PRODUCTIVITY IN THE CANADIAN LUMBER INDUSTRY:

An Inter-regional Comparison

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ABSTRACT

This report contains the results of a comparison of productivity levels and growth rates of forest industries in the four major Canadian lumber-producing regions: (1) the British Columbia (B.C.) Coast, (2) the B.C. Interior, (3) Ontario, and (4) Quebec. These four regions account for roughly 90% of the lumber produced in Canada.

The industry's long-term international competitiveness is determined by its productivity, input prices and product quality. Although this study focused mainly on manufacturing productivity, the industry's input prices and product quality were also examined. Productivity is most important because it is the factor over which the industry has the most control. Measuring changes in productivity provides insight on Canada's evolving competitive position and helps guide decisions on the adoption of future technologies.

Productivity levels and growth rates of the regional lumber industries were measured over the 1962-1985 period. Single-, variable- and total-factor productivities were measured. The most important results of the study are:

1) Labor and capital productivities grew fastest in all four regions, and labor and capital prices rose faster than those of other inputs. Increased labor productivity was likely made possible by substituting materials, energy and/or capital for labor. The fact that the lumber industry has depended particularly heavily on increases in labor productivity underscores the need to ensure the industry has continued access to a functionally literate workforce.

2) Energy and non-wood materials appear to have been substituted to the point at which their productivities have declined in all regions during various time periods. This suggests that energy and other materials were being "over used" during these years (e.g., the 1960s).

3) Growth in the productivity of wood was moderate in all regions, and was more a result of better utilization/marketing of chips than of higher recovery factors for lumber. This may reflect the fact that, among all inputs considered, the price of roundwood experienced the lowest average rate of increase. The only exception to this was on the B.C. Coast.

4) The B.C. Coast and Interior lumber industries are the most productive in the country. Aggregate productivities in 1985 were equal in these regions, and were greater than those in Ontario and Quebec by roughly 10 and 20%, respectively.

5) The Ontario and Quebec industries have narrowed the productivity gap with B.C.; from 1962 to 1985, average annual growth rates in aggregate productivity have been more than twice those in the B.C. Coast and Interior. For Ontario, most of this growth occurred in the 1960s and 1970s.

6) Although the results are sensitive to the particular years chosen, from 1981 to 1985 productivity gains in the B.C. Interior and Quebec regions have been significantly greater than those in the B.C. Coast and Ontario regions. This is consistent with the observation that these two regions have accounted for most of the recent increase in Canada's share of the American lumber market. In the B.C. Interior, this performance is the result of relatively low wood prices and high labor, materials, energy and capital productivities. In Quebec, it is the result of relatively low labor prices and high labor, wood and energy productivities. A depreciating Canadian dollar also greatly improved the competitiveness of all Canadian producers in the American market over this period.

7) In Ontario, Quebec and the B.C. Interior the average annual percentage increase in the price of every input has exceeded the increases in lumber prices. These regional industries would have experienced severe cash-flow problems without significant productivity gains and rising real chip prices.

Regression analysis suggested a relationship between output growth and productivity. Reductions in the number of establishments may also be associated with higher productivity. This is consistent with the relatively low productivity growth in the B.C. Coast region, the only region that did not experience a decrease in the number of establishments.

The study results are encouraging for the long-run competitiveness of the industry. However, the real test will be how Canadian productivity compares with that of our major competitors. Such analysis awaits further study, although this paper has laid the foundation for the methods and techniques required. Future productivity growth may depend on output growth, perhaps achieved by continued consolidation of establishments. Additional study, by means of parametric techniques and firm- or plant-specific data, is necessary if more definitive statements on the sources of productivity growth are to be made.

RÉSUMÉ

La productivité et le taux de croissance des industries forestières des quatre principales régions productrices de bois au Canada ont été comparés. Ces régions, soit la côte et l'intérieur de la Colombie-Britannique, l'Ontario et le Québec, fournissent environ 90 % de la production canadienne de bois.

La compétitivité internationale à long terme de l'industrie dépend de sa productivité, du prix des intrants et de la qualité des produits. L'étude a porté principalement sur la productivité manufacturière, mais le prix des intrants et la qualité des produits ont également été examinés. La productivité constitue le facteur le plus important, car il est celui sur lequel l'industrie a le plus de pouvoir. La mesure des changements de la productivité met en lumière l'évolution de la position du Canada face à ses concurrents et aide à la prise des décisions concernant l'adoption de techniques nouvelles.

Les niveaux de productivité et les taux de croissance des industries du bois des régions d'étude ont été déterminés pour la période de 1962 à 1985. La productivité a été mesurée pour des facteurs uniques, des facteurs variables et l'ensemble des facteurs. Voici les principaux résultats de l'étude:

1) Dans les quatre régions, les hausses les plus rapides de la productivité ont été pour le travail et le capital; ces deux facteurs one été ceux dont les prix ont augmenté le plus rapidement. L'augmentation de la productivité du travail a probablement été rendue possible par l'utilisation de matériel, d'énergie et de capital à la place de la main d'oeuvre.

2) Dans le cas de l'énergie et des matières non ligneuses, la substitution semble avoir été d'une telle envergure que leur productivité a diminué dans toutes les régions au cours de diverses périodes. On en déduit qu'il y a eu surutilisation de l'énergie et d'autres matières au cours de ces années (par example les années 60).

3) L'accroissement de la productivité du bois a été modéré dans toutes les régions; il est davantage imputable à une plus grande utilisation et commercialisation des copeaux qu'à une récupération supérieure du bois. Il pourrait refléter le fait que, de tous les intrants examinés, le prix du bois rond est celui qui a présenté le plus faible taux moyen d'augmentation dans toutes les régions, sauf la côte de la Colombie-Britannique.

4) Les industries du bois de la côte et de l'intérieur de la Colombie-Britannique sont les plus productives au pays. En 1985, leur productivité globale était égale; elle dépassait d'environ 10 et 20 % la productivité des industries québécoise et ontarienne respectivement.

5) Les industries de l'Ontario et du Québec ont rétréci leur écart de productivité par rapport à celles de la Colombie-Britannique: de 1962 à 1985, leurs taux annuels moyens de croissance de la productivité globale dépassaient deux fois ceux de ces dernières. Dans le cas de l'Ontario, les gains ont surtout eu lieu au cours des années 60 et 70.

6) De 1981 à 1985, les hausses de productivité ont nettement été plus élevées dans l'intérieur de la Colombie-Britannique et au Québec. Un parallèle peut être établi avec le fait que ces deux régions sont les principales responsables de l'augmentation récente de la part canadienne du marché américain du bois. La performance de l'intérieur de la Colombie-Britannique est attribuée aux prix relativement faibles du bois et aux niveaux élevés de productivité du travail, du matériel, de l'énergie et du capital; celle du Québec est le résultat du prix relativement faible de la main d'oeuvre et des niveaux élevés de productivité du travail, du bois et de l'énergie. La dépréciation du dollar canadien a également favorisé grandement la compétitivité de tous les producteurs canadiens sur le marché américain au cours de cette période.

7) En Ontario, au Québec et dans l'intérieur de la Colombie-Britannique, le pourcentage annuel moyen d'augmentation du prix de chaque intrant a été supérieur aux augmentations des prix du bois. Les industries de ces régions auraient connu de sérieux problèmes d'encaisse en l'absence de gains importants de productivité et d'une augmentation des prix des copeaux.

Un analyse de régression a mis en évidence un lien entre l'accroissement de la production et la productivité. Une réduction du nombre d'établissements peut également avoir influé sur la hausse de la productivité. D'ailleurs, la côte de la Colombie-Britannique, où l'accroissement de la productivité a été relativement faible, est la seule région où le nombre d'établissements n'a pas diminué.

Les résultats de l'étude sont encourageants en ce qui concerne la compétitivité à long terme de l'industrie. Toutefois, le facteur déterminant à cet égard sera la productivité de l'industrie canadienne par rapport à ses principaux concurrents. Une analyse plus poussée est requise, bien que le présent rapport pose les bases d'une telle comparaison en ce qui a trait aux méthodes et techniques requises. L'augmentation de la productivité à l'avenir pourrait dépendre de l'accroissement de la production; une concentration continue des établissements permettra peut-être de l'obtenir. Il faudra une étude plus poussée faisant appel à des techniques paramétriques et à des données au niveau des entreprises ou des usines pour pouvoir établir avec plus de certitude les sources d'accroissement de la productivité.

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INTRODUCTION

The objective of this study was to assess and compare productivity levels and growth in the four major Canadian lumber-producing regions: the British Columbia (B.C.) Coast, the B.C. Interior, Ontario and Quebec. These four regions account for roughly 90% of the lumber produced in Canada.

In 1986, the Canadian lumber industry (i.e., the sawmill and planing-mill industries) made a greater contribution to Canada's net trade balance than the farm, fish, petroleum and coal industries combined (Anon. 1983 and Statistics Canada, special compilation). As a result, Canada's prosperity depends to a significant degree on the competitiveness of its lumber industry in international markets.

In the long term, the lumber industry's international competitiveness will be determined by its productivity, input prices and product quality. Although the present study focused primarily on manufacturing productivity, input prices and product quality were examined briefly. Productivity in distribution activities was not dealt with. Exchange-rate movements also affect international competitiveness, but their impact tends to be limited more to the short term (see Roberts (1988) for details). The reason for our focus is that productivity is the factor over which the industry has the most control. Measuring changes in productivity provides insight into the factors behind Canada's evolving competitive position and helps guide decisions on the adoption of future technologies.

Productivity may be viewed as the efficiency with which an industry can manufacture and deliver a product to the market. Productivity change is both the cause and consequence of the evolution of dynamic forces that operate in an industry. These forces include technological progress, accumulation of human and physical capital, and institutional arrangements. Growth in productivity must be monitored in order to assess the lumber industry's evolving competitive position accurately in the long run.

Several studies have estimated productivity measures in the Canadian lumber industry at the national and/or regional levels (e.g., Martinello 1985, 1987; Constantino and Uhler 1987; Anon. 1988; Bernstein 1988; Meil et al. 1988; Meil and Nautiyal 1988; Constantino and Haley 1989). A later section of the present study discusses the results of these recent studies. There are two fundamental approaches to the measurement and analysis of productivity. The first uses econometric (parametric) techniques to determine productivity and its sources statistically. Apart from studies by Constantino and Haley (1989) and Anon. (1988), all recent studies on the lumber industry use a parametric approach and typically estimate trans-log cost functions.

The second approach applies the theory of index numbers. This approach is "nonparametric" in that a formal model of the industry's production structure need not be constructed or statistically estimated. Typically, this approach has been used to determine trends in or growth rates of productivity. However, recent advances in this approach allow comparison of productivity levels among regions or countries.

Each of these approaches has strengths and weaknesses. The advantages of the parametric approach are that:

- it identifies the sources of productivity growth over time (e.g., Denny et al. (1981) identify three sources of productivity growth: increased productive efficiency, economies of scale, and deviations from marginal-cost pricing);

- it allows the researcher to examine key attributes of the structure of production, such as returns to scale and input-substitution possibilities;

- it provides a formal measure of the factor-bias (e.g., substitution of capital for labor) of technological progress (cf. Binswanger 1974); and

- it permits analysis of cases in which firms are not in equilibrium with respect to some of their inputs.

The advantages of the nonparametric approach are that:

- it allows productivity levels and growth rates to be calculated;

- it is easily understood by most policymakers and lay-persons;

- its results are insensitive to statistical estimation procedures or specifications of the theoretical model (e.g., the empirical results of various parametric models of the Canadian lumber industry differ significantly and have contradictory implications);

- it does not conceal the data underlying statistical parameters, which are generated based on various assumptions, but instead displays the data in a form (index numbers) that draws attention to anomalies in the data. These anomalies are often the result of data entry or programming errors as well as underlying errors in the reporting of data by firms. Although parametric techniques do not preclude displaying data so that problems are revealed, this is often de-emphasized because of the focus on model development and estimation;

- it allows greater focus on total-factor productivity (TFP) and its components (aggregate input and output, plus the individual factor productivities, quantities and prices) that reveal information on trends and changes in an industry.

The present study used a nonparametric approach to measure productivity in the lumber industry. The three primary reasons for this decision were: (1) to compare productivity levels as well as productivity growth rates; (2) to obtain an unambiguous measure of productivity that would not vary with minor changes in the theoretical model or estimation techniques; and, (3) to make the approach comprehensible to policymakers and lay-persons.

The study differs from most existing work in four ways. First, in addition to single-factor productivities (SFPs), such as output per person-hour paid (labor productivity), TFP is also measured. One region's labor productivity may be higher than that of the other inputs, but if this is a result of massive expenditures on capital, for instance, overall or total productivity may not be higher; TFP is a better measure of the overall performance of an enterprise. In a study of the Canadian and American pulp and paper industries, Oum and Tretheway (1988) have shown that despite Canada's lower labor productivity in relation to that of the United States, TFP is equal to that of the American industry. One problem with TFP measurements, especially for subprovincial regions and industries at the four-digit-code level of Statistics Canada's Standard Industrial Classification (Anon. 1980), is the lack of reliable data on capital. Accordingly, we also computed a measure of variable-factor productivity (VFP). Although VFP is also a multi-factor productivity measure, it excludes capital and thus may be a more useful measure in the short run; VFP is defined as the output per unit of the variable inputs (i.e., labor, wood, non-wood materials and energy). Even if technical change is embodied largely in capital, a VFP index still contains a great deal of information; this is because the benefits of new capital tend to result in improved productivity of labor, materials and energy. Measuring annual levels of VFP is something no other study has done for the Canadian forest sector.

Second, by applying the multilateral index-number approach to four regions, the regional industries' productivity levels and relative rates of productivity growth could be compared. Differences in regional productivity levels help explain differences in regional input prices and reveal relative levels of productivity. Relative productivity growth rates are useful because they provide insight into the evolving competitive position of each region.

Third, the index-number measures (SFP, VFP and TFP) were complemented by preliminary parametric investigations to detect sources of change in productivity over time and across regions. However, the regression equations developed were *ad hoc* in nature, and were only meant to be exploratory. It is still necessary to model the production/cost structure of the industry formally in order to identify the sources of productivity growth definitively.

Fourth, the scope of the study was expanded by detailed analyses of historical trends in the data base. As noted above, much can be learned from careful inspection of the raw data, a point often overlooked in parametric studies.

The report is organized into six main sections: an examination of the concept of productivity and how to measure it; a description of the data base; a review of historical trends in the data; a summary of the resulting productivity measurements; an analysis of the main sources of change in VFP; and a comparison of the results with those of other studies. A final summary is then presented.

THE CONCEPT AND MEASUREMENT OF PRODUCTIVITY

The theory of productivity measurement is well established and has been widely discussed in the literature (e.g., Christensen and Jorgenson 1969, Nadiri 1970, Christensen 1975, Christensen et al. 1980, Berndt and Watkins 1981, Caves et al. 1982). This section provides a conceptual overview of productivity and the measurement techniques adopted in the present study.

The Concept of Productivity

In its broadest sense, productivity is the amount of output per unit of input(s). Although there are many specific indicators of productivity, analysts have typically emphasized labor productivity. This can be misleading because aggregate productivity cannot be attributed to a single input. If a high SFP of labor is observed, for example, it may be the result of intensive use of capital. A more illuminating alternative measure is TFP (or VFP for a shorter time horizon and in the absence of reliable capital data). This study presents both SFP and TFP measures. In addition, because reliability of the data on capital is suspect, VFP measures were also analyzed.

Productivity Measurement Techniques

The multilateral index-number procedure developed by Caves et al. (1982) was used in this study. The multilateral procedure allows multi-country/region comparisons in terms of productivity levels. Productivity measures are based on the following production function:

$$Y_{jt} = f(K_{jt}, L_{jt}, W_{jt}, M_{jt}, E_{jt}, T_{jt}) \tag{1}$$

where Y is an aggregate (or total) index of lumber and chip output; K, L, W, M and E are quantities of capital, labor, wood, other materials and energy, respectively; T is a trend variable expected to indicate technological change; and the subscripts j and t, respectively, stand for a specific regional lumber industry and year.

Single-factor productivities (SFP) can be calculated as:

$$SFP_{ijt} = \frac{Y_{jt}}{F_{ijt}} = \frac{\text{Total output quantity}_{jt}}{\text{Single input quantity}_{jt}} \tag{2}$$

where F stands for the quantity of a specific input (e.g., labor), subscripts j and t are as defined in equation (1), and i stands for an input (capital, labor, wood, other materials and energy). As discussed earlier, SFPs depend on the levels of all inputs. For instance, high labor productivity can be the result of the use of a high level of capital stock. In the context of the production function, SFP can be specified as:

$$SFP_{ijt} = f(K_{jt}, L_{jt}, W_{jt}, M_{jt}, E_{jt}, T_{jt}) \quad (3)$$

TFP is the ratio of aggregate output to aggregate input:

$$TFP_{jt} = \frac{\text{Total output quantity}_{jt}}{\text{Total input quantity}_{jt}} \quad (4)$$

If production technology exhibits constant returns to scale, then in most cases TFP will only be a function of technological change. However, if economies or diseconomies of scale are present, the SFP and TFP measures will reflect scale effects in combination with technological change. This is because the SFP and TFP measures cannot distinguish between pure productivity gains (i.e., shifts in the underlying production or cost relations) and efficiency gains resulting from increases in the scale of operations (i.e., changes in its underlying production or cost relations). If technology is subject to constant returns to scale, we can specify TFP, in terms of the parameters of the production function, as:

$$TFP_{jt} = f(T_{jt}) \quad (5)$$

If technology is homothetic (for a definition of homotheticity, see the discussion in Chiang [1984]) but does not produce constant returns, then:

$$TFP_{jt} = f(Y_{jt}, T_{jt}) \quad (6)$$

If technology is nonhomothetic, then:

$$TFP_{jt} = f(K_{jt}, L_{jt}, W_{jt}, M_{jt}, E_{jt}, T_{jt}) \quad (7)$$

In addition, VFP is a function of the level of capital stock, K_{jt}.

As a result of the especially complex relationship between the various inputs and their productivity levels in the lumber industry, there is a greater-than-normal need for a measure of multi-factor productivity (e.g., VFP and TFP). Timber characteristics such as species and log size and grade greatly influence mill design and the types of products milled. For example, factory-built mills that use the "Chip-n-Saw" concept or the recently introduced Linck system from Germany depend on a supply of uniform logs and on the existence of markets for dimension lumber. Both systems are highly automated and have low labor requirements.

The traditional problem with TFP measurement has been in the proper measurement of aggregate outputs and inputs. One cannot obtain a meaningful measure of aggregate input simply by adding hours of labor, liters of fuel and cubic metres of wood. Economists have developed methods of aggregating these disparate quantities into meaningful total-quantity indices. These procedures have recently been refined to permit meaningful comparison of productivity levels among regions.

Such indices are referred to as multilateral. One of the pioneering approaches is the multilateral-index procedure developed by Caves et al. (1982). Without discussing the intricacies of its derivation, the formulation of this procedure is:

$$TFP_{kt} = \exp\left[\sum_i 0.5(R_{ikt} + \overline{R}_i) * \ln(Y_{ikt}/\tilde{Y}_i) - \sum_i 0.5(S_{ikt} + \overline{S}_i) * \ln(X_{ikt}/\tilde{X}_i) \right] \quad (8)$$

where R_{ik} represents the revenue share of output i in region k; $\overline{R}_i$ is the revenue share of output i averaged over all regions and time periods; S_{ik} is the cost share of input i in region k; $\overline{S}_i$ is the average cost share of input i; t is the specific year; and $\ln\tilde{Y}_i$ and $\ln\tilde{X}_i$ are geometric (i.e., natural-log) averages of the quantities of output i and input i, respectively. Equation (8), in effect, constructs a reference point, the mean of the data, and compares every observation (time period or region) to the reference point. In this way, regions and/or time periods can be compared consistently.

The main advantage of the multilateral-index technique in equation (8) is that it is both base-region and base-year invariant. In other words, unlike the traditional bilateral index[2], it does not change when we use alternative years and/or regions as reference points. One potential drawback of this multilateral approach is that it destroys the fixity of historical comparisons: as new observations are incorporated, the multilateral approach results in new comparisons of the entire time series. A bilateral approach leaves the historical figures intact. However, just because historical comparisons with a bilateral index are fixed, it does not necessarily mean they are correct. In practice, the multilateral approach will not vary much when additional data is added if a single output's share in total revenue and a single input's share in total cost are roughly constant.

As noted in a study by the International Woodworkers of America[3], productivity measurement is complicated in practice by the fact that output consists of a wide variety of tree species and lengths and grades of lumber

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[2] The "bilateral" index is one in which a traditional chain-linked time-series index is constructed separately for each region. These are then linked together in a single year by constructing a one-year index between the regions.

[3] Anon. (1985). Productivity and unit production costs in the softwood lumber industries of the United States and Canada, 1978 to 1984. Internat'l Woodworkers of America, unpubl. rep.

-- all of which bring different returns when sold. Although the index procedure of equation (8) can, in principle, reflect shifts between products of different value, it is difficult to do so in practice because there are no quantity and price data for the various species, lengths and grades. Hence, real productivity may in fact rise when high-value endproducts are sawn, even though the piece count may have remained stable or even declined. This problem is likely to be greatest in the B.C. Coast region.

In analyzing the growth and performance of the Canadian transcontinental railways, Freeman et al. (1987) demonstrated the practical application of the multilateral-index procedure. The present study applied the same procedure to generate multilateral indices of SFPs, VFPs and TFPs across the four regional lumber industries over a 24-year period. The Ontario lumber industry in 1962 was arbitrarily chosen as the basis for the indices, a choice that has no effect on calculations and conclusions.

THE DATA

Annual statistics for 24 years (1962-1985) were used for the four regions in the current study. The main sources of data are Statistics Canada publications and Forestry Canada reports: for outputs and wood input, Anon. (1984a); for purchased fuels and electricity, Anon. (1975, 1984b, 1984c, 1986); and for tax and interest rates, Freeman et al. (1987), updated for this paper.

The use of regional-level statistics necessitates the averaging of quantities and prices within a region and results in a significant loss of information. That loss is greatest in those regional industries that are most diverse (e.g., B.C. Coast). Unfortunately, consistent time series are only available at the regional level. Firm- or mill-level data are unavailable.

The following sections briefly describe the output and input variables used in the present study. The data do not distinguish between softwood and hardwood lumber; however, softwood lumber dominates in each of the regions analyzed. In 1985, softwood accounted for 95, 91 and 99% of the volume of lumber produced in Quebec, Ontario and B.C., respectively.

Outputs

The primary outputs of the industry are wood chips and lumber. Most studies on the production structure of the industry treat chip revenues as reductions in the cost of raw material (wood) associated with the production of lumber (e.g., Meil et al. 1988). However, because chip production is responsive to relative lumber/chip prices, it is more appropriate to treat chips as an output than a "negative input". This is particularly true in Ontario and Quebec, where chips account for roughly 25% of total industry revenues.

This study treats the industry as having two outputs (i.e., lumber and chips). The quantity of lumber was estimated from production data, and the quantity of chips from shipment data (since production data were unavailable). Implicit prices derived from shipment data were used to derive the revenue generated by each output. Railway ties were not examined because they account for less than 1% of the total value of shipments in the industry.

Inputs

This study aggregates all inputs into five categories: labor, wood, other materials, energy and capital.

Labor: The quantity of labor refers only to production workers, and is measured in terms of person-hours paid; the number of hours paid for includes hours worked and all hours of paid leave. The ideal measure for the quantity of labor is hours worked. The use of hours paid overstates the actual increase in hours worked because average vacation time has risen substantially during the 1980s. Average "vacation hours paid for" have risen more rapidly than annual "hours worked" as junior employees have been displaced from the industry. As a result, the actual number of hours worked has not grown as quickly as average hours paid for. The International Woodworkers of America (see Footnote 3, Page 6) estimate that, in some regions, average hours worked are as much as 2% below hours paid for. This suggests that the labor productivity measures reported in the present study are slightly biased downward.

Several previous studies have equated the quantity of labor with the number of employees. This is misleading in both the short and long terms. changes in the number of employees often diverge from changes in hours worked because companies normally reduce average hours worked more than the number of employees during the early stages of a recession. The number of employees is also misleading in the long term because it does not account for the secular downward trend in the length of the work week.

Administrative workers were not included in our analysis because Statistics Canada officials indicated that a significant component of the reported cost of administrative workers is actually the cost of labor in the logging operations that supply the sawmills. Given the definition of the wood input in this study, inclusion of the administrative workers would have resulted in double counting.

The reported cost of production workers was increased by an estimate of supplementary labor income, where supplementary labor income was defined as the amount paid for unemployment insurance, pension funds, and other social programs by the employer. Data on supplementary labor income is available either for the whole economy at the provincal level or for the manufacturing sector at the national level. Given the highly unionized nature of the lumber industry, the latter figures were used. In the manufacturing sector, supplementary income as a proportion of total labor income has steadily increased, from 5.5% in 1962 to 12% in 1985.

Wood: The quantity of roundwood was measured in cubic metres, and refers to the actual amount used (i.e., purchased and non-purchased roundwood). The cost of non-purchased roundwood was estimated by multiplying the quantity of non-purchased roundwood by the implicit price (total costs divided by total quantity) of the purchased roundwood. The roundwood cost data reflect the cost of delivering the logs to the mill (i.e., delivered wood costs). This assumes that purchased and non-purchased roundwood are homogeneous with respect to price and quality. Although some industry observers believe that non-purchased wood normally has a lower effective price, hard data to support this view are not available.

It is particularly important in productivity studies to take the quantity and cost of non-purchased roundwood into account because the relative use of purchased and non-purchased roundwood has changed over time. In Ontario, for example, purchased roundwood increased from 53% of the total roundwood used in 1962 to 93% in 1985.

Materials: The quantity of non-wood materials is computed implicitly by using the cost of materials and supplies and the Wholesale Price Index. Materials consist of the following: materials or products (lumber, cores, etc.) purchased or transferred for re-sawing, planing, etc.; containers and other packaging materials and supplies; operating, maintenance and repair supplies used (excluding fuel); amounts paid to others for work done on materials owned by establishments; and all other non-wood materials and components used. The cost of materials does not include stumpage fees. Given that a cost was imputed for non-purchased roundwood, the inclusion of stumpage would have resulted in double counting.

Energy: The cost of energy was taken to be the cost of fuel and electricity for each region reported by Statistics Canada (Anon. 1975; 1984 b,c). However, a regional energy-price index for the industry has not been published. As a result, a national energy-price index was constructed by using the five major sources of energy for the Canadian sawmilling industry (i.e., natural gas, gasoline, fuel oils, liquefied petroleum and electricity). The quantity of energy for each region was then computed implicitly from the regional cost data for fuels and electricity and the national price index. Since we are only able to examine the purchased energy that the regional industries consume, our analysis implicitly assumes that the relative use of purchased and non-purchased energy did not change significantly during the 1962-1985 period.

Capital: Ideally, productivity studies should use an estimate of the quantity of capital based on data for the vintage and the class of the capital assets. However, such data are unavailable for the major Canadian lumber-producing regions. In the absence of such data, Statistics Canada's estimates of capital stock are frequently used. Unfortunately, these estimates are not available on a sub-provincial basis and at the four-digit-code level of the Standard Industrial Classification (Anon. 1980).

After consulting with officials at Statistics Canada and reviewing the quantitative exposition of Jorgenson et al. (1987), a value-added approach was used to infer capital costs for the regional industries. After constructing a capital-service price (total cost of capital stock divided by quantity of capital stock), the cost and quantity of capital services were derived. The value of capital-service flow (i.e., capital cost) was calculated by subtracting total wages and salaries from the total-value added. The quantity of capital-services was then implicitly determined by dividing the capital-service flow by the capital-service price.

From Christensen and Jorgenson (1969), the service price for capital is calculated as:

$$R_t = \frac{(1-k_t-u_t z_t)}{1-u_t} (q_{t-1} \rho_t + q_t \delta - \eta_t q_t) + \Phi_t q_t \qquad (9)$$

where R is the rental (service) price for capital; k is the investment tax-credit rate; t is the specific year; u is the effective corporate income-tax rate; z is the present value of depreciation deductions for the purpose of taxation on a dollar's investment; q is a capital-asset price index; ρ is the cost of financing capital, represented here by the McLeod, Young, Weir corporate bond rate; δ is the physical rate of depreciation of a capital asset (which is assumed to follow the double-declining method); η is the capital gains rate; and Φ is the property-tax rate.

Equation (9) indicates that the price of using a unit of a given capital asset for a year depends on: the cost of purchasing, q; the rate of physical decay, δ; the cost of financing, ρ; and the rate of appreciation, η. All of these terms are then adjusted by the appropriate tax rates, defined by the tax term, the first part of the right-hand side of equation (9).

The terms z and η are calculated from equations (10) and (11), respectively, as follows:

$$z_t = \delta \frac{(1 + \rho_t)^{0.5}}{(\rho_t + \delta)} \qquad (10)$$

$$\eta_t = \ln(q_t / q_{t-5}) / 5 \qquad (11)$$

where ln stands for the natural logarithm. Equation (11), a 5-year moving-average method for computing the capital-gains rate, is a minor modification of Christensen and Jorgenson's (1969) approach, which uses an annual series of asset prices.

Finally, the real stock (or consumption) of capital, K_{jt}, for a regional lumber industry j in year t, is computed as:

$$K_{jt} = \frac{V_{jt}}{R_t} \qquad (12)$$

where V is the annual value (cost) of the capital-service flow and R_t is computed from equation (9).

An implicit assumption of this approach is that the industry's return on equity is constant over the period. One implication of this is that the quantity (and thus the productivity) of capital is unrealistically volatile. The quantity of capital is too high when the industry is earning high profits, and too low when it is earning low profits. As a result, the year-to-year changes in the quantity and productivity of capital must be viewed with suspicion. However, the secular trends are likely to be indicative of the true underlying series.

HISTORICAL TRENDS IN THE DATA

The first step in the measurement of single- and multi-factor productivities involves computation of input and output prices as well as factor shares in total cost and output shares in total revenue. This section presents a detailed analysis of the trends and cycles in these market variables. Such preliminary analysis, which is overlooked by many productivity studies, provides useful insights into the behavior of the single- and multi-factor productivities over time.

Factor Shares in Total Cost

Total cost refers to the long-term cost of production. It includes expenditures on capital in addition to expenditures on the variable inputs labor, wood, other materials and energy. A factor's share in total cost is the ratio of the annual expenditure on a given input to the annual total cost expended on all inputs. Factor shares are interesting because they reveal which inputs account for the greatest proportion of costs. Thus, they give a crude signal as to which inputs should be emphasized in competitive analyses and targeted for productivity improvement.

Table 1 summarizes the average factor shares in total cost over the 1962-1985 period. Figures 1 through 4 illustrate, respectively, factor shares in total cost for the B.C. Coast, B.C. Interior, Ontario and Quebec industries. The data suggest that the industry on the B.C Coast is significantly different from that in the rest of the country.

Table 1. Average annual factor shares in total cost, by region, 1962-1985.

	Average annual factor shares (%)			
	B.C. Coast	B.C. Interior	Ontario	Quebec
Wood	53	37	41	41
Labor	22	20	19	18
Other materials	10	21	17	18
Capital	14	19	20	20
Energy	1	3	3	3

Wood: As expected, delivered wood accounts for the dominant factor share, ranging from an average of 53% of total cost on the B.C. Coast to 37% in the B.C. Interior. This regional difference suggests that wood plays a relatively larger role in determining the competitive position of the B.C. Coast industry than it does in the other regions. While the share of wood has declined slightly on the B.C. Coast, it has remained largely unchanged in the other regions (Fig. 1-4). The share of wood reflects the cost of both purchased wood and the imputed cost of non-purchased wood. As noted earlier, the relative importance of non-purchased roundwood varies significantly among regions.

Labor: Labor's share in total cost is generally about 20%. On average, it is the second-largest cost share on the B.C. Coast and the third-largest share in the other three regions. The regional cost shares of labor have been surprisingly stable over time, despite significant increases in the relative price of labor.

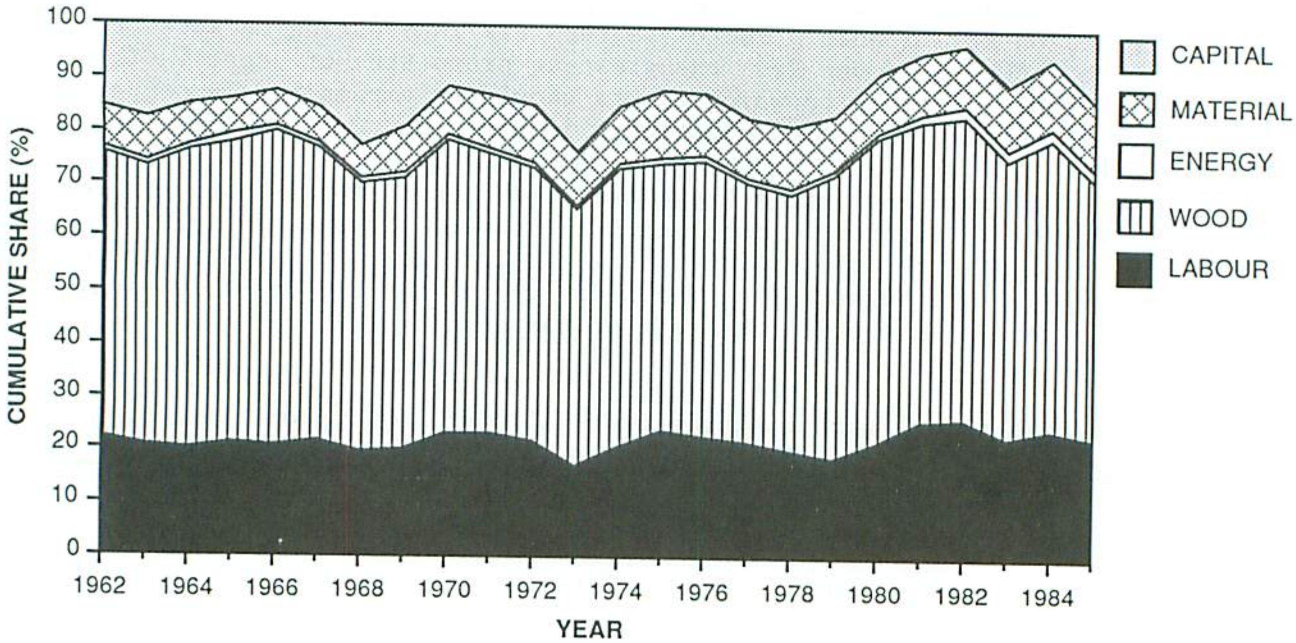

Figure 1. Factor share in total cost, B.C. Coast region.

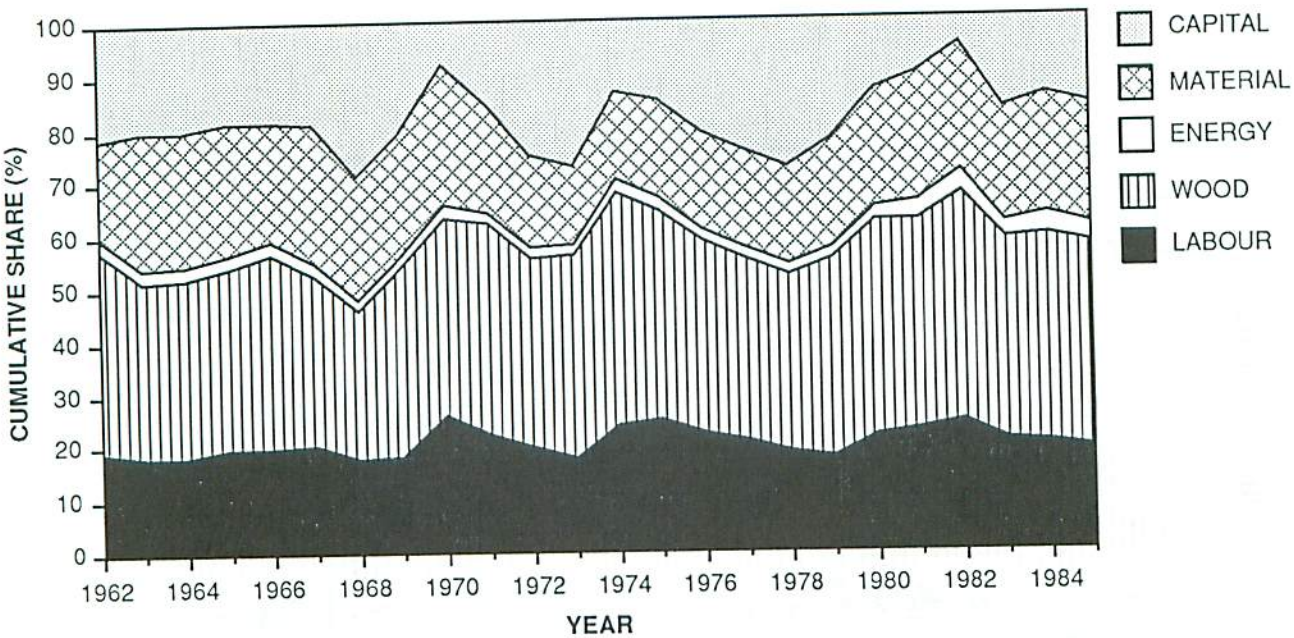

Figure 2. Factor share in total cost, B.C. Interior region.

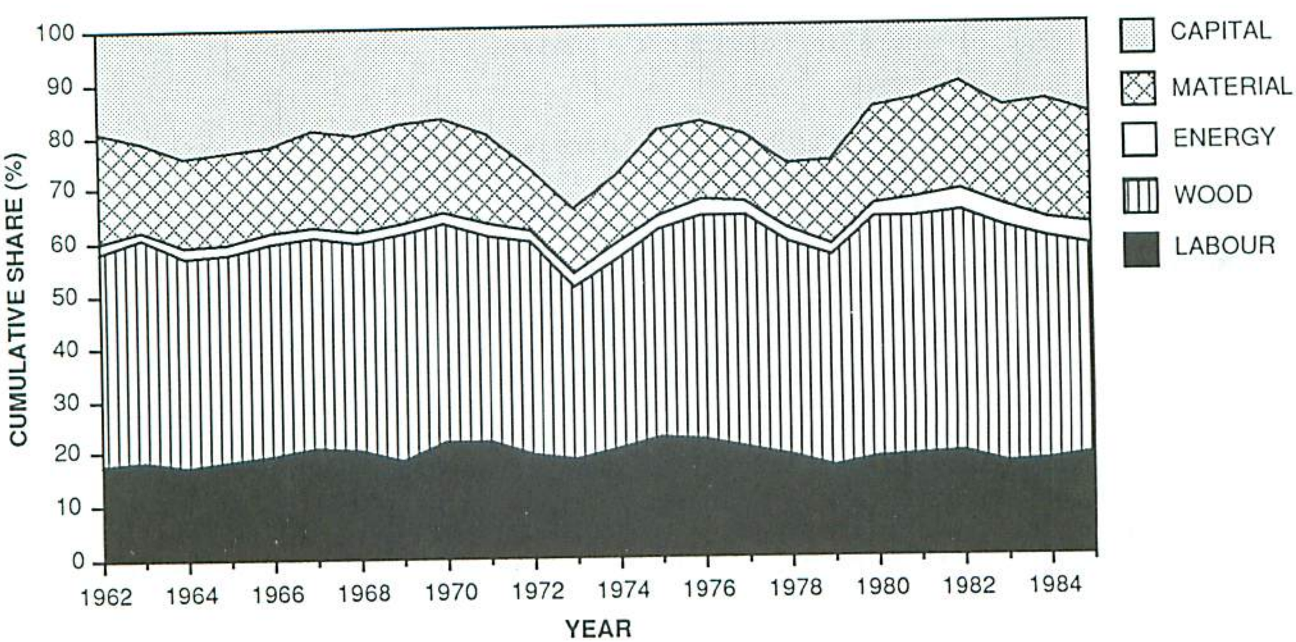

Figure 3. Factor share in total cost, Ontario.

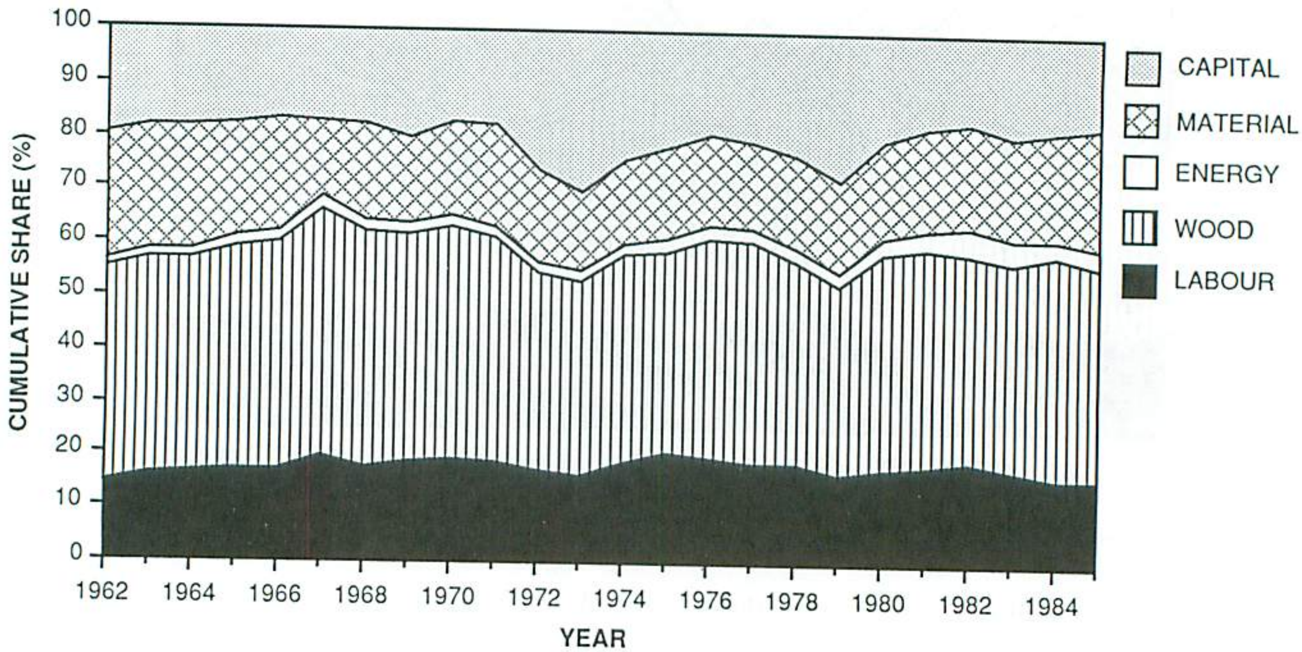

Figure 4. Factor share in total cost, Quebec.

Energy: Although there has been an increasing trend in the share of energy in all regions, energy still accounts for a small proportion of total cost. Purchased energy accounts for about 3% of total cost.

Materials and Capital: The average annual cost shares of materials and capital are also about 20% in all regions except the B.C. Coast. Materials account for only 10% of total cost on the B.C. Coast, whereas capital accounts for 14%. There has been a slight increasing trend in the cost share of materials in the B.C. Coast and Interior regions.

When analyzing an industrial cost structure, one must bear in mind that changes in cost shares embody movements in both the price and quantity of all inputs. Even if there is no change in the price of a given input, a change in its cost share can result from changes in the prices of other inputs. It is useful to think of changes in cost shares as being made up of two components: one that depends on the input's own price and quantity and the other on the prices and quantities of all other inputs (Freeman et al. 1987).

Input Quantities

Figures 5 to 9 illustrate the trends for each input quantity, and Figures 10 and 11 depict trends for the variable and total inputs, respectively. Table 2 summarizes the data by presenting the average annual percentage changes in input and output quantities over the 1962-1985 period. The generally lower percentage increases in the use of variable inputs by the B.C. Coast industry are a result of the region's relatively lower increases in physical output.

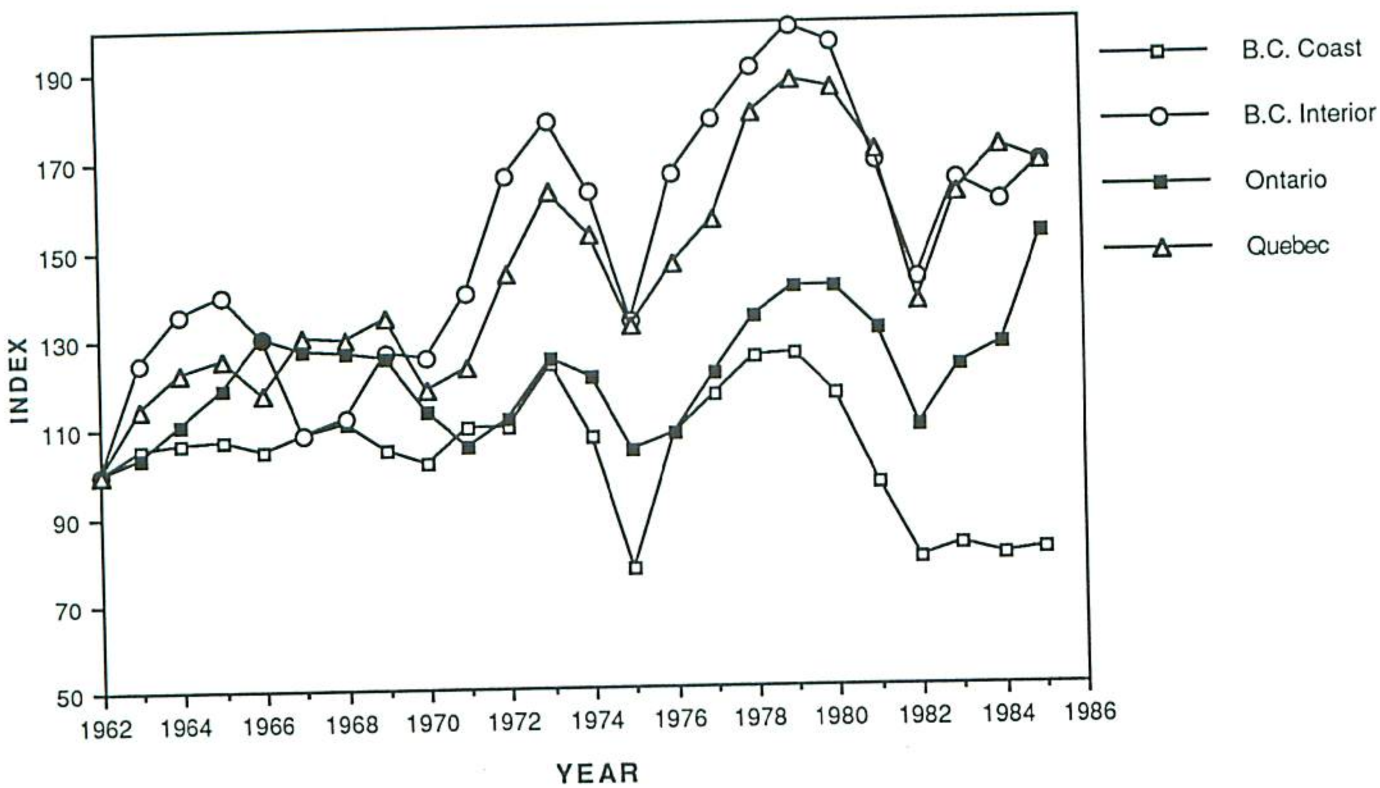

Figure 5. Quantity indices of labor, by region (1962 = 100).

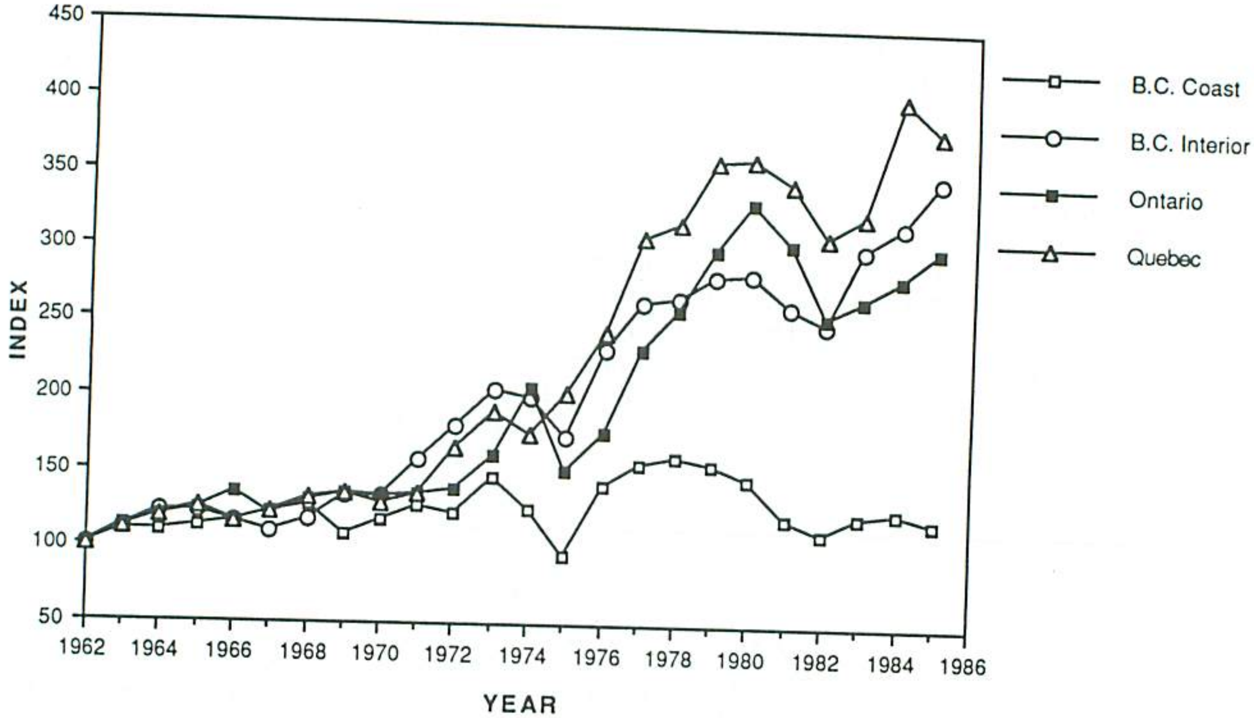

Figure 6. Quantity indices of roundwood, by region (1962 = 100).

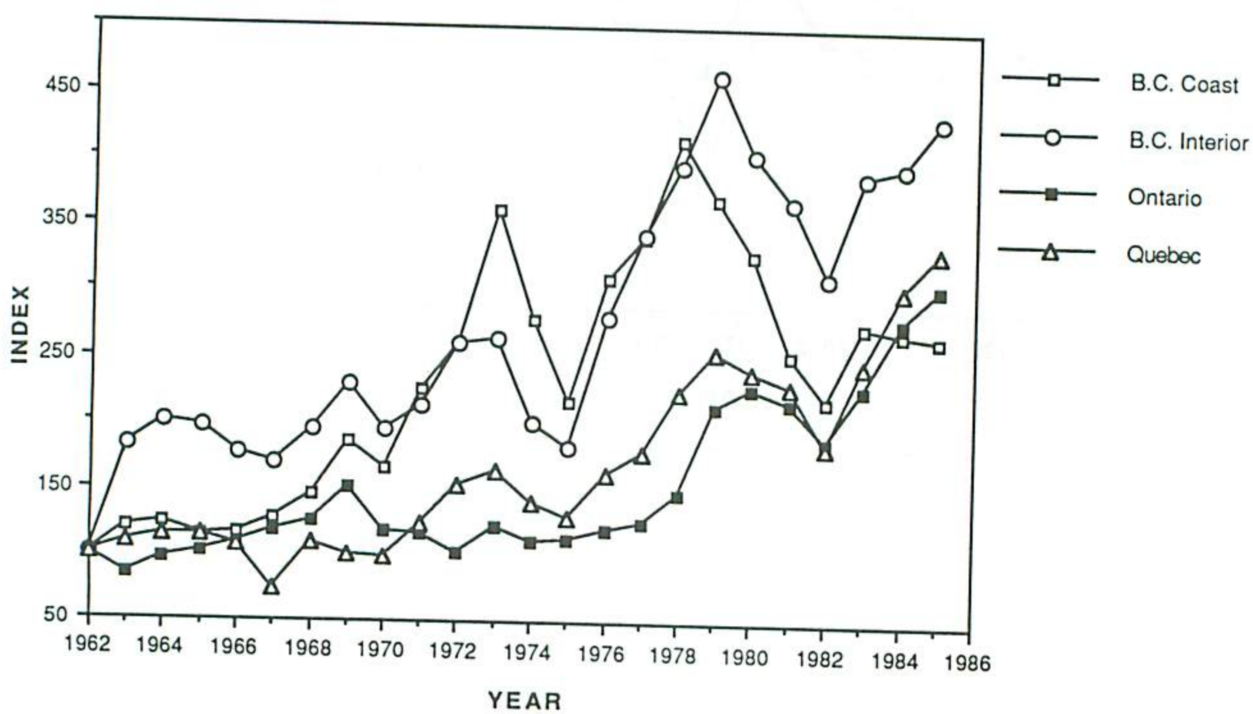

Figure 7. Quantity indices of materials, by region (1962 = 100).

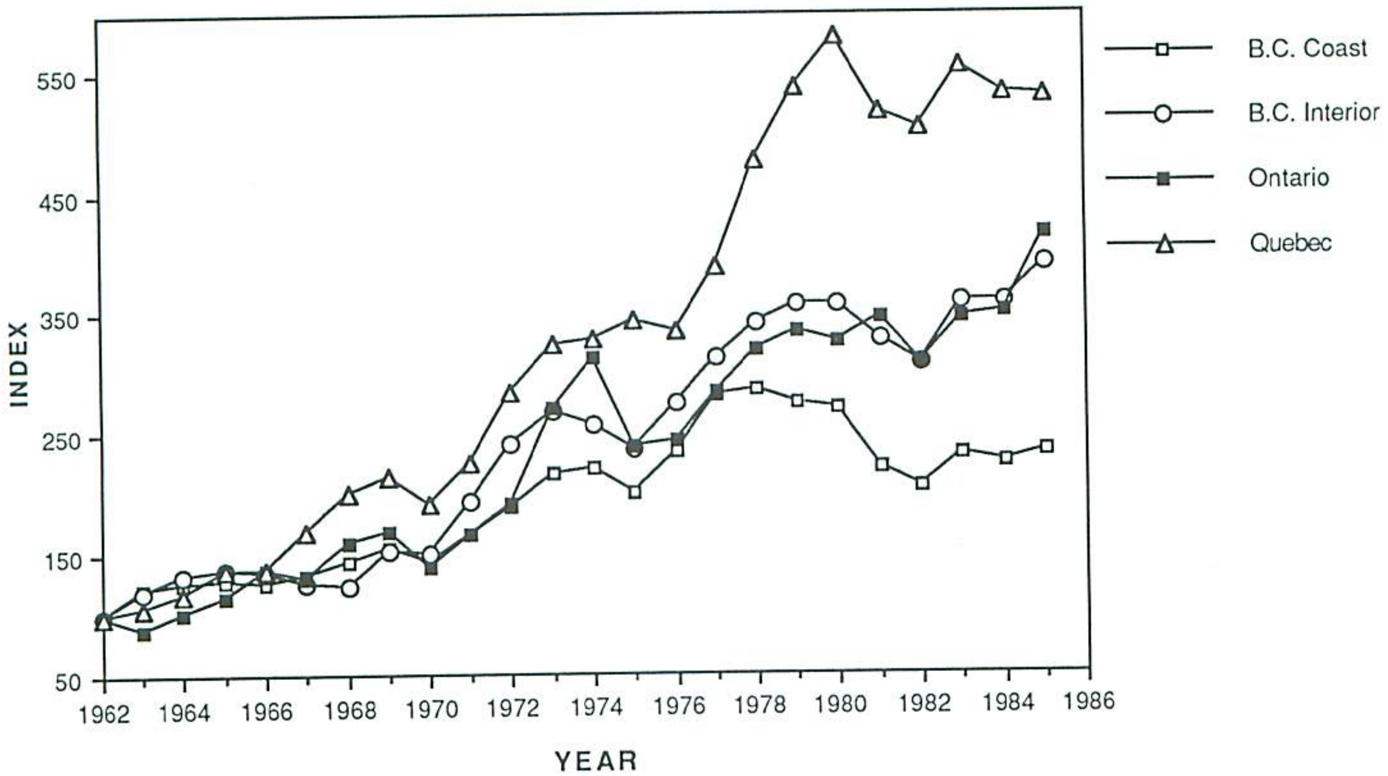

Figure 8. Quantity indices of energy, by region (1962 = 100).

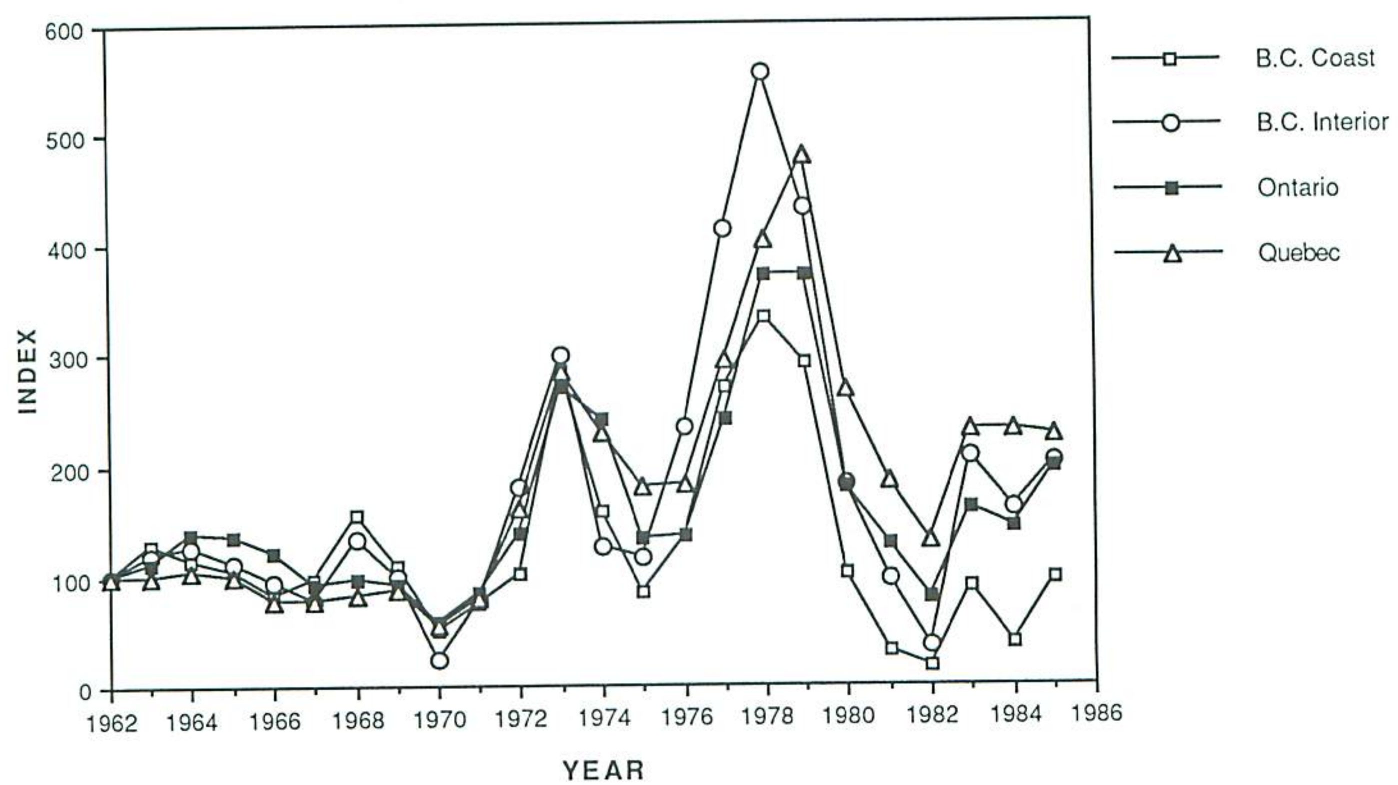

Figure 9. Quantity indices of capital, by region (1962 = 100).

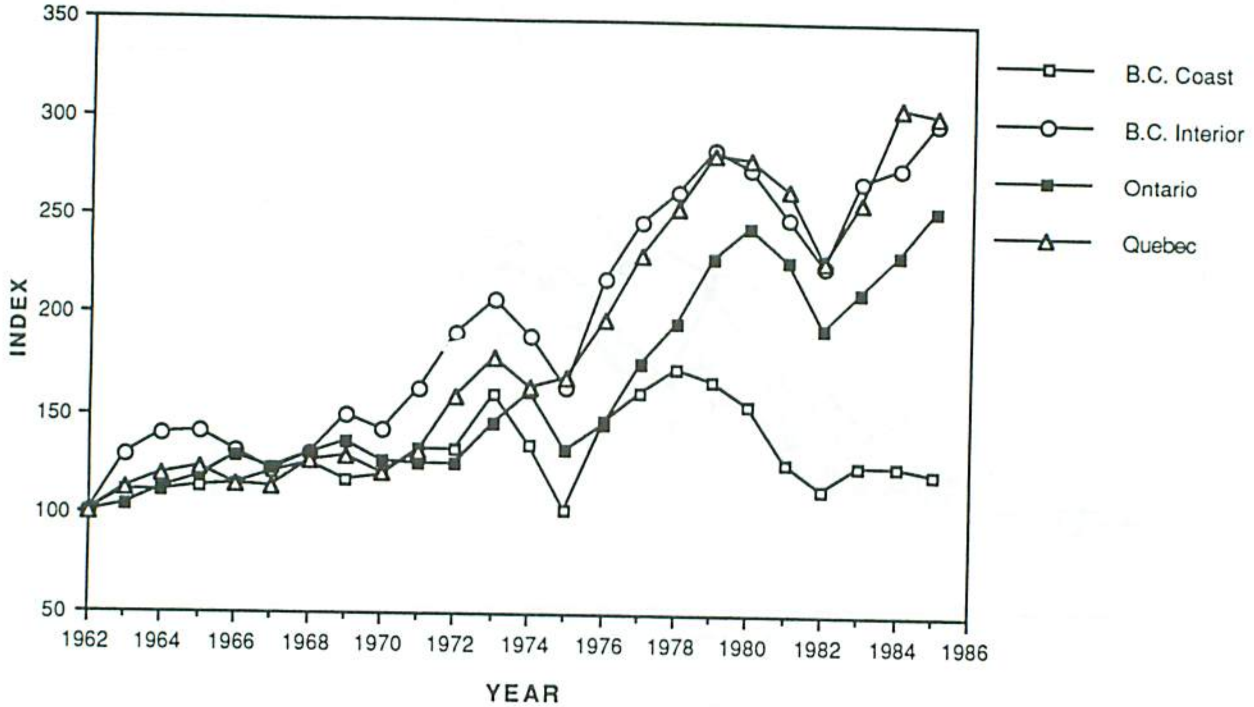

Figure 10. Aggregate quantity indices of variable inputs, by region (1962 = 100).

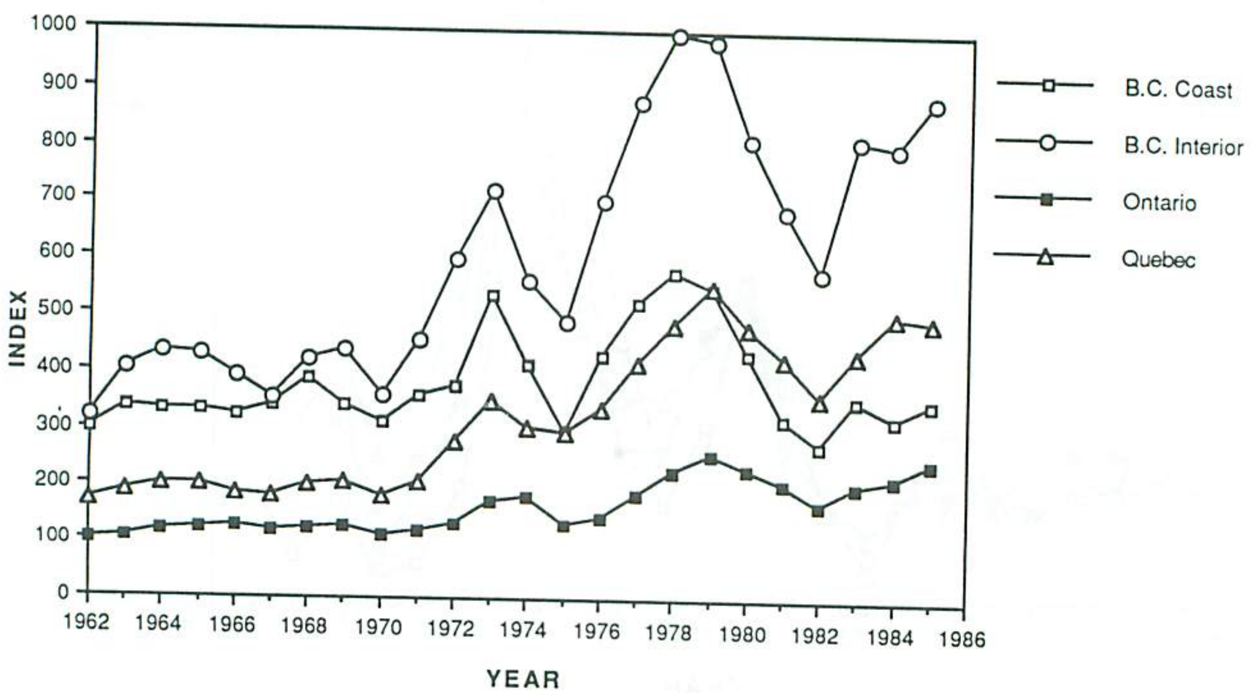

Figure 11. Aggregate quantity indices of all inputs, by region (Ont. 1962 = 100).

Table 2. Annual compound changes in input and output quantities, by region, 1962-1985.

	Annual compound changes in quantities (%)			
	B.C. Coast	B.C. Interior	Ontario	Quebec
Labor	-0.9	2.2	1.8	2.2
Wood	0.8	5.5	4.9	5.9
Other materials	4.3	6.5	4.9	5.3
Energy	3.7	6.1	6.4	7.5
Capital	0.0	3.1	2.9	3.6
Variable inputs	0.8	4.9	4.2	4.9
Total inputs	0.7	4.5	3.9	4.7
Lumber	0.8	5.4	5.2	5.7
Chips	3.9	8.4	11.8	11.8
Total output	1.1	5.5	5.9	6.2

Labor: The B.C. Interior and Quebec industries recorded the largest quantity of labor used, which appears to have peaked in each region in 1979 (Fig. 5). Significant cutbacks were registered in all regions during the early 1980s. Only in Ontario has the use of labor in 1985 surpassed its 1979 high.

The most significant cuts in labor were in the B.C. Coast region, where the quantity of labor decreased by 35% from 1979 to 1985. Decreases were 15% in the B.C. Interior and 10% in Quebec; Ontario's use of labor increased by 8%. These results are interesting because the B.C. Interior, Ontario and Quebec industries all registered approximately the same percent increases in output over this period, and they all faced roughly the same relative prices. It appears that, during the early 1980s, the Ontario industry lagged behind the other regions in introducing labor-saving technology. This conclusion is consistent with that of a recent study of the Ontario lumber industry, which stated "... the level of automation and processing technology lags behind the competition" (Anon. 1987).

Wood: From 1962 to 1985, the utilization of roundwood in the B.C. Interior, Ontario and Quebec industries more than doubled (Fig. 6). However, roundwood consumption on the B.C. Coast peaked in 1978, and was only 20% higher in 1985 than it was in 1962. In conjunction with the significant increases in real value added over the period, this suggests that the B.C. Coast industry has opted to emphasize quality instead of quantity.

It is interesting to note that the proportion of roundwood purchased (or transferred from affiliated operations) has been relatively stable in the B.C. Coast and Interior industries, at roughly 95 and 55%, respectively. The higher proportion on the coast simply reflects the greater importance of affiliated logging operations as opposed to contract loggers. In Ontario and Quebec, the proportion of roundwood purchased/transferred has generally increased during the 1962-1985 period; it has increased from 53 to 93% in Ontario, and from 44 to 61% in Quebec. This suggests that there has been a trend away from the use of contract loggers in the eastern industry.

Materials and Energy: As illustated by Figures 7 and 8, respectively, consumption of materials and energy fluctuated considerably in all regions. Over the period studied, the British Columbia Interior consumed the most materials, while Quebec was the largest consumer of energy.

Aggregates of Variable and Total Inputs: The B.C. Interior and Quebec industries ranked first and second, with some exceptions, in utilization of variable inputs (excluding capital) (Fig. 10). The B.C. Coast industry used the least variable inputs. However, the British Columbia Interior industry tended to have the highest total input utilization followed by Quebec (Fig. 11).

These results are reflected in the levels of VFP and TFP, which are discussed in the next section. Clearly, excessive use of inputs without a proportional increase in output leads to a productivity decline. However, a number of factors, such as plant utilization efficiency and technological progress, must be taken into account.

Capital: As indicated in the section on data collection and analysis, data on the quantity of capital must be treated with caution, and Figure 9 indicates that the capital series are volatile. The only conclusion regarding capital that one can reasonably draw from Table 2 is that the increase in the use of capital over the period examined has been lower on the B.C. Coast than in the rest of the industry.

Input Prices

Table 3 summarizes the input and output prices depicted in Figures 12 to 19 by presenting the average annual compound changes over the 1962-1985 period. As stated in the section on data collection, it has been assumed that all regions face the same prices for materials, energy and capital, and that the price of purchased roundwood is representative of the price of all roundwood used. Changes in regional Consumer Price Indices are included in Table 3 to provide a reference point.

Labor: Labor has experienced the fastest price increases from 1962 to 1985. These increases in the relative prices of labor have provided the industry with an incentive to economize in its use of labor by substituting capital, energy and materials. As indicated above, this has occurred in all regions of the country.

There is a striking difference in the levels of wage rates when we compare the western and eastern industries (Fig. 16). In 1985, the rate paid on the B.C. Coast was only marginally higher than that in the B.C. Interior, but it was 57 and 78% greater than those in Ontario and Quebec, respectively. As discussed in the section on measures of productivity, these wage differences are largely accounted for by differences in labor productivity among these regions.

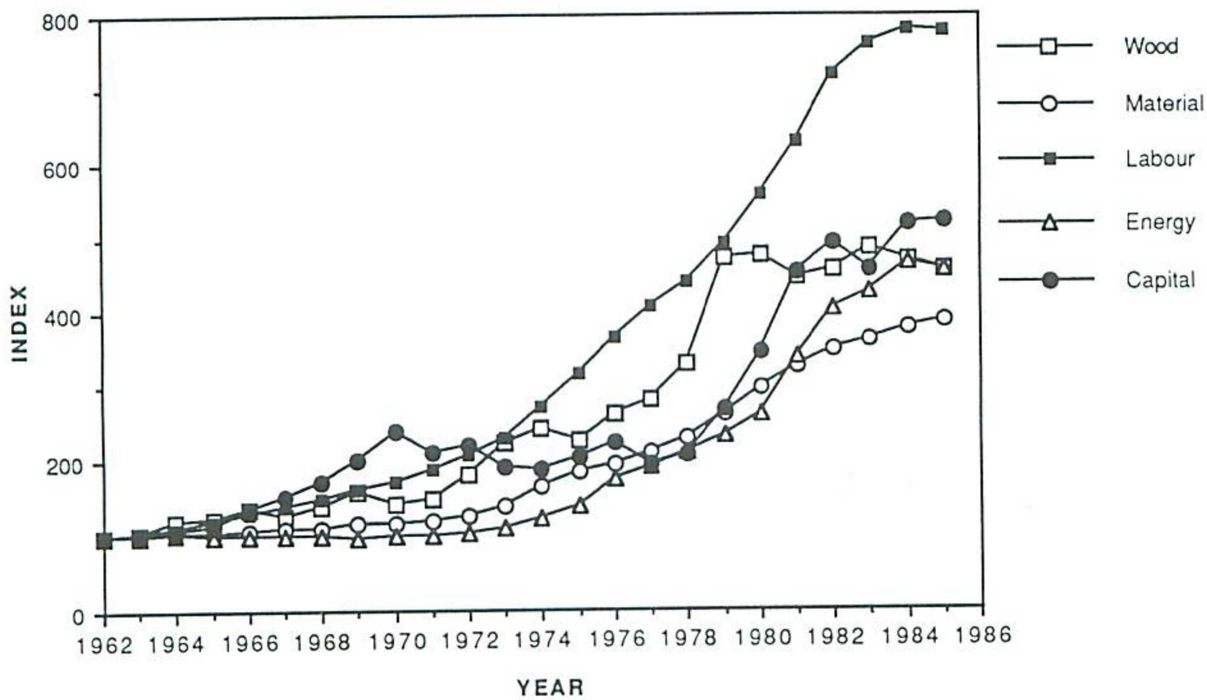

Figure 12. Input-price indices, B.C. Coast region (1962 = 100).

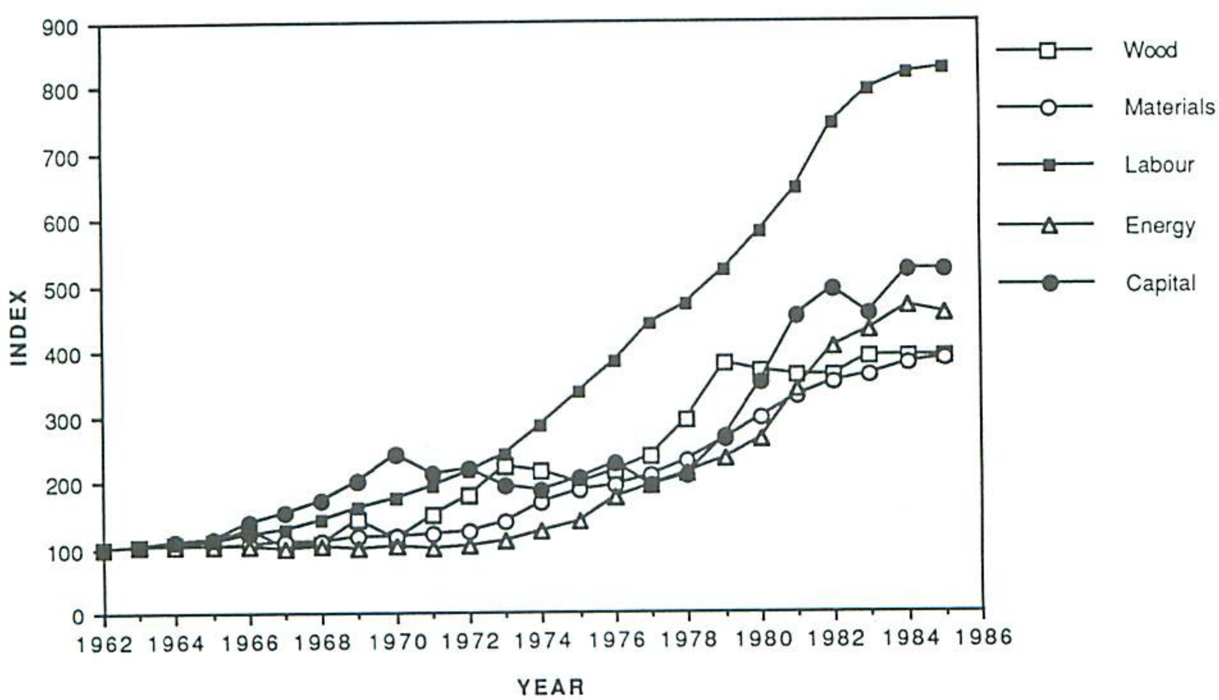

Figure 13. Input-price indices, B.C. Interior region (1962 = 100).

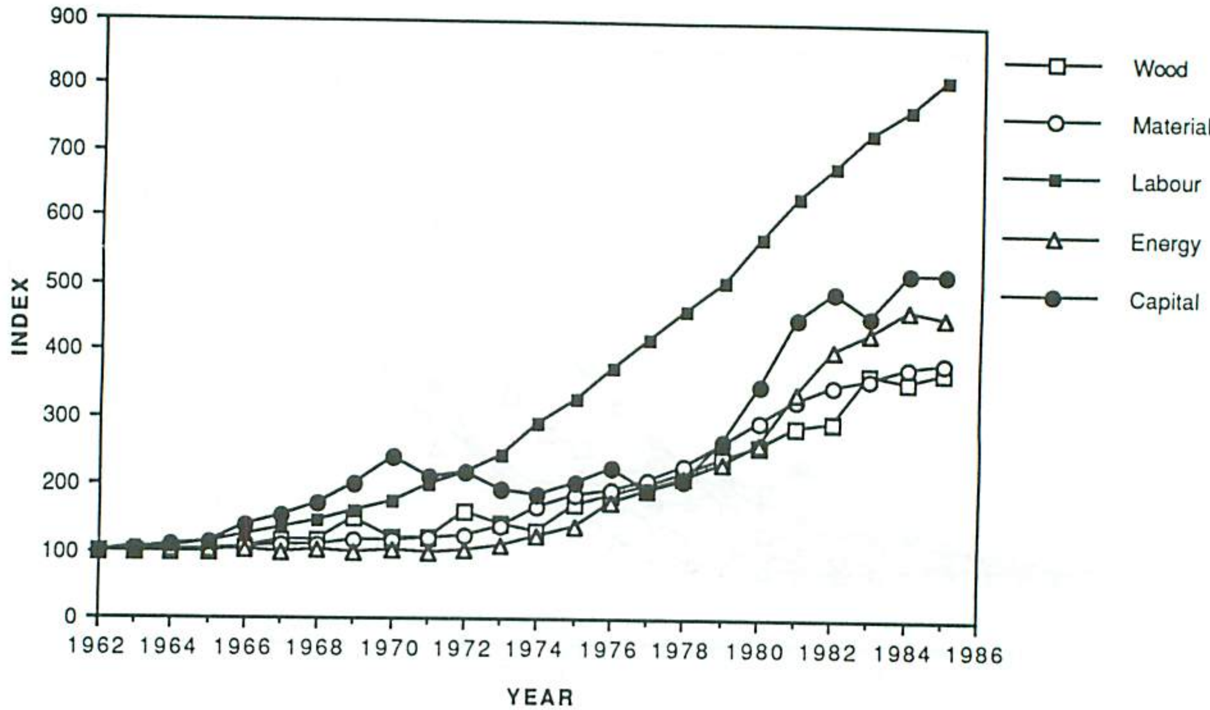

Figure 14. Input-price indices, Ontario (1962 = 100).

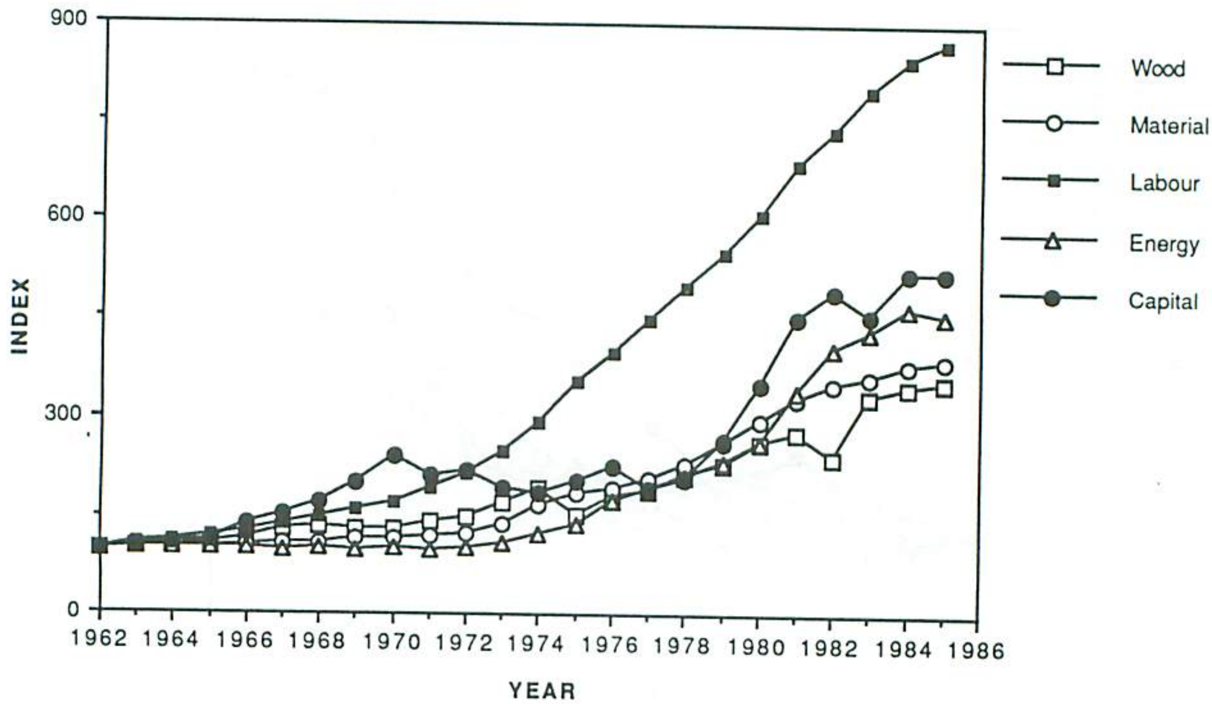

Figure 15. Input-price indices, Quebec (1962 = 100).

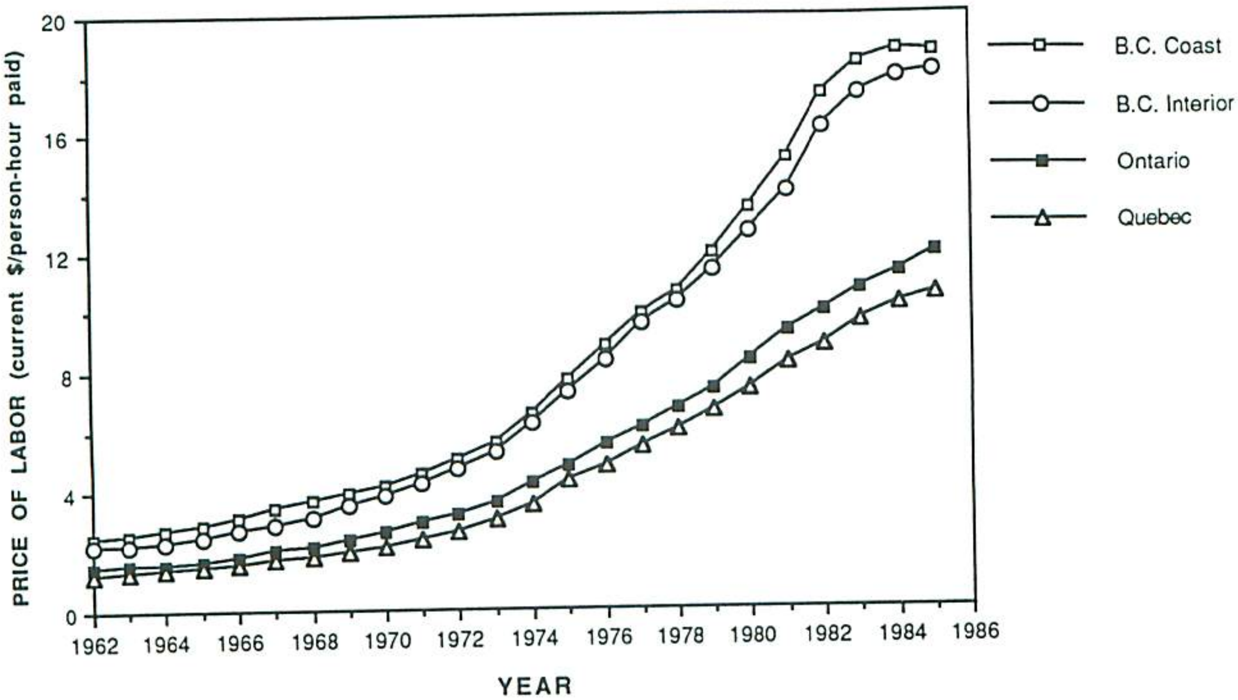

Figure 16. Price of labor (current $/person-hour paid), by region.

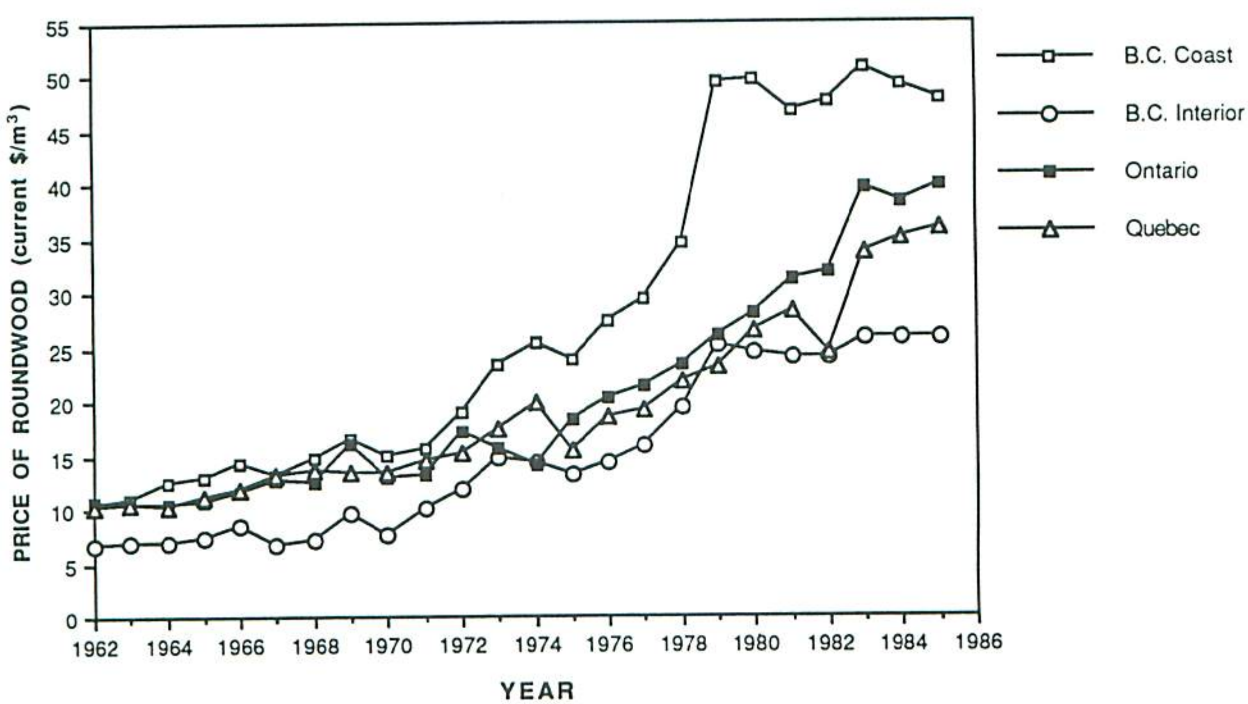

Figure 17. Price of roundwood (current $/$m^3$), by region.

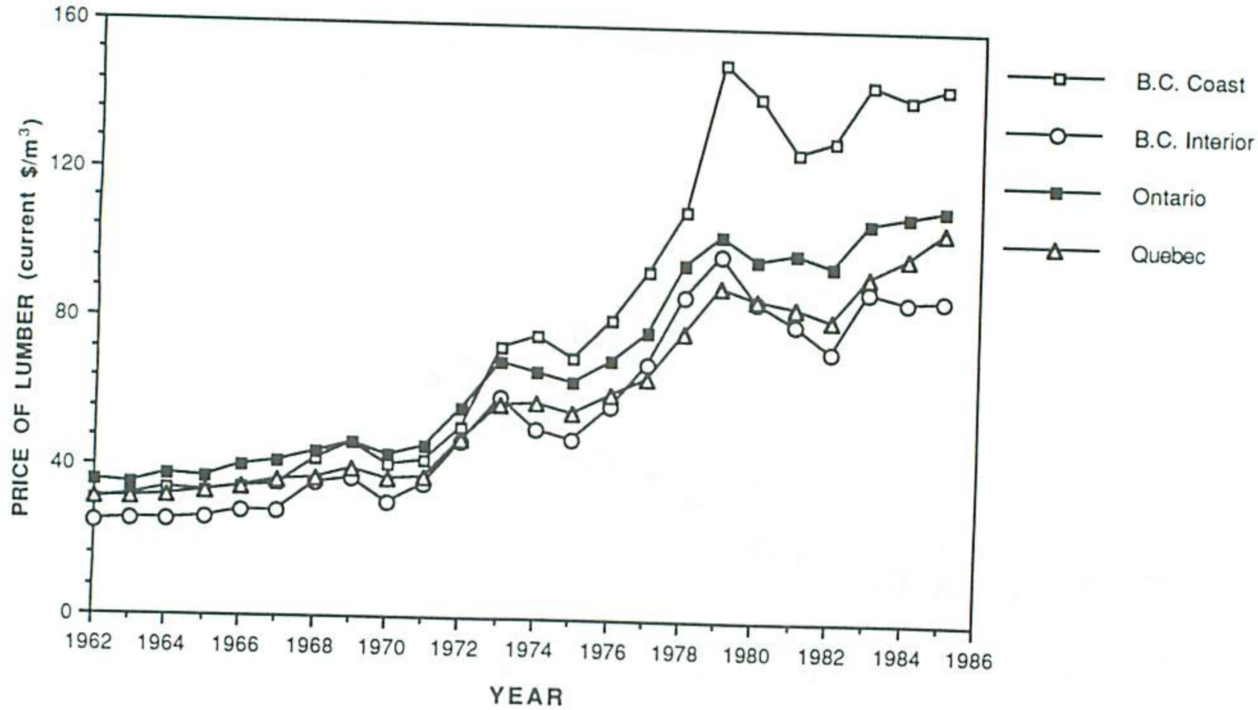

Figure 18. Price of lumber (current $\$/m^3$), by region.

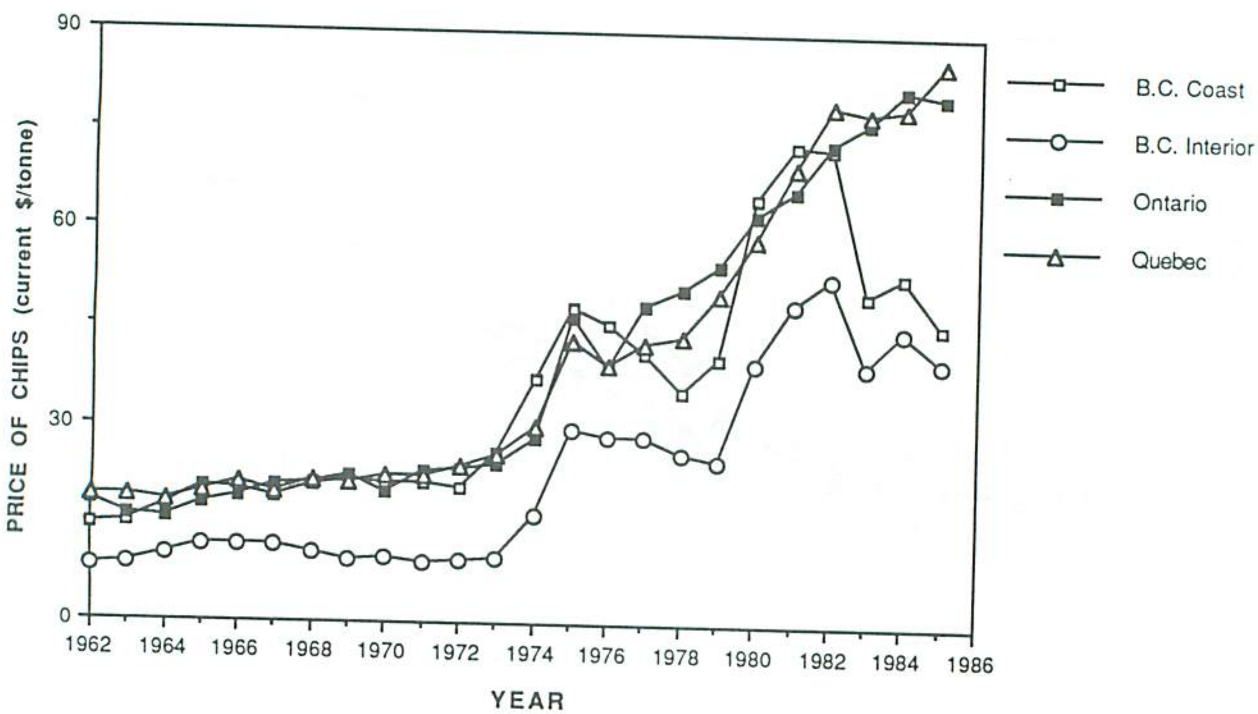

Figure 19. Price of oven-dried chips (current \$/tonne), by region.

Table 3. Average annual compound change in input and output prices, by region, 1962-1985.

	Average annual compound change in prices (%)			
	B.C. Coast	B.C. Interior	Ontario	Quebec
Labor	9.3	9.6	9.6	9.9
Wood	6.8	6.0	5.8	5.6
Other materials	6.0	6.0	6.0	6.0
Energy	6.8	6.8	6.8	6.8
Capital	7.4	7.4	7.4	7.4
Lumber	7.0	5.7	5.1	5.5
Chips	5.1	7.0	6.7	6.7
CPI[a]	5.9	5.9	6.0	5.9

[a] Consumer Price Index (CPI) data are not available at the provincial level. The CPIs for Vancouver, Toronto and Montreal were used for B.C., Ontario and Quebec, respectively.

Wood: Some of the smallest price increases for inputs, particularly in Ontario and Quebec, have been for roundwood. If prices reflect the economic scarcity of inputs in the Canadian lumber industry, this suggests that roundwood is not relatively scarce. A logical implication of this is that policymakers should perhaps rethink their common statement that the industry should maximize its return per unit of roundwood. On the other hand, if prices do not reflect true economic scarcity, this leads one to wonder why not. Note that various sources indicate roundwood prices increased significantly in B.C. and in Quebec during 1988 as the provincial governments in these provinces raised their stumpage fees. At the end of 1988, stumpage comprised roughly 20% of total delivered wood costs for B.C. Coast mills, and 25% for B.C. Interior mills (Anon. 1989).

Figure 17 shows trends in the level of roundwood prices by region. As expected, the highest prices are on the B.C. Coast, where the quality of logs is highest. In 1985, the average price of roundwood on the B.C. Coast exceeded that in Ontario, Quebec and the B.C. Interior by 20, 33 and 85%, respectively. Figures 17 and 18 reveal that these regional differences in roundwood prices largely mirror the regional differences in lumber prices. In 1985, the average price of lumber shipped from the B.C. Coast was higher than that shipped from Ontario, Quebec and the B.C. Interior by 29, 36 and 64%, respectively. This suggests that wood in these regions is generally priced to reflect the product market. Table 3 indicates that, in Ontario, Quebec and the B.C. Interior, the average annual percentage increase in the price of every input has exceeded the increase in lumber prices. This suggests a severe cash-flow squeeze in these regions in the absence of significant productivity gains and/or rising real chip prices.

Outputs: Revenue Shares, Quantities and Prices

As indicated above, the two outputs we considered were lumber and chips. Figures 20 to 22 present regional output indices, and Figures 23 to 26 illustrate the trends in output revenue shares by region over the period under review (1962-1985).

Lumber is a relatively more important source of revenue for the industry in B.C. than it is in Ontario and Quebec. In 1985, lumber accounted for roughly 90% of total revenue in the B.C. Coast and Interior regions, but only 75% in Ontario and Quebec. These regional differences largely reflect, among other factors, the greater role played by the pulp and paper industry in eastern Canada.

The greater dependence on lumber in the B.C. industries, indirectly reflected in the quantity-of-capital series depicted in Figure 9, results in their cash flows being more volatile. One implication of the greater volatility is that the B.C. industries must pay relatively more attention than the Ontario and Quebec industries to risk management if they are to avoid the cost of financial distress (i.e., reduced profits or competitiveness).

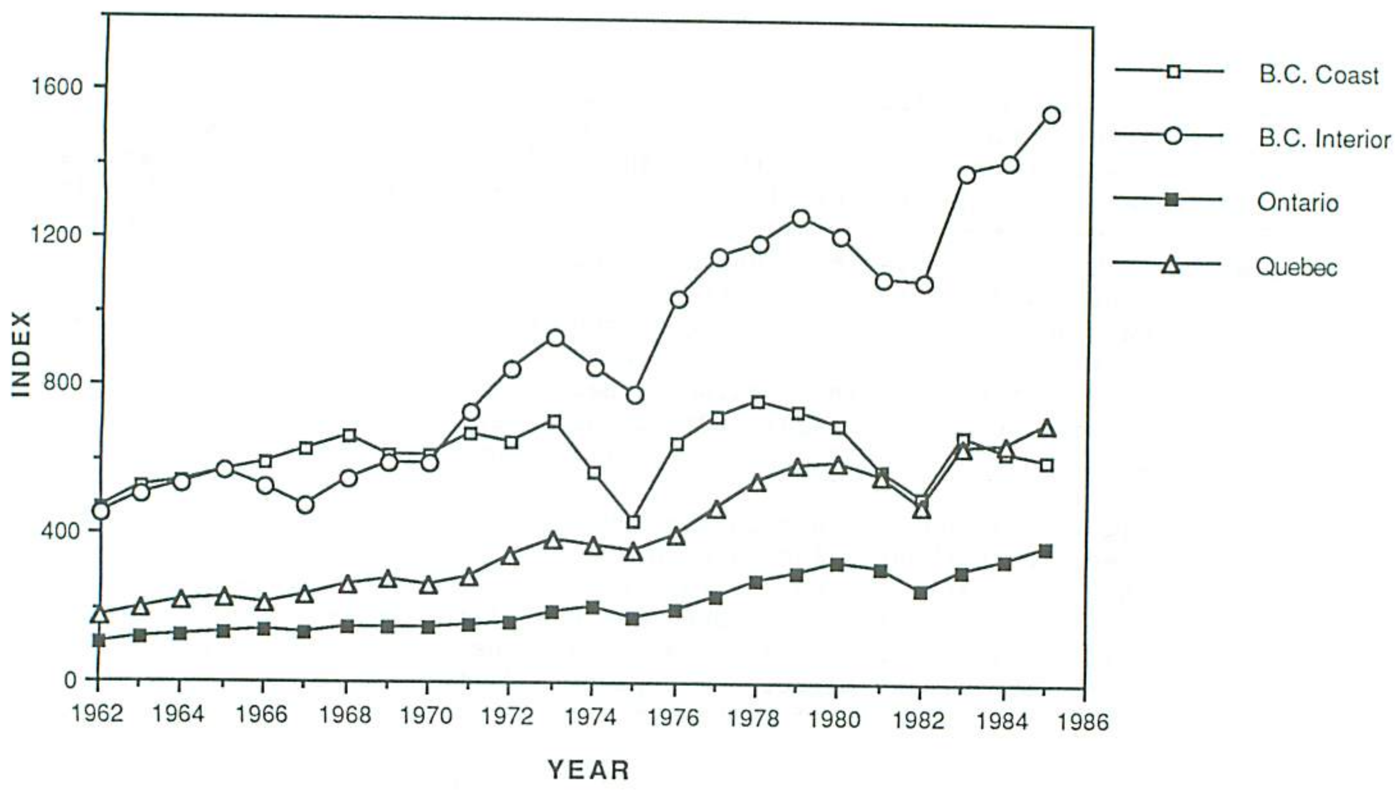

Figure 20. Quantity indices of total output, by region (Ontario 1962 = 100).

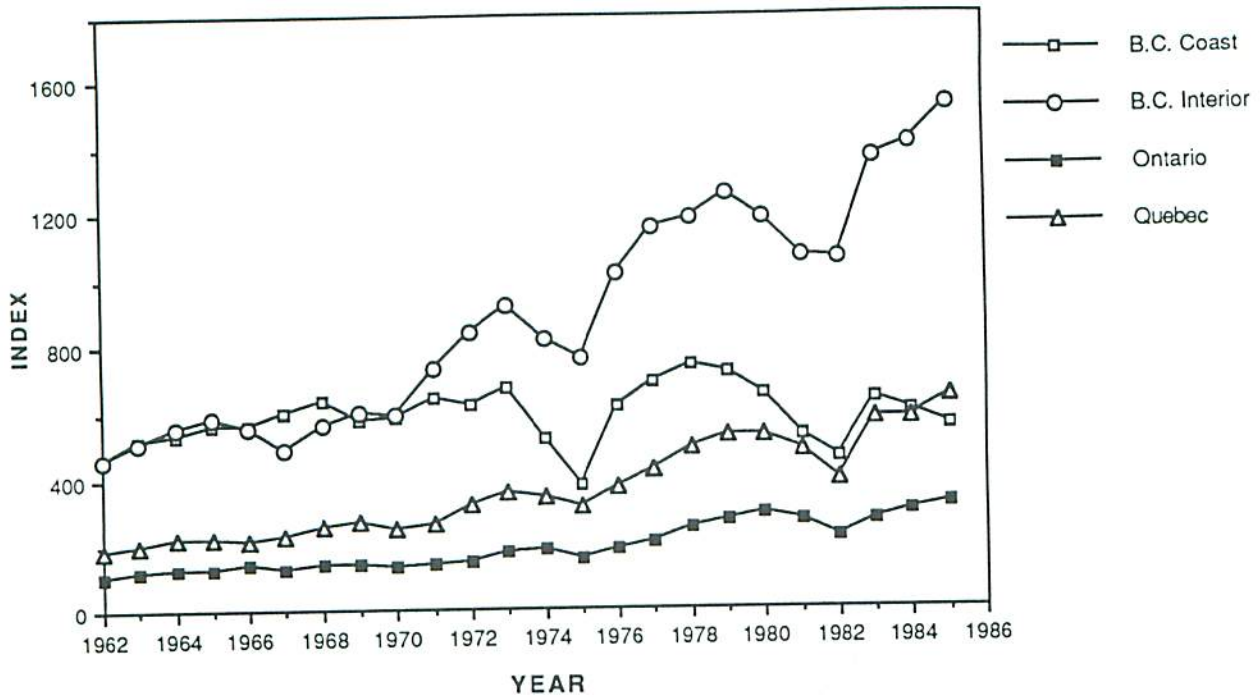

Figure 21. Lumber production indices, by region (Ontario 1962 = 100).

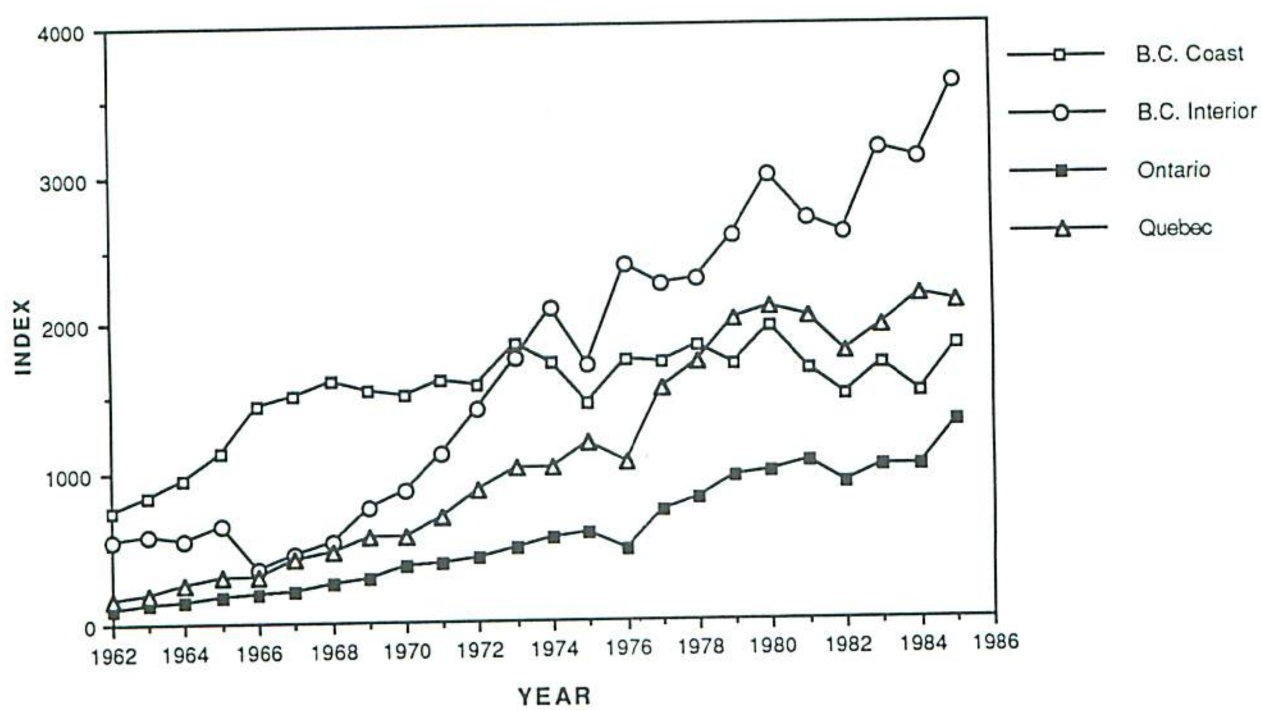

Figure 22. Wood-chip production indices, by region (Ontario 1962 = 100).

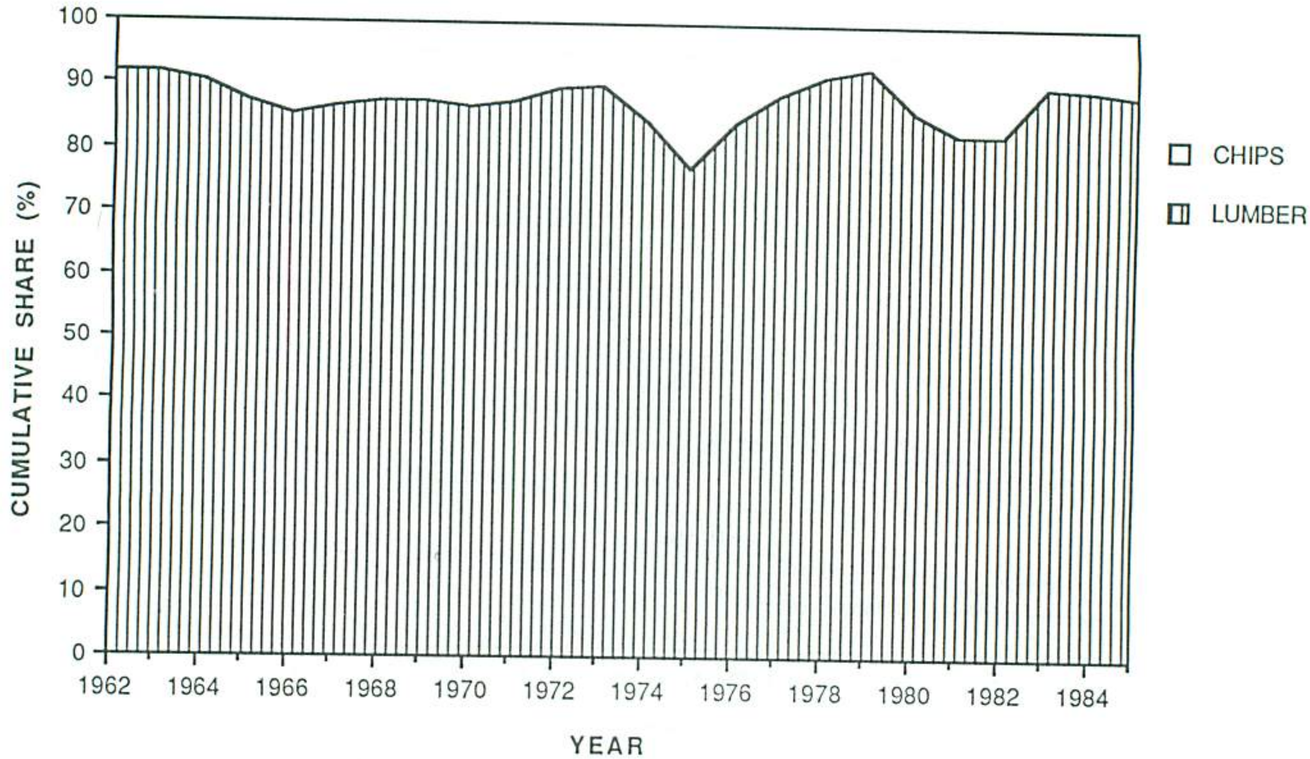

Figure 23. Output revenue shares, B.C. Coast region.

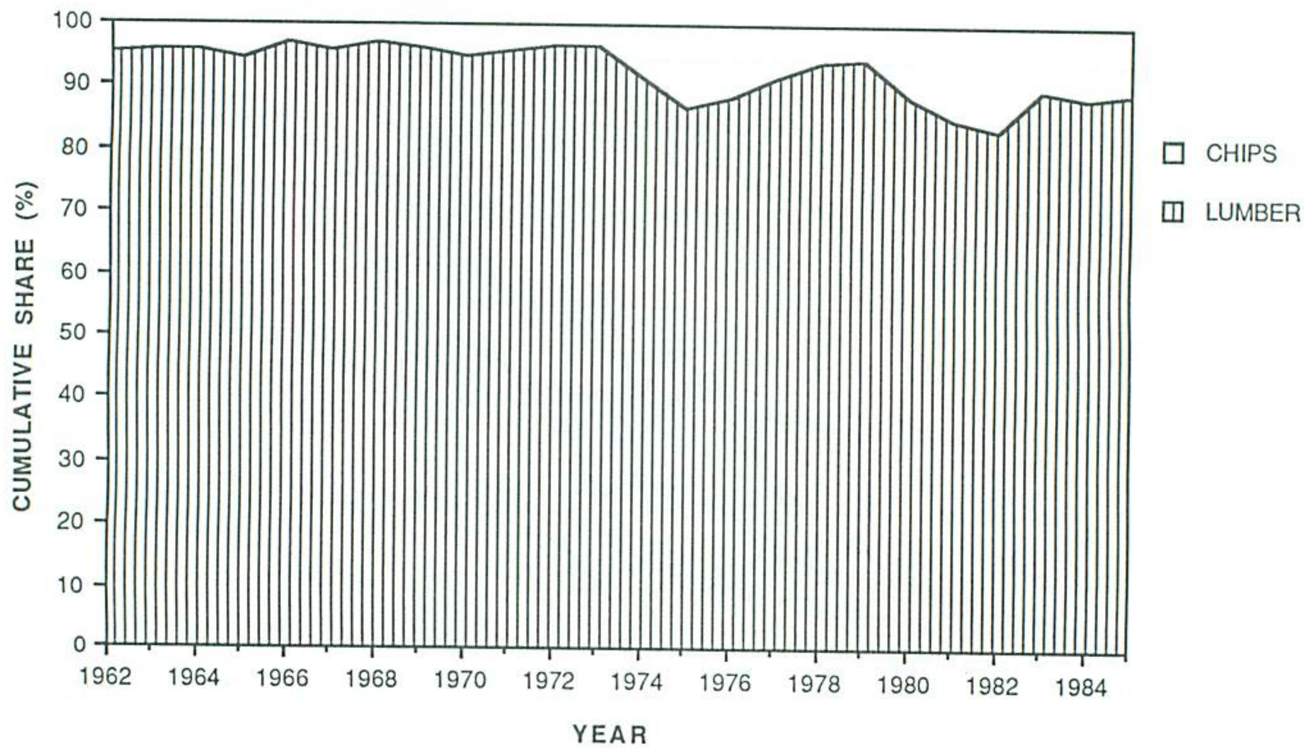

Figure 24. Output revenue shares, B.C. Interior region.

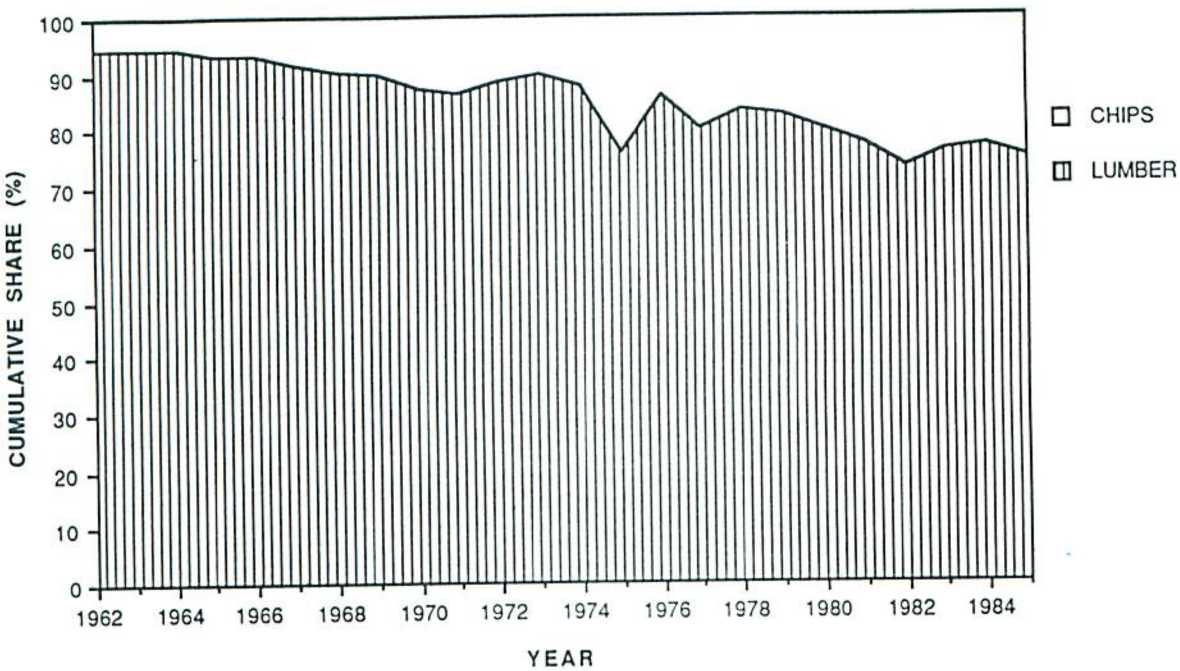

Figure 25. Output revenue shares, Ontario.

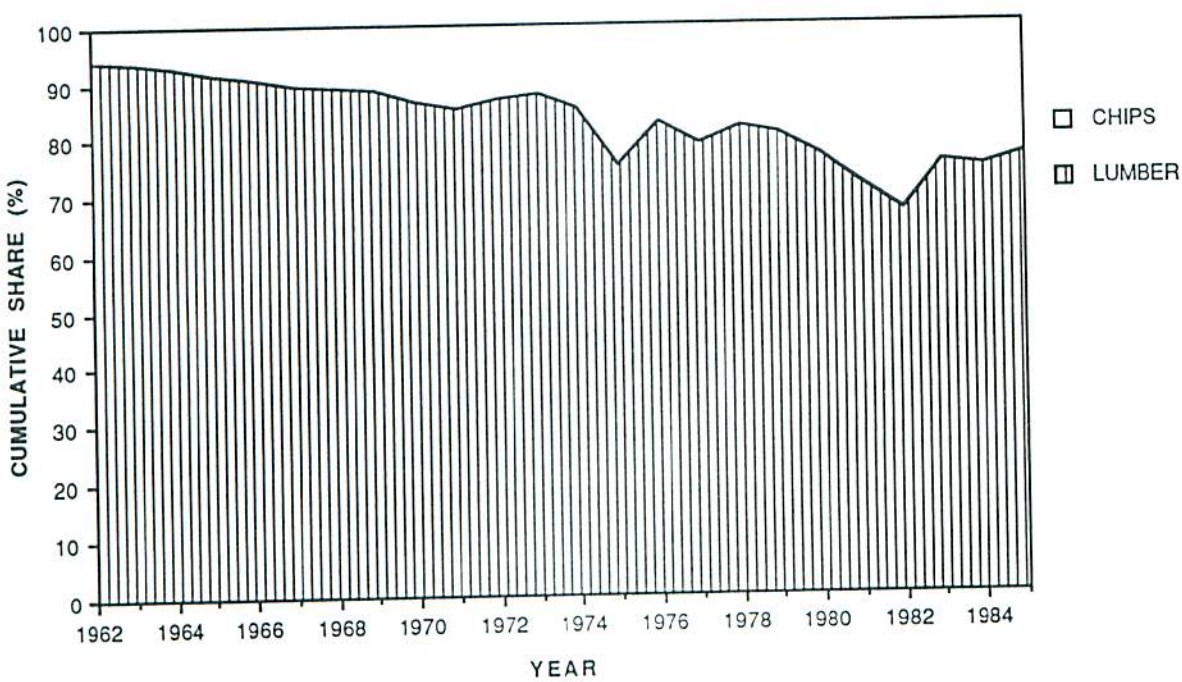

Figure 26. Output revenue shares, Quebec.

All else being equal, firms with higher total risk are more likely to find themselves in financial distress. Financial difficulties in turn are likely to disrupt the operating side of the business, reducing the level of future operating cash flows. Perhaps most important, financial distress can give rise to management incentives that conflict with the interests of other parties who do business with the firm. The adverse effect of such incentives on sales and operating costs is compounded by the aversion to risk exhibited by customers, managers, employees, suppliers and other corporate stakeholders.

One of the more interesting changes in the lumber industry during the 24-year period examined has been the increasing importance of wood chips. From 1962 to 1985, the revenue share of chips roughly doubled in the B.C. Interior and increased by a factor of almost four in Ontario and Quebec (Fig. 23-26). Because wood-chip quantities and revenues were estimated from shipment (as opposed to production) data, these increases reflected not only increases in chip production, but also increases in the proportion of chip production that was sold. Increases in the production and marketing of chips are in response to: (1) higher lumber production, (2) increasing chip-to-lumber price ratios, and (3) greater integration of the lumber and pulp and paper industries. The increased reliance on chips as a source of revenue should contribute to greater stability in cash flows for the industry.

In order to appreciate the changing structure of the lumber industry, the trends in output should be examined on a per-establishment basis. First, the number of establishments in the B.C. Interior, Ontario and Quebec industries dropped from 702 to 209, 436 to 212, and 863 to 355, respectively, from 1962 to 1985 (Fig. 27). This trend towards greater consolidation has likely been a byproduct of the high capital intensity of new technologies and the drive to attain economies of scale in production. In some instances, consolidation also occurred because pulp producers wanted to secure a supply of chips. Greater consolidation, in conjunction with the significant increases in industry output, has meant that the average output per establishment has increased dramatically, except in the B.C. Coast region (Fig. 28). Lumber output per mill increased over the 24-year period by a factor of nine in the B.C. Interior, by a factor of almost eight in Quebec, and by roughly a factor of five and one-half in Ontario.

Figure 27 illustrates the regional trends in the number of establishments, and Figures 28 and 29 show the quantities of lumber and chips per establishment, respectively. In 1985, the average lumber output per mill in the B.C. Interior was roughly four times higher than that in Ontario and Quebec.

In the B.C. Coast region, lumber output per mill peaked in 1977 and has decreased during the 1980s. Only in the B.C. Coast industry did the number of establishments increase (from 108 in 1962 to 120 in 1985). This recent trend likely reflects the region's greater emphasis on specialty products with higher value added. It should also be noted that the B.C. Coast industry started the period with a vast superiority in output per establishment and that, in a sense, the other regions have been catching up to it.

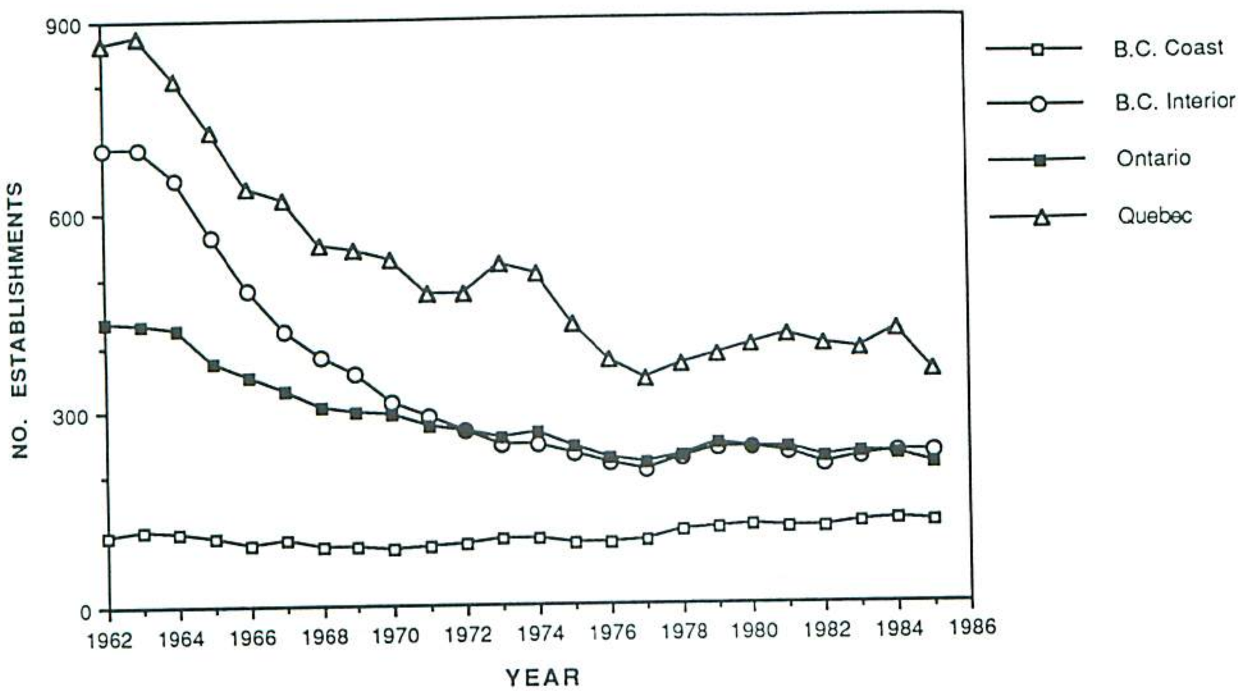

Figure 27. Number of establishments, by region.

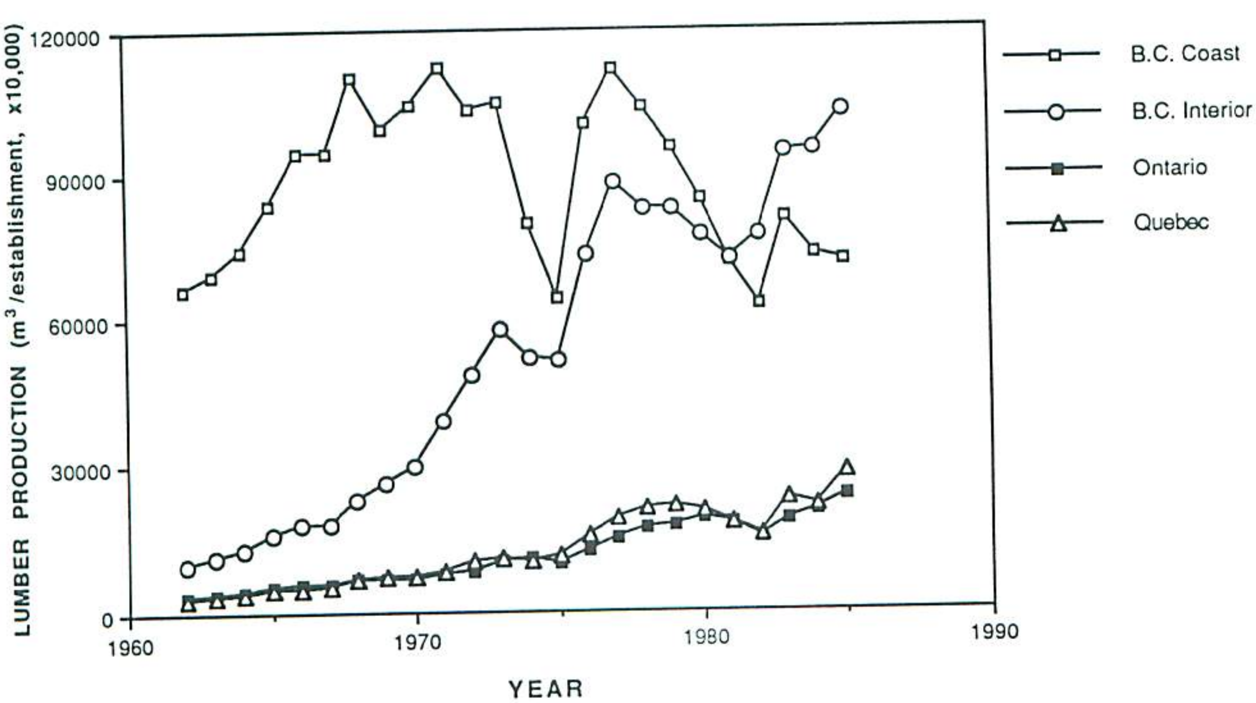

Figure 28. Production of lumber (m^3) per establishment, by region.

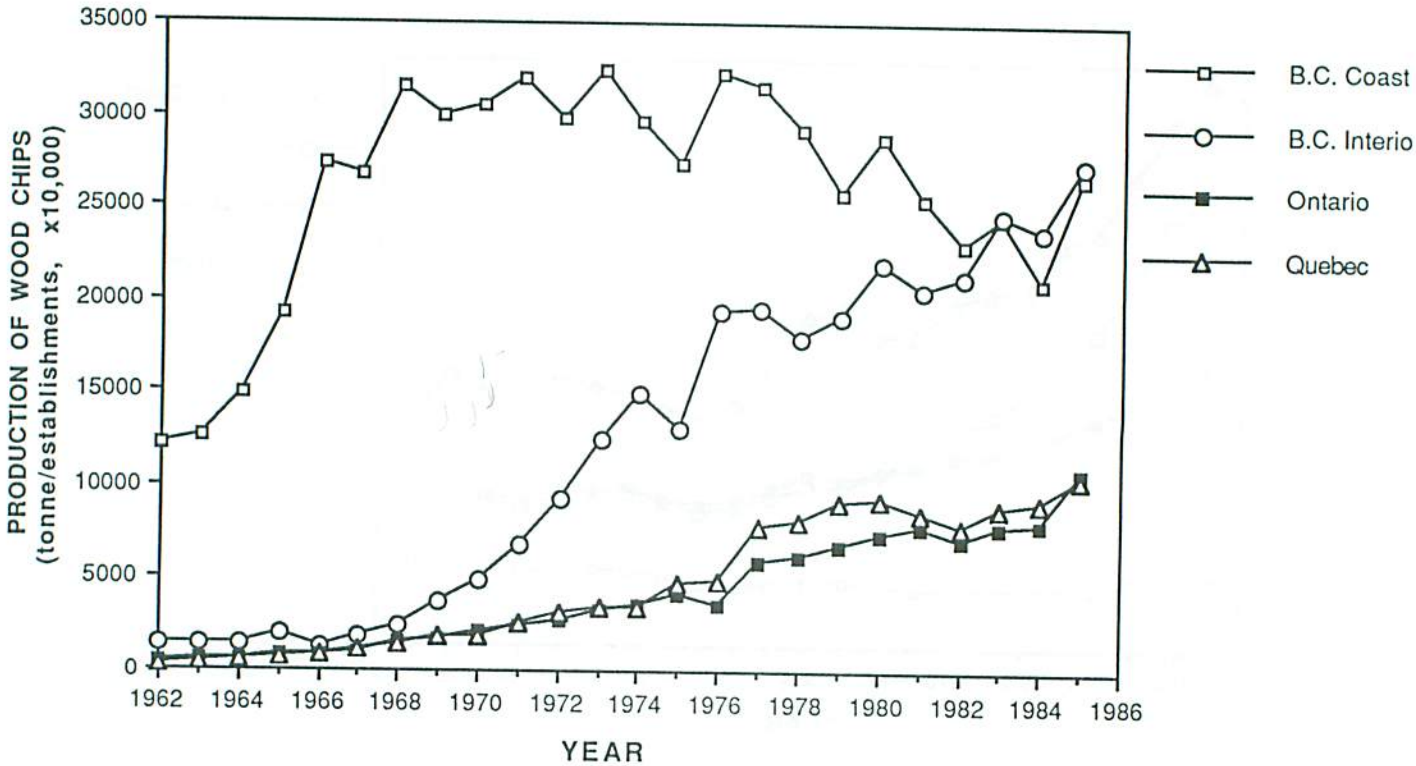

Figure 29. Production of wood chips (tonnes) per establishment, by region.

MEASURES OF PRODUCTIVITY

Single-factor Productivity

Figures 30 to 33 reveal the differences in SFP growth in each region, whereas Figures 34 to 40 can be used to examine and compare SFP levels among regions. When our analysis revealed that the SFP of capital was very volatile, it was removed from Figures 30 to 33 in order to illustrate better the SFPs of the other inputs. Table 4 summarizes the changes in SFP measures for the various regions.

Labor: Over the long term, labor has been the variable input that experienced the highest productivity growth. This is a consistent result across all regions.

The discussion of input prices in the previous section pointed out that labor prices grew faster than the prices of the other inputs. Given such increases in relative prices, it is natural to observe increasing labor productivity. Faced with a high price for labor, it appears that firms

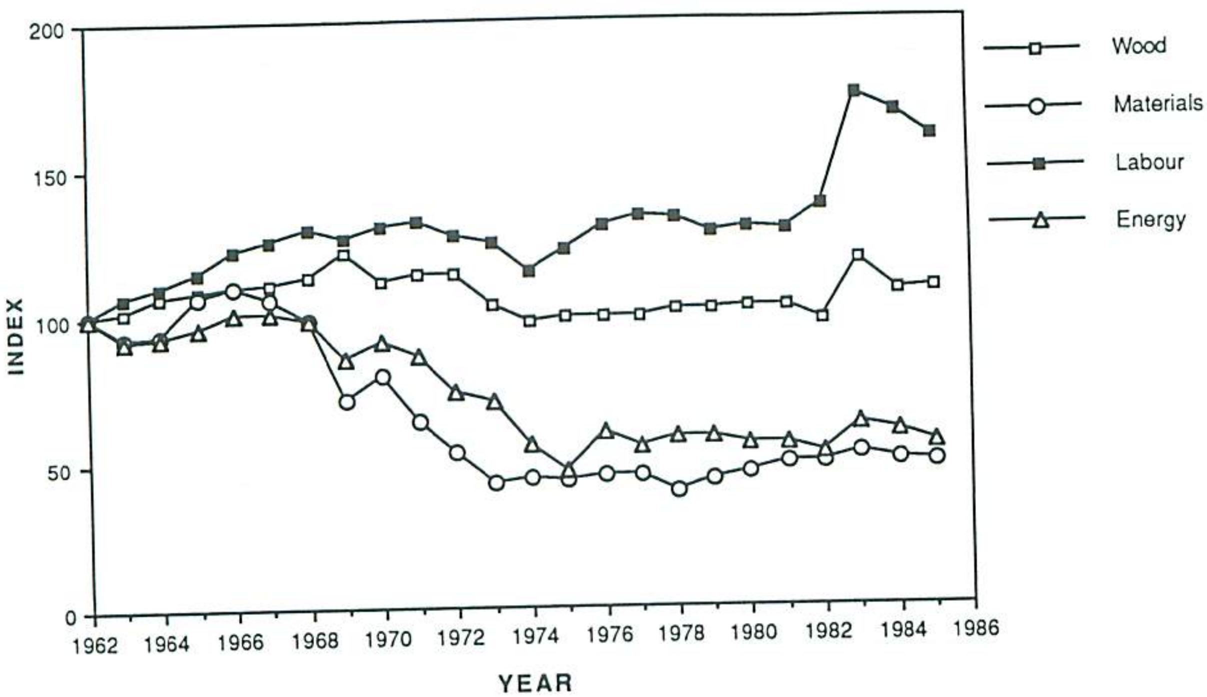

Figure 30. Single-factor productivity indices, B.C. Coast region (1962 = 100).

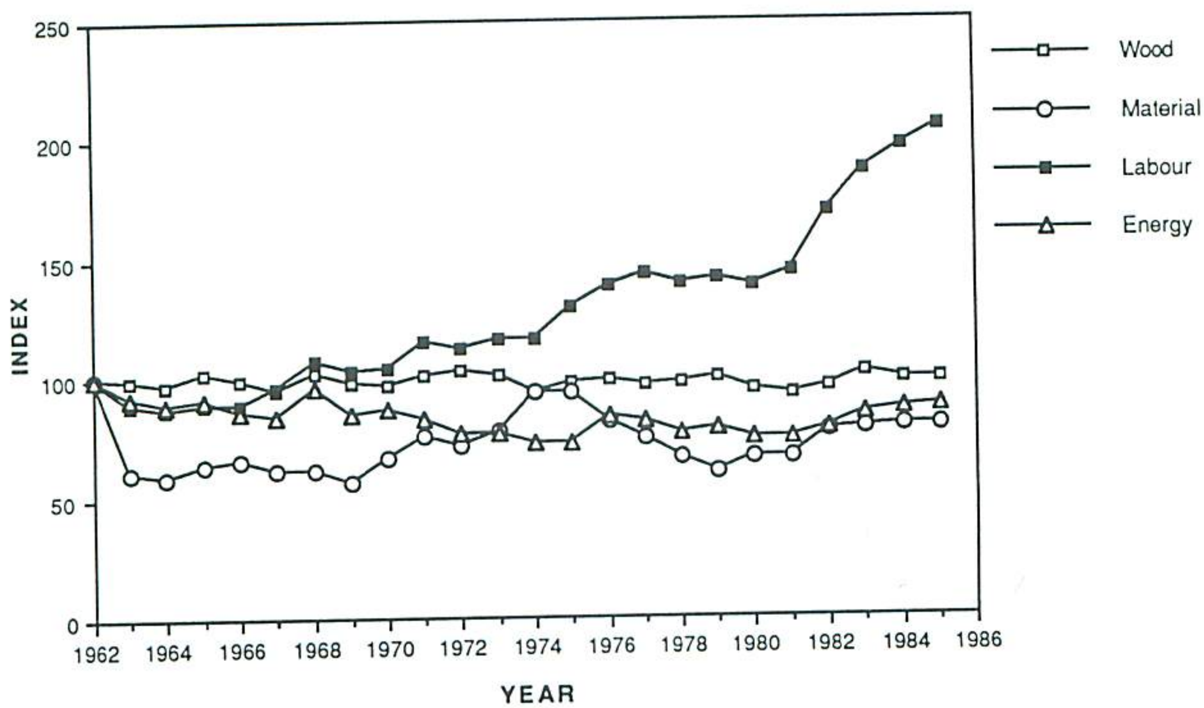

Figure 31. Single-factor productivity indices, B.C. Interior region (1962 = 100).

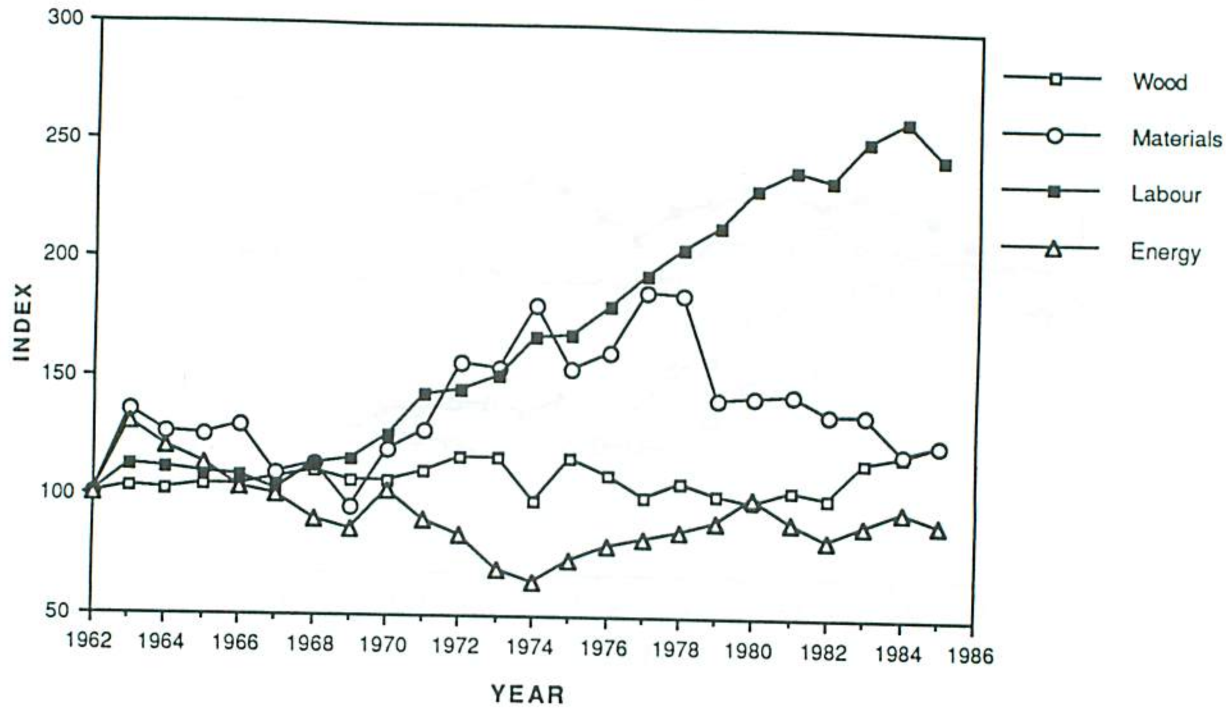

Figure 32. Single-factor productivity indices, Ontario (1962 = 100).

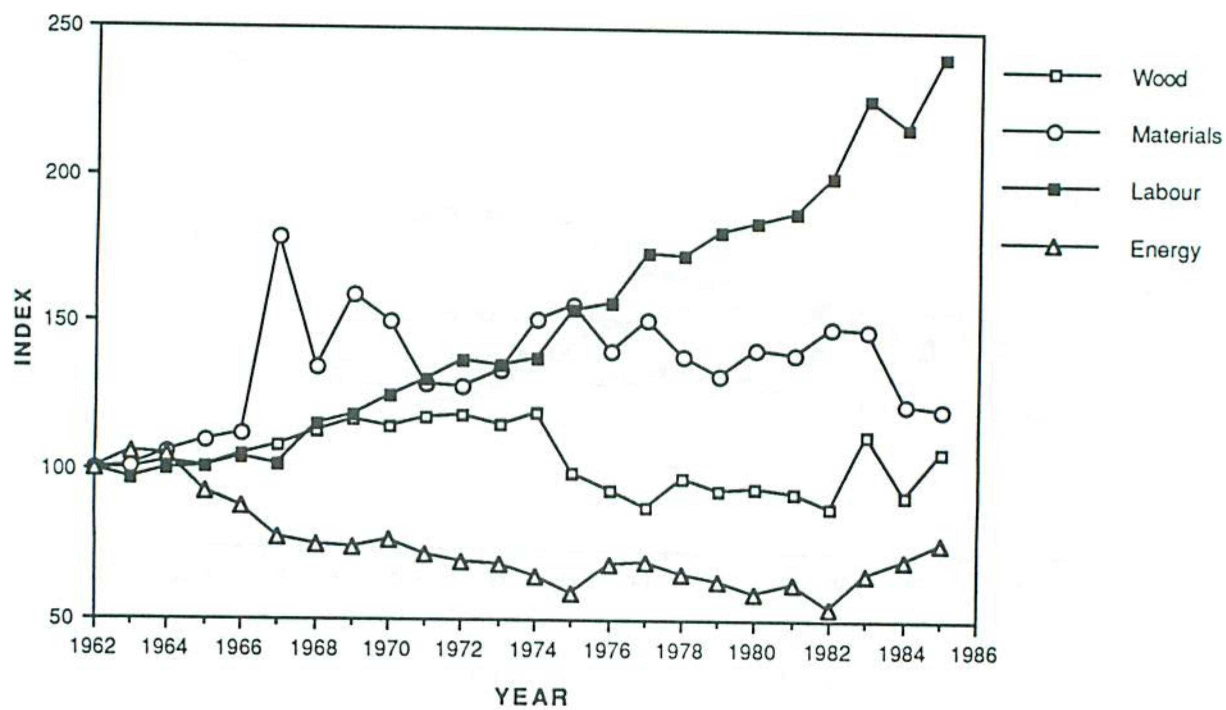

Figure 33. Single-factor productivity indices, Quebec (1962 = 100).

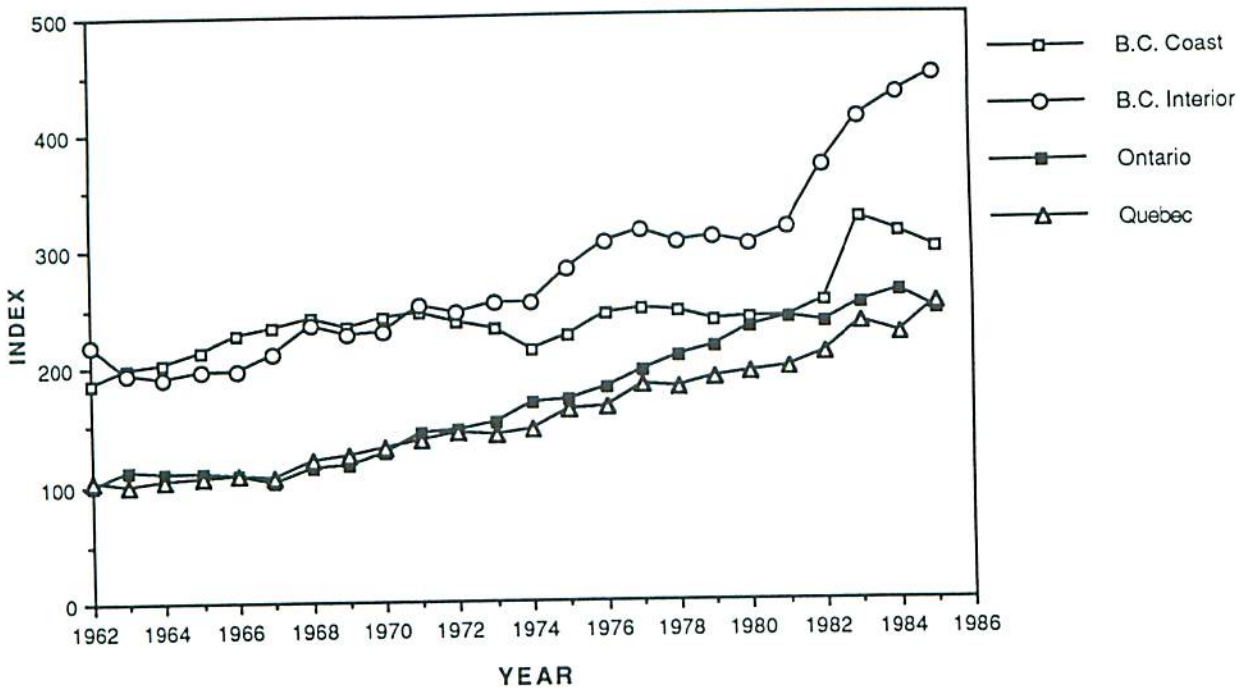

Figure 34. Productivity indices of labor, by region (Ontario 1962 = 100).

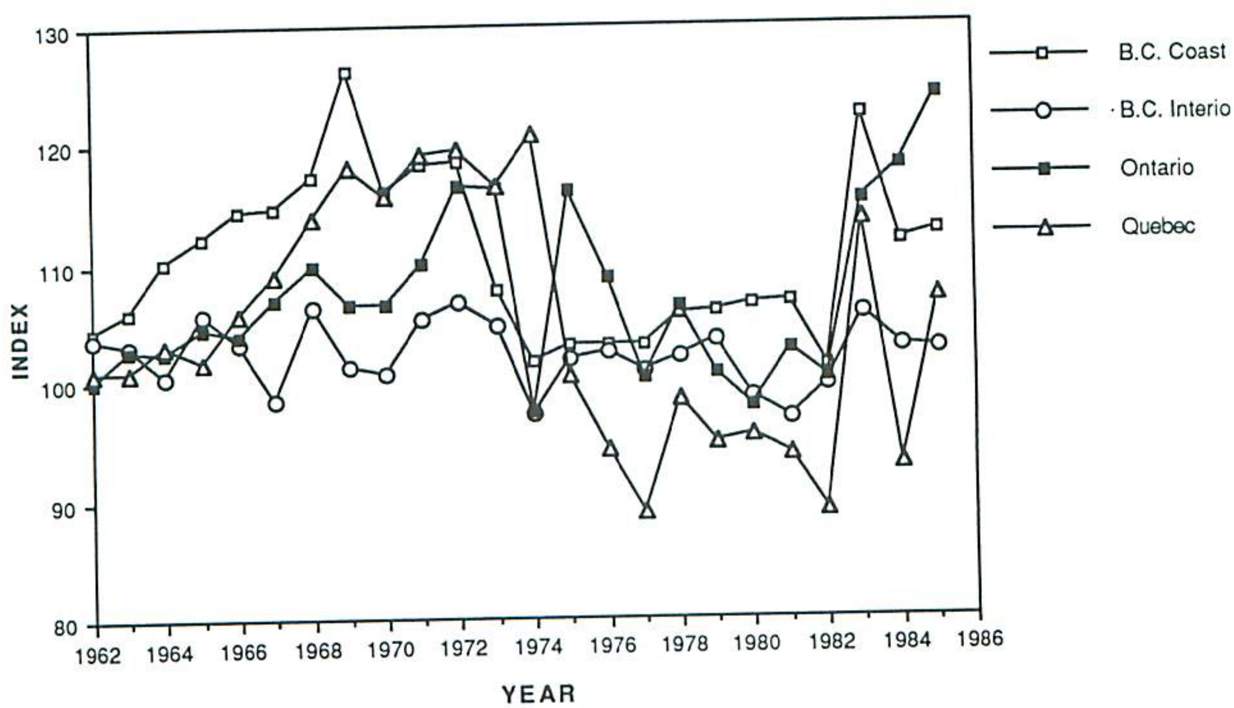

Figure 35. Productivity indices of wood, by region (Ontario 1962 = 100).

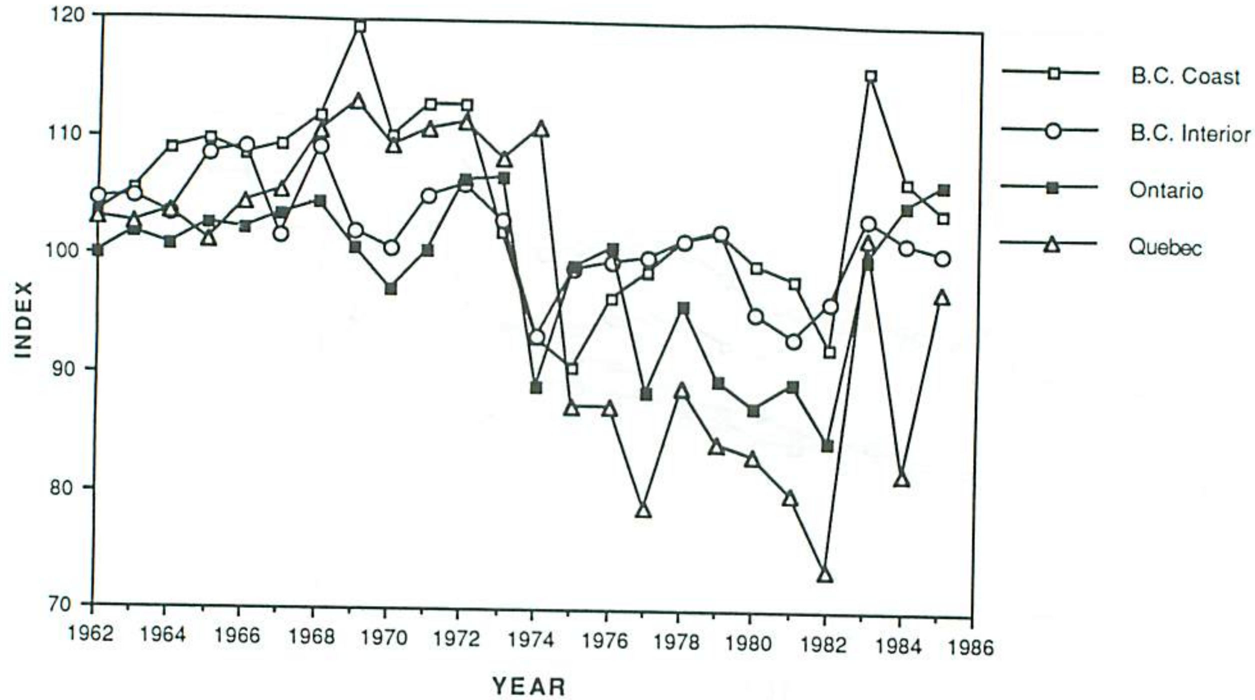

Figure 36. Production of lumber per m^3 of roundwood input, by region.

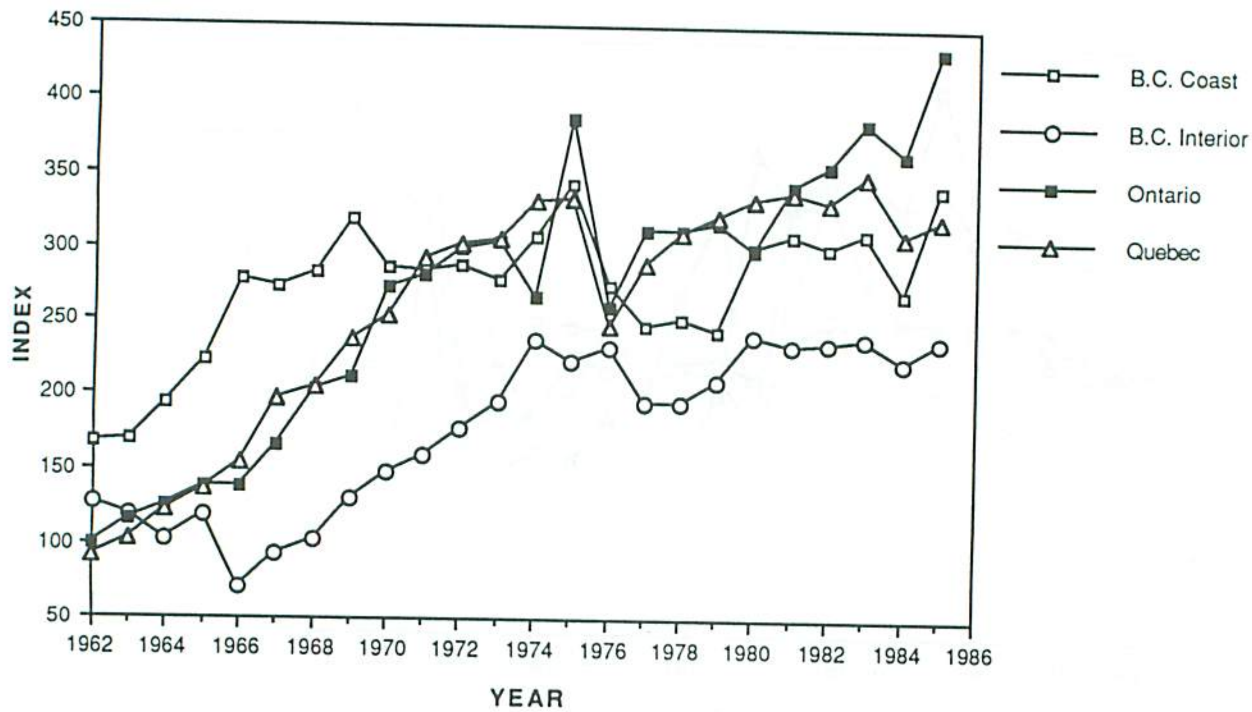

Figure 37. Shipments of oven-dried wood chips per m^3 of roundwood, by region (Ontario 1962 = 100).

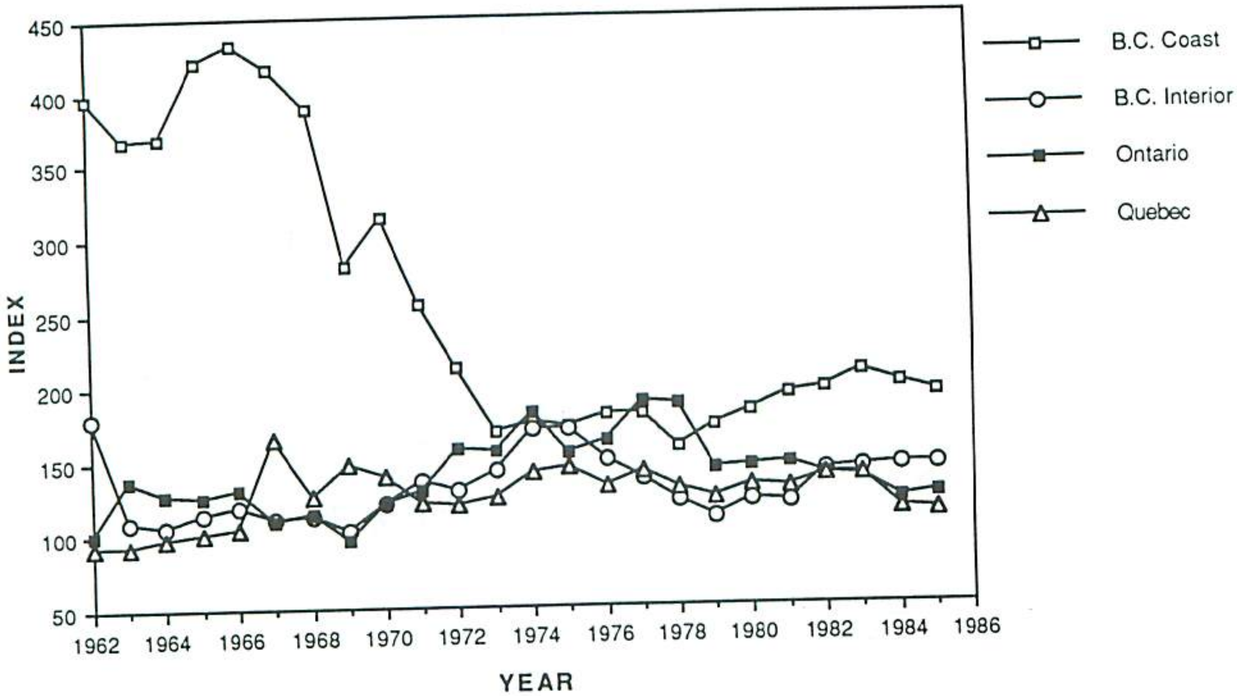

Figure 38. Productivity indices of other materials, by region (Ontario 1962 = 100).

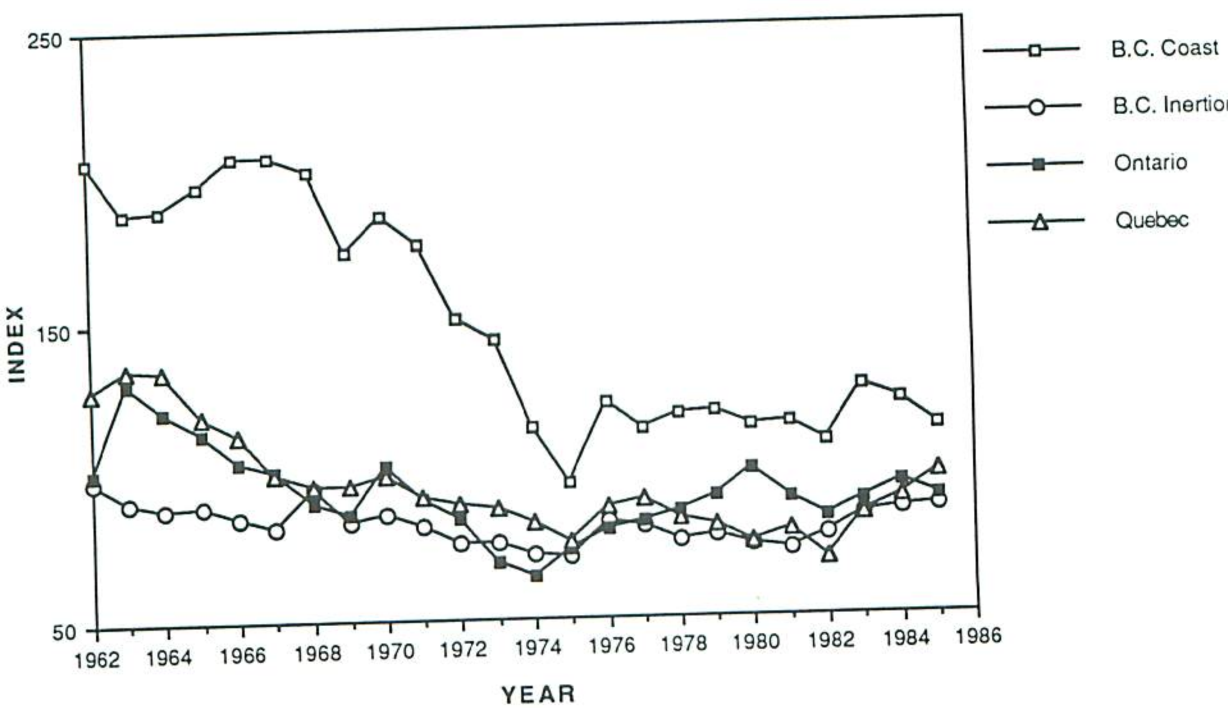

Figure 39. Productivity indices of energy, by region (Ontario 1962 = 100).

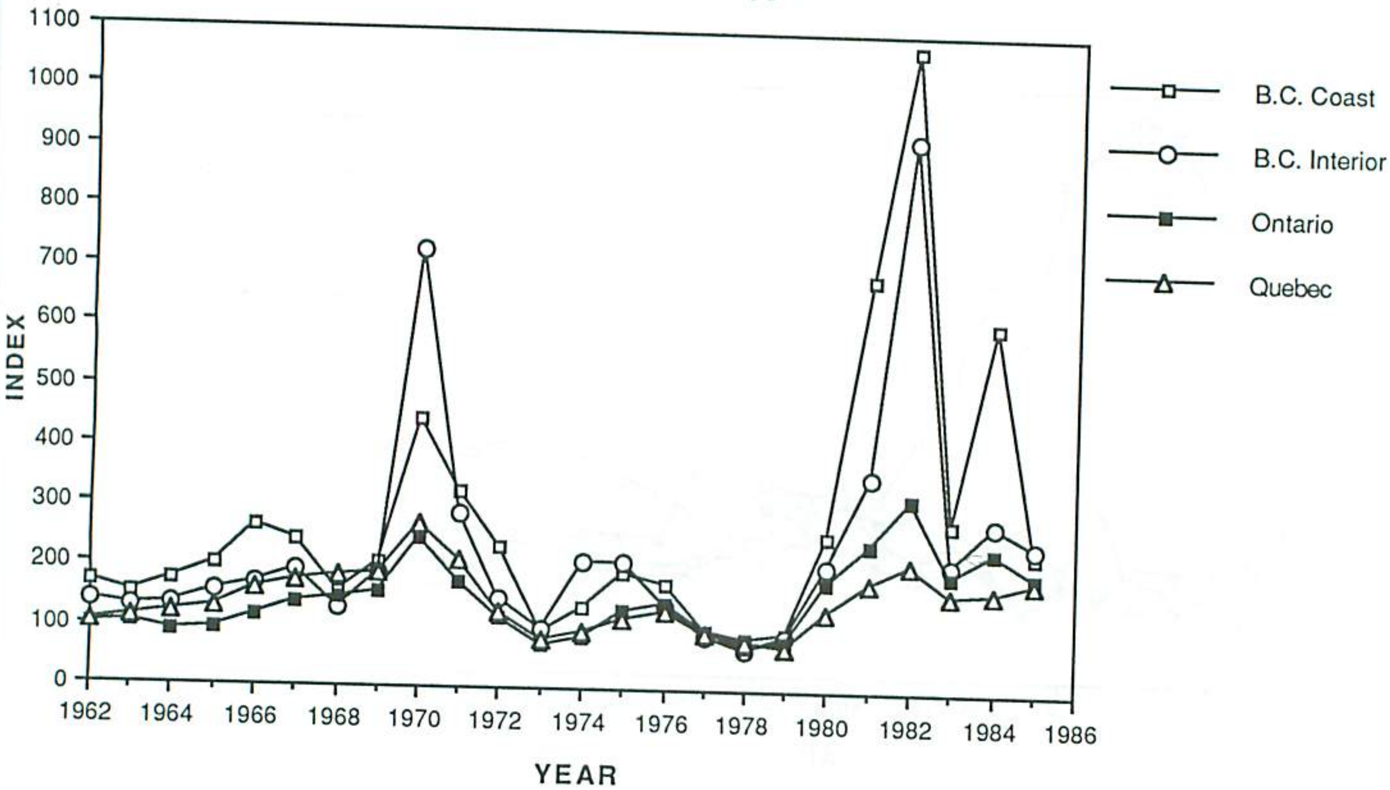

Figure 40. Productivity indices of capital, by region (Ontario 1962 = 100).

substituted other materials, energy and capital for it in order to reduce overall costs. As a result, the remaining labor has more of the other inputs to assist it.

In 1985, labor productivity in the B.C. Interior region was roughly 50% higher than that on the B.C. Coast region and 80% higher than in Ontario and Quebec (Fig. 34). These differences are likely, in part, to be a result of the fact that the B.C. Interior region possesses much greater economies of scale in production. The uniform log quality and a focus on the dimension lumber market also allow the B.C. Interior industry to use the various "factory-built" mills, which are highly automated and have a correspondingly low labor content.

The relatively high productivity of labor in the B.C. Interior region is rewarded by relatively high wage rates. However, the labor-productivity gap between the B.C. Interior and the eastern regions is still larger than the wage gap (80 vs 70%, respectively, in 1985). This result appears inconsistent with the thesis of Copithorne (1978), who argued that the B.C. government's approach to valuing stumpage gave the lumber industry an incentive to pay labor more than it was worth to the firm. The result was that labor was able to capture some of the economic rent that should have accrued to roundwood.

Table 4. Annual compound changes in single-factor productivities, by region, 1962-1985.

	Annual compound change in single-factor productivities (%)					
	1962-1969	1969-1973	1973-1977	1977-1981	1981-1985	1962-1985
LABOR:						
B.C. Coast	2.9	-0.3	1.4	-0.8	4.5	2.1
B.C. Interior	0.4	2.3	4.3	0.1	7.2	3.2
Ontario	1.8	5.5	5.1	4.3	0.5	4.0
Quebec	2.2	2.7	5.0	1.6	5.1	3.9
WOOD:						
B.C. Coast	2.4	-3.1	-0.8	0.7	1.1	0.3
B.C. Interior	-0.3	0.6	-0.7	-0.8	1.2	0.0
Ontario	0.8	1.8	-2.9	0.5	3.8	0.9
Quebec	2.0	-0.3	-5.2	1.1	2.7	0.3
OTHER MATERIALS:						
B.C. Coast	-4.2	-9.7	1.2	1.4	0.0	-3.1
B.C. Interior	-6.8	6.6	-0.9	-2.4	3.8	-1.0
Ontario	-0.6	10.1	3.9	-5.1	-3.1	0.9
Quebec	6.0	-3.4	2.5	-1.5	-2.8	0.8
ENERGY:						
B.C. Coast	-2.0	-3.7	-4.7	0.3	-0.2	-2.5
B.C. Interior	-2.0	-1.9	1.2	-1.9	3.4	-0.5
Ontario	-1.9	-4.0	3.4	1.7	0.0	-0.5
Quebec	-3.6	-1.7	0.4	-2.3	4.2	-1.1
CAPITAL:						
B.C. Coast	2.2	-14.8	1.3	47.3	-19.9	1.2
B.C. Interior	3.6	-12.3	-2.1	32.2	-7.4	2.4
Ontario	5.8	-15.0	6.9	19.9	-4.6	2.8
Quebec	8.0	-16.0	3.4	13.5	0.6	2.5

Labor in the B.C. Coast region is also paid a slight premium over that in the Interior region, despite the fact that it appears to be less productive. One possible reason for this is that our productivity measure only reflected the contribution to output volume and not quality. Indeed, the B.C. Coast industry has concentrated more on manufacturing specialty products than have the other regional industries. The resulting increases in productivity and mill returns cannot be reflected by a volumetric measure of output. If additional resources are required to carry out operations to add value, then average productivity may be understated. As a result, the lower rate of productivity growth in the B.C. Coast industry is not necessarily a cause for concern. Nonetheless, the issue merits further study.

The fact that the lumber industry has depended particularly heavily on increases in labor productivity underscores the need to ensure that the industry has continued access to a well educated workforce. Unfortunately, early signs are appearing that the lack of functional literacy may be a constraint on the adoption of new technologies. The Council of Forest Industries of B.C. and the International Woodworkers of America have begun a joint project that will study the effects of the literacy problems of workers on sawmill operations in both traditional and computerized mills.

Although the level of labor productivity is relatively higher in the B.C. Interior, the growth in labor productivity over the 1962-1985 period has been greater in Ontario and Quebec. The B.C. Coast industry appears to have experienced the lowest rate of labor productivity growth over the 24-year period (Table 4).

From 1981 to 1985, the growth rate in labor productivity accelerated throughout B.C. and Quebec, but dropped sharply in Ontario. At first glance, this recent drop in Ontario appears to be a result of the province's slower adoption of labor-saving technology. However, Ontario experienced strong growth in labor productivity throughout the 1970s.

Wood: Because wood accounts for the largest share of total costs, growth in wood productivity is particularly important for the industry. Contrary to the case of labor productivity, wood productivity in 1985 is highest in Ontario. In 1985, Ontario's wood productivity was 10% higher than that of the B.C. Coast, 15% higher than that in Quebec, and 20% higher than that in the B.C. Interior. In order to understand this, it is useful to think of increases in wood productivity as coming from two sources. First, the increases result from the introduction of new technologies, such as thin-kerf saws and microcomputer-run scanners, which improve lumber recovery. Second, they result from the increased marketing of chips, which have not traditionally been fully utilized. One can separate the relative importance of these two sources by examining how the quantity of lumber and chips per unit of roundwood has changed over time. Figures 36 and 37 illustrate the trends in m^3 of lumber produced and tonnes of chips produced per m^3 of roundwood, respectively. It is apparent from these figures that the growth in wood productivity has been more a result of increased marketing of chips than of improvements in lumber recovery. From 1962 to 1985, the average annual percentage changes in the lumber/roundwood measure for the B.C. Coast, B.C. Interior, Ontario and Quebec industries were 0.0, -0.2, 0.5 and -0.2%, respectively. In contrast, the average annual percentage changes in the chips/roundwood measure were 3.1, 2.7, 6.6 and 5.5%, respectively. The growth in the lumber/roundwood measure has accelerated in all regions, particularly in Quebec and Ontario, over the 1981-1985 period. The long-term decrease in the lumber/roundwood measure for the B.C. Interior region and Quebec is likely a result of the decreasing size of logs over time. However, the regional pattern in wood-productivity growth can only partly be explained by differences in the nature of the wood resource and introduction of new technologies. Log sizes in the B.C. Interior, Ontario and Quebec industries are all small when compared with those in the B.C. Coast region, and their mills are characterized by high-speed automated processing of timber into relatively homogeneous products. An additional explanation may be the fact that the pulp and paper industry (which consumes the chips) is playing a relatively more important role over time in Ontario and Quebec. This is supported by the significantly higher chip prices and increasing chip/lumber output ratios observed in these provinces. In 1985, the average prices of an oven-dried metric tonne of chips in the B.C. Coast, B.C. Interior, Ontario and Quebec regions were $45, $40, $80 and $85, respectively.

Another explanation may simply be that, over the period considered, the price of roundwood did not signal lumber producers to emphasize wood productivity. In other words, the relative price of roundwood decreased in every region except the B.C. Coast.

Other Materials: The productivity of other materials tended to decrease moving from west to east. Although the B.C. Coast region continued to have the greatest productivity in the use of other materials, its advantage vis-a-vis the other regions has fallen dramatically since the early 1960s (Fig. 38). Over the 1962-1985 period, other materials productivity increased by roughly 1% per year in Ontario and Quebec, but decreased by an average of 3.1% per year in the B.C. Coast and 1% per year in the B.C. Interior regions. Of particular interest is the fact that the productivity of other materials and energy decreased in a parallel fashion from the mid-1960s to the early 1970s. The reason for the precipitous drop in other materials productivity over this period is not clear, and merits further study.

Energy: In the section on historical trends in the data, it was pointed out that nominal energy prices were stable and real energy prices declined (particularly in relation to wage rates) from the early 1960s to the early 1970s. This signalled the industry to substitute energy for the other inputs. As a result, all of the regional industries increased their use of energy per unit of output, which resulted in decreased energy productivity (Fig. 39). The energy crises of the mid-1970s, however, forced the industries in all regions to halt this general trend. Since 1981, the B.C. Interior and Quebec industries have registered the greatest improvements in energy productivity.

Because the share of energy in total costs is quite small, its relatively low productivity is not unduly alarming at the moment. However, it may warrant considerable attention in the longer term if the industry again faces sharp increases in relative energy prices, as happened in the 1970s. This is becoming increasingly likely because of potential "carbon taxes" imposed in response to global warming, as well as political uncertainty in the Middle East.

Capital: As indicated above, capital productivity must be treated with caution. Because the methods used to calculate the cost and the quantity of capital are not very reliable, our estimates of the productivity of capital may be biased downward when firms are earning high profits, and biased upwards when they are earning low profits. These biases are obvious, particularly for the B.C. Coast and Interior industries, in Figure 40. Because of this, the year-to-year changes in capital productivity must be viewed with suspicion, although the overall 24-year trend may be indicative of the overall performance of this important input. Given the above caveat, one may conclude that, after labor, capital has experienced the fastest growth in productivity over the 1962-1985 period.

Growth of capital productivity is lower in the B.C. Coast industry than in the other major regions. The reason for this likely lies in the nature of the wood resource and the types of products milled. In the B.C. Coast industry, greater use is made of custom-built mills in order to take advantage of higher quality logs. These mills use a wide range of breakdown equipment (headrigs), which can include a variety of band-saw and carriage combinations, circular saws (gang or other combination), chipping canters, or some combination of the above. Other pieces of processing equipment such as edgers and re-saws with a wide range of features are also used. The comparative advantage of these different types of machinery and equipment is in increasing value rather than volume. As a result, our volume-based measures of productivity do not accurately reflect the contribution of capital in the B.C. Coast industry.

Variable- and Total-factor Productivities

Variable-factor productivity (VFP) is a weighted average of single-factor productivities (SFPs) for the four variables studied (the short-run inputs labor, wood, other materials and energy) and total-factor productivity (TFP) is a weighted average of the SFPs of all five inputs studied (capital plus the four variable inputs); VFP is more an indication of factor utilization than of technological efficiency. Figure 41 presents a regional comparison of VFP levels over the study period, and Figure 42 shows the trends in the growth of VFP in each region. Similarly, Figures 43 and 44 present a regional comparison and growth trends in TFP, respectively. Table 5 provides a summary of the average annual compound growth rates.

During the 1960s, the B.C. Coast industry's VFP was significantly higher than those in all other regions (Fig. 41). In the early 1970s, however, it declined sharply. Since then, the B.C. Coast and Interior regions have shared leadership in VFP. The Quebec industry has registered the lowest level of VFP since the mid-1970s, although, on a long-term average (1962-1985), its rate of improvement has been greater than that in the two B.C. regions (Table 5). In 1985, the VFP levels in the B.C. Coast and Interior regions were essentially equal, and were greater than those in Ontario and Quebec by roughly 10 and 20%, respectively.

Although the B.C. Coast and Interior industries have consistently been the most productive in their use of variable inputs, the Ontario and Quebec industries have narrowed the gap in VFP over the period examined (Table 5). From 1962 to 1985, the average annual growth rates of VFP in Ontario and Quebec have been more than twice those in the B.C. Coast and Interior regions. Some of the largest gains in VFP occurred during the 1982-1985 period, and were largest in the B.C. Interior and Quebec industries. This result is consistent with the observation that it has been primarily these two regions that have accounted for the recent increase in Canada's share of the American lumber market. In comparison with other periods, 1981-1985 was one of high productivity growth in all regions.

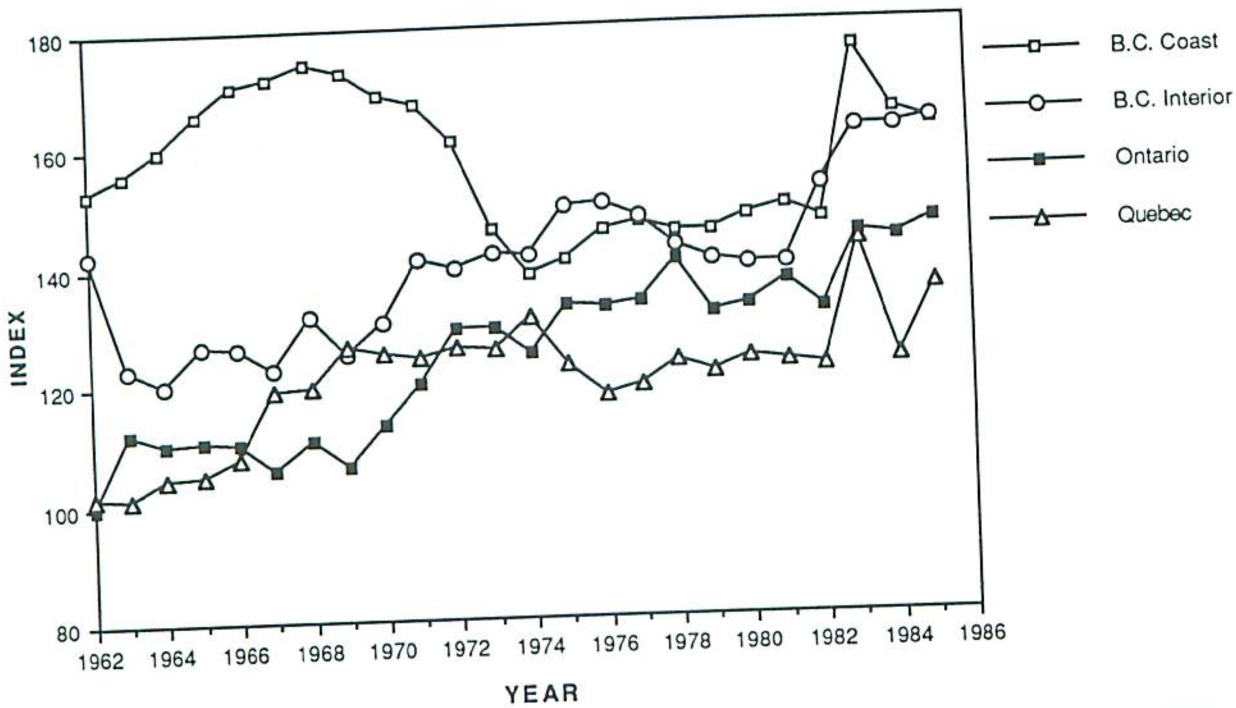

Figure 41. Variable-factor productivity (VFP) indices, by region (Ontario 1962 = 100).

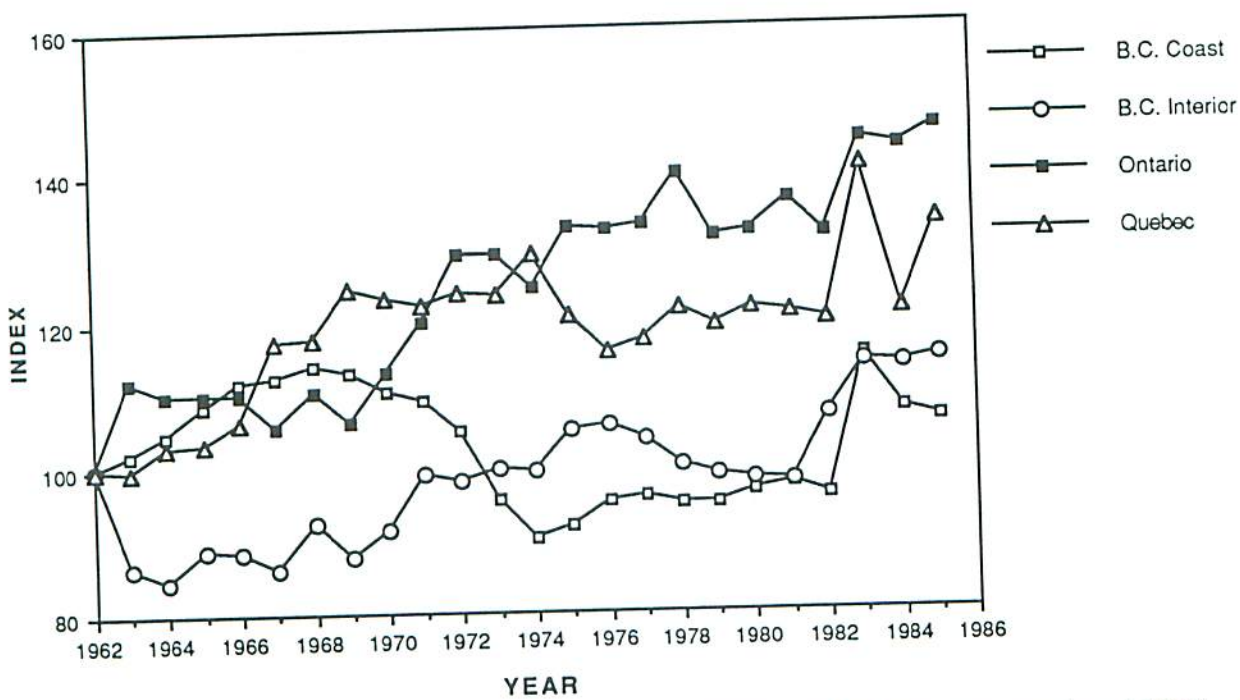

Figure 42. Variable-factor productivity (VFP) indices, by region (1962 = 100).

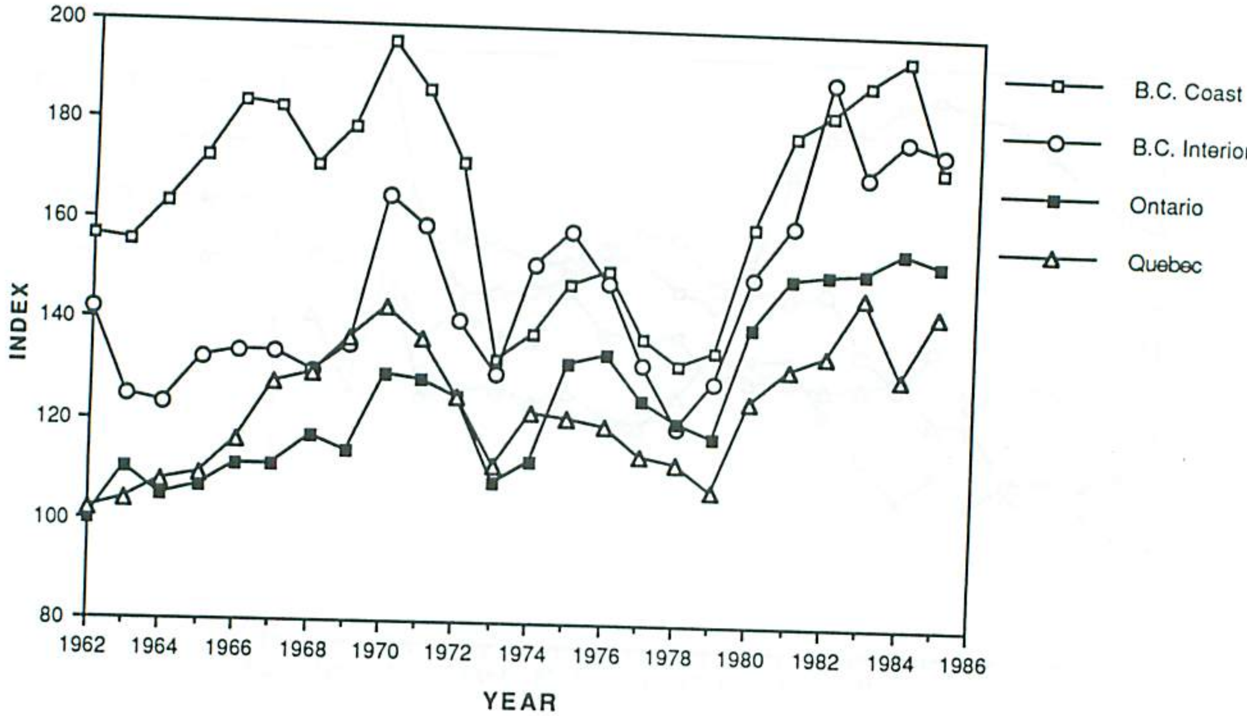

Figure 43. Total-factor productivity (TFP) indices, by region (Ontario 1962 = 100).

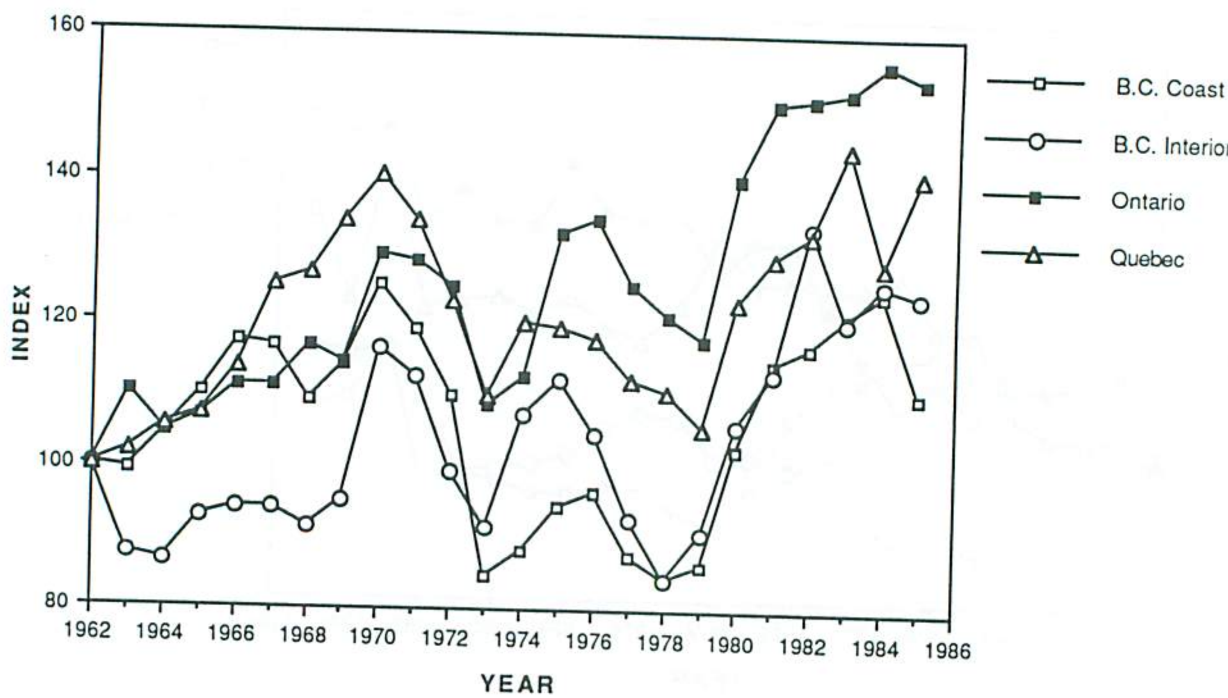

Figure 44. Total-factor productivity (TFP) indices, by region (1962 = 100).

Table 5. Annual compound changes in variable- and total-factor productivities, by region, 1962-1985.

Region	1962-1969	1969-1973	1973-1977	1977-1981	1981-1985	1962-1985
	Annual compound change in variable- and total-factor productivities (%)					
	Variable-factor productivity					
B.C. Coast	1.5	-3.3	0.0	0.3	1.8	0.3
B.C. Interior	-1.6	2.6	0.7	-1.1	3.2	0.6
Ontario	0.7	4.0	0.6	0.5	1.4	1.7
Quebec	2.8	-0.1	-1.1	0.6	2.0	1.2
	Total-factor productivity					
B.C. Coast	1.7	-5.8	0.7	5.4	-0.7	0.4
B.C. Interior	-0.6	-0.8	0.3	4.0	1.8	0.9
Ontario	1.7	-1.0	2.9	3.7	0.4	1.8
Quebec	3.7	-4.0	0.4	2.9	1.7	1.5

Over all, the relative levels of TFP are not different from those of VFP. In 1985, TFP levels in the B.C. Coast and Interior regions were essentially equal, and were roughly 10% greater than those in Ontario and 20% greater than those in Quebec (Fig. 43). The TFP measures are more cyclical than the VFP measures because TFP incorporates a measure of capital.

Because there was significant growth in the productivity of capital in all regions during the 1962-1985 period, the average annual growth of TFP was consistently higher than that of VFP. On average, annual TFP grew by 0.4% on the B.C. Coast, 0.9% in the B.C. Interior, 1.8% in Ontario and 1.5% in Quebec. This implies that the total productivity of the Ontario and Quebec industries has been improving vis-a-vis that of the B.C. Coast and Interior industries during the 1962-1985 period. This has accentuated the advantage that Ontario and Quebec producers have in serving the central Canadian market because of relatively lower freight costs.

IDENTIFYING SOURCES OF PRODUCTIVITY CHANGE

The previous section reported measures of productivity for the four regional industries. In this section, we will attempt to identify the major sources of variation in productivity, with a primary focus on variable-factor productivity.

From the previous section, it appears that differences in the regional productivity measures (particularly those for labor) may be related to differences in output levels. If this is the case, then it suggests that one possible source of productivity growth is exploitation of economies of utilization. If such economies exist, then the poor productivity performance of the B.C. Coast industry in relation to that of the other regions may be a result of rapid output growth in the other regional industries. In other words, the B.C. Coast industry may have been unable to enjoy the same benefits from continuing exploitation of economies of scale.

It is instructive to examine contemporaneous correlations between the SFP measures and output, by region. Table 6 indicates that, among individual inputs, only labor productivity appears to be highly correlated with output. That this correlation is strong in every region except the B.C. Coast may simply reveal the Coast industry's greater focus on value as opposed to volume. As indicated earlier, the B.C. Coast industry concentrates more on manufacturing specialty products than do the other regional industries. These processes bring about increases in productivity and mill returns that cannot be reflected by a volumetric measure of output.

It is interesting to note that the correlation between output and energy productivity is negative in all regions. This is consistent with the notion that the industry increases its relative use of energy when product markets are strong.

The correlations between output and variable-factor productivity are highest for Ontario and the B.C. Interior. The correlation for Quebec is somewhat lower because the highly positive labor correlation is offset by the negative energy and wood correlations. These results suggest that

Table 6. Correlations (ρ) between output and single-factor productivity measures, by region, 1962-1985.

	Correlation (ρ) between output and SFP				
Region	Labor	Wood	Other materials	Energy	Capital
B.C. Coast	0.37	0.21	-0.36	-0.18	-0.32
B.C. Interior	0.93	-0.07	0.21	-0.42	0.06
Ontario	0.96	0.23	0.29	-0.31	0.39
Quebec	0.97	-0.37	0.22	-0.66	-0.07
	VFP	TFP			
B.C. Coast	0.05	-0.22			
B.C. Interior	0.83	0.49			
Ontario	0.88	0.79			
Quebec	0.67	0.38			

economies of plant utilization or economies of scale may be greatest in Ontario and the B.C. Interior.

To examine further the relationship between output and productivity, a series of regressions was run on VFP and TFP. However, the TFP regressions are not presented because the highly cyclical nature of the capital series led to nonsensical results. It should be noted that these regressions are *ad hoc* in nature, and are only meant to be exploratory. It is still necessary to model the production/cost structure of the industry formally in order to identify the sources of productivity growth definitively.

Table 7 provides the results of regressions in which data from the four separate regions are pooled. A pooled data set is used for two reasons. First, the number of observations is smaller (i.e., one-quarter the size of the pooled data set) when we estimate regional regressions. Second, the regional regressions rely only on variation in the variables within the region over time. By pooling the data (and not using regional dummy variables) we can also draw conclusions on variations in the variables among regions. For comparative purposes, various results of separate regressions (by regional industry) are presented in Appendix B (Tables B1 to B4).

The first three regressions in Table 7 include dummy variables to account for regional differences. Regression (1) indicates that the average VFP growth across the four regional industries was 1.2% per year, whereas regression (2) indicates that there is a statistically significant relationship between output and VFP. The R^2 value for regression (1) indicates that the trend variable "explains" roughly 87% of the variation in VFP. The regional results in Appendix B indicate that the explanatory variables explain considerably less of the VFP variation in the B.C. Coast and Quebec industries than they do in the B.C. Interior and Ontario industries. The time trend in regression (2) is smaller and statistically insignificant (at the 90% confidence level). This is because most of the growth in VFP appears to be explained by growth in output. The correlation coefficient between the trend and output variables is 0.46. As a result, there is no problem with multicollinearity (i.e., the explanatory variables have more independent than joint effects on TFP). A 10% growth in output is associated with a 1.7% growth in VFP. This suggests some form of economies of scale.

Regressions (1) and (2) hide the effect of economies of scale at the firm level. For example, such economies can be exploited by consolidation of establishments within the industry, even if total industry output is constant. To test for this, regression (3) gives results that include the number of establishments as an additional explanatory variable. If firm-level economies are available, then productivity should go up when the number of establishments goes down, for a given level of total industry output. In other words, the hypothesis is that the coefficient of the variable (number of establishments) would have a negative sign (i.e., a negative

Table 7. Log-linear Cochrane-Orcutt regressions of variable-factor productivity on pooled data for four regions (t-statistics in parentheses).

Parameter	Regression 1	2	3	4
Constant	4.67 (81.91)	3.85 (18.82)	3.93 (17.90)	4.08 (34.99)
Time trend	0.012 (5.85)	0.002 (0.83)	-0.0003 (- .08)	-0.001 (.55)
Output	-	0.17 (4.08)	0.17 (4.04)	0.15 (6.90)
Number of establishments	-	-	-0.0002 (-1.03)	-0.0003 (-3.40)
DUMBCC[a]	0.077 (0.85)	-0.002 (-0.04)	-0.022 (-0.33)	-
DUMBCI[a]	0.20 (3.68)	-0.08 (-1.07)	-0.061 (-0.77)	-
DUMQUE[a]	-0.072 (-1.31)	-0.15 (-3.43)	-0.10 (-1.63)	-
R^2	0.87	0.89	0.89	0.89
Durbin-Watson statistic	2.36	2.10	2.09	2.11

[a] DUM indicates a dummy variable, and BCC, BCI and QUE stand for B.C. Coast, B.C. Interior, and Quebec, respectively. The Ontario industry is the control/base region to which the value of zero was assigned.

relationship with productivity). If there are economies at the firm level, then this should be reflected in faster productivity growth for the B.C. Interior, Ontario and Quebec industries than for the B.C. Coast industry. We have already observed that the productivity record is consistent with this notion. This is generally supported by the results reported in Table B4 (Appendix B).

Regression (3) incorporated the number of establishments. The results indicate that productivity declines when the number of establishments increases. This is the expected result, although the coefficient's magnitude is small and not statistically significant. The addition of this variable does not alter the impact of the output variable, but it does reduce the impact of the trend variable.

Because each regional dummy variable was statistically insignificant in regression (3), they were dropped from regression (4). This regression produced a statistically significant negative coefficient for the number of establishments. The omission of the regional dummy variables also resulted in a decrease in the coefficient of the output variable and an increase in the coefficient of the trend variable.

In summary, these regressions suggest that output growth plays a role in the determination of industry productivity levels. The regressions with the number of establishments as an explanatory variable suggest that mergers leading to larger output levels for remaining firms also improve productivity. This is consistent with the low productivity growth of the B.C. Coast industry in relation to those of the other regional industries. The B.C. Coast region had a slight increase in the number of establishments, and only a slight increase in output. In contrast, the other three regions had strong output growth along with dramatic reductions in the number of establishments (Fig. 27).

Other factors that may help to explain some of the regional differences in productivity growth include tree species mix, wood density and average log size.

COMPARISON WITH RECENT STUDIES

Before concluding this report, it is useful to compare our results with those of other recent studies on the Canadian lumber industry, at both regional and national levels. A caveat, however, is in order at the outset. Comparing results from different studies can be misleading and, in most cases, confusing. Empirical results should not be compared literally (i.e., from the face values of either parametric coefficients or changes in index measures). Differences in data structures, model specifications, sample sizes (lengths of time, if a time series), regional variations in socio-economic environments, accessibility and structure of market(s), and supplies of raw material must all be taken into account. The results summarized in Table 8 are more useful for general information than for direct comparative purposes. Only the present study examines the productivity of individual inputs in addition to the multifactor productivity levels and growth rates.

The study that is most comparable with the present study is that of Constantino and Haley (1989). Their study, like ours, used nonparametric techniques. They reported an annual improvement in TFP of 0.4% for B.C. Coast sawmills over the period 1957-1982. This is exactly equal to the annual rate of TFP growth found for the region in our study.

The other nonparametric study is that of the United Nations Economic Commission for Europe (Anon. 1988). That study reported 0.4% per year growth in TFP for the whole Canadian sawmill industry from 1974-1983. This compares with our results for the same period of 3.5% per year for the B.C. Coast, 1.3% for the B.C. Interior, 3.4% for Ontario and 2.1% for Quebec. Given the very strong growth we have observed in labor, capital and materials productivity, we feel that the United Nations study results for this time period are implausible.

The other studies in Table 8 dealt with parametric determination of technological change. Our measure of TFP (or VFP) is equal to that of technological change only if the industry does not experience economies of scale or utilization. The regressions in the previous section suggest such economies exist. The time trend in those regressions represents productivity growth after the effect of output is controlled (i.e., output is held constant). This is conceptually comparable to the results of the parametric studies. The time-trend coefficient in regression (2) in Table 7 implies a 0.2% per year growth in productivity, and we use this figure to compare with other studies when a national growth rate is needed. The time-trend coefficients from Table B2 (Appendix B) might be used for regional-level comparisons, although there is the problem of too few degrees of freedom in these regressions.

Bernstein (1988) reported productivity growth of 0.3% per year for the national industry from 1963-1982. Over the same period, our results indicated an average annual productivity growth of 0.2%.

Constantino and Uhler (1987) considered the B.C. Coast, B.C. Interior and Ontario industries, and segmented their study into three time periods. Their productivity growth rates are generally positive, and echo our finding that productivity growth in the B.C. Coast industry is lower than those in the other regional industries. The declining productivity (0.4% per year) they found for the B.C. Interior region during the 1962-1969 period is consistent with our finding of a 0.6% per year decline for the same period.

The remaining parametric studies find declining productivity, in contrast to our findings of small, but generally positive growth rates. Meil and Nautiyal (1988) examined the same four regional lumber industries considered in this study, and categorized the regional industries into four classes of mills on the basis of the number of person-years (PYs) employed: Class I = 1-49 PYs, Class II = 50-99 PYs, Class III = 100-200 PYs, and Class IV = more than 200 PYs. The results included in Table 8 are for the Class III mills. Over the 1968-1984 period, this category showed an annual decline of 0.4% per year in VFP for the B.C. Interior region, and a 1.0% per year decline in the other three regions. Martinello (1985) also reported total productivity growth rates of -0.9 and -0.1% per year for the B.C. Coast and Interior regions, respectively, over the 1963-1979 period.

Table 8: Comparison of productivity changes reported in various recent studies (all results rounded to one decimal place).

Study and region	Period covered	Methodology[a]	Rate of productivity change (% per year)
Constantino and Uhler (1987), regional lumber industries:	1962-1984	TL-total	
1976-1984 B.C. Coast			0.6
B.C. Interior			1.1
Ontario			2.3
1970-1975 B.C. Coast			1.3
B.C. Interior			3.6
Ontario			2.9
1962-1969 B.C. Coast			0.3
B.C. Interior			-0.4
Ontario			0.2
Constantino and Haley (1989), sawmills on B.C. Coast	1957-1982	Index number	0.4
Meil and Nautiyal (1988), softwood lumber industries	1968-1984	TL-variable	
B.C. Coast			-1.0
B.C. Interior			-0.4
Ontario			-1.0
Quebec			-1.0
Meil et al. (1988), B.C. Interior softwood lumber industry	1948-1983	TL-variable	-0.6
Martinello (1987), B.C. Coast lumber industry	1963-1982	TL-total	-1.1
Martinello (1985), lumber industries	1963-1979	TL-total	
B.C. Coast			-0.9
B.C. Interior			-0.1
Bernstein (1988), sawmill and shingle mill (national)	1963-1982	TL profit function	0.3

(cont'd)

Table 8: Comparison of productivity changes reported in various recent studies (all results rounded to one decimal place) (concl.).

Study and region	Period covered	Methodology[a]	Rate of productivity change (% per year)
Anon. (1988), Canadian sawmilling	1974-1983	Index-number procedure	0.4
Present study	1962-1985	Index-number procedure	
B.C. Coast		VFP	0.3
		TFP	0.4
B.C. Interior		VFP	0.6
		TFP	0.9
Ontario		VFP	1.7
		TFP	1.8
Quebec		VFP	1.2
		TFP	1.5

[a] TL-total indicates that a trans-log total-cost function was estimated; accordingly, the reported results are TFP growth rates. TL-variable indicates that a trans-log variable-cost function was estimated; hence, the reported results are VFP growth rates.

The reason for the declining productivity reported by Meil and Nautiyal (1988) and Martinello (1985) likely lies in their treatment of wood chips. Both studies treated chips as a "negative wood input" instead of as an output. This is important because, as indicated earlier for all four regions, the growth in the amount of chips used per unit of roundwood has been significantly higher than the growth in lumber per unit of roundwood. The latter measure has actually been negative for the B.C. Coast and Interior regions from 1972 to 1985.

The present study indicates that although the B.C. Coast and Interior industries continue to be the most productive, the Ontario and Quebec industries have narrowed the productivity gap over the period examined. From 1962 to 1985, the B.C. Coast, B.C. Interior, Ontario and Quebec industries have registered average annual growth in total-factor productivity of 0.4, 0.9, 1.8 and 1.5%, respectively (Table 8). This growth is a result of the combined effects of technological change and economies of scale.

The ranking of the various regions revealed by this study is generally consistent with that suggested by Constantino and Uhler (1987). Since 1981, however, the B.C. Interior and Quebec industries have registered higher productivity growth rates than have the B.C. Coast and Ontario industries.

SUMMARY AND CONCLUSIONS

The present study measured productivity levels and growth rates of the four regional lumber industries over the 1962-1985 period. Single-factor productivities were measured, along with variable-factor and multi-factor productivities. The following primary results were observed:

- The highest rates of productivity growth were observed for labor and capital in all four regions. This is not surprising, as labor and capital prices rose faster than the prices of the other inputs. The rise in labor productivity was likely made possible by substituting other materials, energy and/or capital for labor. The fact that the lumber industry has depended particularly heavily on increases in labor productivity underscores the need to ensure the industry has continued access to a well educated workforce.

- Energy and other materials appear to have been substituted for other factors to the point at which their productivities have actually declined in all regions during various time periods. This suggests that energy and other materials were being "over-used" during these years (e.g., the 1960s).

- Growth in the productivity of wood has been moderate in all regions, and has been more a result of better utilization/marketing of chips than of higher recovery factors for lumber. This may reflect the fact that, among all the input prices considered, the price of roundwood experienced the lowest average rate of increase. The only exception to this was on the B.C. Coast.

- The B.C. Coast and Interior lumber industries are more productive than those in Ontario and Quebec. In terms of total productivity in 1985, the two B.C. regions were essentially equal, and were more productive than Ontario and Quebec by roughly 10 and 20%, respectively.

- Although the B.C. Coast and Interior lumber industries were the most productive over the reviewed period, the Ontario and Quebec industries were able to narrow the productivity gap. From 1962 to 1985, their average annual growth rates in total productivity were more than twice those in the B.C. Coast and Interior. For Ontario, most of this superior growth occurred in the 1960s and 1970s.

- Although the results are sensitive to the years chosen, from 1981 to 1985 the B.C. Interior and Quebec industries registered significantly greater productivity gains than the other regions. This is consistent with the observation that these two regions have primarily accounted for the recent increase in Canada's share of the American lumber market. In the B.C. Interior, this recent superior performance was a result of relatively low wood prices and high productivities of labor, other materials, energy and capital. In Quebec, relatively low labor prices and high productivities of labor, wood, and energy were responsible. We believe that a depreciating Canadian dollar also greatly improved the competitiveness of all Canadian producers in the American market over this period.

- In Ontario, Quebec, and the B.C. Interior from 1962-1985, the average annual percentage increase in the prices of every input exceeded the increases in lumber prices. This indicates that these regional industries would have been subject to a severe cash-flow squeeze in the absence of significant productivity gains and rising real chip prices. It also suggests the necessary conditions for profitability in the commodity lumber trade.

Regression analyses suggest that there may be a relationship between output growth and productivity. There is also evidence that reductions in the number of establishments are associated with higher productivity. This is consistent with the relatively lower productivity growth in the B.C. Coast industry, the only one of the four regional industries that did not experience a decrease in the number of establishments.

The study results seem relatively encouraging for the long-run competitiveness of the industry. From a national perspective, however, the real test will be how Canadian productivity compares with that of our major foreign competitors. Such analysis awaits further study, although this study has laid the foundation for the methodologies and techniques required. The report also suggests that future productivity growth may depend on output growth. One method to achieve this could be continued consolidation of establishments. Additional study by means of parametric techniques and with data at the firm or plant level is necessary to make more definitive statements on the sources of productivity growth.

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APPENDICES

Appendix A: Productivity indices

Table A1. Productivity indices for labor, by region (Ontario 1962=100).

Year	Labor productivity indices, by region			
	B.C. Coast	B.C. Interior	Ontario	Quebec
1962	185.9	218.3	100.0	104.0
1963	197.7	194.8	112.0	100.9
1964	202.9	190.7	110.9	104.6
1965	212.5	195.3	109.6	105.2
1966	226.9	195.5	108.5	108.1
1967	231.7	210.7	102.3	105.9
1968	240.2	234.7	113.4	119.9
1969	233.1	226.2	115.5	123.8
1970	240.5	228.3	125.9	130.3
1971	244.4	251.0	142.4	136.5
1972	235.8	245.1	144.8	142.7
1973	230.0	253.2	151.3	141.5
1974	212.6	253.4	167.1	144.2
1975	225.4	282.0	168.7	160.4
1976	241.9	303.4	180.4	163.0
1977	247.4	314.4	193.8	180.6
1978	245.4	303.9	205.5	180.0
1979	236.1	309.0	214.7	188.2
1980	239.2	301.9	231.1	192.0
1981	238.1	316.6	239.0	195.5
1982	254.0	370.4	235.0	208.1
1983	323.9	409.5	251.9	235.3
1984	312.5	430.8	261.5	225.3
1985	297.3	447.6	245.3	250.6

Table A2. Productivity indices for wood, by region (Ontario 1962=100).

Year	Wood productivity indices, by region			
	B.C. Coast	B.C. Interior	Ontario	Quebec
1962	104.3	103.6	100.0	100.8
1963	106.0	103.1	102.7	100.8
1964	110.3	100.5	102.4	103.1
1965	112.3	105.7	104.5	101.6
1966	114.3	103.2	103.9	105.6
1967	114.6	98.4	106.9	109.0
1968	117.3	106.2	109.8	113.9
1969	126.1	101.2	106.5	118.0
1970	116.1	100.6	106.5	115.5
1971	118.2	105.2	109.9	119.0
1972	118.4	106.8	116.4	119.4
1973	107.7	104.6	116.3	116.5
1974	101.6	97.1	97.5	120.6
1975	103.1	101.8	116.0	100.5
1976	103.0	102.5	108.8	94.2
1977	103.2	100.9	100.3	88.9
1978	105.7	102.1	106.4	98.5
1979	106.0	103.5	100.6	94.7
1980	106.5	98.6	97.8	95.4
1981	106.7	96.7	102.6	93.8
1982	101.2	99.6	100.2	89.0
1983	122.3	105.7	115.3	113.5
1984	111.9	102.9	118.1	92.9
1985	112.7	102.7	123.9	107.1

Table A3. Productivity indices for other materials, by region (Ontario 1962=100).

Year	Other materials productivity indices, by region			
	B.C. Coast	B.C. Interior	Ontario	Quebec
1962	396.1	179.4	100.0	92.1
1963	366.4	108.8	136.1	92.8
1964	368.4	106.1	126.3	97.7
1965	421.3	114.1	125.6	101.3
1966	431.8	118.4	129.5	103.7
1967	416.2	110.3	109.5	164.6
1968	387.7	111.3	113.7	124.4
1969	280.0	102.2	95.1	146.7
1970	312.2	119.7	119.5	138.2
1971	253.4	135.6	127.9	119.5
1972	211.6	128.3	156.1	118.1
1973	168.2	140.7	154.1	123.6
1974	173.4	169.0	181.0	139.0
1975	171.2	168.8	153.6	143.6
1976	178.8	147.7	161.2	129.9
1977	179.3	134.3	186.6	139.6
1978	156.6	119.8	185.3	127.9
1979	170.2	109.0	141.9	122.3
1980	181.0	120.1	142.5	130.2
1981	192.7	119.0	143.9	128.9
1982	195.4	139.1	135.9	136.6
1983	206.3	142.2	135.3	136.2
1984	197.8	143.4	119.4	113.3
1985	192.8	143.6	123.0	112.0

Table A4. Productivity indices for energy, by region (Ontario 1962=100).

Year	Energy productivity indices, by region			
	B.C. Coast	B.C. Interior	Ontario	Quebec
1962	205.3	98.1	100.0	128.0
1963	187.8	90.3	130.5	135.3
1964	188.6	87.7	120.7	134.1
1965	196.9	89.0	113.3	118.8
1966	205.9	84.7	103.2	112.5
1967	206.6	81.9	100.0	99.6
1968	201.7	94.7	89.6	95.7
1969	174.2	83.5	85.8	95.6
1970	185.8	85.5	101.9	98.4
1971	176.5	81.3	90.2	91.5
1972	151.3	75.9	84.0	89.0
1973	144.3	75.8	69.8	87.6
1974	113.6	71.9	64.6	82.7
1975	95.3	71.4	73.4	75.9
1976	122.2	82.4	79.7	87.5
1977	113.0	80.6	82.7	89.3
1978	118.4	75.6	85.9	83.4
1979	118.8	77.1	90.2	80.6
1980	113.7	73.9	99.6	75.4
1981	114.5	73.0	89.9	79.3
1982	108.1	77.2	83.0	69.5
1983	126.7	83.8	88.7	83.9
1984	122.3	85.8	94.8	89.6
1985	113.4	86.4	89.9	97.6

Table A5. Productivity indices for capital, by region (Ontario 1962=100).

Year	Capital productivity indices, by region			
	B.C. Coast	B.C. Interior	Ontario	Quebec
1962	172.0	141.1	100.0	102.8
1963	150.7	130.5	102.9	114.5
1964	176.4	133.5	88.6	121.0
1965	201.7	157.0	96.2	129.6
1966	264.0	171.5	116.1	159.8
1967	241.4	191.6	139.7	174.4
1968	157.8	128.1	148.0	183.5
1969	205.5	187.7	157.8	190.3
1970	444.4	725.7	244.8	268.0
1971	324.4	288.3	175.6	209.3
1972	234.8	146.2	116.0	126.3
1973	92.4	97.4	69.9	79.6
1974	133.2	210.0	83.4	95.0
1975	191.5	209.3	132.4	117.2
1976	176.9	140.5	142.2	128.4
1977	98.8	87.7	97.4	94.4
1978	85.1	67.2	73.9	79.2
1979	93.5	91.8	81.2	72.4
1980	255.3	208.5	181.4	130.8
1981	687.0	355.0	241.8	178.0
1982	1074.6	918.8	319.3	213.0
1983	277.0	210.1	191.2	162.9
1984	611.6	277.0	232.2	165.5
1985	226.8	241.5	190.9	183.2

Table A6. Variable-factor productivity indices, by region (Ontario 1962=100).

Year	Variable-factor productivity indices, by region			
	B.C. Coast	B.C. Interior	Ontario	Quebec
1962	152.9	142.3	100.0	101.5
1963	155.6	122.9	112.1	101.0
1964	160.0	120.2	109.9	104.3
1965	166.0	126.4	110.2	104.6
1966	170.8	126.0	110.1	107.6
1967	171.9	122.6	105.5	118.8
1968	174.2	131.4	110.5	119.4
1969	172.8	124.8	106.1	126.2
1970	168.8	130.2	113.0	124.8
1971	166.9	140.5	119.7	124.0
1972	160.4	139.2	129.0	125.6
1973	145.8	141.7	129.0	125.3
1974	138.1	141.3	124.4	130.7
1975	140.2	149.3	132.5	122.3
1976	145.1	149.8	132.4	117.3
1977	146.2	147.1	132.9	118.8
1978	144.9	142.2	139.8	123.1
1979	145.0	140.1	131.2	120.9
1980	147.2	139.3	132.0	123.3
1981	148.7	138.9	136.2	122.5
1982	146.4	152.1	131.6	121.6
1983	175.7	161.9	144.2	142.7
1984	164.4	161.8	143.3	122.9
1985	162.4	163.0	145.9	135.0

Table A7. Total-factor productivity indices, by region (Ontario 1962=100).

Year	Total-factor productivity indices, by region			
	B.C. Coast	B.C. Interior	Ontario	Quebec
1962	157.0	142.3	100.0	101.9
1963	155.6	124.9	110.0	103.7
1964	163.7	123.2	104.6	107.5
1965	172.6	132.3	106.7	109.1
1966	184.1	134.1	111.0	115.8
1967	183.2	133.8	111.2	127.6
1968	171.2	130.1	116.8	129.4
1969	179.3	135.6	114.2	136.7
1970	196.7	165.4	129.6	143.3
1971	186.9	159.9	128.7	136.7
1972	172.3	140.9	125.0	125.3
1973	132.9	130.1	108.3	111.6
1974	138.5	152.2	112.5	122.1
1975	148.5	159.4	132.6	121.4
1976	151.3	148.8	134.4	119.8
1977	137.7	132.2	125.3	114.1
1978	132.5	120.0	121.0	112.6
1979	135.5	129.2	117.7	107.3
1980	160.7	150.4	140.2	125.3
1981	179.3	161.1	150.5	131.8
1982	183.3	190.2	151.2	134.9
1983	189.9	171.1	152.1	147.1
1984	194.9	178.7	156.2	130.6
1985	172.9	176.3	153.8	143.6

Table A8. Single-factor productivity indices, B.C. Coast (1962=100).

Year	Single-factor productivity indices				
	Wood	Other materials	Labor	Energy	Capital
1962	100.0	100.0	100.0	100.0	100.0
1963	101.6	92.5	106.4	91.5	87.6
1964	105.7	93.0	109.1	91.9	102.6
1965	107.7	106.4	114.3	95.9	117.3
1966	109.6	109.0	122.0	100.3	153.5
1967	109.9	105.1	124.6	100.6	140.4
1968	112.4	97.9	129.2	98.3	91.8
1969	120.9	70.7	125.4	84.9	119.5
1970	111.3	78.8	129.4	90.5	258.5
1971	113.3	64.0	131.5	86.0	188.7
1972	113.5	53.4	126.8	73.7	136.6
1973	103.3	42.5	123.7	70.3	53.7
1974	97.4	43.8	114.4	55.4	77.5
1975	98.9	43.2	121.2	46.4	111.3
1976	98.8	45.1	130.1	59.5	102.9
1977	98.9	45.3	133.1	55.0	57.5
1978	101.3	39.5	132.0	57.7	49.5
1979	101.6	43.0	127.0	57.9	54.4
1980	102.1	45.7	128.7	55.4	148.4
1981	102.3	48.6	128.1	55.8	399.5
1982	97.0	49.3	136.7	52.6	625.0
1983	117.3	52.1	174.2	61.7	161.1
1984	107.2	49.9	168.1	59.6	355.7
1985	108.0	48.7	159.9	55.2	131.9

Table A9. Single-factor productivity indices, B.C. Interior (1962=100).

Year	Single-factor productivity indices				
	Wood	Other materials	Labor	Energy	Capital
1962	100.0	100.0	100.0	100.0	100.0
1963	99.5	60.6	89.2	92.1	92.5
1964	97.0	59.1	87.4	89.5	94.6
1965	102.0	63.6	89.4	90.7	111.2
1966	99.6	66.0	89.5	86.3	121.5
1967	95.0	61.5	96.5	83.6	135.8
1968	102.5	62.1	107.5	96.6	90.8
1969	97.7	56.9	103.6	85.2	133.0
1970	97.1	66.7	104.6	87.1	514.2
1971	101.6	75.6	115.0	82.9	204.3
1972	103.1	71.5	112.3	77.4	103.6
1973	101.0	78.4	116.0	77.3	69.0
1974	93.8	94.2	116.1	73.3	148.8
1975	98.2	94.1	129.2	72.8	148.3
1976	98.9	82.3	139.0	84.0	99.5
1977	97.4	74.9	144.0	82.1	62.1
1978	98.6	66.8	139.2	77.1	47.6
1979	99.9	60.7	141.5	78.7	65.0
1980	95.1	66.9	138.3	75.4	147.7
1981	93.3	66.3	145.0	74.4	251.5
1982	96.2	77.6	169.7	78.7	651.0
1983	102.0	79.3	187.6	85.4	148.9
1984	99.3	79.9	197.4	87.5	196.3
1985	99.1	80.0	205.0	88.1	171.1

Table A10. Single-factor productivity indices, Ontario (1962=100).

Year	Single-factor productivity indices				
	Wood	Other materials	Labor	Energy	Capital
1962	100.0	100.0	100.0	100.0	100.0
1963	102.7	136.1	112.0	130.5	102.9
1964	102.4	126.3	110.9	120.7	88.6
1965	104.5	125.6	109.6	113.3	96.2
1966	103.9	129.5	108.5	103.2	116.1
1967	106.9	109.5	102.3	100.0	139.7
1968	109.8	113.7	113.4	89.6	148.0
1969	106.5	95.1	115.5	85.8	157.8
1970	106.5	119.5	125.9	101.9	244.8
1971	109.9	127.9	142.4	90.2	175.6
1972	116.4	156.1	144.8	84.0	116.0
1973	116.3	154.1	151.3	69.8	69.9
1974	97.5	181.0	167.1	64.6	83.4
1975	116.0	153.6	168.7	73.4	132.4
1976	108.8	161.2	180.4	79.7	142.2
1977	100.3	186.6	193.8	82.7	97.4
1978	106.4	185.3	205.5	85.9	73.9
1979	100.6	141.9	214.7	90.2	81.2
1980	97.8	142.5	231.1	99.6	181.4
1981	102.6	143.9	239.0	89.9	241.8
1982	100.2	135.9	235.0	83.0	319.3
1983	115.3	135.3	251.9	88.7	191.2
1984	118.1	119.4	261.5	94.8	232.2
1985	123.9	123.0	245.3	89.9	190.9

Table A11. Single-factor productivity indices, Quebec (1962=100).

Year	Single-factor productivity indices				
	Wood	Other materials	Labor	Energy	Capital
1962	100.0	100.0	100.0	100.0	100.0
1963	100.0	100.8	97.0	105.7	111.3
1964	102.3	106.1	100.6	104.8	117.7
1965	100.8	110.1	101.1	92.8	126.1
1966	104.8	112.7	103.9	87.9	155.5
1967	108.2	178.8	101.8	77.8	169.6
1968	113.0	135.1	115.3	74.8	178.5
1969	117.1	159.3	119.0	74.7	185.1
1970	114.7	150.1	125.2	76.9	260.7
1971	118.1	129.7	131.2	71.5	203.6
1972	118.5	128.3	137.2	69.5	122.9
1973	115.6	134.2	136.0	68.4	77.5
1974	119.7	151.0	138.6	64.6	92.4
1975	99.8	156.0	154.1	59.3	114.0
1976	93.4	141.1	156.6	68.3	124.9
1977	88.2	151.6	173.6	69.7	91.8
1978	97.7	138.9	173.1	65.1	77.0
1979	94.0	132.8	180.9	63.0	70.4
1980	94.7	141.5	184.6	58.9	127.2
1981	93.1	140.1	188.0	61.9	173.1
1982	88.4	148.4	200.1	54.3	207.1
1983	112.7	147.9	226.2	65.5	158.5
1984	92.2	123.1	216.6	69.9	161.0
1985	106.3	121.6	240.9	76.3	178.2

Table A12. Variable-factor productivity indices, by region (1962=100).

Year	Variable-factor productivity indices, by region			
	B.C. Coast	B.C. Interior	Ontario	Quebec
1962	100.0	100.0	100.0	100.0
1963	101.8	86.4	112.1	99.5
1964	104.6	84.5	109.9	102.8
1965	108.5	88.8	110.2	103.1
1966	111.7	88.6	110.1	106.1
1967	112.4	86.2	105.5	117.1
1968	113.9	92.4	110.5	117.7
1969	113.0	87.7	106.1	124.4
1970	110.4	91.5	113.0	123.0
1971	109.1	98.8	119.7	122.3
1972	104.9	97.9	129.0	123.8
1973	95.3	99.6	129.0	123.5
1974	90.3	99.3	124.4	128.8
1975	91.7	104.9	132.5	120.6
1976	94.9	105.3	132.4	115.6
1977	95.6	103.4	132.9	117.1
1978	94.7	100.0	139.8	121.4
1979	94.8	98.5	131.2	119.2
1980	96.3	97.9	132.0	121.5
1981	97.2	97.6	136.2	120.7
1982	95.8	106.9	131.6	119.8
1983	114.9	113.8	144.2	140.7
1984	107.5	113.7	143.3	121.2
1985	106.2	114.6	145.9	133.1

Table A13. Total-factor productivity indices, by region (1962=100).

Year	Total-factor productivity indices, by region			
	B.C. Coast	B.C. Interior	Ontario	Quebec
1962	100.0	100.0	100.0	100.0
1963	99.1	87.8	110.0	101.8
1964	104.3	86.6	104.6	105.6
1965	109.9	93.0	106.7	107.2
1966	117.3	94.3	111.0	113.7
1967	116.7	94.1	111.2	125.3
1968	109.1	91.5	116.8	127.0
1969	114.2	95.3	114.2	134.2
1970	125.3	116.3	129.6	140.7
1971	119.1	112.4	128.7	134.3
1972	109.8	99.0	125.0	123.0
1973	84.7	91.5	108.3	109.6
1974	88.3	107.0	112.5	119.9
1975	94.6	112.1	132.6	119.2
1976	96.4	104.6	134.4	117.7
1977	87.7	93.0	125.3	112.0
1978	84.4	84.3	121.0	110.6
1979	86.3	90.9	117.7	105.4
1980	102.4	105.7	140.2	123.0
1981	114.2	113.2	150.5	129.4
1982	116.8	133.7	151.2	132.5
1983	121.0	120.3	152.1	144.4
1984	124.2	125.6	156.2	128.2
1985	110.2	123.9	153.8	141.0

Appendix B: Variable-factor productivity regression analyses

Table B1. Log-linear Cochrane-Orcutt regressions of variable-factor productivity on the time-trend variable (t statistics in parentheses).

	Region			
Parameter	B.C. Coast	B.C. Interior	Ontario	Quebec
Constant	5.12 (44.06)	4.75 (173.64)	4.64 (157.65)	4.69 (97.90)
Time trend	-0.004 (0.544)	0.013 (7.32)	0.014 (7.22)	0.008 (2.52)
R^2	0.62	0.84	0.87	0.61
Durbin-Watson statistic	1.82	1.37	1.74	2.34

Table B2. Log-linear Cochrane-Orcutt regressions of variable-factor productivity on the time-trend variable (t statistics in parentheses).

	Region			
Parameter	B.C. Coast	B.C. Interior	Ontario	Quebec
Constant	4.10 (7.85)	4.44 (8.83)	4.32 (9.32)	3.75 (5.57)
Time trend	-0.001 (-0.18)	0.010 (2.12)	0.010 (1.77)	-0.003 (-0.39)
Output	0.15 (2.05)	0.052 (0.62)	0.069 (0.68)	0.180 (1.41)
R^2	0.67	0.85	0.87	0.64
Durbin-Watson statistic	1.80	1.32	1.75	2.24

Table B3. Log-linear Cochrane-Orcutt regressions of variable-factor productivity on the time-trend variable and the number of establishments (t Statistics in parentheses).

Parameter	Region			
	B.C. Coast	B.C. Interior	Ontario	Quebec
Constant	5.13 (27.98)	4.91 (50.33)	4.61 (27.72)	4.88 (29.18)
Time trend	-0.003 (-0.44)	0.009 (2.60)	0.015 (3.69)	0.003 (0.68)
No. of establishments	-0.0001 (-0.07)	-0.0003 (-1.93	0.00007 (0.18)	-0.0003 (-1.22)
R^2	0.62	0.86	0.87	0.63
Durbin-Watson statistic	1.83	1.69	1.75	2.14

Table B4. Log-linear Cochrane-Orcutt regressions of variable-factor productivity on the time-trend and output variables and on the number of establishments (t statistics in parentheses).

Parameter	Region			
	B.C. Coast	B.C. Interior	Ontario	Quebec
Constant	3.92 (6.73)	4.55 (9.27)	4.32 (9.07)	3.97 (5.65)
Time trend	0.007 (0.49)	0.005 (0.89)	0.009 (1.15)	-0.006 (-0.63)
Output	0.18 (2.43)	0.06 (0.77)	0.07 (0.63)	0.17 (1.29)
No. of establishments	-0.002 (-1.15)	-0.0004 (-2.02)	-0.00003 (-0.06)	-0.0002 (-0.86)
R^2	0.71	0.87	0.87	0.65
Durbin-Watson statistic	1.90	1.66	1.74	2.14