it small in relation to the labour input.

Table II-1

Capital-Labour Input Ratios for Various Industries, (Real Gross Capital Services and Real Labour Services, Weighted Manhours)

	Logging	Paper and Allied Products	Wood Products	Mining	Total Manufacturing
1963	.693	1.205	.722	3.040	.982
1964	.709	1.215	.732	3.251	.980
1965	.771	1.290	.749	3.389	1.009
1966	.779	1.308	.792	3.630	1.033
1967	.841	1.397	.855	3.914	1.066
1968	.972	1.413	.864	4.155	1.121
1969	.979	1.406	.905	4.620	1.160
1970	1.065	n.a.	1.037	4.583	n.a.
1971	1.223	n.a.	1.086	5.018	n.a.

To circumvent the problems created by varying input mixes, a total factor productivity measure is used. Define F_t, the total factor input index used in period t, as the sum of labour and capital inputs. Where there is a pure substitution of capital for labour in a given period, the total factor input series will not change. Total factor productivity is defined as Y_t/F_t and resulting changes in productivity will reflect increases in the efficiency with which factors are used.

In our analysis, total factor productivity is computed for the aggregate logging industry since capital stock data are available. In the provincial analyses, partial productivity measures are used for firms in different size categories since no capital stock data are available. These partial productivity measures, however, are difficult to interpret because of the impact of capital-labour substitution.

III. Measurement of the Variables.[1]

1. Output

In measuring firm or industry output a choice must be made between the gross or net value of output series. The latter concept is measured as gross value of output less purchases of intermediate goods from other industries. These purchases include materials and supplies, fuel and electricity purchased etc. The net value of output is also known as value added.

If the gross value of output series are used, inputs must include not only the basic factors of labour and capital but also the intermediate produce inputs. To be consistent with the economy output estimates, the intermediate products may be netted out and the value added or net output measure used. This enables us to consider only the basic inputs of labour and capital.

Given that value added should be used as the output variable a choice must be made between the production only and total activity concepts of value added. The former measures the value added generated by production workers alone whereas the latter includes the contribution of non-production employees to value added; the value added based on the total activity concept will be greater than value added from production activity.

The purpose of this analysis is to investigate the decisions of logging company management on productivity. The decision to have substantial non-production worker activity or not is a management decision that can have an important impact on productivity. In fact, there may be some important decisions on logging techniques etc. that emanate from the non-production workers.

(1) The definition of the variables are listed in Appendix 1.

The distinction between production and total activity is not particularly crucial in the logging industry since the non-production activity segment is small. However, to be correct the report uses the total activity concept to measure value added.

The ratio of non-production to production workers in the logging industry is presented in table III-1. The importance of non-production workers increased over time but they were of small importance compared to the production labour input.

Table III-1

Ratio of non-production to production workers measured by manhours and the real value of labour input based on 1963 wage rates

	Manhours	Real Value
1963	.118	.147
1964	.116	.128
1965	.123	.152
1966	.137	.169
1967	.148	.183
1968	.163	.203
1969	.173	.214
1970	.166	.206
1971	.180	.223

Value added can be measured as gross or net. Gross value added in any period (GVA_t) is obtained directly from the basic data sources. Net value added in any period (NVA_t) is equal to GVA_t less economic depreciation where economic depreciation is the actual value of capital services used up in the production of the product. If economic depreciation is not deducted,we are measuring as an increase in output the economic deterioration of the capital input.

However, despite the theoretical superiority of net value added, most studies of productivity measure value added on a gross basis. The reason is purely one of ease of measurement. Estimates of economic depreciation are very difficult to obtain and accounting measures of depreciation may not reflect the true or economic depreciation.

In this report both gross and net value added concepts are used. A series for economic depreciation has been constructed but we do not place high confidence in this series as a measure of economic depreciation since it is based on accounting records.

Value added estimates from the basic data sources are measured in current dollars. In order to obtain the real value of output, a logging price index is used to deflate current dollars to constant dollars based on 1963. Therefore, we define real gross value added in period t as $y_t^G = \frac{GVA_t}{PI_t}$ where PI_t is the value of the logging price index in period t. Real net value added is measured as $y_t^N = \frac{NVA_t}{PI_t}$. The actual values of NVA, GVA, and PI are presented in Appendix 2, Table 1.

For the productivity analysis an index of real value added is required with a value in the base period, 1963, equal to 1.0. The index for real gross value added is constructed as

$$Y_t^G = y_t^G / y_o^G$$ where y_o^G is the real gross value added in the base period.

Similarly, the index for real net value added is

$$Y_t^N = y_t^N / y_o^N.$$

2. Inputs

Input indices for capital and labour are constructed to measure the real value of the input used in the production process at values reflecting the efficiency of the base period. To do this, the real physical amount of the input used is multiplied by the base period rate of return for the factor. For labour, the physical amount of input is man-hours paid and for capital, it is the real dollar value of the capital stock. The rate of return for labour is the wage rate which reflects labour's efficiency in the base period; for capital, the rate of return is the actual rate of return on capital in the base period which reflects capital efficiency.

a) Labour

Since we are using total activity for the value added series, the labour input series must use all workers, both production and non-production. The easiest method of calculating the labour input is to lump all workers together and assume all workers are homogeneous and of the same average skill and efficiency. This implies that a man-hour paid to a production worker is of the same efficiency impact as a man-hour paid to non-production workers.

To get the base period rate of return on labour, the average wage in 1963 is calculated and is equal to the total wage bill in 1963 divided by the total man-hours paid in 1963.[1] This base period wage rate is $\bar{w}_o$ and is equal to $2.00048 in the logging industry.

In any year, t, there are man-hours paid to production workers, $MH_{P,t}$ and to non-production workers, $MH_{NP,t}$. The total man-hours paid $MH_{T,t}$ is equal to $MH_{P,t} + MH_{NP,t}$. The real value of the labour input in period t, ℓ_t, is defined as

$$\ell_t = \bar{w}_o \, MH_{T,t}$$

and the labour input index in year t is

$$L_t = \ell_t / \ell_o$$

Values of $MH_{P,t}$, $MH_{NP,t}$, $MH_{T,t}$, and ℓ_t are presented in Appendix 2, Table 2.

This labour input index is deficient as a measure of base period labour efficiency since it does not consider that production and non-production workers may be of different efficiencies. Thus it does not account for changes in the composition of the logging industry labour force. To circumvent this deficiency, it is important to distinguish between production and non-production labour efficiency. To do this, a new labour input index must be constructed in which a man-hour paid of production labour need not be the same as a man-hour paid of non-production labour.

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(1) In this study we have used man-hours paid and not man-hours worked as the basic labour input variable since the former was all that was available. The total wage bill will include paid vacations and other fringe benefits. Man-hours paid will also include these fringe benefits whereas man-hours worked will not. Thus the average wage rate which reflects economic efficiency is measured correctly by using man-hours worked as the labour input. If the relationship of man-hours paid to man-hours worked is constant, no serious error will be involved in using man-hours paid.

Assume that the base period wage rate to different classes of labour reflects their productivity. The value of the wage rate for a specific labour class divided by the average wage as of the base period gives a relative ranking of efficiency. For the logging industry it was found that production workers had a relative ranking of .975 and non-production workers, 1.210. Therefore non-production workers were more efficient than the average and production workers less efficient.

Another way of interpreting the values of these rankings is that one man-hour of non-production workers is worth 1.21 man-hours of an average or standard man-hour and one man-hour of production workers is worth .975 man-hours of an average man-hour. Therefore, if the number of man-hours paid in each class in any year is multiplied by its ranking in the base period and the product is summed over all labour classes, the resulting value is the physical labour input adjusted for efficiency. This quantity is called total weighted man-hours and is defined as $WMH_{T,t} = 1.21\ MH_{NP,t} + .975\ MH_{P,t}$. To obtain the real dollar value of the labour input the weighted man-hours value is multiplied by the base period average wage, i.e. $\ell^*_t = \bar{w}_o\ WMH_{T,t}$. The labour input index, based on weighted man-hours in period t is defined as

$$\dot{L}^w_t = \ell^*_t / \ell^*_Q$$

The value of $WMH_{T,t}$ and ℓ^*_t are presented in Appendix 2, Table 2.

b) Capital

The capital input in the production process in any year is composed of two parts, the return on the real net stock of capital used during the period and the value of the capital stock used up, i.e. economic depreciation. If the gross value added series is used for output then the capital stock services series must reflect both parts of capital services; this input series is known as gross capital services. If the net value added output series is used then capital services should not reflect the economic depreciation and the capital stock series is net of economic depreciation; this is called the net capital services. The basic data are shown in Appendix 2, Table 3.

i) Gross Capital Stock Services Input

As in the labour input series, the gross capital stock services series is the product of the gross real value of the capital stock in any year and the rate of return on capital in the base year. The gross real value of capital stock is calculated as the average gross capital used in a year deflated by an appropriate capital stock price index. The rate of return in the base period is equal to the value of output attributable to capital in the base year divided by the average real value of physical capital in the base period. Since, in the base period, the gross value added is equal to the sum of the values of labour and capital inputs, the value of output attributable to capital is calculated as $GVA_o - l_o$.

The real gross value of capital services in any year is defined as k_t^G. The index constructed for gross capital services input is $K_t^G = k_t^G/k_o^G$.

ii) Net Capital Stock Services Input

The real net value of physical capital in any year is the gross value less the estimated real value of economic depreciation. The rate of return on net capital in the base year is measured as net value added in the base year less the real value of labour input divided by the real net value of physical capital in the base period. The net real value of capital services is denoted by k_t^N and the resulting index is

$$K_t^N = \frac{k_t^N}{k_o^N}.$$

Note that no adjustment to either capital stock series is made to account for the use of new machines that are of different efficiencies than old machines. This is deliberate and forces the increased efficiency to show up in the productivity indices as a change in productivity.

c) Total Factor Input

The total factor input used in any period is the sum of the labour and capital inputs. Since there are 2 labour indices and two capital indices, there are 4 possible total factor inputs. Instead of considering each separately we will present the input series for weighted labour input and gross capital services. The value of total factor input in year t is equal to $\ell_t^* + k_t^G$. The index of real total factor input is

$$F_t = \frac{\ell_t^* + k_t^G}{\ell_o + k_o^G}.$$

IV. Analysis of Productivity Measures.

1. Introduction.

This section will present and analyse the productivity measures for the logging industry. In addition, productivity measures for the Mining, Wood Products, and Paper and Allied Products industries and Total Manufacturing will be presented and used for comparative purposes. It is important to remember that the productivity measures and the resulting average annual percentage changes calculated for this report may not be equal to the statistics calculated by other investigators. The differences are due to different measurement techniques and base periods. However, our productivity estimates are useful for ranking the industries investigated into those with high and low productivity changes.

As discussed in a previous section there are two bases on which to measure productivity change, i.e. gross or net of economic depreciation. Although we present productivity measures based on both concepts, we have more faith in the gross basis.

For each industry, both on a gross and net basis, we present two tables; the first lists the input-output data necessary to measure productivity, in index form. The second presents the productivity indexes both partial and total.

In addition, the average annual changes in all the indexes are calculated for the three following periods; 1963-1971, 1963-1968, 1963-1969. The first time period measures the productivity change over the entire sample period. As can be seen from Table IV-1, this time period covers two recessions, in 1967 and 1970. The second time period covers the first recession period and ends in the first year of the upturn in manufacturing activity. The last time period was chosen to permit comparisons with some of the other industries. Data on capital stock and depreciation for the paper and allied products industry and total manufacturing could not be obtained beyond 1969.

Table IV-1.

Index of Real Domestic Product, Manufacturing and year to year percentage changes
Base 1963 = 1.00

Year	Index	Percentage Change
1963	1.000	-
1964	1.096	9.6%
1965	1.195	9.0
1966	1.279	7.0
1967	1.314	2.7
1968	1.402	6.7
1969	1.503	7.2
1970	1.482	-1.4
1971	1.571	6.0

Source: Canadian Statistical Review, November 1974, Selected Economic Indicators.

2. Productivity - Gross Value Added Bases.(1)

a) Total Manufacturing.

Although we are interested specifically in the logging industry, it is useful in the analyses to have a benchmark against which industry specific trends or changes can be compared. Therefore we present first, the analysis of productivity changes for total manufacturing. In Table IV-2 it can be seen that over the whole period real value added grew on average by 3.74% per year. For the period ending in 1968, growth was higher, i.e. 4.87%. The labour input series, whether weighted or not, increased by approximately 1.5% over the whole period. Notice that for the shorter periods the growth rate is substantially higher. This, in fact, mirrors the pattern in gross value added.

The rate of growth of labour productivity is approximately 2.2% per year using either weighted or unweighted labour indexes. (See Table IV-3). In addition, there is very little variation in the labour productivity growth rates as the sample period varies. It appears that reductions in output are obtained by reducing the labour input in proportion.

The use of capital increased over the two shorter time periods by approximately 5.3% and resulted in capital productivity falling at about .45% per year.

Of major interest is total factor productivity. The total factor inputs grew about 4% per year on average, over the shorter sample periods. Total factor productivity until 1968 increased at .77% per annum. If the period to 1969 is considered, total factor productivity increased by .94% per year. This higher growth rate reflects the increasing utilization of capital as the economy continued to move out of the recession of 1967.

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(1) The base period for the study was 1963. The analysis was run using 1965 and 1967 as base periods. Whereas the results in numerical value were not the same, the industries still had the same ranking in terms of rates of productivity change.

Table IV-2.

Total Manufacturing Industries
Indexes of Value Added, Capital, Labour and
Total Factor Inputs, Gross Basis: Base = 1963

Year	Index of Real Gross Value Added	Total Labour Input Index		Gross Total Capital Services Input Index	Index of Total Factor Labour Unweighted	Index of Total Factor Labour Weighted
		Manhours Unweighted	Manhours Weighted			
1963	1.000	1.000	1.000	1.000	1.000	1.000
1964	1.080	1.050	1.048	1.046	1.048	1.047
1965	1.159	1.104	1.101	1.131	1.117	1.116
1966	1.212	1.155	1.151	1.210	1.182	1.180
1967	1.220	1.156	1.155	1.254	1.204	1.204
1968	1.276	1.148	1.147	1.310	1.228	1.228
1969	1.345	1.169	1.167	1.378	1.272	1.271
1970	1.285	1.137	1.134	n.a.	n.a.	n.a.
1971	1.349	1.130	1.125	n.a.	n.a.	n.a.
Annual Average Change						
1963-1971	3.74	1.53	1.47	n.a.	n.a.	n.a.
1963-1968	4.87	2.76	2.74	5.40	4.11	4.11
1963-1969	4.94	2.60	2.57	5.34	4.01	4.001

Table IV-3.

Total Manufacturing Industries
Productivity Indexes, Labour, Capital and Total
Factor, Gross Value Added Basis: Base = 1963.

Year	Labour Productivity Indexes: Manhours Unweighted	Labour Productivity Indexes: Manhours Weighted	Capital Productivity Index	Total Factor Productivity Indexes: Labour Unweighted	Total Factor Productivity Indexes: Labour Weighted
1963	1.000	1.000	1.000	1.000	1.000
1964	1.029	1.031	1.033	1.031	1.032
1965	1.050	1.053	1.025	1.038	1.039
1966	1.049	1.053	1.002	1.025	1.027
1967	1.055	1.056	.973	1.013	1.013
1968	1.111	1.112	.974	1.039	1.039
1969	1.150	1.153	.976	1.057	1.058
1970	1.130	1.133	n.a.	n.a.	n.a.
1971	1.194	1.199	n.a.	n.a.	n.a.
Average Annual Change					
1963-1971	2.22	2.27	n.a.	n.a.	n.a.
1963-1968	2.11	2.12	-.53	.77	.77
1963-1969	2.33	2.37	-.40	.92	.94

Therefore, for total manufacturing, productivity did not grow rapidly. Growing labour productivity reflects substitution of capital for labour in the production process.

b) Logging.

For the logging industry, real gross value added has increased by an annual average of .94% (see Table IV-4). The series displays some variability based on the movements of the economy as a whole but the value added increase is much smaller than that of total manufacturing of 3.74% over the whole sample time period.

Over the entire period the labour input index has decreased by 3.43% per annum for unweighted manhours and 3.30% for weighted manhours. There has been a large decrease in the use of labour in the logging industry and a very small substitution of non-production for production workers. The reduction in the labour input has some variability depending on the measurement period used. In fact, it appears that the reduction accelerated between 1969 and 1971.

The negative growth rate in labour inputs compares with the labour input increase of 1.5% per annum for all manufacturing industries (see Table IV-2).

The small increase in output combined with a large decrease in labour input results in the very large average annual increase in labour productivity. This is 4.37% when labour is measured by unweighted manhours and 4.23% with labour measured as weighted manhours. This is higher than the average annual increase in labour productivity of 2.2% for total manufacturing.

However, it is not correct to leap to the conclusion that labour in logging has become much more efficient than in total manufacturing. In Table IV-4 it is seen that the real value of the capital services input has increased by 3.82% per year over the sample period. This increase is about

Table IV-4.

Logging Industry
Indexes of Value Added, Capital, Labour, and
Total Factor Inputs, Gross Basis: Base = 1963.

Year	Index of Real Gross Value Added	Total Labour Input Index: Manhours Unweighted	Total Labour Input Index: Manhours Weighted	Gross Total Capital Services Input Index	Index of Total Factor Labour Unweighted	Index of Total Factor Input, Labour Weighted
1963	1.000	1.000	1.000	1.000	1.000	1.000
1964	1.018	1.032	1.031	1.055	1.042	1.041
1965	1.011	.999	1.000	1.114	1.046	1.047
1966	1.003	1.021	1.024	1.152	1.074	1.076
1967	.992	.966	.971	1.179	1.053	1.056
1968	1.014	.862	.869	1.219	1.008	1.012
1969	1.099	.894	.902	1.276	1.050	1.055
1970	1.041	.849	.856	1.316	1.040	1.044
1971	1.078	.760	.768	1.357	1.004	1.009
Average Annual Change						
1963-1971	.94%	-3.43%	-3.30%	3.82%	.05%	.11%
1963-1968	.28	-2.97	-2.81	3.96	.16	.24
1963-1969	1.57	-1.87	-1.72	4.06	.81	.89

equal to the decrease in the labour input. The productivity of capital has decreased over the period on average 2.88% (see Table IV-5).

The very close offset of labour and capital productivity leads one to believe that the logging industry has not made any large increases in productivity but has been substituting capital for labour without any basic change in technology. This is confirmed in Tables IV-4 and IV-5. Regardless of how the labour input is measured, the average annual increase in total factor inputs is negligible, i.e. .05% to .11%. The resulting average annual increase in total factor productivity is very small, less than 1% per year.

Therefore, it might be concluded that the logging industry over the sample period did not have any major technological advances to increase overall productivity. The substantial increase in labour productivity occurred due to the substitution of capital for labour. Thus, even though new capital was introduced into the industry, it did not increase over-all productivity. Another hypothesis that is consistent with the productivity measures is that new technology was introduced but was used inefficiently. Unfortunately we cannot determine if new technology was introduced since we did not have a description of the capital investments made by the logging industry. Because capital intensiveness increased rapidly (see Table II-1), the latter assumption appears most plausible.

Table IV-5.

Logging Industry
Productivity Indexes, Labour, Capital and Total
Factor Gross Value Added Basis: Base = 1963.

Year	Labour Productivity Indexes Manhours Unweighted	Labour Productivity Indexes Manhours Weighted	Capital Productivity Index	Total Factor Productivity Indexes Labour Unweighted	Total Factor Productivity Indexes Labour Weighted
1963	1.000	1.000	1.000	1.000	1.000
1964	.986	.987	.965	.977	.978
1965	1.011	1.011	.908	.967	.966
1966	.983	.979	.871	.934	.932
1967	1.027	1.022	.841	.942	.939
1968	1.177	1.168	.832	1.006	1.002
1969	1.229	1.218	.861	1.047	1.042
1970	1.226	1.216	.791	1.001	.997
1971	1.418	1.403	.794	1.074	1.068
Annual Average Percent Change					
1963-1971	4.37%	4.23%	-2.88%	.89%	.82%
1963-1968	3.26	3.11	-3.68	.12	.04
1963-1969	3.44	3.29	-2.49	.77	.68

c) Other Industries.

The discussion of these industries will be brief since they are only used for comparison purposes.

i) Mining.

Tables IV-6 and IV-7 present the growth rates for the mining industry. This industry is very interesting since it was not affected as severely by the 1967 recession. Over the whole period, labour input grew at about 1.44% for unweighted and 1.75% for weighted manhours. This resulted in an increase in labour productivity of approximately 2.4%. However, the capital input series grew at a staggering 8.0% per annum. The total factor input series also grew at a very large 6.7% rate for the whole sample period. This resulted in total factor productivity decreasing at 2.5%. The actual decrease varied with the sample period chosen but for all periods the growth rate was negative. While the mining industry substituted capital for labour at a high rate, it experienced reduced overall productivity. The interpretation of these results is complicated by the exploitation of of lower grade ore.

ii) Wood Products.

The data for this industry are presented in Tables IV-8 and IV-9. This industry was not hurt as badly as the other industries investigated by the 1967 recession, as seen by gross value added. However, the labour input series decreased steadily from 1965 to 1970 except for 1969. The industry ran upon very hard times in 1969 and 1970.

Over the whole period gross value added grew at 3.02% and labour input grew at .56% for unweighted and .50% for weighted. This implies some substitution of production for non-production workers as well. Labour productivity increased by 2.4% for the whole period (2.5% for weighted manhours) but there was some variability in this growth rate.

Table VI-6.

Mining Industry
Indexes of Value Added, Labour, Capital and
Total Factor Inputs, Gross Basis: Base = 1963.

Year	Gross Value Added	Labour Input		Capital Input	Total Factor Input	
		Manhours Unweighted	Manhours Weighted		Manhours Unweighted	Manhours Weighted
1963	1.000	1.000	1.000	1.000	1.000	1.000
1964	1.104	1.016	1.017	1.087	1.070	1.070
1965	1.156	1.059	1.062	1.184	1.153	1.154
1966	1.160	1.061	1.072	1.280	1.226	1.229
1967	1.242	1.071	1.084	1.396	1.315	1.319
1968	1.301	1.090	1.106	1.512	1.407	1.411
1969	1.317	1.053	1.076	1.636	1.492	1.497
1970	1.456	1.141	1.164	1.755	1.603	1.608
1971	1.394	1.122	1.150	1.899	1.706	1.713
Average Annual Percent Change						
1963-1971	4.15	1.44	1.75	8.02	6.68	6.73
1963-1968	5.26	1.72	2.02	8.27	6.83	6.89
1963-1969	4.59	.86	1.22	8.20	6.67	6.72

Table IV-7.

Mining Industry
Productivity Indexes, Labour, Capital, and Total
Factor Gross Value Added Basis: Base = 1963.

Year	Labour Productivity Manhours Unweighted	Labour Productivity Manhours Weighted	Capital Productivity	Total Factor Productivity Manhours Unweighted	Total Factor Productivity Manhours Weighted
1963	1.000	1.000	1.000	1.000	1.000
1964	1.087	1.086	1.016	1.032	1.032
1965	1.092	1.089	.976	1.003	1.002
1966	1.093	1.082	.906	.946	.944
1967	1.160	1.146	.890	.945	.942
1968	1.194	1.176	.860	.924	.922
1969	1.251	1.224	.805	.883	.880
1970	1.276	1.251	.830	.909	.905
1971	1.242	1.212	.734	.817	.814
Average Annual Percent Change					
1963-1971	2.71	2.40	-3.87	-2.53	-2.57
1963-1968	3.55	3.24	-3.02	-1.58	-1.62
1963-1969	3.73	3.37	-3.62	-2.07	-2.13

Table IV-8.

Wood Products Industry
Indexes of Value Added, Labour, Capital and Total
Factor Inputs, Gross Basis: Base = 1963.

Year	Gross Value Added	Labour Input		Capital Input	Total Factor Input	
		Manhours Unweighted	Manhours Weighted		Manhours Unweighted	Manhours Weighted
1963	1.000	1.000	1.000	1.000	1.000	1.000
1964	1.056	1.037	1.031	1.046	1.041	1.038
1965	1.083	1.065	1.058	1.098	1.079	1.079
1966	1.102	1.059	1.050	1.151	1.098	1.092
1967	1.126	1.035	1.026	1.216	1.111	1.106
1968	1.217	1.036	1.028	1.231	1.118	1.113
1969	1.201	1.058	1.049	1.316	1.166	1.161
1970	1.110	.995	.989	1.421	1.173	1.170
1971	1.273	1.046	1.041	1.566	1.264	1.261
Average Annual Percent Change						
1963-1971	3.02	.56	.50	5.61	2.93	2.90
1963-1968	3.93	.71	.55	4.16	2.23	2.14
1963-1969	3.05	.94	.80	4.58	2.56	2.49

Table IV-9.

Wood Products Industry
Productivity Indexes, Labour, Capital, and Total Factor
Gross Value Added Basis: Base = 1963.

Year	Labour Productivity Manhours Unweighted	Labour Productivity Manhours Weighted	Capital Productivity	Total Factor Productivity Manhours Unweighted	Total Factor Productivity Manhours Weighted
1963	1.000	1.000	1.000	1.000	1.000
1964	1.018	1.024	1.009	1.014	1.017
1965	1.017	1.024	.986	1.004	1.004
1966	1.041	1.050	.958	1.005	1.009
1967	1.087	1.097	.926	1.013	1.018
1968	1.175	1.184	.989	1.089	1.093
1969	1.136	1.145	.913	1.032	1.036
1970	1.116	1.123	.781	.946	.949
1971	1.216	1.223	.813	1.007	1.009
Average Annual Percent Change					
1963-1971	2.44	2.52	-2.59	.09	.11
1963-1968	3.23	3.38	-.22	1.71	1.78
1963-1969	2.13	2.26	-1.52	.53	.59

The capital input series increased 5.6% over the whole period and at a lower rate for the shorter time periods. Total factor input grew at 2.9% for the whole period. Thus there was a net addition of capital in this industry. Total factor productivity, however, grew at a very low rate for the whole period, i.e. .09% to .11%. This very low rate is probably a result of underutilized capacity during the recession in 1969 and 1970. When the period 1963-1968 is considered, the growth rate in total factor productivity is 1.7%. 1968 is at the peak of the value added series so that this is probably an over-estimate of the long run productivity growth rates. A reasonable guess would put the long run growth rate in total factor productivity at .6% to .7%.

iii) Paper and Allied Products.

The output pattern of this industry is similar to that of total manufacturing with reductions in gross value added in 1967 and 1971. The overall annual rate of growth in output is 3.38% (see Table IV-10) but this rate reflects the impact of the recession in 1971. The growth rate for the period ending in 1969 is 4.63% which is much higher. The growth rates in labour input also reflect the impact of the recession. Over the whole period (Table IV-10) the growth rate is 1.81% (unweighted) and for the 1963-1969 period it is 3.02%. From Table IV-11 labour productivity growth rates for unweighted labour is 1.57% for the whole period and 1.60% for the 1963-1969 period. The 1963-1968 growth rate is very low and reflects the impart of the 1967 recession.

The capital input series grew at 5.60% for 1963-1969 and 6.18% for 1963-1968 (Table IV-10) and total factor inputs grew at approximately 4.5% - 4.7% depending on the sample period.

Total factor productivity over the period 1963-1968 fell at an annual rate of 1.58% - 1.62%. For the period ending in 1969, total factor productivity rose at a rate of .07% to .1%.

Table IV-10

Paper and Allied Products Industry
Indexes of Value Added, Labour, Capital, and Total Factor
Inputs, Gross Basis: Base = 1963.

Year	Gross Value Added	Labour Input: Manhours Unweighted	Labour Input: Manhours Weighted	Capital Input	Total Factor Input: Manhours Unweighted	Total Factor Input: Manhours Weighted
1963	1.000	1.000	1.000	1.000	1.000	1.000
1964	1.086	1.054	1.053	1.061	1.058	1.058
1965	1.122	1.088	1.089	1.165	1.130	1.113
1966	1.188	1.156	1.159	1.258	1.212	1.213
1967	1.142	1.165	1.169	1.309	1.244	1.246
1968	1.173	1.156	1.162	1.362	1.269	1.272
1969	1.320	1.199	1.205	1.406	1.312	1.315
1970	1.333	1.180	1.188	n.a.	n.a.	n.a.
1971	1.311	1.156	1.163	n.a.	n.a.	n.a.
Average Annual Percent Change						
1963-1971	3.38	1.81	1.89	n.a.	n.a.	n.a.
1963-1968	3.19	2.90	3.00	6.18	4.76	4.81
1963-1969	4.63	3.02	3.10	5.68	4.53	4.56

Table IV-11.

Paper and Allied Products Industry
Productivity Indexes, Labour, Capital and Total
Factor, Gross Value Added Basis: Base = 1963.

Year	Labour Productivity Manhours Unweighted	Labour Productivity Manhours Weighted	Capital Productivity	Total Factor Productivity Manhours Unweighted	Total Factor Productivity Manhours Weighted
1963	1.000	1.000	1.000	1.000	1.000
1964	1.030	1.031	1.024	1.026	1.026
1965	1.031	1.030	.963	.993	1.008
1966	1.028	1.025	.944	.980	.979
1967	.980	.977	.872	.918	.967
1968	1.015	1.009	.861	.924	.922
1969	1.101	1.095	.939	1.006	1.004
1970	1.130	1.122	n.a.	n.a.	n.a.
1971	1.134	1.127	n.a.	n.a.	n.a.
Average Annual Percent Change					
1963-1971	1.57	1.49	n.a.	n.a.	n.a.
1963-1968	.30	.18	-3.00	-1.58	-1.62
1963-1969	1.60	1.51	-1.05	.10	.07

d) Summary.

In Table IV-12, the annual average productivity charges for all industries and the three time periods are presented. For the whole sample period, logging had total factor productivity increases greater than the mining and wood products industries. For the 1963-1968 period, logging total factor productivity increased more than the mining and paper and allied products and less than the other industries. For the 1963-1969 period, total factor productivity for logging increased at a higher rate than paper and allied products and mining; the rate of increase for wood products was approximately equal to logging. Total manufacturing, however, dominated logging in the rate of total factor productivity increase.

The logging industry displayed total factor productivity growth rates inferior to total manufacturing but better than mining and wood products.

However, the analysis might be more conclusive if the sample period could be extended to 1973 and if the missing capital stock series could be obtained.

3. Net Value Added Basis.

The basic difference between the productivity growth rates calculated and presented in this section and those in the previous section is that an estimate of economic depreciation in real terms has been deducted from gross value added and capital services.

The tables comparable to those presented in the previous section are presented in Appendix 3, but Table IV-13 summarizes the productivity measures on a net value added basis. Comparing Table IV-13 to IV-12 we find that the subtraction of our estimate of economic depreciation has altered the actual productivity growth rates, but not substantially. However, for a given industry, the relationship of growth rates to the sample time period has not changed. Also, the position of the logging industry, vis-a-vis the other industries in terms of total factor productivity growth rates has not changed.

Summary Table IV-12.

Average Annual Growth Rates, in percent,
of various productivity indexes,
gross value added basis.

Industry.	Productivity Measure.	Time Period 1963-71	1963-68	1963-69
All Manufacturing	Labour, weighted	2.27	2.12	2.37
	Capital	n.a.	-.53	-.40
	Total, weighted	n.a.	.77	.94
Logging	Labour, weighted	4.23	3.11	3.29
	Capital	-2.88	-3.68	-2.49
	Total, weighted	.82	.04	.69
Mining	Labour, weighted	2.40	3.24	3.37
	Capital	-3.87	-3.02	-3.62
	Total, weighted	-2.57	-1.62	-2.13
Wood Products	Labour, weighted	2.52	3.38	2.26
	Capital	-2.59	-.22	-1.52
	Total, weighted	.11	1.78	.59
Paper and Allied Products	Labour, weighted	1.49	.18	1.51
	Capital	n.a.	-3.00	-1.05
	Total, weighted	n.a.	-1.62	.07

Summary Table IV-13.

Average Annual Growth Rates, in percent, of various productivity indexes, net value added basis.

Industry	Productivity Measure	Time Period 1963-71	1963-68	1963-69
All Manufacturing	Labour, weighted	n.a.	2.07	2.30
	Capital	n.a.	-.71	-.47
	Total, weighted	n.a.	.75	.96
Logging	Labour, weighted	3.90	2.69	3.00
	Capital	-2.79	-4.21	-2.65
	Total, weighted	1.18	.04	.83
Mining	Labour, weighted	1.77	2.80	2.80
	Capital	-3.95	-2.81	-3.53
	Total, weighted	-2.57	-1.37	-1.96
Wood Products	Labour, weighted	2.33	3.34	2.15
	Capital	-3.01	.16	-1.37
	Total, weighted	-.01	2.07	.70
Paper and Allied Products	Labour, weighted	n.a.	2.59	2.97
	Capital	n.a.	-3.92	-1.52
	Total, weighted	n.a.	-2.13	-.10

V. Analysis by Size of Establishment and Province.

To augment the previous analysis and to make it more useful in decision making, an attempt was made to study differences in total factor productivity based on the size of the establishment, measured in terms of value of shipments, and/or aggregate differences among the three major logging provinces of British Columbia, Ontario, and Quebec. Although logging conditions vary within provinces, for example between the coastal and interior regions of British Columbia, an inter-provincial analysis has resulted in some interesting insights into productivity of the production techniques appropriate to different regions.

Labour, capital, and value added data were requested from Statistics Canada for various size categories within each province. The data were then aggregated into three size categories (see Table V-1). Unfortunately, Statistics Canada did not have the capital stock data, but the labour and value added series for 1963 to 1971 inclusive were provided. Since labour productivity only can be calculated from the basic data, limitations are introduced in the analysis of total productivity by size.

The analysis of national data in the previous sections shows that labour productivity (Tables IV-3,5,7,9 and 11) increases at the same time as capital intensity increases (Table II-1). In addition it can be assumed that for a given province the capital intensity increases with the size of the establishment. Therefore, we would expect that labour productivity should increase as the size of the establishment increases. This is, in fact, what happened for the total nation and in British Columbia (see Table V-1). Ontario is consistent with this trend, but Quebec was unique since establishment size and increase in average annual labour productivity appear to be unrelated.

Table V-1

Average Annual Logging Industry Labour Productivity Increase in Percent over the period 1963-1971 by Province and Size

Size in Value of Shipments	Province			
	Quebec	Ontario	British Columbia	Canada
A. ≤ $99,999	6.89	2.59	0.07	2.90
B. $100,000 - $999,999	5.36	4.39	1.54	4.08
C. >$999,999	6.60	3.95	3.20	5.68
Total	7.10	4.33	3.10	5.57

Accordingly, it would be incorrect to infer total productivity increases from the labour productivity growth rates. However, it is possible to glean some insights from the labour productivity estimates.

1. Minimum Efficient Size (M.E.S.)

Economic theory proposes that increases in output (i.e. size) will result in decreasing average unit production costs. This relationship will continue until optimal economies of scale are achieved and the average production costs level off or start increasing again. This point is known as the minimum efficient size. Because of competitive pressures, firms which are smaller than this minimum size will either grow larger or will be driven out of the market. Therefore, for the firms below the M.E.S. real output would be expected to be decreasing over time relative to the overall output in the industry (or increases at less than the industry rate). If the firm is greater than the minimum, we would expect increases in output relative to total industry.

Table V-2 presents the average annual percentage growth rate in output for the three size categories by province.

Table V-2

Average Annual Percentage Growth Rate (in %) in Real Gross Value Added by Size and Province

Size Category	Province: Quebec	Ontario	British Columbia	Canada
A	-13.7	-10.3	-9.4	-9.6
B	-10.5	- 1.3	.05	-1.5
C	1.9	1.0	5.8	3.7
Total	- 1.1	- 0.2	3.1	1.5

It is clear that for Canada as a whole the M.E.S. is slightly greater than size category B. Individually, Ontario mirrors the national relationship, but in Quebec, the M.E.S. is size category C whereas for British Columbia it is category B. These provincial differences may reflect different production techniques due to operating conditions (B.C. vs. Ontario and Quebec) or management policies (Ontario vs. Quebec).

Corroborating evidence can be seen in Table V-3 where the percentage change in the number of establishments over the period 1963-1971 is presented for the three provinces and Canada. In all provinces and in Canada, there is an increase in the number of establishments for size category C. Only in Quebec is there not a positive increase for category B.

2. Labour Productivity.

Tables V-4, V-5, and V-6 provide details of national and provincial labour productivity for size categories A, B, and C respectively. In Table V-1 both Ontario and Quebec firms with less than $1,000,000 in shipments had labour productivity growth rates in excess of the average for Canada whereas British Columbia was much smaller.

The low productivity growth rates for British Columbia may be surprising to some. One possible explanation is that the B.C. logging industry has always been more capital intensive than the other provinces due to the differences in terrain and tree size, especially in its coastal region.

Table V-3

Number of Establishments by Size Category and by Province for the years 1963 and 1971

Size Category	Quebec			Ontario			British Columbia			Canada		
	1963	1971	% Change	1963	1971	% Change	1963	1971	% Change	1963	1971	% Change
A	394	193	-51.0	342	246	-28.1	825	538	-34.8	2116	1376	-35.0
B	155	106	-31.6	107	134	25.2	368	446	21.2	702	826	17.7
C	43	54	25.6	23	28	21.7	59	126	113.6	141	238	68.8
Total	592	353	-40.4	472	408	-13.6	1252	1110	-11.3	2959	2440	-17.5

(Quebec, Ontario, British Columbia and Canada are printed under the spanning heading P R O V I N C E.)

Table V-4

Labour Productivity, Unweighted
Manhours, Base 1963
Size Category A,
Value of Shipments Less than or Equal to $99,999.

	ONTARIO			QUEBEC			BRITISH COLUMBIA			CANADA		
	Index of			Index of			Index of			Index of		
ar	Real Gross Value Added	Labour Input	Labour Product-ivity	Real Gross Value Added	Labour Input	Labour Product-ivity	Real Gross Value Added	Labour Input	Labour Product-ivity	Real Gross Value Added	Labour Input	Labour Product-ivity
63	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
64	.811	.956	.848	.961	.834	1.153	.910	.926	.983	.918	.920	.998
65	.768	.867	.886	.836	.759	1.100	.820	.892	.920	.828	.843	.982
66	.673	.696	.966	.624	.447	1.400	.624	.667	.935	.647	.641	1.009
67	.538	.534	1.008	.549	.402	1.366	.634	.709	.894	.609	.590	1.032
68	.534	.493	1.082	.428	.280	1.529	.558	.572	.975	.540	.469	1.152
69	.568	.524	1.083	.520	.336	1.545	.659	.635	1.038	.644	.536	1.202
70	.624	.548	1.138	.404	.255	1.583	.523	.542	.965	.557	.471	1.182
71	.437	.355	1.230	.333	.192	1.735	.471	.468	1.006	.465	.369	1.261
age al uct- y ease -1971	-10.3%	-12.9%	+2.59%	-13.7%	-20.6%	+6.89%	-9.4%	-9.5%	.07%	-9.6%	-12.5%	2.90%

Table V-5

Labour Productivity, Unweighted
Manhours, Base 1963
Size Category C,
Value of Shipments $100,000 to $999,999.

	ONTARIO			QUEBEC			BRITISH COLUMBIA			CANADA		
	Index of			Index of			Index of			Index of		
Year	Real Gross Value Added	Labour Input	Labour Product-ivity	Real Gross Value Added	Labour Input	Labour Product-ivity	Real Gross Value Added	Labour Input	Labour Product-ivity	Real Gross Value Added	Labour Input	Labour Produc ivity
1963	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1964	.982	1.097	.895	.926	.911	1.016	1.002	1.021	.981	.994	1.003	.991
1965	1.007	1.080	.932	.697	.720	.969	1.004	1.041	.964	.933	.929	1.004
1966	.971	.970	1.001	.663	.639	1.038	.780	.870	.897	.796	.818	.974
1967	.979	.921	1.063	.598	.540	1.107	.775	.825	.939	.774	.743	1.042
1968	.867	.785	1.106	.580	.460	1.259	.882	.856	1.030	.803	.687	1.168
1969	1.014	.866	1.172	.565	.440	1.283	.978	.947	1.032	.881	.733	1.203
1970	.950	.812	1.170	.502	.386	1.298	.947	.914	1.036	.866	.743	1.166
1971	.902	.634	1.421	.430	.280	1.535	1.004	.888	1.131	.888	.641	1.386
Average Annual Product-ivity Increase 1963-1971	-1.3%	-5.7%	+4.39%	-10.5%	-15.9%	5.36%	.05%	-1.5%	1.54%	-1.5%	-5.6%	4.08%

Table V-6

Labour Productivity, Unweighted
Manhours, Base 1963
Size Category C,
Value of Shipments, Greater than $999,999.

Year	ONTARIO			QUEBEC			BRITISH COLUMBIA			CANADA		
	Index of			Index of			Index of			Index of		
	Real Gross Value Added	Labour Input	Labour Productivity	Real Gross Value Added	Labour Input	Labour Productivity	Real Gross Value Added	Labour Input	Labour Productivity	Real Gross Value Added	Labour Input	Labour Productivity
1963	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1964	.935	.973	.961	1.003	1.078	.930	1.106	1.043	1.060	1.051	1.048	1.003
1965	.952	.998	.953	1.130	1.058	1.068	1.197	1.085	1.103	1.118	1.068	1.046
1966	1.076	1.090	.987	1.260	1.224	1.029	1.246	1.164	1.071	1.210	1.193	1.014
1967	1.031	1.027	1.003	1.318	1.165	1.131	1.269	1.126	1.127	1.218	1.133	1.076
1968	.982	.902	1.088	1.181	.918	1.287	1.484	1.214	1.222	1.258	.993	1.267
1969	1.032	.967	1.067	1.235	.856	1.443	1.669	1.386	1.204	1.347	.995	1.354
1970	1.058	.924	1.145	1.247	.787	1.583	1.414	1.249	1.132	1.275	.939	1.358
1971	1.082	.789	1.372	1.167	.689	1.695	1.595	1.238	1.289	1.342	.852	1.575
Average Annual Productivity Increase 1963-1971	.99%	-2.97%	3.95%	1.9%	-4.7%	6.6%	5.8%	2.7%	3.2%	3.7%	-2.0%	5.68%

Therefore there has not been as substantial a substitution of capital for labour as in the other provinces. For example, for size categories A and B the labour input for British Columbia was less than the Canadian average, but for the largest firms, size category C, the labour input series increased 2.7% in contrast to a 2.0% decrease for all of Canada. Therefore, without substantial capital substitution the B.C. labour productivity growth rates are very low.

For Quebec and Ontario data from Tables V-4, 5, and 6, indicate that within each size category the labour input series decreased more during the target period than the Canadian average. In fact the decreases for Quebec were much greater than for Ontario. One possible interpretation is that the substitution of capital for labour was greater in Quebec than in Ontario over the sample period.

In Table V-7 detailed labour productivity for each of the provinces and Canada are presented. Only Quebec has labour productivity increases in excess of the Canadian average of 5.57%. Unfortunately, comparisons among the provinces regarding total productivity cannot be made because of the lack of capital stock data.

Table V-7

Labour Productivity, Unweighted - Logging Activity
Manhours, Base 1963
Size Category - Total Province.

	ONTARIO			QUEBEC			BRITISH COLUMBIA			CANADA		
	Index of			Index of			Index of			Index of		
Year	Real Gross Value Added	Labour Input	Labour Productivity	Real Gross Value Added	Labour Input	Labour Productivity	Real Gross Value Added	Labour Input	Labour Productivity	Real Gross Value Added	Labour Input	Labour Productivity
1963	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1964	.932	1.003	.929	.980	1.004	.976	1.050	1.018	1.031	1.021	1.017	1.005
1965	.945	1.003	.943	.996	.928	1.073	1.092	1.041	1.049	1.037	.995	1.042
1966	1.014	1.009	1.006	1.058	.973	1.087	1.026	.981	1.046	1.038	1.004	1.034
1967	.972	.937	1.037	1.075	.904	1.189	1.038	.952	1.091	1.033	.941	1.098
1968	.914	.820	1.115	.969	.718	1.349	1.186	.987	1.201	1.058	.828	1.277
1969	.983	.884	1.112	1.008	.681	1.481	1.332	1.113	1.197	1.146	.852	1.345
1970	.993	.847	1.173	.991	.615	1.611	1.163	1.022	1.138	1.087	.814	1.336
1971	.982	.694	1.415	.914	.518	1.765	1.278	.997	1.282	1.125	.721	1.561
Average Annual Productivity Increase 1963-1971	-.22%	-4.6%	4.33%	-1.1%	-8.2%	7.10%	3.1%	-.03%	3.1%	1.5%	-4.1%	5.57%

Appendix 1.

Definition of Variables Used in Productivity Study

1. GVA_t: gross value added for the industry measured in period t. This is equal to value of industry output less purchase of inputs, i.e. materials and supplies, electricity, etc.

2. NVA_t: net value added in period t. This is equal to gross value added minus current economic depreciation (measured via the proxy of accounting depreciation).

3. PI_t: this is a price index deflator to be used on either GVA or NVA to obtain the real value of the output series. The Gross National Expenditure implicit price index deflator is used for all industries except logging, where a specific logging price index was constructed.

4. y_t^G: real gross value added in t $= GVA_t/PI_t$

5. y_t^N: real net value added in t $= NVA_t/PI_t$

6. Y_t^G: index of real gross value added. It is constructed by taking the current value of real gross value added and dividing by real gross value added in the base year (1963), i.e. $Y_t^G = y_t^G/y_{1963}^G$.

7. Y_t^N: index of real net value added and is constructed as in (6) above.

8. $MH_{P,t}$: Labour input equal to manhours paid, production workers - from Statistics Canada.

9. $MH_{NP,t}$: Labour input, manhours paid, non-production workers - from Statistics Canada.

10. $MH_{T,t}$: total manhours paid $= MH_{P,t} + MH_{NP,t}$

11. $\bar{w}_o$: average wage rate in base period (1963). It is calculated as total compensation divided by total manhours paid.

12. ℓ_t: value of real labour services valued at compensation at the base period - unweighted,

    i.e. $\ell_t = \bar{w}_o \quad MH_{T,t}$

13. L_t: index of real labour services where $L_t = \dfrac{\ell_t}{\ell_{1963}}$

Appendix 1.

14. $WMH_{T,t}$: total manhours in period t, weighted for different labour efficiencies of productive and non-productive workers. The weight applied to non-production manhours is the average wage rate paid to these workers as of the base period divided by the average wage rate for all workers. A similar calculation is performed for production workers.

15. ℓ^*_t: value of real weighted labour services valued at compensation at the base period,

i.e. $\ell^*_t = \bar{w}_o \; WMH_{T,t}$

16. L^*_t: index of real weighted labour services where $L^*_t = \ell^*_t / \ell^*_{1963}$

17. k^G_t: real gross value of capital services in year t. This is calculated as the real value of mid-year gross capital stock in year t times the rate of return on gross capital measured in the base period.

18. K^G_t: index of real gross capital services where $K^G_t = \dfrac{k^G_t}{k^G_{1963}}$

19. k^N_t: real net value added of capital services in year t. This is calculated as the real value of mid-year net capital stock in year t times the rate of return on net capital measured in the base period.

20. K^N_t: index of real net capital services where

$$K^N_t = \frac{k^N_t}{k^N_{1963}}$$

21. F_t: index of total factor input in year t. This is calculated as the sum of the real value of labour services (either weighted or unweighted) and the real value of capital services (either gross or net) all divided by the sum of the labour and capital input measured at the base period, 1963. For example,

$$F_t = \frac{\ell^*_t + k^G_t}{\ell_{1963} + k^G_{1963}} \quad \text{or} \quad \frac{\ell_t + k^N_t}{\ell_{1963} + k^N_{1963}} \quad \text{or.............}$$

22. $P_{T,t}$: Total factor productivity index in year t. This is calculated as the index of real value added (either gross or net) divided by the index of total factor input. For example, $P_{T,t} = \dfrac{Y^N_t}{F_t}$

Appendix 2.

Table 1(a) - (e)	Gross value added (GVA_t)
	Net value added (NVA_t)
	Price index deflator (PI_t)
Table 2(a) - (e)	Labour input, production workers ($MH_{P,t}$)
	Labour input, non-production workers ($MH_{NP,t}$)
	Total manhours ($MH_{T,t}$)
	Unweighted value of real labour services (ℓ_t)
	Total weighted manhours ($WMH_{T,t}$)
	Weighted value of labour input (ℓ_t^*)
Table 3(a) - (e)	Capital services input data

Appendix 2

Table 1(a) - Logging

Basic data to calculate real value of output series

	Real GVA$_t$(1) ($000)	Real NVA$_t$(1) ($000)	P.I.$_t$(2)
1963	466,267	419,967	100.0
1964	474,523	425,087	107.0
1965	471,286	418,873	116.0
1966	467,526	413,999	130.8
1967	462,605	408,560	135.5
1968	472,978	417,199	138.6
1969	512,340	453,509	145.8
1970	485.317	425,109	143.8
1971	502,620	440,792	138.8

(1) Logging statistics from Statistics Canada, #25-201, table 1, deflated by logging price index.

(2) This index was constructed as follows: For those products shipped by establishments classified in the logging industry (SIC code 031) the quantities and value of shipments for the year 1963 were used to compute weights.

Let i be product category (e.g. logs and bolts, etc.).

Q_i be quantity in thousands of cubic feet solid wood of product i.

V_i be value of shipments of product i.

$\bar{P}_i = \frac{V_i}{Q_i}$ be average price of product i

W_i be weighting for product type i

then $W_i = \frac{\bar{P}_i}{\bar{P}_T} = \frac{\text{average price of product type i}}{\text{average total price} = \frac{V_i}{Q_i}}$

For each succeeding year, the weights W_i are applied to the quantities of wood chipped by their corresponding product category i. Summing these produces the total weighted quantity of chipment of wood products.

The total weighted quantity for each year is then multiplied by the average total price for 1963 to obtain the value of shipments at 1963 average prices and the logging industry price index.

Appendix 2

Table 1(b) - Mining Industries

(Mines, Quarries and Oil Wells)

Basic Data to calculate real value of output series

	Real GVA_t[1] ($000)	Real NVA_t[1] ($000)	$P.I._t$[2]
1963	2,055,552	1,793,352	100.0
1964	2,268,795	1,983,581	102.5
1965	2,376,436	2,065,584	105.8
1966	2,383,837	2,048,910	110.6
1967	2,553,874	2,190,166	114.9
1968	2,674,680	2,281,392	118.6
1969	2,708,081	2,283,059	123.9
1970	2,993,737	2,539,666	129.5
1971	2,866,115	2,377,007	133.5

(1) Deflated using G.N.E. implicit price index.

(2) G.N.E. implicit price index. Source - Statistics Canada, #13-001.

Appendix 2

Table 1(c) - Wood Industries

Basic Data to calculate real value of output series

	Real GVA_t[1] $000	Real NVA_t[1] $000	$P.I._t$[2]
1963	586,681	553,781	100.0
1964	619,258	584,729	102.5
1965	635,227	598,708	105.3
1966	646,789	608,816	109.6
1967	660,471	620,234	113.7
1968	714,075	673,283	127.4
1969	704,613	660,986	136.8
1970	651,331	604,185	123.1
1971	746,665	694,503	136.2

(1) Deflated using price index for wood industry.

(2) Wood Industries price index. Source - Prices and Price Indexes, Statistics Canada, 62-002.

Appendix 2

Table 1(d) - Paper and Allied Products

Basic Data to calculate real value of output series

	Real GVA_t (1) ($000)	Real NVA_t (1) ($000)	$P.I._t$ (2)
1963	1,193,397	1,062,397	100.0
1964	1,295,537	1,153,852	101.4
1965	1,339,174	1,183,072	101.9
1966	1,417,584	1,248,690	104.2
1967	1,362,815	1,188,315	107.0
1968	1,400,441	1,219,667	107.6
1969	1,574,930	1,389,258	111.0
1970	1,591,057	n.a.	114.2
1971	1,564,339	n.a.	115.3

(1) Deflated using price index, P.I.

(2) Paper and Allied Industries price index.

Appendix 2

Table 1(e) - Manufacturing

Basic data to calculate real value of output series

	Real GVA_t[1] ($000)	Real NVA_t[1] ($000)
1963	12,875,073	12,089,073
1964	13,899,692	13,069,930
1965	14,919,954	14,018,727
1966	15,606,018	14,637,097
1967	15,708,998	14,698,534
1968	16,428,005	15,371,353
1969	17,317,414	16,202,817
1970	16,538,802	n.a.
1971	17,369,199	n.a.

(1) Deflated using G.N.E. implicit Price Index - see Table 1(b).

Appendix 2

Table 2(a) - Logging

Basic data for calculation of labour input series using Man-hours paid

	$MH_{P,t}$ (000's)	$MH_{NP,t}$ (000's)	$MH_{T,t}$ (000's)	ℓ_t (1) ($000)	$WMH_{T,t}$ (2) (000's)	ℓ^*_t (3) ($000)
1963	123,146	14,559	137,705	275,475	137,705	275,475
1964	127,359	14,749	142,108	284,284	142,021	284,110
1965	122,571	15,055	137,626	275,318	137,723	275,512
1966	123,651	16,879	140,530	281,127	140,983	282,034
1967	115,876	17,094	132,970	266,004	133,663	267,390
1968	102,000	16,657	118,657	237,371	119,605	239,267
1969	104,946	18,130	123,076	246,211	124,260	248,580
1970	100,235	16,645	116,880	233,816	117,870	235,796
1971	88,740	15,942	104,682	209,414	105811	211,673

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(1) $\ell_t = MH_{T,t}$ times average 1963 wage of $2.00048

(2) $WMH_{T,t} = .975 \times MH_{P,t} + 1.210\ MH_{NP,t}$ The weight for non-production workers is the average 1963 wage for non-production workers of $2.42 divided by the total average wages. The average wage in 1963 for production workers is $1.95.

(3) $\ell^*_t = WMH_{T,t}$ times average 1963 wage.

Appendix 2

Table 2(b) - Mining

Basic data for calculation of labour input series using Man-hours paid

	$MH_{P,t}$ (000's)	$MH_{NP,t}$ (000's)	$MH_{T,t}$ (000's)	ℓ_t (1) ($000)	$WMH_{T,t}$ (2) (000's)	ℓ^*_t (3) ($000)
1963	154,823	49,232	204,055	508,816	204,055	508,816
1964	157,227	50,170	207,397	517,149	207,448	517,277
1965	162,542	53,610	216,152	538,980	216,717	540,389
1966	158,156	58,250	216,406	539,614	218,745	545,446
1967	159,182	59,432	218,614	545,119	221,205	551,580
1968	160,346	62,088	222,434	554,644	225,698	562,783
1969	151,072	63,896	214,968	536,028	219,630	547,653
1970	164,835	68,060	232,895	580,729	237,495	592,199
1971	158,835	70,115	228,950	570,892	234,715	585,267

(1) $\ell_t = MH_{T,t}$ times the average 1963 wage of $2.49352

(2) $WMH_{T,t} = .906506 \times MH_{P,t} + 1.29402 \times MH_{NP,t}$ The average wage rates for 1963 were $2.26039 for production workers and $3.22666 for non-production workers.

(3) $\ell^*_t = WMH_{T,t}$ times the 1963 average wage rate.

Appendix 2

Table 2(c) - Wood Products

Basic data for calculation of labour input series for Man-hours paid

	$MH_{P,t}$ (000's)	$MH_{NP,t}$ (000's)	$MH_{T,t}$ (000's)	ℓ_t (1) ($000)	$WMH_{T,t}$ (2) (000's)	ℓ_t^{*} (3) ($000)
1963	155,521	29,228	184,749	340,748	184,749	340,748
1964	164,329	27,308	191,637	353,452	190,504	351,362
1965	169,301	27,454	196,755	362,892	195,372	360,341
1966	168,990	26,578	195,568	360,702	193,927	357,676
1967	165,380	25,886	191,266	352,768	189,620	349,732
1968	165,147	26,306	191,453	353,113	189,953	350,346
1969	168,589	26,786	195,375	360,346	193,824	357,486
1970	157,534	26,216	183,750	338,905	182,676	336,925
1971	165,368	27,926	193,294	356,508	192,295	354,666

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(1) $\ell_t = MH_{T,t}$ times average total wage in 1963 of $1.8444

(2) $WMH_{T,t} = .9404 \times MH_{P,t} + 1.3169 \times MH_{NP,t}$ The average wage rates for 1963 were $1.7346 for production workers and $2.4288 for non-production workers.

(3) $\ell_t^{*} = WMH_{T,t}$ times the average 1963 wage.

Appendix 2

Table 2(d) - Paper and Allied Products

Basic data for calculation of labour input series using Man-hours paid

	$MH_{P,t}$ (000's)	$MH_{NP,t}$ (000's)	$MH_{T,t}$ (000's)	ℓ_t (1) ($000)	$WMH_{T,t}$ (2) (000's)	ℓ_t^* (3) ($000)
1963	169,733	49,581	219,314	541,195	219,314	541,195
1964	179,309	51,817	231,126	570,343	230,962	569,938
1965	184,072	54,467	238,539	588,636	238,742	589,137
1966	194,400	59,126	253,526	625,619	254,208	627,302
1967	194,857	60,565	255,422	630,298	256,484	632,918
1968	192,309	61,133	253,442	625,412	254,886	628,975
1969	200,019	62,941	262,960	648,899	264,274	652,142
1970	195,536	63,234	258,770	638,559	260,551	642,954
1971	191,811	61,616	253,427	625,375	255,054	629,390

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(1) $\ell_t = MH_{T,t}$ times 1963 average total wage of $2.4677

(2) $WMH_{T,t} = .91494 \times MH_{P,t} + 1.2912 \times MH_{NP,t}$ The average wage rates for 1963 were $2.2578 for production workers and $3.1863 for non-production workers.

(3) $\ell_t^* = WMH_{T,t}$ times the average total wage in 1963.

Appendix 2

Table 2(e) - Total Manufacturing

Basic data for calculation of labour input series using Man-hours paid

	$MH_{P,t}$ (000's)	$MH_{NP,t}$ (000's)	$MH_{T,t}$ (000's)	ℓ_t (1) ($000)	$WMH_{T,t}$ (2) (000's)	ℓ_t^* (3) ($000)
1963	2,137,977	877,498	3,015,475	6,495,289	3,015,475	6,495,289
1964	2,265,188	902,210	3,167,398	6,822,529	3,159,972	6,806,533
1965	2,384,002	945,167	3,329,169	7,170,981	3,320,177	7,151,613
1966	2,498,012	984,008	3,482,020	7,500,220	3,470,885	7,476,235
1967	2,478,916	1,007,086	3,486,002	7,508,797	3,483,196	7,502,753
1968	2,458,791	1,002,822	3,461,613	7,456,264	3,459,884	7,452,539
1969	2,515,183	1,009,726	3,524,909	7,592,602	3,518,804	7,579,452
1970	2,450,058	977,471	3,427,529	7,382,847	3,419,935	7,366,490
1971	2,448,419	958,036	3,406,455	7,337,454	3,393,807	7,310,211

(1) $\ell_t = MH_{T,t}$ times average total wage rate in 1963 of $2.15399

(2) $WMH_{T,t} = .88942 \times MH_{P,t} + 1.2694 \times MH_{NP,t}$ The average wage rates for 1963 were $1.91579 for production workers and $2.7343 for non-production workers.

(3) $\ell_t^* = WMH_{T,t}$ times average 1963 wage.

Appendix 2.

Table 3(a) - Logging.

Basic data to obtain real value of Capital Services Input

	(1) Value of Gross Stock of Capital in constant 1963 $000	(2) Value of Gross Capital Services Input in constant 1963 $000 [2] k_t^G	(3) Value of Net Stock of Capital in constant 1963 $000 [3]	(4) Value of Net Capital Services Input in constant 1963 $000 [4] k_t^N
1963	804,400	190,792	470,900	144,492
1964	848,938	201,356	494,332	151,682
1965	896,052	212,531	527,272	161,789
1966	926,395	219,727	552,454	169,516
1967	948,446	224,958	567,567	174,154
1968	980,198	232,489	577,121	177,085
1969	1,026,296	243,423	596,389	182,997
1970	1,058,916	251,159	610,755	187,405
1971	1,091,550	258,900	617,830	189,576

(1) To obtain value of gross stock of capital the mid-year gross stock of capital for buildings, engineering and machinery and equipment were summed and deflated by the appropriate implicit price index. The price indexes were obtained from Statistics Canada, #62-002, Table 20.

(2) The value of capital services was obtained by multiplying values in column (1) by the following ratio:

$$\frac{\text{real GVA}_{1963} - \text{labour value in 1963}}{\text{real value of gross stock of physical capital in 1963}} = \frac{466267-275475}{804400} = .2372$$

(3) The real value of net stock was obtained by subtracting from column (1) the real value of economic depreciation in each year.

(4) Column (4) was obtained by multiplying column (3) by the following ratio:

$$\frac{\text{real NVA}_{1963} - \text{labour value in 1963}}{\text{1963 value of net stock of physical capital}} = \frac{419967-275475}{470900} = .30684$$

Appendix 2.

Table 3(b) - Mining.

Basic data to obtain real value of Capital Services Input

	(1) Value of Gross[(1)] Stock of Capital in constant 1963 $000	(2) Value of Gross[(2)] Capital Services in constant 1963 $000	(3) Value of Net[(3)] Capital Stock in constant 1963 $000	(4) Value of Net[(4)] Capital Services in constant 1963 $000
1963	6,637,700	1,546,736	4,676,800	1,284,536
1964	7,215,755	1,681,436	5,019,135	1,378,562
1965	7,858,868	1,831,296	5,404142	1,484,309
1966	8,497,564	1,980,127	5,824,556	1,599,780
1967	9,263,787	2,158,674	6,350,744	1,744,304
1968	10,035,399	2,338,478	6,847,727	1,880,806
1969	10,859,122	2,530,424	7,360,880	2,021,749
1970	11,647,532	2,714,142	7,855,958	2,157,728
1971	12,602,849	2,936,752	8,497,442	2,333,919

(1) See footnote (1), Table 3(a).

(2) Capital services is obtained by multiplying column (1) by the value of .233023 (see footnote (2), Table 3(a)).

(3) See footnote (3), Table 3(a).

(4) Capital services is obtained by multiplying column (3) by the value of .274661 (see footnote (4), Table 3(a)).

Appendix 2.

Table 3(c) - Wood Industries

Basic data to obtain real value of Capital Services Input

	(1) Value of Gross Stock of Capital [(1)] in constant 1963 $000	(2) Value of Gross Capital Services [(2)] in constant 1963 $000	(3) Value of Net Capital Stock [(3)] in constant 1963 $000	(4) Value of Net Capital Services [(4)] in constant 1963 $000
1963	907,700	245,933	530,700	213,033
1964	949,782	257,335	553,136	222,039
1965	996,677	270,041	580,341	232,960
1966	1,045,191	283,185	600,496	241,050
1967	1,103,644	299,022	634,307	254,623
1968	1,117,803	302,858	639,780	256,820
1969	1,194,508	323,641	688,180	276,248
1970	1,289,393	349,349	757,090	303,910
1971	1,421,599	385,169	846,703	339,883

(1) See footnote (1), Table 3(a).

(2) Capital services is obtained by multiplying column (1) by the value .270941 (see footnote (2), Table 3)).

(3) See footnote 3, Table 3(a).

(4) Capital services is obtained by multiplying column (3) by the value .4014189 (see footnote (4), Table 3(a)).

Appendix 2.

Table 3(d) - Paper and Allied Products

Basic data to obtain real value of Capital Services Input

	(1) Value of Gross Stock of Capital in constant 1963 $000 [1]	(2) Value of Gross Capital Services in constant 1963 $000 [2]	(3) Value of Net Capital Stock in constant 1963 $000 [3]	(4) Value of Net Capital Services in constant 1963 $000 [4]
1963	3,683,000	652,202	2,176,000	521,202
1964	3,909,428	692,299	2,312,326	553,855
1965	4,291,795	760,010	2,553,739	611,679
1966	4,632,624	820,366	2,790,176	668,311
1967	4,822,744	854,033	2,935,036	703,009
1968	5,017,553	888,531	3,038,448	727,778
1969	5,179,130	917,143	3,115,990	746,351
1970	n.a.	n.a.	n.a.	n.a.
1971	n.a.	n.a.	n.a.	n.a.

(1) See footnote (1), Table 3(a).

(2) Capital services is obtained by multiplying column (1) by the value .17708 (see footnote 2, Table 3(a)).

(3) See footnote 3, Table 3(a).

(4) Capital services is obtained by multiplying column (3) by the value .23952 (see footnote (4), Table 3(a)).

Appendix 2.

Table 3(e) - Total Manufacturing

Basic data to obtain real value of Capital Services Input

	(1) Value of Gross[(1)] Stock of Capital in constant 1963 $000	(2) Value of Gross[(2)] Capital Services in constant 1963 $000	(3) Value of Net[(3)] Capital Stock in constant 1963 $000	(4) Value of Net[(4)] Capital Services in constant 1963 $000
1963	22,760,000	6,379,784	14,022,000	5,593,784
1964	23,800,238	6,671,370	14,667,641	5,851,349
1965	25,737,110	7,214,288	15,900,258	6,343,076
1966	27,541,127	7,719,967	17,098,805	6,821,211
1967	28,535,219	7,998,617	17,762,985	7,086,172
1968	29,806,593	8,354,992	18,480,366	7,372,356
1969	31,358,031	8,789,871	19,342,494	7,716,284
1970	n.a.	n.a.	n.a.	n.a.
1971	n.a.	n.a.	n.a.	n.a.

(1) See footnote (1), Table 3(a).

(2) Capital services is obtained by multiplying column (1) by the value .280307 (see footnote (2), Table 3(a)).

(3) See footnote (3), Table 3(a).

(4) Capital services is obtained by multiplying column (3) by the value .398929 (see footnote (4), Table 3(a)).

Appendix 3

Net Value Added Basis Tables

Appendix 3.

Table 1.

Total Manufacturing Industries
Indexes of Value Added, Capital and Total
Factor Inputs, Net Basis: Base = 1963.

Year	Index of Real Net Value Added	Net Total Capital Services Input Index	Index of Total Factor Labour Unweighted	Index of Total Factor Labour Weighted
1963	1.000	1.000	1.000	1.000
1964	1.081	1.046	1.048	1.047
1965	1.160	1.134	1.118	1.116
1966	1.211	1.219	1.185	1.183
1967	1.216	1.267	1.207	1.207
1968	1.272	1.318	1.227	1.226
1969	1.340	1.379	1.266	1.265
1970	n.a.	n.a.	n.a.	n.a.
1971	n.a.	n.a.	n.a.	n.a.
Average Annual Change				
1963-1971	-	-	-	-
1963-1968	4.81	5.52	4.09	4.08
1963-1969	4.88	5.36	3.93	3.92

Appendix 3.

Table 2.

Total Manufacturing Industries
Productivity Indexes, Labour, Capital and Total
Factor, Net Value Added Basis: Base = 1963.

Year	Labour Productivity Indexes: Labour Unweighted	Labour Productivity Indexes: Labour Weighted	Capital Productivity Index	Total Factor Productivity Indexes: Labour Unweighted	Total Factor Productivity Indexes: Labour Weighted
1963	1.000	1.000	1.000	1.000	1.000
1964	1.030	1.031	1.033	1.031	1.032
1965	1.051	1.054	1.023	1.038	1.039
1966	1.048	1.052	.993	1.022	1.024
1967	1.052	1.053	.960	1.007	1.007
1968	1.108	1.109	.965	1.037	1.038
1969	1.146	1.148	.972	1.058	1.059
1970	n.a.	n.a.	n.a.	n.a.	n.a.
1971	n.a.	n.a.	n.a.	n.a.	n.a.
Average Annual Change					
1963-1971	-	-	-	-	-
1963-1968	2.05	2.07	-.71	.73	.75
1963-1969	2.27	2.30	-.47	.94	.96

Appendix 3.

Table 3.

Logging Industry
Indexes of Value Added, Capital, and Total
Factor Inputs, Net Basis: Base = 1963.

Year	Real Net Value Added Index	Real Net Capital Services Index	Index of Total Factor Inputs: Labour Unweighted	Index of Total Factor Inputs: Labour Weighted
1963	1.000	1.000	1.000	1.000
1964	1.012	1.050	1.038	1.038
1965	.997	1.120	1.041	1.041
1966	.986	1.173	1.073	1.075
1967	.973	1.205	1.048	1.051
1968	.993	1.226	.987	.991
1969	1.080	1.266	1.022	1.028
1970	1.012	1.297	1.003	1.008
1971	1.050	1.312	.950	.955
Average Annual Change				
1963-1971	.61%	3.39%	-.64%	-.58%
1963-1968	-.14	4.08	-.26	-.18
1963-1969	1.28	3.93	.36	.46

Appendix 3.

Table 4.

Logging Industry
Productivity Indexes, Labour, Capital, and
Total Factor, Net Value Added Basis:
Base = 1963.

Year	Labour Productivity Index		Capital Productivity Index	Total Factor Productivity	
	Manhours Unweighted	Manhours Weighted		Labour Unweighted	Labour Weighted
1963	1.000	1.000	1.000	1.000	1.000
1964	.981	.981	.964	.975	.975
1965	.998	.997	.890	.958	.958
1966	.966	.963	.841	.919	.917
1967	1.007	1.002	.807	.928	.926
1968	1.153	1.144	.810	1.006	1.002
1969	1.208	1.197	.853	1.057	1.051
1970	1.193	1.183	.780	1.009	1.004
1971	1.381	1.366	.800	1.105	1.099
Average Annual Change					
1963-1971	4.04%	3.90%	-2.79%	1.25%	1.18%
1963-1968	2.85	2.69	-4.21	.12	.04
1963-1969	3.15	3.00	-2.65	.92	.83

Appendix 3.

Table 5.

Mining Industry
Indexes of Value Added, Capital, and
Total Factor Inputs, Net Basis:
Base = 1963.

Year	Net Value Added	Capital Input	Total Factor Manhours Unweighted	Total Factor Manhours Weighted
1963	1.000	1.000	1.000	1.000
1964	1.106	1.073	1.057	1.057
1965	1.152	1.156	1.128	1.129
1966	1.143	1.245	1.193	1.196
1967	1.221	1.358	1.277	1.280
1968	1.272	1.464	1.358	1.363
1969	1.273	1.574	1.426	1.433
1970	1.416	1.680	1.527	1.533
1971	1.325	1.817	1.620	1.628
Average Annual Percent Change				
1963-1971	3.52	7.46	6.03	6.09
1963-1968	4.81	7.62	6.12	6.19
1963-1969	4.02	7.56	5.91	6.00

Appendix 3.

Table 6.

Mining Industry
Productivity Indexes, Labour, Capital, and
Total Factor, Net Value Added Basis:
Base = 1963.

	Labour Productivity			Total Factor	
Year	Manhours Unweighted	Manhours Weighted	Capital	Manhours Unweighted	Manhours Weighted
1963	1.000	1.000	1.000	1.000	1.000
1964	1.088	1.088	1.031	1.046	1.046
1965	1.087	1.085	.997	1.021	1.020
1966	1.077	1.066	.917	.958	.955
1967	1.140	1.127	.899	.957	.954
1968	1.167	1.150	.869	.937	.934
1969	1.208	1.183	.809	.893	.889
1970	1.241	1.217	.843	.927	.924
1971	1.181	1.152	.729	.818	.814
Average Annual Percent Change					
1963-1971	2.08	1.77		-2.51	-2.57
1963-1968	3.09	2.80	-2.81	-1.30	-1.37
1963-1969	3.15	2.80	-3.53	-1.89	-1.96

Appendix 3.

Table 7.

Wood Products Industry
Indexes of Value Added, Capital, and Total
Factor Inputs, Net Basis: Base = 1963.

Year	Net Value Added	Capital	Total Factor Manhours Unweighted	Total Factor Manhours Weighted
1963	1.000	1.000	1.000	1.000
1964	1.056	1.042	1.039	1.035
1965	1.081	1.094	1.076	1.071
1966	1.099	1.132	1.087	1.081
1967	1.120	1.195	1.097	1.091
1968	1.216	1.206	1.101	1.096
1969	1.194	1.297	1.150	1.144
1970	1.091	1.427	1.161	1.157
1971	1.254	1.595	1.258	1.254
Average Annual Percent Change				
1963-1971	2.83	5.84	2.87	2.83
1963-1968	3.91	3.75	1.92	1.83
1963-1969	2.96	4.33	2.33	2.24

Appendix 3.

Table 8.

Wood Products Industry
Productivity Indexes, Labour, Capital, and
Total Factor, Net Value Added Basis:
Base = 1963.

	Labour Productivity			Total Factor	
Year	Manhours Unweighted	Manhours Weighted	Capital	Manhours Unweighted	Manhours Weighted
1963	1.000	1.000	1.000	1.000	1.000
1964	1.018	1.024	1.013	1.016	1.020
1965	1.015	1.022	.988	1.005	1.009
1966	1.039	1.047	.971	1.012	1.017
1967	1.082	1.091	.937	1.019	1.026
1968	1.173	1.182	1.008	1.104	1.109
1969	1.129	1.138	.921	1.038	1.043
1970	1.097	1.103	.765	.940	.943
1971	1.200	1.205	.786	.997	.999
Average Annual Percent Change					
1963-1971	2.28	2.33	-3.01	-.04	-.01
1963-1968	3.19	3.34	.16	1.98	2.07
1963-1969	2.02	2.15	-1.37	.62	.70

Appendix 3.

Table 9.

Paper and Allied Products Industry
Indexes of Value Added, Capital, and Total
Factor Inputs, Net Basis: Base = 1963.

Year	Net Value Added	Capital	Total Factor Manhours Unweighted	Total Factor Manhours Weighted
1963	1.000	1.000	1.000	1.000
1964	1.086	1.063	1.058	1.058
1965	1.114	1.174	1.130	1.130
1966	1.175	1.282	1.218	1.220
1967	1.119	1.349	1.255	1.257
1968	1.148	1.396	1.274	1.277
1969	1.308	1.432	1.313	1.316
1970	n.a.	n.a.	n.a.	n.a.
1971	n.a.	n.a.	n.a.	n.a.
Average Annual Percent Change				
1963-1971	n.a.	n.a.	n.a.	n.a.
1963-1968	2.76%	6.67%	4.85%	4.89%
1963-1969	4.48%	5.98%	4.54%	4.58%

Appendix 3.

Table 10.

Paper and Allied Products Industry
Productivity Indexes, Labour, Capital, and Total
Factor, Net Value Added Basis: Base = 1963.

	Labour			Total Factor	
Year	Manhours Unweighted	Manhours Weighted	Capital	Manhours Unweighted	Manhours Weighted
1963	1.000	1.000	1.000	1.000	1.000
1964	1.054	1.053	1.022	1.026	1.026
1965	1.081	1.082	.949	.986	.986
1966	1.143	1.146	.917	.965	.963
1967	1.142	1.145	.830	.892	.890
1968	1.131	1.138	.822	.901	.899
1969	1.188	1.195	.913	.996	.994
1970	n.a.	n.a.	n.a.	n.a.	n.a.
1971	n.a.	n.a.	n.a.	n.a.	n.a.
Average Annual Percent Change					
1963-1971	n.a.	n.a.	n.a.	n.a.	n.a.
1963-1968	2.46%	2.59%	-3.92%	-2.09%	-2.13%
1963-1969	2.87%	2.97%	-1.52%	-.07%	-.10%

ORGANIZATION FACTORS AFFECTING INNOVATION IN THE FOREST HARVESTING INDUSTRY.

Mansfield's[1] research into technological change and innovation has considered several facets. The first is the use of total factor productivity indices to measure the effectiveness of innovation for an industry. Total factor productivity considers the change in output in relation to the total input comprised of both labour and capital. The report entitled, "Total Factor Productivity as a Measure of Innovation in the Forest Harvesting Industry", indicates that the Logging industry may not have been very effective in obtaining a reasonable return on its investment in capital equipment as capital has been substituted for labour. Since the rate of substitution of capital for labour was high between 1963 and 1971, the logging industry's effectiveness in increasing productivity was nearly zero, considerably below that of total manufacturing in Canada.

The second facet introduced by Mansfield is composed of the environmental influence on the industry. These consist of the labour supply, legal constraints, quantity and quality of capital equipment available from manufacturers, the market structure, governmental and other public influences, the resource base, and the amount of research and development conducted in universities and other external agencies. The industry can interact with and influence directly the amount of research and development conducted outside, its labour supply and the quantity and quality of equipment available from manufacturers.

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[1]Mansfield, E. The Economics of Technological Change. Mew York: W.W. Norton, 1968. Mansfield, E. Industrial Research and Technological Innovation: An Econometric Analysis. N.Y.: W.W. Norton, 1968. Mansfield, E., Rapoport, J., Schnee, J., Wagner, S., & Hamburger, M. Research and Innovation in the Modern Corporation. N.Y.: W.W. Norton, 1971.

However, the industry needs to place primary emphasis on adaptation to governmental, public and legal constraints and a changing resource base. The market structure for the logging industry as an external influence would appear initially to fit the latter - or adaptation - category since logging feeds directly into two primary manufacturing industries, wood products and paper and allied products. However, the logging industry is becoming increasingly integrated into both the wood products and paper and allied products industries so that changes in one interact directly with the others and can produce improved productivity across all three.

The third facet which Mansfield postulates as affecting technological change is composed of factors internal to the organization. These include the organization structure, management systems (decision processes, style and characteristics), and employee characteristics. Legendre[2] summarized many of these internal factors in a paper suggesting changes in organization structure, leadership style and compensation.

Contemporary organization theory combines the analysis of the internal environments by relating it directly to the external environment. For example, centralization, standardization, and formalization as organization structure variables are taken from Weber's Theory of Bureaucracy, but these are primarily internal structural considerations. Thompson[3] and Lorsch[4] relate internal segments of the organization to

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[2] Legendre, C. Improving productivity: expensive hardware, better qualified workers, how about organization? Paper presented at the 54th Annual Meeting of the Woodlands Section, Canadian Pulp and Paper Association, Montreal, Quebec, March 18-22, 1973.

[3] Thompson, J.D. Organization in Action. New York: McGraw Hill, 1967.

[4] Lorsch, J.W. Product Innovation and Organization. New York: Macmillan, 1965.

segments of the external environment. As any segment of the external environment, such as harvesting equipment manufacturers, becomes more and more critical to the operation of the organization, the organization must develop an increasingly effective ability to interact effectively with that aspect of the environment. Lawrence and Lorsch[5] use the term differentiation to describe the identification of a functional group (department) which must be developed to work with a segment of the environment which is of primary importance to the effectiveness of the organization. When there is little change in the external environment, the organization interacts with it in a very simple, routine manner, but as the external environment becomes more and more dynamic, the organization must develop increasingly flexible and sophisticated means of interaction[6]. In logging, equipment manufacturers progressed slowly during the 1950s to introduce the skidder, as a simple replacement for a current method. This did not force the harvesting system to change. Thus logging organizations could respond in a simply structured, decentralized fashion. Suddenly equipment development activities mushroomed to introduce many new machines and methods of harvesting wood. Whether the logging industry has changed its organization structure and managerial methods sufficiently to adapt effectively to innovation in logging equipment is a question not fully answered by the industry data provided in "Total Factor Productivity as a measure of Innovation in the Forest Harvesting Industry". The data in that report only indicates that capital

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[5] Lawrence, P.R. and Lorsch, J.W. Organization and Environment: Managing Differentiation and Integration. Boston: Harvard University, 1967.

[6] Burns, T. and Stalker, G.M. The Management of Innovation. London: Tavistock Publications, 1961. Lynton, R.P. Linking an innovative subsystem into the system. Administrative Science Quarterly, 1969, 14, 398-414.

input has not been substituted effectively for labour input.

For a pilot comparison of the structures of innovative and less innovative logging organizations, the division of labour (specialization) and centralization variables of Pugh and his associates[7] were included in structured interviews which also involved the capital investment decision process of the firm. Concurrently the logging organizations were asked to provide the labour and capital input and output data necessary to develop a total factor productivity index for each firm as a measure of that firm's effectiveness in innovation[8]. Nine firms involved in logging in Quebec and Ontario offered to cooperate with our research, and data from seven of these were used in our analysis. Eight British Columbia firms participated along with two from the northwestern United States. Only the data from the B.C. firms could be used in the analysis.

I. INNOVATION IN FOREST HARVESTING FIRMS

An invention has no significance until it is applied[9], and the initial application, an innovation, is expensive and time consuming. However to compensate for the inconvenience successful innovators grow faster than less innovative firms as a result of innovation[10]. Thus investment in new technology appears to be worthwhile. To study what constitutes effective

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[7] Pugh, D.S., Hickson, D.J., Hinings, C.R., and Turner, C. Dimensions of Organization Structure. Administrative Science Quarterly, 1968, 13, 65-105.

[8] Mansfield, E. The Economics of Technological Change. op. cit.

[9] Mansfield, et al, op. cit.

[10] Mansfield, E. Industrial Research and Technological Innovation. op. cit.

innovation in new forest harvesting systems, equipment, and methods, it was assumed that effective innovation would create a growth in productivity equal to or greater than that for total manufacturing in Canada. For example, the capital input must not increase as rapidly as the output when the labour input relationship is constant or labour input should not be displaced by capital input on a one to one ratio.

Few attempts have been made to develop a total factor productivity index at the level of the individual firm, but two references were available. Craig and Harris[11] proposed using total productivity measurement as a means of evaluating trade-offs between various inputs such as better material for less labour, etc. to show a return on invested capital. Olley[12] compared Bell Canada with selected industries to support its brief to the Canadian Transport Commission that Bell's over-all productivity was increasing. Both assumed that management was equally effective in using the various inputs while the interpretation of our data is that the Logging industry has not been as effective in utilizing its capital as it has been in managing its labour input. It is inferred that the limitations in managing the capital input are the result of ineffective processes for managing innovation. It was not feasible to develop total factor productivity indices for each firm because only four of our sample of fifteen wereable to provide adequate capital services data as requested (see Table I-1).

Future work will include the development of substitute measures of innovation such as the following:

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[11]Craig, C.E. and Harris, R.C. Total Productivity Measurement at the Firm Level. Sloan Management Review, 1973, 14 (3), 13-29.

[12]Olley, R.E. Application to Canadian Transport Commission. Part B. February, 1974.

TABLE I-1.

DATA REQUIRED FOR PRODUCTIVITY ANALYSIS OF LOGGING OPERATIONS

The following data are required for the logging operations managed by your firm for the period 1963-1971. Annual breakdowns are necessary.

1) Physical quantities (by type of product, in cunits, is possible) of shipments of goods of own production.

2) Value of shipments of goods produced, net of allowances, sales taxes, excise taxes and duties, and charges for outward transportation by common or contract carriers. Include revenue from repair work and amounts received in payment for work done on materials owned by other establishments.

3) Non-logging revenues (a) depreciable fixed assets produced by own work force for own use; (b) revenue from sale of purchased wood residue (wood chips, etc.). Exclude non-operating revenue such as real property rentals, dividends, interest.

4) Laid down cost of fuel and electricity, and materials and supplies purchased for logging operations only. This should include maintenance and repair supplies not chargeable to fixed assets accounts, and any amounts paid to others for logging work done on a contract basis.

5) Costs of non-logging commodity inputs such as cost of goods purchased for resale and cost of materials and supplies used in the performance of repair work or work done on materials for other establishments.

6) Employees:

   (a) Production and related workers - logging activity
      (i) Number of employees
      (ii) Manhours paid
      (iii) Wages in dollars

   (b) Total employees
      (i) number of employees
      (ii) total salaries and wages

7) Inventories:

   (a) Goods produced - value of inventories of wood produced in Canada; opening and closing figures.
   (b) Goods purchased for resale - value of inventories of goods purchased for resale; opening and closing figures. Inventories owned in Canada only.

8) Fixed Capital:

   (a) Year-end Gross Fixed Capital Stock
   (b) Year-end Net Fixed Capital Stock
   (c) Capital Comsumption Allowance

1. Identification of those firms which:

   a. At least partially funded the research and development of a new harvesting machine or system.

   b. Cooperated with equipment manufacturers in the test of a prototype.

   c. Were first in evaluating/acquiring an invention.

   d. First evaluated/acquired an invention which became successful in contrast to those who evaluated/acquired an invention which phased out of existence before it was financially successful.

2. The amount of time and/or money used to "debug" an innovation, i.e. when it achieves its optimum achievable output.

3. The per cent availability of present equipment.

4. The change in capital investment for forest harvesting equipment and systems.

Data appear to be available on the leasing and purchase of new equipment by forest harvesting organizations[13].

II. RESEARCH AND DEVELOPMENT IN LOGGING EQUIPMENT AND SYSTEMS.

Eight British Columbia based and seven Ontario and Quebec forest product firms were interviewed about their research and development budgets and activities (see Appendix 1 for the interview outline). One executive indicated that no research was being done in Canada by forest products firms. This statement might be construed as true if the very small investment in

[13] Silversides, C.R. Personal Communication. February 20, 1975.

Research and Development is compared to total output or even capital investment.

The principle effort was in applied development activities where minor modifications are made to existing equipment. The amount of effort was normally small enough that the cost is absorbed as a part of budgeted maintenance expense. In isolated instances modifications were done again and again until a relatively new piece of equipment evolved. Eleven companies reported this kind of activity, and there were no regional differences.

Several firms also considered the lease and trial of new equipment and related economic studies as experimentation -- a type of research and development activity if it affected the harvesting system. Some firms budgeted for this activity on a project basis, others absorbed it in their general operating budget. Such projects were usually assigned to a superintendent to be tried as part of his usual day-to-day operations, but special assistance was not made available to him.

All seven Eastern firms reported cooperation with equipment evaluation studies by the Pulp and Paper Research Institute of Canada or with manufacturers. Three of these reported that funds were provided to PPRIC for research and development.

Two Western firms identified ad hoc projects which were extensive enough systems changes or machine designs to be considered as research. In each case the projects were promoted and followed-up at the woodlands executive level.

It appears that not only is the financial investment in research and development small, but the effort is not a continuing one as required to achieve results in such long range activities. Development and experimentation activities receive a limited amount of management attention because responsibility for the activity is divided amongst maintenance expenses, staff personnel (Logging Development Manager), and all levels of operations while the latter must also spend full time on normal operations. Under such circumstances it is difficult to develop the technical skills essential to manage effectively increasing amounts of capital equipment and to contribute innovative ideas for capital expenditures.

III. THE CAPITAL INVESTMENT PROCESS

Fifteen firms, eight headquartered in British Columbia (West) and seven in Ontario and Quebec (East), participated in complete interviews involving the process used to decide upon, implement and evaluate capital investments (see Appendix 2 for the interview outline). Sections 1 through 4 describe the process used in developing ideas about potential capital investments and deciding which ones to fund. Section 5 describes the methods used for implementing the decisions while section 6 describes the evaluation of the decisions after implementation.

This aspect of the pilot study was difficult to analyze since many firms were systematic in developing and implementing replacement and additions like their present equipment but were not systematic in developing proposals for new or innovative equipment or systems.

1. Developing Capital Investment Ideas.

Most capital investment ideas came from lower level operating personnel looking at short-term operating problems. Their emphasis was on replacement and additions (for expansion) of present equipment. These individuals obtained ideas from site visits made by equipment manufacturing representatives. Some reference was also made to trade journals, trade fairs and industry meetings, but the major secondary source was visits to other companies.

At times there were specialized personnel who appeared to be clearly responsible for new ideas and maintaining contact with manufacturers, but the responsibility was normally very diffuse. Executive level personnel entered the process when a major system change or capital investment was involved.

No firm had access to its own research or advanced development technology. In the East there were several references to the Logging Operations Group (LOG) committee of the CPPA, manufacturers trade fairs and industrial association meetings.

The development of innovative ideas appears to be a weak area within the capital investment decision process without research, development, or high technology personnel directly responsible for such an activity.

2. Developing a Capital Investment Proposal.

Capital investment requirements[14] appeared to be typically based on a logging plan, i.e. the volume to be produced, derived from a combination of mill (customer) requirements and the allowable cut (foresters). Using current productivity, equipment availability and maintenance costs, the field personnel developed a replacement schedule with cost estimated. Additional equipment, similar to that already in use, was also included to achieve required productivity goals. In many firms the lower level of supervision was also expected to propose expenditures for new equipment which would be compatible with the present system, but this step at the camp level primarily produced requests for replacements and additions.

For those firms using contract logging as well as those using their own equipment, requests for capital investments on total new equipment and/or those requiring changes in the system of logging occurred at the middle management or executive level. Typically a Maintenance Superintendent,

[14] Firms that leased equipment prepared capital budgets in a similar manner to those who purchased it.

Equipment Coordinator or Logging Development Manager was expected to aid operations middle management or executives in proposing new equipment. Special project teams to evaluate new systems or new equipment were set up in only three firms to aid in proposing new capital equipment purchases.

Since the primary source of capital investment proposals was lower level field supervision, who were expected to concentrate on short-term operating problems and were limited in their authority to initiate capital expenditures, innovative proposals for equipment are limited. Lower level personnel in most organizations are not aware of corporate problems, impact or capability. In addition, when support to implement new technology is not present, operating supervisors will limit the risk in developing capital proposals by concentrating on familiar equipment.

The final proposal for woodlands capital expenditures was compiled at the executive level in the woodlands division and submitted to an appropriation committee, chief financial officer, and/or chief executive officer of the firm for review prior to formal approval by the Board of Directors. No firm reported that the capital expenditures proposal had been returned to the woodlands executive level with a request that it be cut back. In most interviews the comment was made that the executive level above woodlands was composed of non-woodlands personnel so they could not evaluate the proposal effectively anyway.

The time interval covered in the capital budget was primarily one year although two firms reported a five year plan, two others prepared three year plans and one handled each acquisition on an ad hoc basis. The amount of time taken to prepare the capital investment plan was one to six months with most firms using three months. Because equipment manufacturers could not specify a delivery date for new equipment, it was impossible for the firms to describe a "typical" length of time between the initial proposal for the purchase of equipment to the time of delivery.

3. Evaluation of Capital Investment Proposals.

The initial evaluation of a capital investment proposal (an aggregate of all proposed equipment purchases for the coming year completed as part of the annual budgeting process) was done in five firms by a middle management team of operating management, technical support and accounting personnel. A sixth firm used a middle management team of operating management and accounting without technical support staff. Five additional firms also used a team approach, but employed personnel from the top management level within woodlands and the purchasing function. Eastern Canadian firms tended to convene the evaluation team at a lower level than did the Western firms. The remaining four firms used an individual, sequential approach starting with operating management and ending with financial management. One firm used technical support to assess new equipment only.

Multiple criteria for evaluating proposed capital investments were used by every firm with the average being 4.20 and the range from three to six (see Table III-1). There did not appear to be any differences according to region or size of firm. Every firm used financial analysis with several reporting a special concentration on new equipment. Smaller firms tended to use payback period analysis and return-on-investment while larger firms reported using a discounted cash flow method, often supplemented by ROI and possible payback period.

Secondary criteria are often good indicants of the problems faced by a firm in achieving the economic performance required to stay in business. For example, all Western firms and the majority of Eastern

TABLE III-1.

Criteria for evaluating Capital Investment Proposals
(N = 15)

Criterion Category	Region East	Region West	Total
Economic Factors;			
Financial	7	8	15
Cost Improvement	4	0	4
Availability of Capital	0	1	1
Manpower Requirements	4	8	12
Mill Demand	4	4	8
Regulatory Requirements:			
Safety	0	5	5
Ecology	1	4	5
Replacement	4	1	5
Operating Conditions	4	0	4
Supplier Service	1	1	2
Quality of Output	1	0	1
Company Image	0	1	1
Total	30	33	63

(average = 4.20/co.)

firms considered manpower requirements and social factors as an important criterion. Usually this was reflected as a turnover-type problem in which morale, satisfaction and insufficient numbers were specifically noted. However, two firms indicated problems of quality of manpower by referring to the availability of skills to operate or maintain the equipment. This may be an important reason for making the industry more capital intensive although one firm also referred to it as a deterrent. This firm did not have sufficient numbers of skilled operators to run the more sophisticated equipment at a profitable level of two shifts per day.

The third primary criterion was mill demand with eight of fifteen firms specifically identifying this category. Since many firms initiated the capital investment proposal to meet a logging plan, this criterion was probably underestimated as a factor in the decision process. The importance of this criterion probably was indicated more accurately by one woodlands executive when he stated that the mills had materially overestimated their requirements for four years over the objections of the logging division. Logging was required to meet the mill forecasts, forcing logging operations to shut down in mid-year until wood inventories were reduced to an acceptable level. Another indicated that the return on investment in logging was less than in the mills, but logging got the capital to keep the mills adequately supplied.

Regional differences became very noticeable when secondary criteria were identified. Eastern firms stipulated the importance of supplementary cost criteria such as replacement, cost improvement, and equipment standardization to meet financial objectives more than did Western firms. Western firms demonstrated a high awareness of governmental regulatory statutes by including safety-health and ecological criteria. Eastern firms also reflected a greater sensitivity to operating conditions although Western firms referred to these often under ecological criteria.

Supplier service was not brought out in the interviews as often as had been expected. This could be because there are no problems associated with it, there aren't sufficient differences among the equipment manufacturers to make it an effective measure or logging firms tend to stay with those manufacturers which have supplied them in the past.

Only one firm made direct reference to any start-up or learning curve costs associated with the acquisition of new types of equipment or changes in their system of logging. This reference involved the training of operators without reference to training maintenance personnel, increasing spare parts inventories, increasing technical support personnel and systems, and initially low productivity and availability. In a logging system the latter problem can curtail total output if there is no standby equipment or interim inventory to provide for sustained output from the other components of the system. Field operations managers must then concentrate on replacing present equipment with known items rather than innovative ones.

To apply their criteria the decision makers appeared to use two types of information; quantitative, developed from their own records emphasizing age of equipment, costs, and availability, and qualitative, developed from judgments about the accuracy of suppliers' data, the experience of other firms, employees' comments and estimates of personnel problems. Eastern firms often referred to their contacts with and through the Canadian Pulp and Paper Association, especially the Woodlands Division LOG committee, as good sources for qualitative information to help in decision making. One firm's procedure for developing a capital investment proposal stipulated five criteria. Thus the proposal included information for each criterion, and the decision makers primarily evaluated the adequacy of the information supplied and emphasized personal references less than in most other firms.

The majority of the interviewees felt that the logging activity got its fair share of the funds available to the total firm for capital investment. None reported getting a capital project turned down once it got to the top level within logging. The justification that investment in logging equipment was essential to keep the wood supply flowing to the mills seemed sufficient to the boards of directors of the firms. Most interviewees reported that they were not aware of how the corporate officers apportioned the available capital across the various functional groups though one reported that logging received two-thirds of the capital available to his firm in 1974 and 1975.

4. Capital investment Budget Approval.

The formal approval authority for the annual capital expenditures budget was normally the board of directors or owners of the firm in the fourteen firms using this procedure. However, most firms found that when the proposed budget had been approved at a lower level such as executive vice president, subsidiary president, president, or an appropriations committee, it was approved for all practical purposes.

This step was not the final step to obtain approval for individual expenditures. Each individual expenditure went through a re-evaluation at the time the expenditure was requested. Most firms had clearly identified limits of authority in dollar terms for each level of management within the organization, including woodlands. The limits for approved budget items were typically higher than for unallocated ones as referred to in the organization structure section on centralization. Smaller firms had lower limits, approximately $2,500 or less, for middle management approval than did larger firms, $15,000 or less.

5. Implementation of the Capital Investment Decision.

The implementation of the capital investment decision was controlled in different ways by firms and by regions. Four Eastern and two Western firms required approval by someone outside Woodlands operating management like Purchasing, Finance or an officer of the firm. The remaining corporations used financial limits allowing different levels of operating management to approve expenditures so that only major items were re-analyzed by executive personnel after the capital budget had been approved.

The amount of planning which went into the implementation of capital investments was limited, possibly because the primary effort was in replacing current equipment with the same or similar types. The designation of a specialized individual or team of individuals to assist operating managers through the start-up and evaluation phases for new equipment was reported by just four firms out of fifteen. One firm reported that a project leader had been assigned to a new piece of equipment recently for the first time because the regular superintendent just couldn't handle it along with his normal operations. Only three firms acknowledged any special consideration for an increased inventory of spare parts and other supplies and materials during the start-up of new equipment.

There was at least some acknowledgment of the need for selecting and training personnel for the new equipment by seven firms. Four included it as either a routine part of their plan or did so for all major special projects. Eight firms did no personnel planning for their own new equipment nor did they ensure that their logging contractors did so.

Since the proportion of non-production personnel within the industry has not been increasing as fast as the capital intensiveness, there may have been extreme pressure on the same operating management to manage more and more equipment. This may cause less efficient use of the equipment than is optimum, leading to the industry decrease in capital productivity reported during the 1963-1971 period.

6. Evaluation of the Effectiveness of Capital Expenditures.

Fourteen of fifteen firms kept records of their capital investment decisions and recorded operating data for possible use in evaluating the decision and its implementation. Two of the fourteen maintained such records only on new equipment or special projects.

Financial and productivity post-investment analyses of equipment were done by seven firms. Four did a follow-up on all equipment while three concentrated on items which might have major impact (financial or wide application) upon the firm or had been marginal in the first place. Four firms made a partial analysis of equipment by concentrating on cost figures alone. The remaining four firms did not do any systematic, quantitative post-investment analysis even though two of them had policy statements requiring it. One firm used the Workmen's Compensation Board and Council of Forest Industries inspectors to evaluate its investments intended to improve operating safety. The same firm questionned employees to evaluate the impact of its investment in health and working conditions.

There was no separation of start-up costs from normal operating costs in past investment analysis reported by any firm. The data also did not identify any regional differences, but smaller firms used less complete and systematic procedures in general.

IV. ORGANIZATION STRUCTURE FACTORS

Because of the necessity to limit interviews in the pilot stages of research only two aspects of organization structure could be analyzed. These were centralization and specialization. An attempt was made to collect information on standardization of procedures, i.e. how standardized or routinized are the firms activities, but there was not sufficient time.

Specialization is important because it appears that specialized technical expertise is critical to the effectiveness of technological change[15]. Centralization is important because it measures the level at which decisions are made. If the level at which decisions are made is not congruent with the level which is responsible for maintaining contact with the external environment, then the effectiveness of decisions and actions may be limited.

1. Centralization.

Twenty three decisions (see Table IV-1) were investigated in the interviews with fourteen firms to measure how centralized (the extent to which decision-making authority is delegated) decision-making is within logging organizations. To obtain the measure the basic question was, "Who is the last person whose assent must be obtained before legitimate action is taken - even if others have subsequently to confirm the decision?". The answers to each firm's response was coded as follows:

Chief Operating Officer and above - 5
Executive Vice President and Vice President - 4
Middle Management - 3
First two levels of supervision - 2
Worker - 1

Items 4 and 5 relating to the expenditure of unbudgeted and unallocated funds, could not always be scored according to the above scale. Several companies had delegated authority by establishing limits for approving different amounts at various organization levels. The data on these limits were compared among companies in the sample, and the degree of centralization rated on the five point scale in terms of a) the limit of approval at the middle manager level and b) the range of approval at levels above that of the middle managers.

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[15] Mann, F.C. and Williams, L.K. Observations on the Dynamics of a Change to Electronic Data-Processing Equipment. Administrative Science Quarterly, 1960, 5, 217-256.

TABLE IV-1.

Centralization - Decision Items[1] and Categories.

	Average Score
Manpower:	
1. Appointments to jobs in logging operations (direct worker jobs)	2.79
2. Number of supervisors	3.71
3. Promotion of supervisory staff	3.57
4. Dismissal of supervisor	3.43
Financial:	
5. Spending of unbudgeted or unallocated money on capital items.	4.43
6. Spending of unbudgeted or unallocated money on revenue items.	3.93
7. Price of output (delivered cost of wood)	3.79
8. Costing: i.e., to what costing system, if any, will be applied.	4.00
Operations:	
9. Methods of logging operations to be used (not involving expenditures).	2.93
10. Machinery and equipment to be used for a job.	2.50
11. Selection or type or brand of new equipment.	3.57
12. Delivery dates or priorities of orders.	3.71
Organization:	
13. Altering responsibilities or areas of work of functional specialist departments.	3.54
14. Altering responsibilities or areas of work of line departments.	3.29
15. Creation of a new department (functional specialist or line).	4.36
16. Creation of a new job (functional specialist or line, of any status, probably signified by a new job title).	4.21
Other:	
17. Training methods.	2.50
18. Salaries of supervisory staff.	3.93
19. Inspection.	
20. Buying procedures.	
21. New product or service.	
22. Suppliers of materials to be used.	
23. Welfare facilities to be used.	

[1] Pugh et al, op. cit.

Five items (see Table IV-1) were eliminated from analysis for the following reasons:

Item 19 - Inspection. Government regulations are primary factors in inspection so there appears to be few decisions to be made -- just regulations to be applied.

Item 20 - Buying Procedure. Decisions on buying procedures vary from level to level according to the type and quantity of items. Interviewers tended to dwell on actual purchases rather than decisions on the procedures to be used.

Item 21 - New Product or Service. Responses were inconsistent since respondents felt a new product would also affect the operating system. The decision could also be made by the "customer" (mill).

Item 22 - Suppliers of materials to be used. See Item 20. The items are interdependent.

Item 23 - Welfare facilities to be used. The term "welfare" appears to be inappropriate in North America. The relevant terminology, employee benefits and services, covered too broad an area from camp facilities to pension programs, to be interpreted and scored.

The remaining 18 items were then available to provide an over-all score for centralization.

To make the analysis more meaningful, a group of five judges were asked to categorize the 18 items into sub-groups. Sixteen were grouped with 90% agreement among the judges (Table IV-1) into Manpower, Financial, Operations, and Organization decisions. The remaining two were classified with only 60% agreement so they were not included in any category.

The most decentralized decisions involved Equipment (average = 2.50), Training (average = 2.50), Workers (average = 2.79), and Methods (average = 2.93) applied directly to logging work. The most centralized decisions involved capital expenditures (average = 4.43), creating a new department (average = 4.36) or job (average = 4.21), and determining the cost system to be used (average = 4.00).

Differences among the categories (Table IV-2) were highly significant with Organization and Financial decisions centralized. These decisions were centered at the executive level of the firms. Manpower and operating decisions were more decentralized with the centre of those decisions at the middle management level.

There was no significant difference between the two regions, British Columbia and Ontario-Quebec, but there were wide differences among the firms within each region. The minimum obtainable total score for the 16 items on centralization was 16 and the maximum was 80. The range for the 14 firms was 50 to 75 with an average of 57.86.

TABLE IV-2.

Average Centralization Item Scores for Regions and Categories[1].

	Region[2]		
Category[3]	West[4]	East[4]	Total
Manpower	3.75	3.00	3.38
Finance	4.11	3.96	4.04
Operations	3.21	3.14	3.18
Organization	3.93	3.82	3.88
Total	3.75	3.48	3.62

1. A Mixed Design ANOVA was used for the analysis with firms nested within regions. Categories and Regions were treated as fixed variables and Firms and Items as random. Data from seven firms within each region and four items within each category were used. Training Methods and Supervisory Salary items were not included.

2. Neither the difference between Regions ($F_{1,12} = 1.52$) nor the Regions by Categories interaction term ($F_{3,36} = 2.12$) were significant.

3. The differences among the four Categories were significant at $p \leq .001$ ($F_{3,36} = 13.36$).

4. The differences among the Firms within each Region were significant at $p \leq .001$ ($F_{12,168} = 5.02$), but the interaction with Categories was not significant ($F_{36,168} = 1.31$).

Capital investment decisions appeared to be made at the executive level of the firm, but the data on the evaluation of equipment was not adequate to indicate the locus of these decisions. Training and employment decisions appeared to be quite decentralized, which was probably appropriate for standardized operations. However, during the innovation period such personnel decisions often become more centralized in a specific project manager.

2. Specialization.

In the study of "Total Factor Productivity as a Measure of Innovation in the Forest harvesting Industry" the non-production labour portion of the labour input to the industry was quite small. This would indicate that there is a limited amount of specialization within the logging industry. The study of total factor productivity also indicated that non-production workers were more efficient than production workers and the capital intensiveness of the industry was increasing rapidly. Specialized activities (those performed by someone with that particular function and no other) may be required to support managers and production workers in the effective evaluation and use of new equipment within the harvesting system.

More specific information about specialization was developed from the interviews conducted with the participating companies. The eighteen items representing specialization are shown in Table IV-3.

The items covered fourteen different functions with personnel separated into five subgroupings. Since the personnel activities were over emphasized by individual items, a single representative score for these functions was used to present the level of specialization for that activity within each firm. Twelve of the fourteen functions were clustered into three groups, Administrative Support, Technical Support and Operations. Public Relations (Item 13) and Organization and Methods (Item 14)

TABLE IV-3

SPECIALIZATION: Interview Items[1].

	Average Score
Administrative Support:	
1. Personnel (Employment, training, labour relations, compensation, and benefits-medical-safety)	2.00
2. Purchasing	2.00
3. Accounts	3.64
4. Legal	0.57
Technical Support (Process and Product):	
5. Production control	0.07
6. Quality control	0.64
7. Production methods	0.36
8. Equipment design and development	0.29
Operations:	
9. Sales	1.36
10. Transportation	1.64
11. Maintenance	2.43
12. Equipment operations	2.36
Other:	
13. Public relations	0.43
14. Organization and methods	0.36

1. Items were adapted from Pugh et al (op. cit.), but categories were developed as part of this research.

TABLE IV-4

Specialization - Code for Scoring Interview Responses

Number of Specialists at Organization Level			
Field	Head Office	Description	Score
0	0	No specialists	0
1	0	One specialist at local level *or*	1
0	1	one at Head Office	1
1	1	One specialist at each level	2
>1	0	More than one specialist at one	3
0	>1	level *or* the other	3
1	>1	More than two specialists split	4
>1	1	between local and head office	4
>1	>1	levels	4

were dropped from the analysis because there was very little specialization in those functions within any firm, and the analytical methods required the same number of items within each category.

The items were coded as shown in Table IV-4. It was assumed that the logging function of an integrated firm would not borrow specialists from other functional groups but would have its own or obtain services from the corporate level of the firm.

The most specialized activity is accounting which is highly segmented at both field and corporate levels. The average score for the 14 firms was 3.64 (Table IV-3).

Some specialization was present in Maintenance (average = 2.43), Equipment Operations (2.36), Purchasing (2.00), and Personnel (2.00). The only other activities which averaged a single specialist or more were transportation (1.64), and sales (1.36).

Differences among the categories were highly significant with a high concentration of specialization in the Administrative Support (2.05) and Operations (1.95) activities as shown in Table IV-5. Very little specialization was present in Technical Support activities (0.32).

There was no significant difference between the two regions, British Columbia and Ontario-Quebec, but there were differences among the firms within each region. The minimum total score obtainable for the 12 items scored on specialization was zero (0) and the maximum was 48. The range for the 14 firms was 3 to 25 with an average of 16.79.

The individual items which consider activities directly related to innovations in forest harvesting are production methods and Equipment Design and Development. There is less specialization in these two activities than in any others yet the growth in capital investment directly related to new equipment and methods has been very rapid. This may be

TABLE IV-5

Specialization: Average Item Scores for Regions and Categories[1].

Category	Region[2] West[4]	East[4]	Total
Administrative Support	2.29	1.82	2.05
Technical Support	0.25	0.39	0.32
Operations	2.32	1.57	1.95
Total	1.62	1.25	1.44

1. A mixed design ANOVA was used for the analysis with firms nested within Regions and Items within categories. Categories and Regions were treated as fixed variables and Firms and Items as random. Data from seven firms within each region and four items for each category were used. Public Relations and Organization and Methods items were not included.

2. The difference between Regions was not significant ($F_{1,12} = 1.14$), as was the interaction between Regions and Categories ($F_{2,24} = 2.81$).

3. The differences among the three Categories were significant at $p \leq .001$ ($F_{2,24} = 50.99$).

4. The differences among Firms within each Region were significant at $p \leq .001$ ($F_{12,126} = 3.45$) but the interaction term with Categories was not ($F_{24,126} = 0.76$).

one factor in accounting for the decrease in productivity related to capital input from 1963 to 1971.

V. CONCLUSION

Administrative support systems and general management policies and procedures may have generic applicability across various functions in a multi-function, integrated firm if the external environment for each function has characteristics similar to the others[16]. However, the technical knowledge and skills applicable to forest harvesting operations appear to be different from that required within saw mills and pulp and paper operations. Thus it appears that if increasing capital investment in the form of innovation and technological change is to be developed, acquired and used effectively, forest harvesting functions must develop the essential specialized, technical support personnel and organization structure required to assist operating management in its efforts to do so.

[16] Duncan, R.B. The Implementation of Different Decision Making Structures in Adapting to Environmental Uncertainty: An Expansion of Contingency Theories of Organization. Proceedings of the Academy of Management, 1971, 39-47. Lawrence, P.R. and Lorsch, J.W. op. cit.

Appendix 1.

Research and Development Expenditures in Forest Harvesting Interview Outline

a. How do you distinguish between research activity and development activity?

b. What general guidelines do you use to determine your research and development budget?

c. How are decisions made on the allocation of funds to specific research and development projects?

d. Whay type of research is undertaken?

e. Whay type of development work is undertaken?

f. Describe the organization of your logging research and development activity.

Appendix 2

The Capital Investment Process in Logging

Interview Outline

A. Developing Capital Investment Ideas

1. What are the sources of ideas for new equipment and construction?

2. Who is expected to come up with such ideas?

3. Who is responsible for maintaining contact with equipment manufacturers?

B. Developing a Capital Investment Proposal

4. How and by whom are capital investment needs identified?

5. What procedures are followed in developing an investment proposal?

6. How long does it take to develop your capital investment proposal?

7. What time period does it cover?

C. Evaluation of the Capital Investment Proposal

8. Who is responsible for analyzing the proposals? If it is a team, what functions are represented?

9. What criteria are used to assess a proposal?

10. What kind of information do the assessors seek to aid them?

11. How are capital resources allocated to logging in relation to the other functional groups in your firm?

D. Capital Investment Budget Approval

12. Who, or which group, makes the final decision on the proposed capital expenditures?

13. How do you differentiate between major and minor capital expenditures?

E. Implementation of the Capital Investment Decision

14. How are budgeted and unbudgeted capital expenditures controlled?

15. Planning Implementation

    a. Is a project leader or team assigned to a project during its start-up phase? If so, what functions are represented on a team?

b. What planning is done for spare parts, support equipment, materials and supplies during start-up?

c. What planning is done regarding personnel selection and training during start-up?

F. Evaluation of the Effectiveness of Capital Expenditures

16. What records are kept of the evaluation of capital proposals?

17. Describe the system used to collect information about capital expenditures.

18. How do you monitor the productivity of capital (leased) equipment?

19. How, and how often, do you compare actual performance with the pre-investment proposal?

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