

TOTAL FACTOR PRODUCTIVITY IN THE B.C.
MANUFACTURING SECTOR, 1961-1988

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ABSTRACT

Total factor productivity (TFP) is a measure of the relationship between growth in output and growth in a composite measure of factor inputs. Estimates of total factor productivity for the manufacturing sector of British Columbia, and for selected manufacturing industries, are calculated for the period between 1961 and 1988. The technique used is based on the Tornquist approximation to a Divisia index. Tornquist indices are consistent with a model of production which is based on a translog aggregate production function. Estimates of TFP in B.C. manufacturing indicate that there has been a general shift towards more capital-intensive production technologies, and that a slowdown in productivity growth occurred after 1973.

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CHAPTER I

INTRODUCTION

1.1 Definition of Productivity

Productivity has been described as "the almost miraculous force that enables the wealth of a nation to vastly increase as the hours of work, or effort, are reduced"¹.

However, the concept of productivity and the meaning of productivity measures are frequently misunderstood because the term is used rather loosely to describe a broad spectrum of economic phenomena. For example, productivity is often interpreted as a measure of profitability, of quality, or of the work effort expended to produce a particular commodity or service.

1. Levitan & Werneke (1984, p.6)

Within the context of economic theory, however, productivity is more correctly defined as a measure of the efficiency with which capital, labour, and other factor inputs are converted into goods and services for consumption. Changes in productivity thus reflect changes in economic efficiency, or in the underlying technology.

Although the above definition describes productivity in terms of economic efficiency, it still encompasses a wide range of possible measures. For example, "productivity" can refer to the efficiency of production of a firm, an industry, or even the entire economy. In addition, productivity estimates may quantify the relationship between output and one of the inputs used in production; alternatively, all of the factor inputs used may be taken into account. In order to discuss productivity in a meaningful way, it is therefore necessary to distinguish between some of these different kinds of productivity estimates.

In this thesis, productivity changes at the level of the firm are not analyzed; instead, productivity is defined in terms of economic efficiency within an industry. More specifically, productivity change is determined residually as the difference between growth in output and growth in

the factor inputs used in production. Following Kendrick's terminology, a distinction is made between two different kinds of productivity measures: "partial factor productivity" refers to the relationship between output and any one of the individual factor inputs which contribute to production. An example of such a measure is labour productivity. "Total factor productivity" (TFP), on the other hand, refers to the relationship between output and total factor input, where total factor input is a composite measure of all of the inputs which are used in production.

Tangible inputs are defined to be physical inputs, such as labour, capital and materials. Intangible inputs, on the other hand, are factors which influence the services of the tangible inputs, but are not necessarily measurable. For example, improvements in education and changes in the "work ethic" of the labour force would be considered to be intangible inputs.

It is important to note that the correct interpretation of a productivity estimate depends on the way in which both output and factor inputs are defined and measured. For example, if the effects of intangible factors are quantified and incorporated into the input measures, estimates of productivity will basically measure economic efficiency. Alternatively, productivity may be calculated

using estimates of factor inputs which have not been adjusted for changes in quality. In this case, the measure of productivity will include a component which is due to changes in the intangible factors which contribute to input quality.

1.2 Why is productivity important?

Productivity and productivity change are important because improvements in productivity are a major cause of economic growth and development. Productivity gains frequently result in higher standards of living and growth in real income. Hence, trends in productivity are often viewed as significant indicators of the health of the economy.

The relationship between productivity improvements and economic growth was recognized by Adam Smith (1937, p.326), who stated that growth in output could only occur if either the number of workers or the "productive powers" of existing workers were increased. Smith argued that the productivity of workers could be increased by using better machinery or, alternatively, by a more efficient distribution of labour.

Other economists, such as David Ricardo, John Stuart Mill and Thomas Malthus, also acknowledged the association between productivity change and economic growth, but did not believe that future growth would be high enough to offset the increased demands imposed on a fixed supply of resources by a rapidly growing world population. Their pessimism has proved to be unfounded, largely because of improvements in productivity (caused by technological change) which have been much greater than was anticipated. Most western nations have actually experienced relatively high growth rates since the beginning of the Industrial Revolution in the late 1700's.

In fact, until the early 1970's, it was generally believed that, even though economies were subject to business cycle fluctuations, in the long run sustained economic growth was not only possible, but also very probable. However, the economic instability and generally lower growth rates which followed the energy crisis of 1973 raised some doubts about the validity of this view. This led to a re-examination of the factors which contribute to economic growth, as researchers sought to explain the causes of the "productivity slowdown".

Understanding and quantifying the sources of economic growth is therefore important, not only because it helps to

explain past economic performance, but also because knowledge of trends in productivity may permit more accurate forecasting of economic performance in the future.

1.3 Productivity Measures: an Overview

1.3.1 Labour Productivity

The most commonly used productivity measure is labour productivity, which is generally calculated as the ratio of output to labour inputs. However, labour productivity is not a pure measure of economic efficiency unless labour is the only factor input used. When other inputs enter the production process, estimates of labour productivity indicate the effects of factor substitution between labour and the other inputs as well as the contribution of labour to growth in output. This can, perhaps, be best illustrated by an example.

Suppose that labour and capital are substitutes and that the price of capital decreases relative to the price of labour. A profit maximizing firm would substitute between capital and labour inputs. Assume, for the sake of the argument, that the firm continues to produce the same quantity of output using less labour and more capital. In

these circumstances, an estimate of labour productivity would seem to indicate an increase in the efficiency with which labour inputs are used, since less labour is required to produce the same quantity of the final product. However, the increase in the ratio of output to labour input would simply be due to substitution from the higher cost labour inputs to the less expensive capital inputs. Hence, when other factor inputs (which are substitutes for labour) are used in production, a measure of labour productivity does not indicate the efficiency with which labour inputs are converted into goods and services.

It should be noted that labour productivity is not necessarily a "bad" measure of productivity; partial productivity estimates can be useful analytical tools, if the meaning of these estimates is well understood. In fact, since labour income typically accounts for well over half of the value of net output, a labour productivity estimate probably gives a reasonably good indication of the efficiency of labour utilization.

1.3.2 Capital Productivity

Up until the 1940's, capital was not explicitly included in productivity measures; productivity was always defined in terms of output per man-hour or output per

employee. However, with the increasing importance of capital in the production process, it became evident that a measure of economic efficiency ought to reflect the contributions of both capital and labour to output.

The measurement of capital inputs poses some problems. In contrast to labour inputs, which can be quantified using employment or man-hours, there are no standard units of capital; capital can take many very different forms. In addition, although the value of capital stocks can be estimated, there is no clear way of measuring the flow of capital services. The general approach to measuring capital inputs has therefore been to assume that the flow of services from capital is proportional to the value of the capital stock, and that the standard "unit" of capital is a dollar.

Despite the difficulty of measuring capital inputs, partial productivity estimates for capital are frequently used. However, measures of capital productivity are subject to the same limitations as are estimates of labour productivity, since the effects of factor substitution between capital and the other inputs used will be reflected in the measure.

1.3.3 Total Factor Productivity

As discussed above, the usefulness of partial productivity estimates is limited by the fact that they do not differentiate between changes in technology and changes in the mixture of inputs used in production. In other words, outward shifts in the production function are not separated from movements along the isoquant. Movements along the isoquant do not represent technical progress; instead, they indicate responses to changes in the relative prices of factor inputs.

Stigler (1961, p.50) defines a "pure measure of economic progress" as a measure of growth in the output of a fixed basket of factor inputs, or alternatively, as a measure of the decrease in factor inputs required to produce a fixed quantity of output. In other words, Stigler argues that the effects of changes in the relative proportions or even the mixture of factor inputs used should be reflected in the input estimate rather than in a measure of productivity. A "pure measure of economic progress" should only represent the cumulative effects of shifts in the production function over time.

The total factor productivity measure satisfies Stigler's criterion. TFP is defined in terms of the

relationship between output and total factor input, where the latter is calculated as a share-weighted composite of all of the inputs used in production. In the absence of any measurement errors, TFP can therefore be considered a "pure measure of economic progress". As such, it is theoretically superior to a partial productivity estimate.

1.4 Historical Development of the TFP Measure

The first empirical attempt to calculate total factor productivity was made by Jan Tinbergen in 1942. Tinbergen used an econometric model to produce estimates of TFP, which he defined as the value of real output divided by real labour and capital inputs. His study covered the period between 1870 and 1914, and included international comparisons of TFP for the United States, France, Germany, and the United Kingdom. Tinbergen's work, however, did not receive widespread attention, presumably because it was not written in English. Some years later, in 1947, George Stigler (independently of Tinbergen) developed a similar measure of total factor productivity for the U.S. manufacturing industry. His composite measure of factor

input was calculated by weighting real capital and labour inputs by their marginal products.²

Tinbergen's and Stigler's work, together with other analyses of growth published in the 1950's were part of a major post-World War II effort to identify and measure the sources of economic growth³. Two fundamental studies of the United States economy, which were published in the early 1960's, laid the foundation for further developments in this area. Both of these studies were based on the concept of total factor productivity. John Kendrick (1961) outlined a methodology for calculating total factor productivity by industry and used it to generate estimates of TFP for the period from 1889 to 1957. A similar study by Edward Denison (1962) also examined the sources of economic growth in the United States, but from a slightly different angle. Denison disaggregated growth in output into growth in both tangible and intangible factor inputs, and technical change.

2. The pioneering work of Tinbergen and Stigler is discussed briefly in Christensen, Cummings and Jorgenson (1980).

3. These include some well-known studies by Schmookler (1952), Abramovitz (1956), Solow (1957) and Fabricant (1959).

1.5 Purpose and Outline of this Thesis

1.5.1 Justification for Estimating TFP in B.C.

As indicated in section 1.3, total factor productivity is a better estimate of economic efficiency than is partial factor productivity. However, although there is a movement toward increased use of TFP estimates, labour productivity remains the most commonly used measure of economic efficiency. As Denny (1986, p.5) indicates, this is undoubtedly because the data requirements for measuring TFP are substantial⁴, hence the necessary data are not always available.

Nevertheless, in the United States, total factor productivity measures are now an important part of the body of available social statistics. The U.S. Bureau of Labor Statistics regularly publishes estimates of TFP, while Kendrick, Denison, and other researchers (such as Jorgenson et al.) all update their studies periodically.

This is not the case in Canada. Although there have been some studies of Canadian economic growth based on the

4. Denny also suggests that widespread use of TFP measures may be "hindered in practice by a lack of understanding of the concept by policy makers".

concept of TFP , this measure of economic efficiency is neither generally used nor readily available. For example, a study by Dorothy Walters (1968, 1970)⁵ of the sources of economic growth in Canada has not been updated since 1970. Although other Canadian studies of TFP exist⁶, they do not extend beyond the mid-1970's. Furthermore, Statistics Canada, unlike the U.S. Bureau of Labor Statistics, does not calculate any TFP measures; the only Canadian productivity data which they publish are estimates of labour productivity.

At a regional level, there is an even greater paucity of data, both in the United States and in Canada. Most studies of economic growth focus on national rather than regional trends in productivity. However, since the underlying industrial structure varies greatly between regions and since productivity can vary across industries, regional economic efficiency can be quite different from that which characterizes the national economy. This is

5. Walters' study was based on Denison's methodology.

6. Other Canadian analyses of growth include a study of the effect of education on economic growth by Bertram (1966), as well as two studies of TFP in the Canadian manufacturing sector [Denny, Fuss and Waverman (1979) and Denny, Fuss and May (1970)]. These studies were part of an examination of the role of energy in the Ontario telecommunications industry during the period from 1961 to 1975.

especially important in a country like Canada, where two provinces are economically dominant, so that national economic statistics tend to reflect trends in Ontario and Quebec. The mixture of industries in British Columbia is quite different from that which exists in Central Canada, hence the most useful measure of economic efficiency for this province is one which is based on regional, rather than national, data.

The purpose of this thesis is, therefore, to provide a basis for developing estimates of total factor productivity in British Columbia. This is done by establishing a general framework within which such estimates can be calculated, and then applying the methodology to the B.C. manufacturing sector for the period between 1961 and 1988.

1.5.2 Reasons for Limiting the Study to Manufacturing

Although it would obviously be preferable to look at total factor productivity for the entire business sector in British Columbia, and to construct similar estimates for the rest of Canada, this study is restricted to the B.C. manufacturing sector for a number of reasons. Most importantly, as Denny has pointed out, the data requirements for calculating total factor productivity can be prohibitive; an inter-regional comparison would be far

beyond the scope of this study. Secondly, while many of the required data series are fairly readily available at the provincial level for manufacturing, this is not true for other sectors of the economy.

A third reason for confining the study to manufacturing is that, even where data for other industries are available, the quality of statistical information at the provincial level is not always high. For example, in the **British Columbia Economic Accounts** (BCEA), fairly disaggregated estimates of gross domestic product (GDP) by industry are published. In many cases, however, there is no way of measuring GDP directly, even at the national level. Hence, for most of the service sector, the estimates of GDP by industry which are in the BCEA are calculated using relative ratios of "income components" (wages and salaries, supplementary labour income, profits, miscellaneous investment income, and so on) to allocate a share of Canada's GDP in each industry to British Columbia. The quality of the final estimates, therefore, depends not only on the accuracy of the Canadian GDP by industry measures, but also on the quality of the estimates of provincial and national income components by industry.

For many of the service industries, estimates of GDP at the national level are produced using growth in labour

inputs to project a benchmark estimate of GDP. By definition, output therefore grows at the same rate as labour input, hence productivity estimates for these industries are not very meaningful. In addition, disaggregated information on capital and labour inputs in the service sector (by province) are not always available.

It can be argued that since the data at the industry level are poor, it would be more appropriate to look at total factor productivity for the entire economy rather than by industry. However, in most of the previous studies of economic growth, a strong case is made for building up overall productivity estimates from disaggregated data, for two reasons. First, by using a low level of aggregation, inter-industry differences in TFP can be identified. Second, building up an overall estimate of TFP from individual estimates of TFP by industry means that there is, in some sense, a quality adjustment mechanism. For example, an estimate of sectoral total factor productivity can be calculated in two ways. Unweighted totals of capital, labour and other inputs can be related to total output. Alternatively, estimates of factor inputs can be constructed as internally-weighted composites of factor inputs by industry. For example, labour inputs by industry can be aggregated up into an estimate of sectoral labour input using shares of labour income as weights. The

advantage to choosing the second approach is that, if factor inputs are paid the value of their marginal products, then higher-quality inputs (i.e. those which command a higher price) will be more heavily weighted in the composite measure. Using internally weighted estimates of factor inputs to calculate TFP therefore results in a more "pure" measure of economic efficiency for the sector. This is essentially the method of quality adjustment which is used by Denison (1985) and by Jorgenson, Gollop and Fraumeni (JGF, 1987).

For reasons of practicality and because of limitations in data availability, only the manufacturing industries of British Columbia are examined in this thesis. However, the methodology which is developed here could easily be extended to cover more industries in the future if better data become available.

The choice of the manufacturing sector as the focus of this study is largely due to the fact that the data for manufacturing are reasonably good and are quite readily available. Statistics Canada conducts an annual census of manufacturers, hence census data can be used to develop estimates of output and labour input which are internally consistent. The census of manufacturing served as the basic database for the studies of TFP in the Canadian

manufacturing industries by Denny, Fuss and May (1981) and Denny, Fuss and Waverman (1979). In this study, updated data from the annual census of manufacturers and from other sources will be used to extend and to modify the TFP estimates for the B.C. manufacturing sector which were produced by Denny, Fuss and May. In order to incorporate a quality adjustment mechanism into the estimate of TFP for manufacturing, the overall measure is calculated using estimates of labour and capital inputs for individual industries, and for different types of labour and capital within the manufacturing sector.

1.5.3 Outline of the Thesis

This study is presented in five chapters. This chapter has outlined the background of total factor productivity estimates and the justification for studying TFP in the British Columbia manufacturing sector. Chapter Two summarizes the theoretical framework which underlies the measure of total factor productivity. In the third chapter, conceptual issues that affect the calculation of TFP, and the way in which they have been addressed in this study, are discussed. The fourth chapter outlines and discusses the empirical results. The estimates of total factor productivity which are obtained are analyzed with respect to differences in productivity over time, and between

industries. Finally, the summary and conclusions are presented in Chapter Five.

CHAPTER II

THEORETICAL BASIS OF THE TOTAL FACTOR PRODUCTIVITY MEASURE

The framework for analyzing economic growth is based on the theory of production. An expression for calculating total factor productivity can be derived from a general specification of the production function. This chapter describes the model which is used to estimate TFP in the British Columbia manufacturing sector.

2.1 Derivation of the Total Factor Productivity Measure

The derivation of a total factor productivity measure depends on some fundamental assumptions. The first assumption, which is frequently made in economic analysis, is that the economy is characterized by perfectly competitive markets in which factor input prices are equal to their marginal products. The second assumption is that an aggregate production function exists for the economy.

This production function is single-valued, continuous, and has the regular curvature properties (it has continuous first and second order partial derivatives). Finally, the production function is assumed to exhibit constant returns to scale.

In the specific model used in this study, for any given period, output can be expressed as a function of capital, labour, material inputs and time. Thus, for each industry, the production technology can be characterized by a function of the form:

$$(1) \quad Q = F(K, L, M, t)$$

Where Q = gross output. Since Q has been defined as gross rather than net output, it is necessary to include material inputs in the production function.

$K = \{K_1, \dots, K_n\}$ is a composite measure of the flow of services of n capital inputs.

$L = \{L_1, \dots, L_m\}$ is a composite measure of m individual labour inputs.

$M = \{M_1, \dots, M_p\}$ is a composite measure of p material inputs used in production.

t is a time trend which is used to proxy the "state of the arts".

If the production function is weakly separable with respect to time (i.e. if the marginal rate of substitution between any two individual inputs is independent of time)

then technical change will be Hicks-neutral, and equation (1) can be rewritten as:

$$(2) \quad Q = A(t) \cdot f(K,L,M)$$

$A(t)$ is a cumulative measure which represents the state of the technology at time t . The assumption that the aggregate production function exhibits constant returns to scale implies that the function $f(K,L,M)$ is linearly homogenous.

If the actual form of the production function were known, it would be possible to calculate the value of $A(t)$ (and hence the rate of technical change) simply by rearranging equation (2) and dividing gross output by the value of $f(K,L,M)$. However, since the exact form of the production function is not known, it is necessary to calculate $A(t)$ indirectly.

There are two ways of estimating the relationship between growth in output and technical change. One approach involves assuming a specific form for the aggregate production function and estimating the value of $A(t)$ using econometric techniques. A major drawback to adopting this approach is that econometrics will not yield a time series of estimates of changes in technology; instead, an average rate of change will be generated. However, for the purposes of determining intertemporal changes in productivity, time

series are generally preferred to estimates of the trend rate of growth. For example, an estimate of the average rate of technical change for the period between 1961 and 1988 would not give any information about whether there was a productivity slowdown after 1973; it would only indicate whether or not, on average, productivity increased during the entire period. Because estimates of average annual growth rates are very sensitive to the choice of end-years, the use of time series allows for more flexibility in analyzing changes in productivity. Consequently, most researchers prefer to use index numbers to measure technical change.

An added advantage to this approach is that it does not require knowledge of the exact form of the production function. That is, although various index number formulae can be shown to be consistent with specific functional forms, it is not necessary to estimate the parameters of the production function in order to obtain a measure of TFP. Instead, technical change can be expressed as a function of inputs, output and prices, all of which are measurable. The exact relationship between technical change and the quantity and prices of output and factor inputs is derived below.

Taking the total derivative of equation (1) with respect to time, and using the assumption that the

production function is separable in t , we obtain the following expression:

$$(3) \quad \frac{dQ}{dt} = \frac{dA}{dt} \cdot f(K,L,M) + \sum_i \frac{\delta Q}{\delta X_i} \cdot \frac{dX_i}{dt}$$

Where $X = \{K,L,M\}$. An expression which relates output to technical change and the quantity and prices of factor inputs is derived by dividing equation (3) by Q (the dot notation indicates time derivatives):

$$(4) \quad \frac{\dot{Q}}{Q} = \frac{\dot{A}}{A} + \sum_i \frac{\delta Q}{\delta X_i} \cdot \frac{\dot{X}_i}{Q}$$

By Euler's theorem, the value of output must be equal to the sum of factor incomes¹:

$$(5) \quad p_Q \cdot Q = \sum_i w_i \cdot X_i$$

Where p_Q = the price of output
 $w_i = \{p_K, p_L, p_M\}$ are input prices

The income share of each input in the value of total output can be defined as:

1. Euler's theorem states that the value of a linearly homogeneous function $Q = f(K,L,M)$ can be expressed as $(K \cdot \delta Q / \delta K) + (L \cdot \delta Q / \delta L) + (M \cdot \delta Q / \delta M)$. Since we have assumed that factors are paid the value of their marginal products, this implies that the value of output is equal to the sum of factor incomes, since $K \cdot p_K + L \cdot p_L + M \cdot p_M = p_Q \cdot Q$.

$$(6) \quad s_i = \frac{w_i \cdot X_i}{p_q \cdot Q} = \frac{w_i \cdot X_i}{\sum_i w_i \cdot X_i}$$

A necessary condition for equilibrium is that the value shares of the inputs must be equal to their output elasticities²:

$$(7) \quad s_i = \frac{\delta Q / \delta X_i}{Q / X_i}$$

An expression which defines the change in technology as the difference between the growth in output and a share-weighted average of the growth in factor inputs is derived by substituting (7) into (4) and rearranging the result.

$$(8) \quad \frac{\dot{A}}{A} = \frac{\dot{Q}}{Q} - \sum_i s_i \cdot \frac{\dot{X}_i}{X_i}$$

In other words, productivity change is expressed entirely in terms of measurable variables (factor inputs, output, and their respective prices), which do not require direct knowledge of the exact form of the aggregate production

2. From the first order conditions for profit maximization, we know that $w_i = p_q \cdot A(t) \cdot \delta f / \delta X_i$. This expression can be substituted into equation (7) to obtain:

$$s_i = \frac{1}{p_q \cdot Q} \cdot (p_q \cdot A(t) \cdot \delta f / \delta X_i) \cdot X_i$$

Since $\delta Q / \delta X_i = A(t) \cdot \delta f / \delta X_i$, this can be rewritten as

$$s_i = (\delta Q / \delta X_i) \cdot (X_i / Q)$$

function. In addition, since the sum of factor incomes must be equal to the value of total output, it is only necessary to determine the income shares of $n-1$ inputs. The n^{th} income share can be calculated residually.

2.2 Divisia and Tornquist Indices

Equation (8) defines growth in total factor productivity as the difference between growth in output and the change in a composite measure of the growth of total inputs. The composite input estimate derived above is, in fact, a Divisia index, which is defined as "...a weighted sum of growth rates, where the weights are the components' shares in total value"³. If I is used to designate the composite input estimate, then the Divisia input index can be calculated as:

$$(9) \quad \frac{\dot{I}}{I} = \sum_i s_i \cdot \frac{\dot{X}_i}{X_i}$$

3. Hulten (1973, p.1017). See also Richter (1966, pp.739-755)

Given the existence of a linearly homogeneous aggregate production function, the Divisia index can be shown to be at least as good as any other input index⁴.

The Divisia index in equation (9) is defined in terms of continuous data. Since the data used to calculate TFP are not continuous, it is necessary to employ a discrete approximation to this index. The discrete approximation to a Divisia index is called a Tornquist index and has the general form:

$$(10) \quad \ln I_t - \ln I_{t-1} = \sum_i v_i \cdot (\ln X_{it} - \ln X_{it-1})$$

where v_i is the average value of the income shares in periods t and $t-1$:

$$(11) \quad v_i = \frac{s_i(t) + s_i(t-1)}{2}$$

Diewert (1976) argues that the choice between various types of index numbers should be based on the particular production function for which they are exact. An exact index for a production function is an index for which the value of the index number at any time t is equal to the ratio of the value of the production function at time t

4. See Hulten (1973)

relative to its value in the base year. Diewert also suggests that index numbers which are exact for second order approximating functions⁵ should be chosen over index numbers which are exact for first order approximating functions. Diewert defines superlative index numbers as index numbers which are exact for second order approximating functions. He shows that the Tornquist index number is an exact and superlative index for a translog production function.

Although the calculation of total factor productivity does not require that the parameters of the production function be estimated, it is necessary to assume a general form for the aggregate production function. For example, if the aggregate production function is assumed to be a Cobb-Douglas function, then the appropriate index number formula to use would be a geometric index, which assumes that income shares do not change over time. Solow (1957) and Denison (1962) used geometric indices to calculate total factor productivity, while Kendrick's (1961) estimates are based on a variant of the geometric index.

The translog specification of the aggregate production function is generally preferred over other functional forms

5. The translog production function is a second order approximation to a constant returns to scale production function. An example of a first order approximating function is the Cobb-Douglas production function.

because less restrictive assumptions are required. For example, the Cobb-Douglas production function assumes that the elasticity of substitution between factor inputs is constant; this assumption can be relaxed if a translog production function is used. There is considerable support in the literature for using a Tornquist index to calculate total factor productivity⁶. Second order approximating functions such as the translog function are generally expected to fit the data better than first order approximating functions do. In addition, the empirical evidence suggests that income shares change over time, so that floating weights, such as those used in the Tornquist index, are likely to produce more realistic estimates of productivity change.

Following the methodology of JGF (1987), as well as other researchers, the aggregate production function is assumed in this study to be a translog function in capital, labour and material inputs. In addition, aggregate labour and capital inputs are assumed to be translog functions of their individual components.

6. For example, Jorgenson, Gollop and Fraumeni (1987); Denny, Fuss and May (1981); and The Bureau of Labour Statistics (1983) all assume that the aggregate production function has the translog form.

Using the Tornquist approximation of the Divisia index, equation (8) can therefore be restated in terms of the change in productivity between times t and $t-1$:

$$(12) \quad \ln A_t - \ln A_{t-1} = (\ln Q_t - \ln Q_{t-1}) - (\ln I_t - \ln I_{t-1})$$

This expression is used to calculate changes in total factor productivity by industry for the manufacturing sector in British Columbia. It should be noted that equation (12) yields, not an index, but a series of growth rates which can be used to construct indices of individual capital, labour, and material inputs, as well as a composite index of total factor input (I). Indices of output, total factor inputs and total factor productivity are constructed by applying these growth rates to a base-year value of 100.

In the following chapter, some conceptual issues which relate to the measurement of total factor productivity are discussed within the context of the literature, and with respect to the specific approach taken in this study.

CHAPTER III

FROM THEORY TO PRACTICE: CONCEPTUAL ISSUES

As outlined in the previous chapter, the derivation of an expression for calculating total factor productivity is based on the theory of production. The specific form which is assumed to characterize the aggregate production function influences the choice of the appropriate discrete index number approximation to a continuous time series of changes in technology. In this thesis, the aggregate production function is assumed to be a translog production function. The translog specification is generally preferred to other functional forms because less restrictive assumptions about the nature of production are required, hence the results obtained are more likely to approximate reality. For a translog function, the appropriate discrete index number approximation is a Tornquist index.

In the following sections, the data requirements for calculating a Tornquist index of technical change are

summarized and discussed. The actual data which are used in this study are also described.

3.1 The Measurement of Output

3.1.1 Gross vs. Net Output

The particular measure of output which is chosen is fundamental to the study since it determines which factor inputs need to be included in the production function. Output can be measured either gross or net of intermediate inputs.

Gross output for an industry is a measure of the total quantity of goods and services produced by that industry. This measure implicitly includes commodities or services which may be purchased from other industries and are used to fabricate the final product. If a gross output measure is used, the production function must be specified in terms of the relationship between output and all of the factor inputs used, including intermediate inputs such as materials and energy. Alternatively, if a net output or value added estimate is used, then intermediate inputs have already been subtracted from the value of output and they do not need to appear in the specification of the production function.

The choice between using a net or a gross output measure is very much influenced by the focus of the study. For example, if total factor productivity for the entire economy is being estimated, then the appropriate measure to use is net output, since aggregating up gross output estimates would involve double-counting. For the entire economy, what matters is not how much output was produced by each individual industry; rather, what is important is how much value has been added in each industry.

If, on the other hand, productivity at the industry level is being analyzed, the choice between gross and net output is less obvious. For example, Kendrick (1974) uses net output or value added for his industry analysis. He maintains that net output is the most appropriate measure for two reasons. First, he argues that value added is more relevant for a productivity study because it "indicate(s) changes in the efficiency with which the basic factors resident in the industry are used to add value to the intermediate products purchased from other industries"¹. Of even more importance is the fact that value added estimates by industry sum up to the overall estimate of net output for the economy. If industry productivity estimates are

1. Kendrick (1973 p.17)

calculated using net output, the overall measure of productivity for the economy can then be regarded as a weighted average of productivity in each industry.

An alternative approach is taken by Jorgenson, Gollop and Fraumeni (JGF, 1987), who argue that at the sectoral or industry level, gross output is the most appropriate measure, since in some cases intermediate inputs are substitutes for capital and labour². Denny, Fuss and Waverman (DFW, 1979) and Denny, Fuss and May (DFM, 1981) also argue that gross rather than net output estimates should be used at the industry level.

3.1.2 The Measure of Output Used in This Study

In this thesis output is measured gross of intermediate inputs. Although Kendrick's argument for maintaining consistency between the industry measures and the overall estimate of productivity in the economy is convincing, that consideration is not vital to this study, which has been limited to the manufacturing sector. By using gross rather than net output, the estimates produced in this study are comparable to those calculated by DFM in their analysis of TFP in Canadian manufacturing between 1961 and 1975.

2. See JGF (1987, p. 149)

Another reason for using gross output measures relates to the consistency of the data. The most widely used estimate of net output in manufacturing is gross domestic product, which can sometimes differ significantly (in terms of growth rates) from the census value added estimates. In order to calculate the TFP index, it is necessary to determine the income share of each factor input. However, the only available historical data for labour income by manufacturing subindustry are in the census. These labour income estimates are not strictly comparable with the estimates of GDP by industry, since Statistics Canada makes various adjustments to the census data when calculating GDP. If estimates of GDP by industry are combined with estimates of the quantity and price of labour inputs from the census, and these in turn are combined with capital stock estimates from another source, the potential error which is introduced into the calculation becomes quite large. Therefore, in order to achieve the maximum possible internal consistency in the measure of TFP, estimates of gross output, and labour and material inputs, are all taken from the annual Census of Manufacturing (Statistics Canada publication 31-203).

Currently, data from the census of manufacturing are available from 1961 to 1985 for all industries, and, for selected industries, to the end of 1986. This study also presents preliminary estimates for 1987 and 1988; these

estimates are constructed by pushing the census data forward using related series, as discussed below.

Following the methodology of DFM, the value of output at any time is defined as the sum of total value added (manufacturing and non-manufacturing activities) plus the value of materials and fuel and energy consumed. However, there are two important differences between the measure of real output which is used by DFM and the measure which is employed in this study. These differences relate to the deflators which are used to calculate real gross output.

DFM calculate real output by deflating the value of gross output using industry selling price indices (ISPI's) for each of the twenty two-digit SIC (Standard Industrial Classification) manufacturing industries. These ISPI's are not available on a regional basis, hence they utilize national price indices.

In this study, the deflators which are used are actually industry product price indices (IPPI's) rather than ISPI's. Since 1981, when DFM's study was published, Statistics Canada has switched over to using IPPI's to measure industry price changes. Because the IPPI's are only available back to 1981, the price indices used to deflate gross output in this study are constructed using IPPI's

which have been linked (in 1981) to the ISPI's in order to produce a consistent price series which goes back to 1961.

The second major difference between the deflators used here and those employed by DFM is related to the way in which the indices are aggregated into a two-digit SIC classification.

The use of national price indices to deflate gross output presents some problems for regional estimates. Most importantly, the national price indices are calculated based on the mix of industries which characterize the Canadian manufacturing sector; the relative importance of these industries may be quite different in each of the provinces. For example, in the British Columbia wood industry, softwood is much more important than hardwood; and some species of trees, such as the Douglas fir, are unique to this province. Although the Canadian deflator for the wood industry clearly includes the effect of price changes in B.C. forest products, it also reflects changes in the relative prices of wood products produced in Ontario, Quebec, and the other provinces.

An alternative set of price indices, which reflect the specific types of manufacturing which exist in British Columbia, have been developed as part of the BCEA.

Individual deflators at the three or four-digit SIC level have been aggregated up to a two-digit SIC classification using weights from the British Columbia input-output model. For some sub-industries, B.C.-specific deflators are available, but in most cases, Canadian price indices are utilized. However, because they are aggregated using B.C. weights, these price indices reflect the industrial structure which exists in B.C. rather than the structure of Canadian manufacturing industries. Hence, the deflators used to calculate real gross output by industry for this study are B.C.-weighted IPPI's which have been linked to ISPI's for the period from 1960 to 1980.

For the calculation of total factor productivity in B.C., the quantity of gross output in manufacturing by industry is therefore derived by dividing total value added plus material inputs by B.C.-weighted price indices for each industry. For 1987 and 1988, the years for which census data are not yet available, the estimate of the value of gross output (in current dollars) is projected using the value of shipments of goods of own manufacture by industry. The shipment data are available on CANSIM, in matrix 9579.

3.2 The Measurement of Capital Input

3.2.1 Conceptual Issues

As indicated in the first chapter, there are some conceptual issues which need to be addressed in order to obtain an estimate of capital input. Most importantly, there is no standard unit of capital which is analogous to, for example, the person-hour measure of labour input. In addition, it is difficult to determine the flow of services from capital, since capital stock, once it is purchased, is available for use at all times. The services of labour inputs, on the other hand, are only offered for specific time periods. The general resolution of these problems involves assuming that the standard unit of capital input is a dollar, and that the flow of capital services is proportional to the value of the capital stock.

Because no direct measures of capital stock are available, it is necessary to construct estimates using information on past and present investment. Capital stock estimates are usually built up using the "perpetual inventory method". This method involves first establishing a benchmark estimate of capital stock for a base year and adding to the benchmark the value of net investment (new investment less discards) in capital for each year. The estimate of capital stock for a particular year is thus a

cumulative total of past patterns of investment. The provincial estimates of capital stocks, which can be found in the Statistics Canada publication **Fixed Capital Stocks and Flows**, are calculated based on a benchmark estimate of capital stock in 1947.

Although most researchers accept the use of the perpetual inventory method to estimate capital stocks, there is some disagreement about whether net or gross stocks should be used to proxy the flow of capital services.

3.2.2 Gross Capital Stock

Gross capital stock estimates are calculated based on the supposition that the services of a capital asset do not diminish as the asset ages. In other words, if a unit of capital has a lifetime of 20 years, a gross stock estimate assumes that it contributes just as much to production at the end of its "life" as it did when it was new. The standard example of gross capital stock is the "one horse shay".

Kendrick and Grossman (1980) argue that, for calculating TFP, gross capital stock is the most appropriate measure of the flow of capital services, since they do not believe that deterioration in the ability of ageing capital stock to produce output is substantial.

Denison (1985) also maintains that gross stock should be used to estimate capital input, but for slightly different reasons. He regards net stock as a measure of the future services of capital, and therefore argues that it does not reflect the current ability of capital to produce output. Denison, however, actually uses a weighted average of gross and net stock estimates, where the weights are .75 and .25 respectively, although he stresses that this is only for convenience:

"My introduction of net stock into the capital input measure is only a convenient way to make a reasonable allowance for deterioration in the contribution of capital goods to production as they age."³

3.2.3 Age-Efficiency Functions and Net Capital Stock

Capital stock estimates may be adjusted in order to take into account deterioration in the ability of ageing stock to produce output. This adjustment is normally made using an age-efficiency function which is based on the premise that changes in the ability of a capital asset to produce services depend only on its age.

A number of general forms for this function are frequently postulated. For example, the age-efficiency function which corresponds to a gross capital stock estimate

3. Denison (1985, p.17)

is one in which efficiency is constant until the end of the lifespan of the capital asset is reached, at which point it goes to 0. Another frequently used age-efficiency function shows relative efficiency decreasing by a constant amount in each period. This corresponds to straight-line depreciation. Alternatively, the age-efficiency function may be assumed to be concave or convex.

Denison's weighted average of gross and net stocks, for example, corresponds to a concave age-efficiency function in which the efficiency of an asset initially decreases quite slowly, but then drops off rapidly as the asset ages. The U.S. Bureau of Labor Statistics (BLS, 1983) also uses a concave age-efficiency function to estimate net stock; they tested various forms of the age-efficiency function before choosing to use a hyperbolic function. JGF (1987) have adopted a convex geometric form which assumes that efficiency initially drops quite rapidly, but levels out as capital stock becomes older.

The choice of an age-efficiency function is important because of its effect on the capital stock estimates, and hence on the estimate of TFP. Net capital stock, which is the most commonly used measure of capital input for productivity analyses, is derived by deducting depreciation from the value of gross stock. Depreciation of the stock of

capital in each period is calculated based on a particular age-efficiency function.

Measures of capital input and of TFP will therefore vary depending on whether the productive capacity of capital stock is assumed to deteriorate quickly, slowly, or not at all. For instance, if estimates of gross stock are used, then the measure of capital inputs will be larger than it would be if net stock figures were used. Consequently, the effect on the capital input measure of new investment will be proportionately lower. Less growth will therefore be attributed to increases in capital inputs, hence the estimated growth in TFP will be higher. For example, between 1948 and 1981⁴, Kendrick, using gross stock, calculates that growth in capital inputs averaged 3.1 percent per year, compared to Jorgenson's estimate (based on net stocks) of 4.3 percent per annum. Similarly (although this is not entirely due to the different estimates of capital stock), Kendrick found that TFP increased, on average, 1.8 percent per year, compared to Jorgenson's annual estimate of 0.9 percent.

4. These comparative figures are taken from an appendix in the BLS paper(1983). Jorgenson's estimates therefore do not actually come from JGF; they were obtained directly from Jorgenson by the Bureau of Labor Statistics.

3.2.4 The Measure of Capital Input Used in this Study

This study utilizes Statistics Canada's provincial estimates of capital stock by industry and by asset type (for buildings and machinery and equipment). In order to allow for the fact that older capital stock usually does not represent the same output-producing capacity as new capital stock does, the actual data used are mid-year net stock estimates. These estimates of net stock are calculated using a linear age-efficiency function (straight-line depreciation).

A major difference between this study and DFM's analysis of manufacturing in Canada is in the measurement of capital stock. Although the same method of depreciation is used to calculate net stock, DFM chose to construct their own benchmark estimates of capital stock in 1947. Their major reason for doing this was that they disagreed with Statistics Canada's methodology for establishing the benchmark (which was based on inverting a Cobb-Douglas production function). Since that time, Statistics Canada has revised the methodology for calculating the 1947 benchmark; it is now based on investment patterns.

Capital stock estimates are not available for each of the twenty manufacturing industries at the two-digit SIC level. For this reason, output, labour, and material

inputs in manufacturing have been aggregated into categories which correspond to the capital stock data. Estimates of TFP are therefore created for the following industries: food and beverages; paper and allied; petroleum and coal; chemicals; wood; metal fabricating; transportation equipment. A residual category, other manufacturing, includes miscellaneous manufacturing, non-metallic mineral products, electrical products, machinery, primary metals, printing, publishing and allied, furniture and fixtures, clothing, textiles, leather, rubber and plastics and tobacco products.

Food and beverages, paper and allied, petroleum and coal, and chemicals are aggregated into non-durable manufacturing, while the remaining industries are classified as durable goods-producing industries.

3.2.5 Other Considerations

Some researchers argue that estimates of capital input should be adjusted for idle capacity. For example, Solow (1957) used the unemployment rate to adjust his estimates of capital input. However, capital inputs are unique in that they represent a cost to the producer whether or not they are actually being used, so there is some justification for including idle capital stock in the measure of capital input. Although Kendrick, Denison, BLS and JGF all cross-

classify capital stock estimates by type of asset, and in some cases, by industry and legal form of organization⁵, no specific adjustment for capacity utilization is made. Similarly, unadjusted capital stock estimates are used in this thesis.

3.2.6 The Aggregate Capital Input Index

An aggregate estimate of capital input is constructed for each industry using the Tornquist index number formula. Implicit rental prices by industry and for each type of asset (machinery and equipment and buildings) are used to derive the income shares for the aggregation. The derivation of these rental prices is discussed in section 3.5 below. As was mentioned earlier, this method of aggregating estimates of capital stock by asset type introduces an implicit quality adjustment mechanism into the calculations.

5. By disaggregating capital inputs by industry, type of asset, and ownership, there is an implicit adjustment made for quality changes. Jorgenson, Gollop and Fraumeni (1987, pp.11-13) discuss this method of quality adjustment.

3.3 The Measurement of Labour Input

3.3.1 Conceptual Issues

The most frequently used measure of labour input is person-hours worked, which is calculated from data on employment and average weekly hours. These data generally come from establishment surveys.

Although employment by itself is sometimes used as a measure of labour input, person-hours are preferred for estimating productivity change. The reason for this is that measures of employment do not quantify the actual amount of labour which is used. For example, if the average worker must work forty hours per week, this represents more labour than if the average work week is only thirty hours long. However, this would not be reflected in a labour input measure which was based only on employment. A related problem is that employment estimates from establishment surveys normally measure jobs rather than persons employed. This means that a multiple job holder would be considered to be one "unit" of labour for each job that is held, regardless of whether these jobs represent full-time or part-time employment. In order to measure labour input more accurately, employment data are therefore multiplied by average weekly hours to obtain an estimate of person-hours paid.

Another important issue relates to the fact that reported average weekly hours typically are hours paid for rather than hours worked. Hours paid for but not worked do not represent a contribution by labour to output and should ideally be excluded from estimates of labour input which are used to calculate productivity.

All of the major studies of productivity change use the concept of person-hours paid to measure labour input. Most researchers adjust the hours-paid-for estimate to an estimate of hours actually worked using data from household surveys. Denison is the only researcher who adjusts hours paid estimates to an hours worked basis, although other researchers (e.g. Kendrick and the BLS) recognize that hours worked is the most appropriate measure.

3.3.2 Changes in Labour Force Characteristics

A major focus of Denison's and JGF's studies is the development of quantitative estimates of the effect on economic growth of changes in the quality of factor inputs used in production. For example, Denison concentrates on adjusting his estimates of labour input so that they reflect changes in the age, sex and educational composition of the work force. The basic assumption underlying Denison's adjustments for changes in intangible labour characteristics

is that differences in average wages (which are used to proxy the marginal product of labour) between workers with different age, sex, or educational characteristics are entirely due to differences in marginal productivity. Using this assumption, estimates of employment are cross-classified by each of these attributes. Denison's measure of labour input is constructed as a weighted composite of individual labour inputs for each of these classifications, where the weights are based on relative earnings. JGF use a similar methodology, but at a much more disaggregated level.

By adjusting for changes in the quality of labour inputs, Denison and JGF argue that their measure of technical change is a purer measure of economic efficiency, since it does not implicitly include the effects of changes in the basic characteristics of the labour force.

Denison and JGF encounter some practical difficulties in developing their estimates, due to limitations in the data. For example, in order to obtain estimates of employment and income which are cross-classified by age, sex, education, occupation and industry, they use data from the census. These data are decennial, hence it is necessary to interpolate the benchmark estimates for the intercensal years. In addition, for each industry, data are generally not available at the required level of detail, so that it is

necessary to fit the census data to the estimates of employment and hours worked by industry. JGF use iterative proportional fitting to calculate their cross-classified estimates of labour input.

The realism of the quality adjustments made is therefore influenced by some fairly major assumptions which are necessary, first in order to obtain the required data, and then to construct the composite measure of labour input. For example, the assumption that differences in relative wage rates between males and females is entirely due to differences in marginal productivity is not necessarily realistic.

The type of detailed information used by JGF and Denison is not available for British Columbia. Therefore, because of data limitations and since, in some cases, the detailed adjustments made may not be very realistic, no specific adjustment for changes in the characteristics of the labour force are made in this study. Hence, the basic approach taken to measuring labour inputs is similar to that adopted by Kendrick, the BLS, and DFM. It should be noted, however, that since labour input is disaggregated on the basis of production workers, non-production workers, and the self-employed, the aggregate measure of labour input does

reflect differences in the general composition of the labour force.

If the study covered a longer period, it might be more important to quantify changes in basic characteristics of the labour force. Most of the other studies discussed, for example, cover much longer time periods, beginning anywhere between 1929 and 1948. Demographic changes, changes in labour force participation by females, and changes in educational levels are much more important in these studies; the difference between the average worker in 1929 and the average worker in 1980 is much greater than the difference between workers in 1961 and 1980.

3.3.3 The Measure of Labour Input Used in this Study

In this study, labour input is defined in terms of person-hours worked. Individual labour inputs by industry are calculated by multiplying estimates of employment from the Census of Manufacturing by average annual hours. The Census of Manufacturing publication does not report actual hours worked as opposed to hours paid for. However, the ratio of hours worked to hours paid (for the total manufacturing sector) is available as unpublished data from the Labour Force Survey (LFS), which is a household survey. Estimates of average weekly hours from the census are

therefore adjusted to an actual hours worked basis using these data.

For the years for which census data are not yet available, the estimates of employment and hours worked are projected using data from the Survey of Employment, Payrolls, and Hours (SEPH). This is consistent with the methodology used by Statistics Canada to produce their estimates of labour productivity by industry for the post-censal years.

In order to include the labour services of the self-employed in the labour input measure, it is necessary to estimate the number of hours worked and the hourly wage of proprietors of unincorporated businesses. The only available data for the non-corporate sector are for employment and total income, which does not separate the income accruing to capital from labour income.

The labour input supplied by the self-employed is therefore calculated by multiplying the number of persons in each industry who are self-employed by average annual hours of non-production workers. Non-production workers' hours were used because it was assumed that they were more likely to reflect the actual hours worked by self-employed manufacturers than were production workers' hours. Even if

this assumption is incorrect, the overall effect on the TFP estimate is likely to be negligible, since self-employment in the manufacturing industry accounts for less than 10 percent of total employment in manufacturing in B.C.

3.3.4 Other Considerations

As discussed above, some researchers incorporate the effects of changes in labour force characteristics in their measures of labour input. For example, Denison's and Jorgenson's estimates of labour input, which are adjusted for quality change, show significantly higher growth than those produced by Kendrick and the BLS. Jorgenson estimates that labour inputs grew at an average annual rate of 1.8 percent per year between 1948 and 1981, while Denison calculates that labour input increased by an average of 1.4 percentage points during that period. The comparative figures for the BLS and Kendrick are 0.9 and 0.8 respectively.

Since growth in TFP is defined as the difference between growth in output and growth in factor inputs, the assumptions which are made with respect to the measurement of capital and labour inputs will influence the TFP estimate. Jorgenson's estimate of annual growth in TFP between 1948 and 1981 is the lowest, at an average rate of 0.9 percent per year. Kendrick's estimate, as expected, is

the highest, at 1.8 percent per year. His estimate of TFP includes some elements which are incorporated in the labour and capital estimates used by Denison and Jorgenson. The BLS estimate of growth in TFP is 1.5 percent per year, while Denison's estimate is 1.4 percent per annum.

3.3.5 The Aggregate Labour Input Index

The aggregate labour input index is constructed as a Tornquist index of individual labour inputs. For each industry, labour is disaggregated into production workers, non-production workers, and the self-employed. Average hourly earnings are used to determine the income shares of each type of labour. Since no estimates of hourly earnings are available for proprietors of unincorporated businesses, it is assumed that the self-employed receive the same hourly wage as do non-production workers. This is consistent with the way in which the labour input estimates are generated.

3.4 The Measurement of Material Input

As explained above, in this study output is defined as a measure which is gross of intermediate inputs. Materials must therefore be included in the composite measure of factor inputs. The Census of Manufacturing includes data on

the value of material inputs used in each industry; however, no price or quantity information is provided.

In this study, estimates of the quantity of material inputs used in each industry are imputed based on the method of DFM. They calculate real material inputs residually by subtracting real value added from real output. This follows from the definition of gross output as the sum of value added and material inputs. Following DFM's methodology, estimates of GDP by industry in constant dollars are used to proxy real value added. The real gross output measure is calculated as described in Section 3.1. An implicit price index for material inputs is derived from the ratio of the total value of material inputs to the estimated quantity of material inputs.

3.5 The Rental Price of Capital

The rental price of capital is needed to determine the income shares which are used to aggregate estimates of capital stock by asset type into a composite measure of capital input for each industry. Implicit rental prices are utilized because there is no direct way of measuring the marginal product of the capital stock. This section

discusses the method used to calculate the rental price of capital.

The derivation of an implicit rental price of capital is based on the assumption that the marginal cost of acquiring an asset must equal the discounted value of the stream of services of that asset⁶. The following formula, which is used in this study, comes from the BLS paper (1983, p.49), and is based on the general expression for calculating the rental price of capital which was developed by Jorgenson and Hall (1967):

$$(1) \quad c = \frac{(1-e-u \cdot z) \cdot [p \cdot (r+\delta) - dp]}{1-u}$$

Where

- c = the rental price of capital
- e = the investment tax credit rate
- u = the corporate income tax rate
- z = the present value of \$1 of tax depreciation allowances
- δ = the rate of economic depreciation
- r = the nominal interest rate
- p = the deflator for new capital goods
- dp = the expected inflation rate for new capital goods.

6. Bureau of Labor Statistics (1983 p.51)

An explanation of the way in which the above expression for calculating the rental price of capital is formulated follows below.

At any point in time, a capital asset will only be purchased if the rental price is high enough to cover the interest and depreciation costs of holding the asset, less the capital gain due to inflation⁷. This can be expressed mathematically as:

$$(2) \quad c = p \cdot (r + \delta) - dp$$

If corporate income is taxed, then the income from the investment will be decreased by the amount of the tax ($c \cdot u$), hence at the margin, the rental price of capital must be high enough to cover this expense as well:

$$(3) \quad c = \frac{p \cdot (r + \delta) - dp}{1 - u}$$

However, various tax incentives which decrease the tax burden must also be taken into account. For example, an investment tax credit permits the purchaser of a unit of capital to reduce his tax liability by a portion of the cost of the asset. The purchase price of the asset must therefore be decreased by the value of the investment tax credit, e.p.

7. Boadway (1980, p.253)

Similarly, owners of capital assets are permitted to deduct a depreciation allowance from the income accruing to the asset. A further reduction to the purchase price of a unit of capital is therefore made. This reduction is equal to the corporate income tax rate, u , times the present value of one dollars' worth of tax depreciation allowances, z . Equation (1) can thus be derived by incorporating these adjustments into equation (3).

The following sections describe the sources of the data used to calculate the rental price of capital in this study.

3.5.1 Investment Tax Credit, e

In Canada, a federal investment tax credit has applied to the purchase of manufacturing and processing equipment since June of 1975. The rate of the tax credit varies in different parts of the country; in B.C., the investment tax credit was initially set at 5 percent of the value of investment, but was increased to 7 percent in November of 1978. In 1987, the rate was dropped back to 5 percent, and was further reduced to 3 percent in 1988.

3.5.2 Corporate Income Tax Rate, u

The rate of corporate income tax is defined to be the marginal tax rate faced by a profitable firm. Although it

is often estimated by calculating the ratio of total corporate tax payments to corporate profits, some analysts feel that it is more appropriate to use a marginal tax rate. For example, the Bureau of Labor Statistics argues that:

"... the average tax rate is not conceptually appropriate for the rental price expression. The tax rate should reflect marginal incentives afforded investors in new capital by current tax laws and it should be specific to the type of asset..."⁸

Coen (1975, p.65) also maintains that "the tax rate (should be) set equal to the maximum statutory corporate income tax rate". The corporate income tax rate used in this study is the marginal tax rate for manufacturing industries in British Columbia. The data are obtained from various issues of **The National Finances**, an annual publication of the Canadian Tax Foundation.

3.5.3 Present Value of \$1 of Tax Depreciation Allowances, z

This component represents the "portion of investment expenses which can be recovered in capital consumption allowances after discounting these allowances for nominal interest charges"⁹. Z is calculated for both construction and machinery and equipment, using statutory depreciation rates and patterns.

8. Bureau of Labor Statistics (1983 p.51)

9. Bureau of Labor Statistics (1983 p.51)

For most of the years between 1961 and 1988, investment in machinery and equipment for manufacturing and processing is depreciated using straight-line depreciation at fifty percent per year. Buildings, on the other hand, are depreciated at an annual rate of 5%, using a declining balance pattern of depreciation.

For straight-line depreciation, the proportion of the original cost of the asset which may be deducted in any period is $1/T$, where T is the tax life of the asset. As shown by Hall and Jorgenson (1967, p.395), the present value of one dollars' worth of tax depreciation allowances, Z , is therefore equal to:

$$(4) \quad Z = (1/r \cdot T) \cdot [1 - e^{-rT}]$$

The discount rate(r) which is used is the McLeod-Young-Weir 10-industrial bond rate. It is available on CANSIM in matrix 2560.

3.5.4 The Average Rate of Economic Depreciation, δ

The average rate of economic depreciation is calculated as the inverse of the average service life for each asset type and each industry. The service lives used were obtained from the annual publication **Fixed Capital Stocks**

and Flows and are the same as the ones used by Statistics Canada to create estimates of capital stocks.

3.5.5 The Deflator for New Capital Goods

The deflator for new capital goods (p) and the expected rate of inflation (dp) are calculated from the current and constant dollar estimates of investment by asset type and industry for British Columbia. These data are from the annual publication **Fixed Capital Stocks and Flows**.

3.6 The Income Shares of Aggregate Labour, Aggregate Capital and Material Inputs

Total factor input is calculated as a Tornquist index of the aggregate estimates of labour, capital and material inputs. The weights used to construct the index of total factor input are the respective income shares.

As indicated in chapter two, the value of the inputs must sum to the value of total output at equilibrium. Income shares need only be calculated for labour and material inputs, since capital's income share can be calculated residually.

Labour's share of income is defined to be to the ratio of total labour income (the sum of the wages and salaries

of production, non-production and self-employed workers) to the value of gross output in current dollars. Similarly, the income share of material inputs (materials, supplies, fuel and electricity) is calculated as the ratio of the total cost of material inputs to the value of gross output. Capital's share of income is defined residually. The main reason for estimating capital's share of income residually is that the indices of output, labour, and material inputs are all calculated using data from the Census of Manufacturing, so that they are internally consistent. The estimates of capital stock and the rental price of capital, on the other hand, come from other sources. Residually defining the share of capital in total income therefore reduces the possibility of using weights which are inconsistent with the output measure.

It should be noted that labour's share of income includes the labour income which accrues to the self-employed. Since estimates of unincorporated business income are usually not divided into returns to labour and returns to capital, it is necessary to allocate this income between these two factor inputs. Various approaches to resolving this problem have been taken by different researchers. For example, Kendrick assumes that the wage rate for proprietors is equal to the wage rate for employed persons in a particular industry. He obtains an estimate of labour

income by multiplying the hours worked by proprietors by the average wage rate in each industry; capital income is then calculated residually. Jorgenson uses a similar methodology, except that labour income, rather than capital income is calculated as a residual. The BLS and Denison calculate capital and labour income for unincorporated businesses based on estimates of wages and the return to capital from the corporate sector. Their initial estimates are then prorated so that they sum to the correct total estimate of proprietors' income. DFM do not make any specific provision for unincorporated businesses.

In this study, it is assumed that the self-employed receive the same wage as non-production workers in manufacturing. Labour's share of proprietors' income is thus calculated based on this assumption, and capital's share is determined residually.

In the following chapter, the estimates of TFP for manufacturing are presented and analyzed in terms of differences in productivity over time and between industries.

CHAPTER IV

EMPIRICAL RESULTS

A general discussion of TFP estimates for the British Columbia manufacturing sector during the period between 1961 and 1988 follows below. The results which are reported here include preliminary estimates for 1987 and 1988. For output, labour and materials, these estimates are constructed by projecting census data forward using related series. The capital stock estimates for 1987 and 1988 are obtained directly from Statistics Canada, but should also be regarded as preliminary.

4.1 Total Factor Productivity in Manufacturing

For total manufacturing, estimates of total factor input (TFI) are constructed using aggregate input indices of labour, capital and material inputs. For example, the labour input index for total manufacturing is a Tornquist

index of labour inputs which have been cross-classified by industry and by type of labour (e.g. production workers, non-production workers, and proprietors of unincorporated businesses). The income shares which are used to aggregate the individual labour input indices are calculated using estimates of wage rates by industry and by type of labour. Similarly, the composite indices for capital and material inputs for total manufacturing are also constructed as Tornquist indices of capital stock and material inputs in each industry. Finally, the index of total factor input which is used to calculate TFP is itself a Tornquist index of the composite labour, capital and material input indices¹.

Table 1 presents the estimates of total factor productivity, as well as the relevant output and input indices for the B.C. manufacturing sector. Also included at the bottom of the table are average annual growth rates for selected periods. These growth rates are calculated using a logarithmic approximation. For this reason, the estimates of growth in total factor inputs and total factor productivity may not sum exactly to growth in total output².

1. An example of how these estimates are calculated can be found in Appendix A.

2. Since the growth rates are presented as percentages, the discrepancy generally exists only at the third decimal place.

TABLE 1

TOTAL FACTOR PRODUCTIVITY FOR THE MANUFACTURING SECTOR

Year	Output	Labour	Capital	Material	TFI	TFP
1961	46.5	68.7	46.9	46.9	53.4	86.0
1962	49.8	71.9	47.6	49.4	55.8	88.1
1963	52.2	74.8	49.2	51.5	58.0	89.0
1964	57.5	77.9	51.8	57.6	62.6	90.9
1965	60.6	82.0	55.8	59.9	65.7	91.3
1966	65.3	85.1	61.1	65.4	70.5	91.7
1967	66.1	83.6	65.5	66.2	71.4	91.6
1968	69.4	84.0	67.4	68.6	73.3	93.9
1969	73.3	86.4	69.4	72.0	76.2	95.5
1970	72.4	84.2	72.7	72.6	76.6	93.6
1971	75.7	88.8	76.8	75.1	79.9	94.0
1972	81.3	91.7	80.1	81.6	84.8	95.1
1973	89.4	97.0	81.9	88.7	90.4	98.3
1974	89.7	95.8	83.5	87.9	90.0	99.1
1975	78.9	85.9	84.4	78.0	81.7	96.3
1976	88.0	93.9	84.5	85.1	87.5	100.6
1977	90.0	94.7	85.6	86.5	88.7	101.4
1978	97.0	101.3	87.2	94.9	95.1	102.0
1979	99.6	105.9	89.2	98.5	98.6	101.0
1980	101.4	106.5	93.3	100.4	100.6	100.8
1981	100.0	100.0	100.0	100.0	100.0	100.0
1982	87.1	91.6	104.6	88.6	91.2	95.9
1983	89.9	87.7	103.5	89.7	90.8	99.4
1984	91.4	86.3	100.5	88.9	89.5	102.5
1985	98.0	90.3	98.3	96.8	94.6	104.1
1986	96.2	85.5	96.4	90.8	89.5	107.8
1987	107.6	95.6	96.3	100.9	97.0	111.5
1988	107.7	100.5	99.9	100.2	98.4	110.0
Average Annual Growth Rates (%)						
61-73	5.4	2.9	4.6	5.3	4.4	1.1
73-88	1.3	0.2	1.3	0.8	0.6	0.8
61-75	3.8	1.6	4.2	3.6	3.0	0.8
61-88	3.1	1.4	2.8	2.8	2.3	0.9

4.1.1 General Observations

Total factor productivity in manufacturing increased at an average annual rate of 0.9 percent between 1961 and 1988. For comparative purposes, DFW (1979) quote an estimated growth rate of about 1 percent per year for total factor productivity in Canadian manufacturing between 1952 and 1976.

An analysis of the growth of output, TFP and TFI indicates that between 1961 and 1988, only 29% of output growth could be explained by improvements in productivity. On average, gross output increased at 3.1 percent per year, while increases in factor inputs accounted for 2.3 percentage points of the total growth. Most of the growth in output was due to increases in the factor inputs used in production. This is particularly important because these estimates of total factor productivity include the effects of changes in intangible factors, as well as the influence of market imperfections and scale economies. Consequently, only part of the 0.9 percent annual growth in TFP can be attributed to improvements in economic efficiency, or technical change. As a rough benchmark, Kendrick and Grossman (1980) calculate that approximately half of the growth in their estimate of TFP is due to advances in

knowledge; this estimate is similar to Walters' (1970) findings for TFP in Canada between 1962-67.

The total factor input index is constructed from a weighted average of growth in the individual factor inputs. Between 1961 and 1988, the relative importance of material inputs in this index stayed more or less constant, but capital's share increased and the share of labour declined. At the same time, growth in labour inputs lagged behind increases in the use of capital and material inputs. This is consistent with a general trend towards substituting capital for labour inputs in production.

These estimates indicate that total factor productivity declines during periods of economic slowdown. For example, 1975 was a recession year for British Columbia. As Table 1 shows, output in manufacturing decreased by about 12% between 1974 and 1975. The change in total factor productivity, at -2.8%, was proportionately less, mainly because manufacturing companies utilized fewer labour and material inputs in 1975 than they did in 1974. However, although labour inputs decreased by 10%, the decline in output between 1974 and 1975 was even larger (12%). The decrease in TFP could therefore be partially due to labour market rigidities which result in employers keeping workers on their payroll even when they are not able to fully

utilize their labour services. Capital inputs actually increased between 1974 and 1975, possibly because planned investment in plant and equipment may not have been abandoned during the first part of the slowdown. The fact that labour and material inputs grew in 1976 while capital inputs stayed more or less the same tends to support this view.

In 1982, which is another recession year, productivity in manufacturing drops significantly, but rises again quite rapidly starting in 1983. This rise in TFP is a consequence of the fact that the factor input index has remained at about its 1983 level, while output has risen more or less constantly since 1982. This observation therefore tends to corroborate a popular view which holds that industries are operating much more efficiently and with less slack now than they did prior to the recession of 1982/83.

4.1.2 The Post-1973 Productivity Slowdown

Comparisons of average annual growth in TFP between 1961-1973 and 1973-1988 tend to substantiate the hypothesis that there was a productivity slowdown after 1973, since average annual growth in TFP declined from 1.1 percent before 1973 to 0.8 percent from 1973 to 1988. An analysis of the components of total factor input indicates a significant decline in the growth of each of the individual

inputs used in production. However, the relative decline in growth was much less marked for capital than for materials and labour inputs. Again, this is consistent with a general trend towards a greater dependence on using capital rather than labour in production.

It should be noted that average annual growth rates are very sensitive to changes in the choice of end-years. The importance of choosing appropriate years for a comparison of productivity is strongly emphasized by Denison (1962), who argues that the end-years chosen should be similar in terms of the position in the business cycle which they represent. For example, if estimates of TFP between 1961 and 1975 are compared with TFP measures for 1975-1988, there is no evidence to support the hypothesis of a productivity slowdown, since the average annual growth rate of TFP increases from 0.8 to 1.0 percent between 1961-75 and 1975-88. This apparent contradiction occurs because 1975 is a recession year and, as Table 1 indicates, there was a fairly significant decline in TFP in 1975, hence the estimate of average annual growth in TFP between 1961 and 1975 is biased downward.

4.1.3 Comparison with Other Studies of Manufacturing

Kendrick, JGF, the Bureau of Labor Statistics, and Denny, Fuss and May, all examine TFP in manufacturing.

However, Kendrick's estimates do not extend beyond 1978, and JGF and DFM do not construct aggregate estimates for the manufacturing sector; their studies concentrate more on TFP in individual industries. Consequently, the estimates of TFP for total manufacturing in British Columbia are only compared to the TFP estimates prepared by the BLS.

From a theoretical point of view, the BLS estimates are probably the most appropriate U.S. estimates to use for a comparison, since many of the assumptions made by the BLS are also made in this study. For example, the BLS does not adjust its estimates of labour or capital inputs to incorporate the effects of changes in intangible factors. The effects of improvements in education, changes in the age-sex characteristics of the workforce, and other intangible elements are therefore included in the BLS estimates of TFP, as they are in the estimates presented in this study.

The BLS estimates of TFP in manufacturing between 1961 and 1981 support the hypothesis that a slowdown in productivity occurred after 1973. The BLS calculates that the average annual increase in productivity for manufacturing between 1961 and 1973 was 2.9 percent per year; between 1973 and 1981, the increase in TFP dropped to only 0.4 percent per year. As discussed above, the

comparable estimates for British Columbia show a similar trend, since growth in TFP decreased from 1.1 percent per year from 1961-1973 to 0.2 percent per annum between 1973 and 1981.

These comparisons have important implications. Not only do they suggest that a productivity slowdown occurred in both B.C. and the United States after 1973, they also imply that productivity growth in the British Columbia manufacturing sector is much lower than in U.S. manufacturing. In fact, productivity growth in B.C. is only half as high as in the United States.

A possible explanation for this difference may relate to basic inefficiencies in manufacturing in this province relative to the United States. For example, although growth in output was roughly the same for the two jurisdictions, increases in the factor inputs used in British Columbia were significantly higher than in the U.S. This suggests that the role of productivity improvements was much more important in the U.S. Most of the output increase in B.C. can be attributed to growth in inputs.

4.2 Durables and Non-durables

In this section, trends in total factor productivity for manufacturers of durable and non-durable goods are briefly examined. Non-durable goods producing industries include manufacturers of food and beverages, paper and allied products, petroleum and coal, and chemicals. All other manufacturing industries produce durable goods.

The estimates of total factor input and total factor productivity for these two sub-sectors are calculated as Tornquist indices using estimates of aggregate labour, capital and material inputs. As in total manufacturing, these aggregate indices are constructed from individual inputs which are cross classified by industry and by type.

4.2.1 Non-durables

As indicated in Table 2, total factor productivity in non-durables manufacturing has grown slowly compared to TFP in total manufacturing. For example, between 1961 and 1988, growth in TFP for all manufacturing industries was almost double the growth in the nondurable sector. Output growth in this sector was also significantly lower than for total manufacturing during the period being considered.

TABLE 2
TOTAL FACTOR PRODUCTIVITY, NON-DURABLES

Year	Output	Labour	Capital	Material	TFI	TFP
1961	52.1	75.7	47.5	48.0	53.7	96.3
1962	55.2	78.6	48.6	51.1	56.3	97.2
1963	56.5	78.8	51.2	51.8	57.4	97.6
1964	61.9	82.0	55.0	57.4	62.1	99.0
1965	63.8	83.3	60.6	58.7	64.4	98.3
1966	69.4	90.4	68.3	65.4	71.2	96.7
1967	71.4	91.9	75.4	67.4	74.1	95.5
1968	75.6	91.9	78.6	71.6	77.2	97.0
1969	78.4	91.4	80.0	72.4	78.0	99.7
1970	77.7	90.0	82.4	71.8	77.8	99.0
1971	81.6	94.4	86.7	75.9	82.0	98.7
1972	88.6	95.4	90.7	83.9	87.8	100.2
1973	96.1	97.8	91.4	88.7	91.3	104.7
1974	95.9	100.2	90.7	87.2	90.6	105.1
1975	84.4	88.2	90.4	79.6	83.8	100.5
1976	93.3	98.5	89.4	84.0	87.8	106.2
1977	90.3	99.8	89.1	83.2	87.5	103.2
1978	98.0	102.2	89.2	90.9	92.6	106.0
1979	99.4	102.8	89.4	92.0	93.5	106.5
1980	103.4	106.3	92.4	99.8	99.4	104.1
1981	100.0	100.0	100.0	100.0	100.0	100.0
1982	94.0	96.3	106.0	94.4	96.5	97.5
1983	97.8	88.7	105.3	96.1	96.4	101.6
1984	94.7	86.9	102.0	91.7	92.5	102.4
1985	101.2	89.8	99.5	99.7	97.7	103.7
1986	105.7	89.7	97.2	98.1	96.2	109.9
1987	111.0	91.3	96.5	102.1	98.8	112.4
1988	105.2	96.1	99.7	96.7	96.8	108.9
Average Annual Growth Rate (%)						
61-73	5.1	2.1	5.5	5.1	4.4	0.7
73-88	0.6	-0.1	0.6	0.6	0.4	0.3
61-75	3.5	1.1	4.6	3.6	3.2	0.3
61-88	2.6	0.9	2.8	2.6	2.2	0.5

After 1973, there is a substantial drop in the growth rate of TFP for nondurable manufacturing which coincides with a marked decrease in output growth. However, in relative terms, the contribution of TFP to output growth has increased. That is, before 1973, TFP grew at an average annual rate of 0.7 percent per year; during that time, increases in total factor input accounted for 86 percent of the growth in output. After 1973, although the average annual growth rate of TFP dropped to 0.3 percent per year, increases in productivity accounted for half of the annual growth in output.

The increase in the relative importance of the contribution of TFP to growth in output may be a consequence of changes in investment patterns by non-durable goods producing industries. For example, prior to 1973, the increase in capital inputs averaged 5.5 percent per year. After 1973, however, the growth of capital inputs slowed down considerably to an average rate of only 0.6 percent per annum. If firms were changing over to a more capital intensive technology during the 1960's and early 1970's, this would explain the relatively large growth in capital inputs compared to the more moderate annual rate of growth for labour inputs of 2.1 percent per year between 1961 and 1973. Similarly, once the investment in new capital stock

is made, capital input would not be expected to grow as rapidly. In fact, since 1973, growth in capital inputs has been much more moderate, and on average, labour inputs have declined. This is consistent with a substitution of capital for labour inputs in the nondurables manufacturing industry. In this subsector, capital inputs accounted for about 23% of total factor income in 1988, compared to only 16% of total income for labour inputs.

4.2.2 Durables

Estimates of total factor productivity and total factor inputs for the durable goods manufacturing sector are presented in Table 3. For the entire period between 1961 and 1988, increases in TFP averaged 1.4 percent per year, while output increased at an annual rate of 3.5 percent. As these figures indicate, changes in productivity in the durable goods manufacturing sector are significantly different from those in nondurable manufacturing. First, growth is much higher in the durables sector. Second, although there is definitely a slowdown in productivity growth after 1973, the slowdown is less marked in durable goods manufacturing than it is for the non-durables sector.

TABLE 3
TOTAL FACTOR PRODUCTIVITY, DURABLES

Year	Output	Labour	Capital	Material	TFI	TFP
1961	42.1	66.0	47.7	46.7	54.5	76.3
1962	45.5	69.3	47.8	48.8	56.6	79.5
1963	49.0	73.5	48.1	52.3	59.8	81.1
1964	54.2	76.5	49.2	59.0	64.4	83.5
1965	58.3	81.9	51.3	62.5	68.2	84.9
1966	62.3	83.1	53.6	66.7	71.3	86.9
1967	62.0	80.2	55.0	66.2	70.4	87.6
1968	64.6	80.8	55.5	66.7	71.0	90.6
1969	69.5	84.4	58.2	72.8	75.8	91.3
1970	68.2	81.9	62.7	74.8	76.9	88.4
1971	71.5	86.6	66.5	75.8	79.4	89.5
1972	76.0	90.2	69.1	81.3	83.8	90.3
1973	84.7	96.9	72.0	91.2	91.4	92.5
1974	84.9	94.0	75.8	90.0	90.6	93.4
1975	74.5	85.1	78.0	77.0	80.5	92.4
1976	84.0	92.0	79.2	87.1	88.0	95.6
1977	89.9	92.6	81.8	90.6	90.4	99.7
1978	96.3	101.0	84.9	99.6	97.8	98.6
1979	99.8	107.3	89.0	105.8	103.5	96.5
1980	99.8	106.6	94.5	101.5	102.0	98.0
1981	100.0	100.0	100.0	100.0	100.0	100.0
1982	80.3	89.5	102.6	81.6	85.8	94.6
1983	82.4	87.2	100.9	82.4	85.2	97.7
1984	87.6	85.8	98.6	85.3	86.0	103.0
1985	94.3	90.4	96.6	92.9	90.9	105.0
1986	86.7	83.4	95.3	81.8	82.8	105.8
1987	102.7	97.0	96.0	97.7	93.5	111.6
1988	107.8	102.0	100.0	108.9	97.6	112.3
Average Annual Growth Rates (%)						
61-73	5.8	3.2	3.4	5.6	4.3	1.6
73-88	1.6	0.3	2.2	0.7	0.4	1.3
61-75	4.1	1.8	3.5	3.6	2.8	1.4
61-88	3.5	1.6	2.7	2.9	2.2	1.4

As was the case for nondurables manufacturing, the relative importance of productivity growth in the durable goods sector has increased since 1973. That is, for the period between 1961 and 1973, increases in total factor productivity were a much less important source of economic growth than were increases in factor inputs. Growth in total factor productivity accounted for only 28 percent of economic growth for the period between 1961 and 1973, whereas improvements in TFP explained 69 percent of the average annual growth in output from 1973 to 1988. These results indicate that although growth in productivity has decreased since 1973, improvements in productivity have become a much more important source of economic growth. This can be interpreted as indicating that firms are not increasing output by hiring more labour or capital, or using more material inputs; instead, increases in output are due to a more efficient use of existing factor inputs.

In terms of overall growth during the period under study, both output and total factor productivity have shown greater increases in the durable goods producing industries than in the nondurables industry. For example, between 1961 and 1988, total factor productivity for durables increased by 47%, while output grew by 156%. For the nondurables sector, the increase in TFP was only 13% compared to total growth in output of 102%. Since growth in the factor inputs

used in production for the two sectors is roughly comparable, these results suggest that there are either significant differences in the adoption of new production technologies in the two sectors, or that factor inputs have become much more efficiently utilized in the durable goods producing sector.

4.3 Industries within the Non-durables Sector

Manufacturers of food and beverages, paper and allied products, petroleum and coal, and chemicals all produce non-durable goods. The indices of output, factor inputs and total factor productivity for these industries can be found in Tables 4 to 7.

4.3.1 Food and Beverages

Productivity change in the food and beverage industry accounts for about a third of the growth in output between 1961 and 1988. However, the food and beverage industry does not show a productivity slowdown after 1973. On the contrary, as indicated in Table 4, average annual growth in TFP was 0.6 percent before 1973 compared to 0.7 percent per year between 1973 and 1988.

TABLE 4
TOTAL FACTOR PRODUCTIVITY, FOOD & BEVERAGES

Year	Output	Labour	Capital	Material	TFI	TFP
1961	59.6	91.0	44.3	58.7	61.8	96.2
1962	62.9	93.5	45.8	61.1	64.0	98.0
1963	62.5	90.3	47.1	60.4	63.3	98.4
1964	64.8	92.8	47.7	63.8	66.0	97.9
1965	65.7	91.6	49.5	64.0	66.3	98.8
1966	71.4	96.8	52.2	69.5	71.1	100.2
1967	72.2	95.4	54.5	69.9	71.6	100.6
1968	74.5	95.7	56.7	72.6	73.8	100.7
1969	73.1	92.6	59.2	69.8	71.9	101.5
1970	74.7	90.7	64.8	72.3	74.2	100.5
1971	76.8	89.3	72.2	73.4	76.0	100.7
1972	82.4	93.9	76.7	79.9	81.6	100.7
1973	85.3	92.7	79.7	81.0	82.7	102.9
1974	84.4	93.6	84.1	80.2	83.1	101.3
1975	77.9	93.7	88.4	75.0	80.2	97.0
1976	79.0	97.4	91.4	76.6	82.3	95.9
1977	79.6	99.3	92.9	75.0	81.8	97.2
1978	85.5	102.5	93.6	81.0	86.4	98.9
1979	85.0	101.8	94.6	80.2	85.9	99.0
1980	92.2	103.9	97.2	91.0	93.9	98.1
1981	100.0	100.0	100.0	100.0	100.0	100.0
1982	92.0	95.6	101.0	89.5	91.8	100.2
1983	90.8	90.4	101.8	88.5	90.5	100.3
1984	91.2	89.9	103.1	87.5	90.0	101.2
1985	95.3	90.1	103.7	88.1	90.6	105.2
1986	98.5	89.8	103.8	78.8	84.0	116.4
1987	104.3	86.1	104.0	83.4	86.6	119.6
1988	94.2	89.4	105.0	75.3	81.6	115.0
Average Annual Growth Rates (%)						
61-73	3.0	0.2	4.9	2.7	2.4	0.6
73-88	0.7	-0.2	1.8	-0.5	-0.1	0.7
61-75	1.9	0.2	4.9	1.7	1.9	0.1
61-88	1.7	-0.1	3.2	0.9	1.0	0.7

However, output growth has declined significantly since 1973. For the period from 1961 to 1973, output in the food and beverage industry increased at an average rate of 3.0 percent per year, whereas average output growth has only been 0.7 percent per annum since 1973.

Since TFP has also grown at about 0.7 percent per year, these figures imply that all of the annual growth in output after 1973 is due to improvements in productivity. In fact, the estimate of total factor inputs actually declined slightly during that period. However, the figures suggest that 1988 was a bad year in the food and beverage industry, so the estimates of average annual growth between 1973 and 1988 are biased downward. Using 1987 as the end-year does not really change the conclusions, though, since most of the growth in output between 1973 and 1987 (1.4% per year) can still be explained by improvements in total factor productivity. TFP grew at an average rate of 1.1% per annum during that period.

The index of labour input for the food and beverage industry in 1988 is at about the same level that it was at in 1961, while the index of capital inputs has more than doubled. This suggests that most of the improvement in productivity is due to a substitution of capital for labour inputs.

DFM calculated total factor productivity in the B.C. food and beverage industry for the period between 1961 and 1975. They found that TFP increased at an average annual rate of 1.0 percent per year. In this study, the average rate of increase in TFP between 1961 and 1975 was only 0.1 percentage points per year.

One possible explanation for this difference may be the fact that DFM use their own estimates of capital stock rather than the estimates produced by Statistics Canada. In all of the industries for which the discrepancy between DFM's estimates and the estimates from this study is large, capital inputs are calculated to have increased at a much higher rate than output or either of the other factor inputs. Unfortunately, DFM do not publish the actual indices of inputs and output which they used, so it is impossible to verify whether the capital input estimate is indeed the source of the differences.

4.3.2 Paper and Allied Products

Changes in productivity in the paper and allied products industry follow the general trend in nondurable manufacturing. Table 5 shows that, prior to 1973, most of the average annual growth in output (7.3% per year) was due

TABLE 5
TOTAL FACTOR PRODUCTIVITY, PAPER & ALLIED

Year	Output	Labour	Capital	Material	TFI	TFP
1961	58.6	64.0	45.7	46.5	54.4	103.1
1962	61.4	67.6	47.1	50.8	57.8	101.6
1963	66.5	70.4	50.3	55.6	61.9	102.8
1964	77.1	74.9	54.8	66.9	70.0	105.8
1965	80.9	80.2	61.6	70.9	75.3	103.0
1966	87.5	90.2	71.8	82.5	86.1	96.5
1967	90.8	93.7	81.0	87.6	91.8	93.8
1968	101.1	93.8	84.5	98.6	99.0	97.1
1969	111.3	96.1	85.9	106.1	104.2	101.9
1970	105.4	91.9	88.2	94.7	97.0	103.5
1971	111.6	101.9	92.9	105.8	106.4	99.5
1972	127.2	101.3	97.5	126.9	118.8	101.9
1973	140.7	106.6	97.5	134.8	124.6	107.7
1974	135.5	110.9	95.1	118.8	115.9	111.2
1975	94.0	86.8	92.7	81.8	88.4	103.5
1976	118.4	104.2	90.3	95.0	97.3	120.0
1977	104.4	106.1	89.6	90.7	95.4	108.2
1978	117.6	107.2	89.7	104.4	102.4	113.9
1979	118.6	108.6	89.7	102.5	101.8	115.6
1980	124.0	113.5	92.6	116.8	110.4	111.1
1981	100.0	100.0	100.0	100.0	100.0	100.0
1982	93.0	98.9	105.6	98.1	99.7	93.3
1983	104.5	88.8	103.7	105.0	100.7	103.8
1984	97.6	85.2	99.2	95.1	93.2	104.7
1985	110.5	90.1	96.3	120.5	106.4	103.8
1986	119.5	89.1	93.2	126.5	108.6	110.1
1987	130.6	93.0	92.4	138.2	114.8	114.0
1988	128.6	97.7	97.1	136.1	116.1	111.1
Average Annual Growth Rates (%)						
61-73	7.3	4.3	6.3	8.9	6.9	0.4
73-88	-0.6	-0.6	0	0.1	-0.5	0.2
61-75	3.4	2.2	5.0	4.0	3.5	0
61-88	2.9	1.6	2.8	4.0	2.8	0.3

to increases in total factor inputs; changes in TFP accounted for only 0.4 percentage points of total growth.

This very high growth in output was obviously supported by hiring more labour, and increasing the use of both capital and material inputs. Between 1973 and 1988, however, average annual growth in output actually becomes negative, declining by 0.6 percent per year. It should be noted, though, that 1973 was a boom year in the paper and allied industries, so that estimates of average annual growth relative to 1973 are biased upward for the period from 1961-1973 and downward for 1973-1988. In addition, the period between 1982 and 1984 was one of great instability in this industry. Large changes in the growth of output and factor inputs tend to bias the estimates of average annual growth.

A slightly more realistic pattern may be obtained by looking at productivity growth over the entire period under study. Between 1961 and 1988, output grew at an average annual rate of 2.9 percent. Most of the increase in output is due to growth in factor inputs; only 0.3 percentage points of total growth can be explained by increases in total factor productivity. Interestingly, although capital inputs doubled between 1961 and 1988, the substitution of capital for labour in production does not seem to have had

the beneficial effect on output that it did in the food and beverage industry.

For the paper and allied industry, DFM estimated that total factor productivity increased by 1.04 percent per year between 1961 and 1975, whereas the estimates of TFP produced in this study show an average increase of only .03 percent per year. Again, since DFM do not publish their estimates of factor inputs, it is difficult to explain the discrepancy between the two sets of numbers.

4.3.3 Petroleum and Coal

As indicated in Table 6, TFP in the petroleum and coal products industry grew at an average annual rate of 2.0 percent between 1961 and 1973, accounting for about 40% of the average annual growth in output. The petroleum and coal products industry shows a strong decline in productivity growth after 1973, since average growth in TFP was only about 0.1 percent per year compared to average growth in output of 1.3 percent per annum. Growth in total factor inputs has therefore been the major determinant of increases in output since 1973. Relative to 1961, labour inputs in this industry have actually declined, and capital has increased very slightly; the average annual growth in capital inputs between 1961 and 1988 was only 0.4 percent.

TABLE 6
TOTAL FACTOR PRODUCTIVITY, PETROLEUM & COAL

Year	Output	Labour	Capital	Material	TFI	TFP
1961	39.1	92.4	82.8	39.5	49.9	77.2
1962	43.1	90.3	81.1	43.4	52.6	81.0
1963	41.5	87.5	79.2	41.8	50.8	80.9
1964	46.3	84.9	77.2	46.5	54.1	84.9
1965	46.6	50.1	75.5	46.6	51.8	89.0
1966	51.4	54.7	74.0	50.9	55.4	92.0
1967	52.0	56.6	75.3	51.9	56.5	91.3
1968	54.8	57.2	78.5	54.5	59.0	92.2
1969	56.7	56.2	81.1	56.6	61.0	92.2
1970	59.0	61.2	81.2	58.9	63.3	92.5
1971	62.7	61.3	80.3	62.3	65.9	94.3
1972	61.6	59.2	80.2	61.8	65.4	93.6
1973	70.8	61.3	80.2	69.5	71.6	98.5
1974	79.2	66.3	81.3	79.1	79.4	99.6
1975	86.3	61.1	87.2	85.2	84.9	101.6
1976	84.3	63.5	93.3	83.9	84.8	99.3
1977	87.7	65.5	94.0	86.8	87.3	100.4
1978	90.5	66.9	94.1	90.2	90.2	100.3
1979	96.1	64.6	94.1	96.6	95.6	100.5
1980	95.7	72.2	95.2	96.2	95.6	100.1
1981	100.0	100.0	100.0	100.0	100.0	100.0
1982	100.6	67.6	105.2	98.4	98.4	102.2
1983	96.1	55.6	106.4	94.5	95.0	101.2
1984	91.5	54.7	105.3	90.9	91.6	99.9
1985	90.7	57.7	103.0	89.5	90.3	100.5
1986	93.0	69.0	99.9	91.8	92.3	100.8
1987	90.3	67.8	96.8	89.2	89.7	100.8
1988	86.1	74.9	93.5	85.0	85.8	100.4
Average Annual Growth Rates (%)						
61-73	4.9	-3.4	-0.3	4.7	3.0	2.0
73-88	1.3	1.3	1.0	1.3	1.2	0.1
61-75	5.7	-3.0	0.4	5.5	3.8	2.0
61-88	2.9	-0.8	0.4	2.8	2.0	1.0

Material inputs, on the other hand, have more than doubled. This is not very surprising, since petroleum and coal products industries have a very low value-added component. DFM do not publish estimates of TFP for this industry in B.C.

4.3.4 Chemicals

Indices of output, factor inputs, and total factor productivity for manufacturers of chemicals are presented in Table 7. In the chemicals industry, total factor productivity increased at an average annual rate of .23 percent between 1961 and 1988. Increases in total factor inputs accounted for most of the growth in output, which averaged 3.0 percent annually. The estimates of productivity in the chemicals industry confirm a productivity slowdown after 1973; in fact, after 1973 the TFP index actually declines. Most of the growth in factor inputs can be attributed to an increased use of capital. For the period between 1973 and 1988, growth in capital inputs has averaged 3.8 percent per year, which exceeds the average growth in output for that period (2.2%).

DFM estimate that total factor productivity in the chemicals industry increased by 2.3 percent per year between 1961 and 1975. The comparable estimates of growth in TFP

TABLE 7
TOTAL FACTOR PRODUCTIVITY, CHEMICALS

Year	Output	Labour	Capital	Material	TFI	TFP
1961	51.4	98.5	38.1	48.3	54.8	94.5
1962	55.8	103.2	40.0	53.7	58.9	95.7
1963	56.7	105.1	43.8	54.8	61.0	93.7
1964	62.1	107.9	51.6	60.1	66.6	94.1
1965	68.6	112.2	60.5	66.0	73.0	94.9
1966	71.2	112.1	65.3	71.2	77.1	93.1
1967	78.1	113.8	68.1	75.5	80.5	98.1
1968	72.8	110.7	69.8	71.6	78.3	94.1
1969	71.9	103.3	68.0	68.9	74.9	98.3
1970	67.8	119.6	66.5	67.3	77.0	88.5
1971	75.2	113.8	65.5	71.1	77.6	97.6
1972	77.3	108.3	67.2	73.0	77.9	100.0
1973	83.5	108.5	69.0	78.2	81.0	104.0
1974	81.4	104.0	71.7	77.6	80.8	101.7
1975	83.8	102.3	74.9	77.1	81.3	103.9
1976	92.5	92.2	74.2	85.8	84.0	111.4
1977	93.5	85.2	72.7	82.7	80.8	116.8
1978	96.9	93.6	71.7	88.4	84.6	115.6
1979	101.0	97.8	72.1	95.6	89.1	114.3
1980	99.8	94.6	79.1	99.4	92.8	108.1
1981	100.0	100.0	100.0	100.0	100.0	100.0
1982	80.8	97.9	120.0	82.3	95.0	85.9
1983	93.8	98.6	124.5	94.1	102.8	92.6
1984	100.4	103.3	121.6	96.5	104.1	97.9
1985	107.2	104.4	117.4	104.8	107.6	101.2
1986	111.8	102.6	118.3	109.3	110.1	103.2
1987	118.1	116.5	120.5	115.5	116.1	103.5
1988	116.0	129.4	121.9	113.4	117.3	100.5
Average Annual Growth Rates (%)						
61-73	4.0	0.8	4.9	4.0	3.3	0.8
73-88	2.2	1.2	3.8	2.5	2.5	-0.2
61-75	3.5	0.3	4.8	3.3	2.8	0.7
61-88	3.0	1.0	4.3	3.2	2.8	0.2

for this study are much lower, at 0.2 percent per annum.

4.3.5 General Observations

For most of the non-durable goods industries, (with the exception of the petroleum and coal industry), capital accounted for a large part of the growth in factor inputs. It is interesting to note that in all of these industries, the share of labour in total income is lower, and on average the share of capital in total income is higher, than for the durable goods industries. The relatively poor performance of industries within the non-durables sector in terms of growth in TFP may be due to the fact that, during the period under study, there have been greater outlays on capital in the non-durable goods producing industries. It is certainly true that the paper and allied products industry has undergone significant capitalization since 1961. Capital represents a cost to the industry whether it is fully utilized or not, hence estimates of capital inputs do not decline when output falls³. Therefore, during downturns, when output falls, capital's share in income can be disproportionately high. This would tend to increase the estimate of growth in total factor inputs. Growth in TFP, which is calculated as the difference between growth in

3. The only reason for a decline in capital inputs would be that firms might defer investment in new capital until the end of the downturn.

output and growth in total factor inputs, would therefore be lower.

4.4 Industries within the Durables Sector

The industries which are included in the durables sector are wood, metal fabricating, transportation equipment, and other manufacturing industries (a residual category which includes furniture and fixtures, primary metals, and numerous other industries). The indices of output, factor inputs and total factor productivity are presented in Tables 8 to 11.

4.4.1 Wood

As indicated in Table 8, in the wood industry productivity growth accounted for almost half of the growth in output between 1961 and 1988. For the period between 1961 and 1973, TFP grew at an average annual rate of 1.1 percent per year while growth in total factor inputs averaged 3.6 percent. However, since 1973, productivity growth has become a much more important determinant of growth in output. Unlike most other industries, annual growth in TFP for the wood industry actually increased after 1973; between 1973 and 1988, TFP grew by 1.8% per year, on average. Increases in output during that period averaged 2.0 percent per year.

TABLE 8
TOTAL FACTOR PRODUCTIVITY, WOOD

Year	Output	Labour	Capital	Material	TFI	TFP
1961	54.3	89.5	34.9	59.4	68.6	78.5
1962	55.4	91.7	35.8	56.6	67.6	81.3
1963	60.1	97.7	36.7	60.3	71.7	83.2
1964	65.8	100.6	38.1	67.3	76.9	85.0
1965	66.7	102.2	40.2	67.8	78.0	85.0
1966	67.9	99.0	42.4	69.8	78.7	85.8
1967	69.1	94.2	43.3	71.0	78.2	87.7
1968	71.8	96.7	43.9	67.8	77.0	92.5
1969	74.3	97.4	47.5	73.7	81.5	90.4
1970	79.4	94.3	53.3	84.8	88.3	89.1
1971	79.6	104.4	59.0	78.4	87.8	89.7
1972	83.3	111.0	63.5	84.9	94.3	87.3
1973	95.1	120.1	68.8	98.2	105.2	89.6
1974	87.5	108.9	74.0	88.0	96.5	89.8
1975	75.5	88.2	76.3	76.3	82.3	90.7
1976	96.7	105.5	77.4	95.7	97.7	99.3
1977	105.5	111.6	79.3	103.2	103.7	102.2
1978	107.1	118.4	83.3	107.0	108.4	99.2
1979	110.3	121.3	89.0	114.6	114.6	96.4
1980	110.7	118.5	95.3	109.7	111.6	99.3
1981	100.0	100.0	100.0	100.0	100.0	100.0
1982	85.3	85.1	100.4	87.0	85.9	99.3
1983	98.5	92.1	97.4	96.6	93.5	106.0
1984	101.1	88.0	95.2	97.9	92.8	109.6
1985	110.9	93.5	93.6	107.8	99.8	112.1
1986	103.3	82.9	92.6	99.4	91.9	113.1
1987	131.2	104.2	94.8	126.4	109.9	121.6
1988	129.1	109.7	101.6	124.3	111.5	117.8
Average Annual Growth Rates (%)						
61-73	4.7	2.5	5.7	4.2	3.6	1.1
73-88	2.0	-0.6	2.6	1.6	0.4	1.8
61-75	2.4	-0.1	5.6	1.8	1.3	1.0
61-88	3.2	0.8	4.0	2.7	1.8	1.5

Growth in capital inputs between 1961 and 1988, at an average rate of 4% per year, was much higher than growth in labour inputs (0.8 percent per year). In fact, since 1973, labour inputs have actually declined at an average rate of 0.6 percent per year. This decrease, together with a much slower growth in capital inputs since 1973, has contributed to the greater importance of productivity growth as an explanatory factor for growth in output.

DFM calculate that total factor productivity in the B.C. wood industry increased at an average annual rate of 0.7 percent between 1961 and 1975. Their estimates are slightly lower than the estimates produced in this study, which indicate that the average annual growth of TFP between 1961 and 1975 was 1.0 percent.

4.4.2 Metal Fabricating

Indices of output, total factor inputs, and total factor productivity in the metal fabricating industry are presented in Table 9. In the metal fabricating industry, growth in total factor productivity accounted for about half of the growth in output between 1961 and 1988.

TABLE 9
TOTAL FACTOR PRODUCTIVITY, METAL FABRICATING

Year	Output	Labour	Capital	Material	TFI	TFP
1961	35.9	48.6	52.0	37.7	46.7	73.4
1962	41.8	54.8	51.5	45.2	52.3	76.8
1963	44.1	59.9	51.2	46.7	54.5	77.8
1964	51.2	66.9	52.3	54.4	60.8	81.5
1965	57.8	76.0	55.0	60.6	67.1	83.4
1966	66.7	83.0	57.5	69.8	74.3	87.4
1967	61.1	79.1	60.3	60.8	68.8	86.4
1968	60.4	75.8	64.3	59.8	68.1	86.3
1969	70.7	84.7	67.3	70.4	76.5	90.5
1970	73.0	84.2	69.8	71.9	77.7	92.0
1971	76.9	87.5	72.0	76.6	81.4	92.5
1972	74.3	81.8	72.3	75.9	79.4	91.7
1973	84.2	84.4	74.8	85.8	85.6	96.8
1974	96.4	89.2	79.3	100.8	95.3	99.8
1975	77.6	81.0	82.8	80.4	82.1	94.1
1976	72.4	80.4	87.0	70.5	77.2	93.4
1977	74.3	83.1	90.3	71.3	79.1	93.7
1978	84.1	91.2	90.8	83.0	87.2	96.4
1979	90.9	99.6	91.9	92.5	94.5	96.1
1980	99.7	104.6	95.9	102.5	101.8	98.0
1981	100.0	100.0	100.0	100.0	100.0	100.0
1982	72.9	84.9	100.0	73.9	80.0	92.9
1983	70.4	79.7	97.0	72.0	76.9	93.3
1984	69.5	72.6	93.8	70.4	73.4	96.4
1985	72.2	80.2	89.7	71.5	75.3	97.6
1986	71.5	73.4	90.8	67.3	71.4	101.7
1987	86.7	68.9	92.9	81.6	77.8	114.2
1988	94.6	76.5	90.8	89.0	82.5	117.7
Average Annual Growth Rates (%)						
61-73	7.1	4.6	3.0	6.9	5.0	2.3
73-88	0.8	-0.6	1.3	0.2	-0.2	1.3
61-75	5.5	3.6	3.3	5.4	4.0	1.8
61-88	3.6	1.7	2.1	3.2	2.1	1.7

Unlike the wood industry, metal fabricating does show a slowdown in productivity after 1973. However, despite the fact that productivity growth in metal fabricating decreased after 1973, its relative importance to growth in total output actually increased. Annual growth in TFP averaged 1.3 percent between 1973 and 1988, compared to 2.3 percent per year from 1961 to 1973. Total factor inputs, on the other hand, declined at an average annual rate of 0.3 percent after 1973, compared to an average increase of 5.0 percent before that time. The decline in total factor inputs is due to a decrease in labour input during that period. Labour's income share in metal fabricating is higher than capital's share, hence the average annual increase of 1.3 percent per year for capital and 0.2 percent per year for materials has not been great enough to offset an average annual decline in labour inputs of 0.7 percent between 1973 and 1988.

For the period between 1961 and 1975, DFM estimated that TFP in the metal fabricating industry increased at an average rate of 1.7 percent per year. The comparable estimates from this study are almost identical, since they suggest that annual growth in productivity averaged 1.8 percent per year during that period.

4.4.3 Transportation Equipment

In the transportation equipment industry, increases in TFP explain almost half of the growth in output for most years. As indicated in Table 10, output in the B.C. transportation equipment industry grew at an average annual rate of 11.2 % between 1961 and 1973. However, output growth dropped sharply after 1973, averaging -2.4% per year between 1973 and 1988.

Between 1981 and 1982, gross output in the transportation equipment industry dropped by 50%; total factor inputs, and labour and material inputs also dropped very sharply in 1982. The discrete approximation which is used to calculate the Tornquist indices of inputs and factor outputs is based on the assumption that the change between two time periods is relatively small. The approximation is less exact when changes of the magnitude observed between 1981 and 1982 occur. Consequently, estimates of changes in TFP which include the 1981 and 1982 data are less reliable than the estimates for the other industries.

DFM calculate that total factor productivity increased by 2.7 percent between 1961 and 1975, compared to an estimate in this study of growth in TFP of 4.2 percent per year during that period.

TABLE 10

TOTAL FACTOR PRODUCTIVITY, TRANSPORTATION EQUIPMENT

Year	Output	Labour	Capital	Material	TFI	TFP
1961	21.7	58.5	32.7	19.8	39.5	50.1
1962	28.2	74.3	32.8	25.8	48.0	54.3
1963	30.7	73.3	33.7	28.5	49.1	57.9
1964	30.2	65.1	34.9	29.9	46.7	59.7
1965	39.7	77.5	36.6	38.9	55.8	67.0
1966	37.5	77.1	41.0	36.5	55.0	64.2
1967	40.6	76.4	44.6	39.3	56.8	67.3
1968	43.6	69.0	45.6	44.0	57.1	72.1
1969	54.1	78.1	46.0	54.7	66.0	78.1
1970	47.4	67.6	49.3	49.5	59.5	76.1
1971	50.6	68.3	52.6	52.4	62.0	78.0
1972	66.1	78.8	53.2	68.3	74.3	86.6
1973	82.9	95.9	55.5	87.2	89.8	90.4
1974	93.7	104.5	61.2	98.7	99.7	92.2
1975	76.9	92.3	67.0	78.2	83.4	90.8
1976	79.3	85.1	71.3	75.7	80.4	96.9
1977	81.4	77.3	76.0	80.9	81.9	97.6
1978	98.6	93.2	77.1	101.0	96.5	100.9
1979	115.3	109.2	80.9	119.0	110.4	103.4
1980	94.0	97.8	88.8	98.2	96.4	97.4
1981	100.0	100.0	100.0	100.0	100.0	100.0
1982	51.9	86.5	106.9	48.2	63.6	88.3
1983	33.5	61.5	105.5	30.6	43.6	84.8
1984	50.0	65.8	103.5	47.1	50.6	112.8
1985	53.9	70.8	106.2	50.5	53.3	115.6
1986	50.0	64.5	108.9	45.1	50.4	113.6
1987	53.5	65.7	109.3	48.2	51.9	118.2
1988	57.5	71.3	115.6	51.8	55.4	119.1
Average Annual Growth Rates (%)						
61-73	11.2	4.1	4.4	12.4	6.8	4.9
73-88	-2.4	-2.0	4.9	-3.5	-3.2	1.8
61-75	9.0	3.3	5.1	9.8	5.3	4.2
61-88	3.6	0.7	4.7	3.6	1.2	3.2

4.4.4 Other Manufacturing

The residual "other manufacturing" category includes such industries as furniture and fixtures, primary metals, machinery and equipment, nonmetallic minerals, miscellaneous manufacturing, as well as other small industries. Indices of output, inputs and TFP for other manufacturing are presented in Table 11.

Improvements in productivity accounted for almost half of the growth in output in other manufacturing between 1961 and 1988; output grew at an annual rate of 3.2 percent per year, while TFP increased at 1.5 percent per annum. Although "other manufacturing" shows a post-1973 productivity slowdown, the contribution of productivity change to growth in output has become more important since 1973. Between 1961 and 1973, increases in TFP accounted for less than half of the growth in output, whereas for the period from 1973 to 1988, TFP accounted for 90% of average annual output growth. In this industry, growth in capital inputs has not been as strong as growth in labour and material inputs. For example, between 1961 and 1988, labour inputs increased at almost twice the annual rate of growth in capital inputs.

DFM do not publish estimates of TFP for this subsector, hence no data are available for comparison.

TABLE 11

TOTAL FACTOR PRODUCTIVITY, OTHER MANUFACTURING

Year	Output	Labour	Capital	Material	TFI	TFP
1961	39.3	54.0	69.3	46.5	55.7	68.7
1962	44.3	55.0	68.3	52.5	58.6	74.0
1963	47.4	58.3	67.6	57.1	61.5	75.3
1964	53.2	62.6	68.2	65.2	66.8	78.2
1965	59.2	68.8	70.3	70.9	71.8	81.2
1966	66.9	72.8	72.6	79.5	77.4	85.3
1967	65.8	71.2	74.3	78.3	76.8	84.6
1968	69.8	72.6	74.2	83.8	79.6	86.7
1969	74.5	76.3	75.5	87.8	83.0	88.8
1970	64.0	75.3	77.8	75.5	77.1	82.5
1971	70.7	75.9	78.9	84.7	81.7	86.3
1972	76.3	77.8	78.7	89.1	84.3	90.4
1973	79.3	81.2	77.9	91.5	86.5	91.6
1974	81.9	81.6	79.2	94.0	88.0	93.0
1975	75.6	83.4	80.6	81.0	82.6	91.5
1976	76.3	83.3	81.4	86.5	85.3	89.5
1977	81.3	78.9	84.9	85.3	83.8	96.9
1978	90.0	87.2	87.2	98.6	92.7	96.9
1979	89.5	94.7	89.3	97.8	95.1	93.9
1980	90.4	97.1	93.8	92.4	94.3	95.6
1981	100.0	100.0	100.0	100.0	100.0	100.0
1982	82.3	96.0	105.7	83.8	91.7	90.6
1983	77.2	87.3	106.1	78.4	86.1	90.6
1984	81.7	89.2	103.5	76.7	85.4	96.5
1985	86.2	91.7	100.9	84.1	89.0	97.8
1986	76.2	88.6	98.5	66.0	79.5	96.8
1987	80.3	99.2	97.0	69.5	84.2	96.4
1988	92.3	102.6	97.5	80.2	90.0	104.2
Average Annual Growth Rates (%)						
61-73	5.8	3.4	1.0	5.7	3.7	2.4
73-88	1.0	1.6	1.5	-0.9	0.3	0.9
61-75	4.7	3.1	1.1	4.0	2.8	2.0
61-88	3.2	2.4	1.3	2.0	1.8	1.5

4.5 Summary

In the durable goods producing industries, as in the non-durables industries, there is considerable inter-industry variation in productivity growth. As might be expected, those industries which are not amenable to capitalization (such as the food and beverage industry, for example) show much lower growth in TFP than do other industries in which modernization of production has taken place in the last three decades.

A good example of an industry in which investment in capital has led to productivity growth is the wood industry. During the recession of 1982/83, this industry was quite hard-hit; as a consequence, some plants closed down and a large number of people were laid off. However, during the early part of the 1980's, a substantial amount of investment in new equipment (representing the most recent production technology) occurred. The B.C. wood industry is now very efficient: since 1981, output in this industry has increased by 29%, and total productivity has risen by a total of 17.8%.

In the following and final chapter, some general conclusions about total factor productivity in the B.C. manufacturing sector are presented.

CHAPTER V

SUMMARY AND CONCLUSIONS

In this thesis, estimates of total factor productivity which are based on the Tornquist index number formula, have been calculated for the B.C. manufacturing sector and for selected manufacturing industries. These estimates of TFP lend support to the hypothesis that a productivity slowdown occurred after 1973, since in most of the industries analyzed, growth in total factor productivity after 1973 is significantly lower than it was before.

Total factor productivity measures are generally preferred to estimates of partial productivity because the measure of input which is used takes into account the effects of substitution between factor inputs. As discussed in the previous chapter, substitution of capital for labour inputs occurred in several industries within the manufacturing sector in B.C. between 1961 and 1988.

The estimates of productivity change in the B.C. manufacturing sector seem to be generally consistent with estimates produced by other researchers. For example, the Bureau of Labor Statistics' estimates for the United States show similar general trends in productivity, although they do indicate that increases in TFP have been much stronger there than in this province. Relative to the United States, the B.C. manufacturing sector has not performed very well at all in terms of productivity growth. One possible explanation for this may be that manufacturing industries in the United States could benefit from locational advantages and economies of scale which are not possible in the B.C. manufacturing industry. These factors are reflected in the growth of TFP since they are not explicitly accounted for in the estimation.

Aggregate estimates of labour and capital inputs include an implicit partial quality adjustment mechanism; however, no specific adjustments were made to account for changes in intangible inputs such as education levels and the age-sex composition of the work-force. This is a possible area for future exploration, although data limitations make adjustments of this type rather questionable at the provincial level. Further examination of the role of scale economies and market imperfections

would also be useful, although they are beyond the scope of the present study.

Finally, as stated in the introductory chapter, the methodology for calculating total factor productivity used in this study could easily be extended to other sectors of the economy, subject of course to data availability. More information on the role of productivity change in economic growth in the other sectors of the B.C. economy vis-a-vis the rest of Canada or the United States could be very useful, particularly in light of the recent free trade agreement.

APPENDIX A

A general example of the method used to calculate a Tornquist index follows below. For simplicity, it is assumed that only two individual inputs are used in the overall index. Although the calculation is only done for a comparison between two years, the actual indices of labour, capital and total factor inputs which are presented in this study are calculated by applying this index number formula to data for the entire period between 1961 and 1988. The indices of total factor productivity for each industry are derived by subtracting growth in total factor inputs (the end result of the Tornquist calculation) from growth in output.

Suppose that two capital assets, A and B, are being combined into an aggregate index of capital input, K. The stock and the rental prices of the assets are as follows:

	Year 1	Year 2
Asset A:		
Quantity (a)	950	1000
Rental price	9	10
Asset B:		
Quantity(b)	700	750
Rental price	4	5

The shares of capital income for each component are calculated using the rental price of capital to weight the estimates of the individual capital inputs. In each time period, these shares are:

For asset a:

$$sa_1 = (9 \cdot 950) \div [(9 \cdot 950) + (4 \cdot 700)] = .755$$

$$sa_2 = (10 \cdot 1000) \div [(10 \cdot 1000) + (5 \cdot 750)] = .727$$

For asset b:

$$sb_1 = (4 \cdot 700) \div [(9 \cdot 950) + (4 \cdot 700)] = .247$$

$$sb_2 = (5 \cdot 750) \div [(10 \cdot 1000) + (5 \cdot 750)] = .273$$

The Tornquist index number formula calculates the change in the aggregate input index by weighting the change in individual input indices between two periods by their average income shares for the two periods. In other words, if the Tornquist index is designated by K, then the change in K between years 1 and 2 can be calculated using equation (A.1):

$$(A.1) \quad \ln(K_2 \div K_1) = [.5 \cdot (sa_1 + sa_2) \cdot \ln(a_1 \div a_2)] \\ + [.5 \cdot (sb_1 + sb_2) \cdot \ln(b_1 \div b_2)]$$

Thus,

$$\ln(K_2 \div K_1) = .5 \cdot (.755 + .727) \cdot \ln(1000 \div 950) \\ + .5 \cdot (.247 + .273) \cdot \ln(750 \div 700) \\ = .038 + .018 = .056$$

The index of capital input is set equal to 100 in year 1; in year 2, it is equal to $100 \cdot (1.056) = 105.6$

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