INTENSIVE AND EXTENSIVE GROWTH IN THE FINNISH AND U.S. FOREST INDUSTRIES

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ABSTRACT

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This study examines the sources of growth in the Finnish and U.S. mechanical forest and pulp and paper industries during the period 1958-82. The main objective is to separate growth into extensive and intensive components, the former meaning increasing use of resources at the same technological level, the latter meaning more efficient use of existing resources. These components are analyzed to learn about the role of technological change, labor, capital, material inputs and energy in the growth process as a guide for future Finnish and U.S. forest policies.

Two approaches containing four basic models for the pulp and paper industry and three for the mechanical forest industry were applied. The production functions applied were two variations of a Cobb-Douglas function and a factor augmenting CES production function. Translog production function was applied implicitly in a total factor productivity index.

The growth processes in the Finnish and U.S. forest industries were shown to differ in nature, the differences being more apparent after the mid-70's. Growth in Finland has become more intensive over time, emphasizing the role of technological change or total factor productivity. In the U.S.,

growth has been more of the extensive type, emphasizing the role of capital deepening.

Total factor productivity analysis in a gross output framework showed that capital and increased use of wood, chemicals and other material inputs have become more central to the growth process in the U.S. P & P industry, while in Finland their relative importance decreased towards the end of the study period.

Comparison of the gross output and value added productivity measures revealed that the value added framework overestimated the role of productivity both in the Finnish and U.S. P & P industries.

Although the results emphasize the importance of technological change to output growth, capital investment is suggested to be central to the growth process through a complementary relationship between the two factors. Capital intensity of production has increased significantly faster in the Finnish forest industries than in the U.S., which could explain the differences in the role of total productivity.

Increased capital intensity of production with limited substitution possibilities has meant greater vulnerability to changes in demand for forest products. As a result, forest industries in both countries have experienced short-term fluctuations in total productivity, especially during the mid-70's.

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I INTRODUCTION

The Problem

Economic growth is a sustained increase in the output of goods and services used to satisfy human wants. Widely accepted as a national goal, economic growth implies greater real income per capita, and usually makes other economic and social objectives easier to achieve. Measures of growth are widely used as indicators of overall economic performance; the presence or absence of growth is looked upon as an indicator of the success or failure of economic policy.

Formation of economic policy is conditioned by views about the causes of growth. In quantitative studies of growth, growth has usually been separated into extensive and intensive components, the former meaning increasing use of resources at the same technological level, the latter meaning more efficient use of already existing resources by use of a different technology and/or improved quality of inputs. In the more precise terminology used in production theory, extensive growth refers to capital and material deepening, intensive growth corresponds to the concepts of technological progress or total factor productivity (TFP) growth.[1] The essential quantitative characteristic of intensive growth or

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[1]In this study the terms technological and total factor productivity change are used interchangeably.

technological change is a shift of a production function, enabling greater output to be produced with the same quantity of inputs, while extensive growth or capital deepening corresponds to a movement along a production function whose shape is determined by given technology (Solow 1957; Usher 1980a, p. 259-60).

In Finland there have been only a few studies on the sources of economic growth. This is true especially at the industry level - also in the forest industries (related research is reviewed in Appendix A). This study is carried out to learn more about the process of growth in the forest industries both in Finland and the U.S.

Since the 1950's the output of the Finnish forest industries has been growing rapidly; the average annual growth rate in output volume for the period 1955-80 was 5 percent. High growth rates have meant increased use of resources needed to produce the desired output. A raw material and production oriented "growth strategy" has been possible because of advantageous preconditions for growth. Demand for forest products has risen steadily, providing new market opportunities for Finnish forest products. The domestic timber base has been growing even faster than needed to satisfy the actual demand for industrial roundwood. In addition, low real interest rates and institutional factors (e.g., tax laws) have created a positive economic environment for new forest industry investments.

However, the Finnish forest industries now face a situation where growth based on the increased use of inputs will not be possible to the same extent as before. Significant expansion of production capacity is not possible because present capacity is already nearly equivalent to the allowable cut, and imports of roundwood cannot be increased in a significant amount. Even if the plans for increasing the allowable cut were succesful, the changed selling behavior of nonindustrial private forest owners may reduce the supply of roundwood permanently below the allowable cut. Future expansions may also be reduced by increased real interest rates and by uncertainty about future energy supply (prices).

Thus, it appears that future growth of the Finnish forest industries must be based on the more efficient use of existing resources. The assessment of opportunities for growth and formulating of new growth strategies requires knowledge of the factors underlying past growth. Information about the role of total factor productivity (that is, technology) in growth is especially needed. International competitiveness depends not only on price and cost development of forest products and factor inputs, but also on productivity growth. Increases in total factor productivity improve profitability, and can secure and even create jobs in the long run and provide higher wages. High unemployment levels since the mid-1970s, and increasing competition for resources, especially for capital, have also increased the need to know more about the sources of growth in the Finnish forest industries to improve the allocation of resources.

Objectives and Scope

This study estimates the contributions of various factors to the growth of output in the Finnish and U.S. forest industries during the period 1958-82, with emphasis on growth in the Finnish forest products industries. The study aims at decomposing the growth into extensive and intensive components, and analyzing these components in more detail as a guide for future forest policy. The role of capital, labor, material inputs, energy, and especially, the role and nature of technological change responsible for this growth are examined. Trends in the use of factors of production and their partial productivities are also studied. Before discussing empirical applications, the theoretical aspects of growth analysis and the measurement of variables are examined.

Comparative analysis of the sources of growth in the Finnish and U.S. forest industries is carried out for two main reasons. First, it helps in appraising a country's past performance and provides information about possible differential technological opportunities for increasing the role of productivity in growth. Second, international comparison facilitates validation of applied models.

Production functions are estimated separately for the mechanical wood and pulp and paper industries. Total factor productivity indices are calculated for pulp and paper industries. The study period, the level of aggregation and the inclusion of forest industry subsectors for study were determined by the availability of comparable data. The following industry sectors are included in the study under the headings "Mechanical Wood" and "Pulp and Paper" (note: the Finnish coding system changed in 1970):

	Finland ISIC code	USA SIC code
<u>Mechanical Wood</u>		
Sawmills and planing mills	331111	2420
Other manuf. of wooden stuct.	331122	2430
Veneer and plywood mills	331191	
<u>Pulp and Paper</u>		
Pulp mills	34111	2611
Paper and paperboard mills	34112	2621,2631
Building paper and board mills		2661

The "mechanical wood" industry in the United States is defined to consist of SIC (Standard Industrial Code) industry 2420, which includes Sawmills and Planing Mills (SIC 2421), Hardwood Dimension and Flooring (SIC 2426) and Special Product Sawmills (SIC 2429), and of the industry SIC 2430, which includes Millwork (SIC 2431), Wood Kitchen Cabinets (SIC 2434), Hardwood Veneer and Plywood (SIC 2435), Softwood Veneer and Plywood (SIC 2436) and Structural Wood Members (SIC 2439). In 1972 small revisions took place in the classification of products in SIC industries 2420 and 2430, but those changes partly cancel each other out, and the remaining source of error is insignificant. The Finnish and U.S. data are not fully consistent in coverage and classification, but it is assumed that these differences will not have a significant effect on the results.

Method

In this study both a production function and total factor productivity (TFP) index approach is applied to quantify the sources of growth in the Finnish and U.S. forest industries. Functional forms for the production functions are chosen on the basis of their suitability for growth analysis. The validity of underlying assumptions and the robustness of the results are studied with the use of alternative models. The production functions used here are the Cobb-Douglas and the CES (constant elasticity of substitution) functions. A third type of function - the translog production function - is applied implicitly in a TFP productivity index.

Application of index number theory permits circumvention of some of the problems generally associated with explicit production function analysis. Given certain assumptions, TFP indices allow the estimation of the contributions of various factors to the growth of output without explicitly specifying the form of the production function. They are also easier to apply than production functions in growth analysis when more than two factors of production are considered. This is important in this study because an attempt is made to quantify the role of four factors in the growth process: labor, capital, material inputs and energy. On the other hand, TFP indices cannot be used to test the associated hypotheses (e.g., the type of the production function or technological change), or to obtain parameter estimates describing production relationships.

The choice of applying two alternative approaches to study the sources of economic growth of the defined forest industry sectors in Finland and the U.S. is based on the recognitions that the choice of the study approach may have a great effect on the results, and that the two approaches complement each other to some extent. When alternative models are used the validation of the results also becomes easier. It is also valuable for future research to find out to what extent the two approaches produce comparable results.

II ANALYTICAL FRAMEWORK

Aggregate Production Functions

In an attempt to identify the sources of economic growth, or to examine the policies affecting growth, the explicit or implicit use of an aggregate production function is almost indispensable.[2] A production function defines the relationship (based on physical or engineering considerations) whereby alternative combinations of factors of production are transformed into outputs. In the economic theory of production, a production function represents the locus of minimum input requirements needed to produce given level of output. Mathematically production function can be written as

$$Q = f(x) \qquad \delta f/\delta x_i = f_i \geq 0, \ \delta^2 f/\delta x_i^2 = f_{ii} \leq 0 \qquad (1)$$

where Q is the quantity of output, x represents the vector of inputs, δ is the derivative, and f is a concave function. Often output is expressed as a function of only two homogeneous inputs - labor (L) and capital (K):

$$Q = f(L,K). \qquad (2)$$

A production function is not an unambiguous concept, but it can represent a number of diverse concepts. One can make a distinction between ex ante and ex post, micro and macro, frontier and average, and short- and long-run production

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[2]The (neoclassical) concept of a production function is not accepted by all economists (see discussion in e.g., Jones 1975).

functions. An ex ante or blueprint production function represents the set of most advanced techniques currently available (Sato 1975, p. xxiv). In empirical work we are not studying theoretical relationships, but we try, ex post, to link the actual recorded output with the actual factors of production. Ex post functions are of a short-run nature because techniques are more or less fixed. Macro production functions are employed to describe industry or economy-wide production relationships. They are traditionally built from micro units assuming that all firms share an identical production function. This kind of traditional macro production function can produce results that are difficult to interpret or operationalize, because it represents average technology that does not necessarily exist as such. Firms do, however, differ in productive efficiency, and due to this, they are not so much interested in average as in best-practice technology. (Johansen 1972; Sato 1975, xxi)

Macro functions based on the efficiency distribution of firms, and frontier production functions, which refer to the best-practice technologies existing at a given point of time, have been developed to provide a more realistic description of the industrial structure and productive efficiency of a firm or an industry, and to produce results that would be easier to operationalize at a firm level or in developing instruments for industrial policy (see e.g., Johansen 1972;

Sato 1975; Forsund et al. 1980). The lack of suitable data does not permit to use this approach in this investigation.

The production function has four characteristics which are central in the analysis of changes in the production technology: the efficiency of production, degree of economies of scale (or returns to scale), factor intensity, and the elasticity of substitution. An increase in the efficiency of production refers to a reduction in the quantities of factors used in producing the unit output. Alternatively, it can be seen as an equal reduction in the unit cost of all factors of production by applying better techniques. The degree of economies of scale expresses the change in output that results from an equiproportional change in all inputs. A production function is said to be homogeneous of degree n, if $Q=f(\alpha x)=\alpha^n f(x)$ for all $\alpha>0$. Factor intensity refers generally to capital intensity; i.e., the capital-labor ratio for given relative prices. Capital intensity may change as a result of changes in relative prices, or the change may have a purely technological origin.

The fourth central characteristic of a technology is the ease with which one input can be substituted for another. It can be measured locally by the elasticity of substitution (σ)

$$\sigma = d\ln(K/L)/d\ln(f_L/f_K) \tag{3}$$

Assuming perfect competition and profit maximization, σ can be written

$$\sigma = \frac{d\ln(K/L)}{d\ln(w/r)} = \frac{d(K/L)/(K/L)}{d(w/r)/(w/r)} \tag{4}$$

where w and r represent factor prices. The elasticity of substitution is therefore a measure of how rapidly factor proportions can change for a change in relative factor prices (Brown 1966, p. 12-20; Intriligator 1978, p. 264-5). Production functions can be classified according to the size of σ (see e.g., Ollonqvist 1974). When $\sigma = 1$, we have one of the most widely used production functions for empirical applications - the <u>Cobb-Douglas (CD) function</u>. In a two-factor case it is written

$$Q = AL^{\alpha}K^{\beta} \qquad A\geq 0,\ \alpha\geq 0,\ \beta\geq 0 \qquad (5)$$

where α and β are elasticities of output with respect to inputs, and A is a parameter embodying changes in the efficiency of technology. The sum of the parameters α and β indicates the degree of economies of scale.

In the <u>constant elasticity of substitution (CES) production function</u>, the elasticity of substitution is not given a priori, but it is assumed to be constant (Arrow et al. 1961):

$$Q = \mu[(\delta K^{-\alpha} + (1-\delta)L^{-\alpha}]^{-v/\alpha} \qquad \mu>0,\ v\geq 0,\ 0<\delta<1,\ \alpha\geq -1 \quad (6)$$

where μ is the efficiency parameter, v shows the degree of economies of scale, δ is a distribution parameter representing capital intensity, and α is a substitution parameter. The elasticity of substitution (σ) is derived from the substitution parameter as $\sigma = 1/(1+\alpha)$.

The CD-function is a special case of the CES production function, because when α --> 0, σ approaches one. <u>Leontief's</u>

input-output function ($Q=\min(aL,bK)$) is also a special case of the CES-function, for as $\alpha \to \infty$, σ approaches zero (Intriligator 1978, p. 273-5). The isoquants of these three types of production functions are shown in Figure 1.

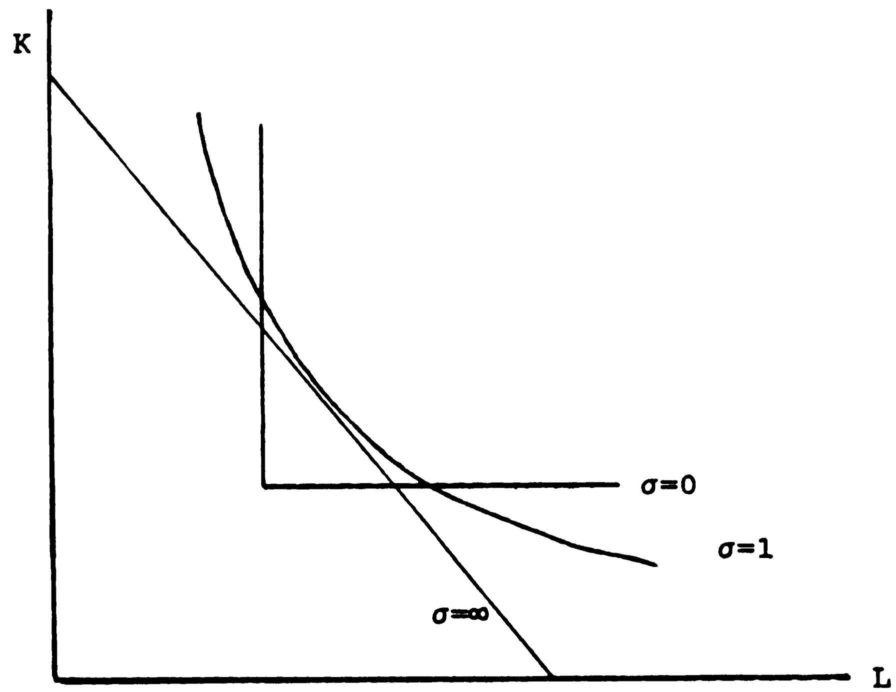

Figure 1. Isoquants of Production Functions with Alternative Elasticities of Substitution.

All the above described production functions share one common characteristic - the elasticity of substitution is constant. In the variable elasticity of substitution production function, σ is allowed to vary with changes in factor proportions (see Sato & Hoffman 1968; Revankar 1971). In the recent years, one of the most widely used production functions is the transcendental logarithmic (translog) production function of the form

$$\ln Q = \ln\alpha_0 + \Sigma\alpha_i \ln x_i + (1/2)\Sigma\Sigma\beta_{ij} \ln x_i \ln x_j \quad (7)$$

where Q=output, α_0=efficiency parameter, and x_j=input j. α_i and β_{ij} are unknown parameters such that $f_0(x)$ is concave, nondecreasing, and linearly homogeneous over the relevant range of x's (Christensen et al. 1973).

The translog production function can be viewed in three alternative ways: as an exact production function, as a second-order Taylor-series approximation to a general but unknown production function, or as a second-order approximation to a CES production function (Boisvert 1982, p. 5-6). Because of its generality and flexibility, translog production functions have most often been used to approximate any unknown linearly homogeneous production function, either explicitly, or implicitly in TFP indices (see p. 20).

Representation of Technological Change

Technological change has been claimed to play a crucial role in the process of economic growth, and consequently its analysis occupies a central place in growth studies. Technological change (progress) can be characterized in several ways, but its essential quantitative characteristic is to shift the production function enabling greater output to be produced with the same <u>quantity</u> of inputs, or the same output with lesser inputs (Kennedy & Thirwall 1972, p. 12). More formally, technological change (TC) can be defined by:

$$TC = d\ln(Q)/d\ln(t) \quad (8)$$

where time (t) represents technology. Technological change can also be defined from the dual side of production. According to the theory of duality, for each production function there exists a dual cost function reflecting the production technology (e.g., Smith 1978). On the cost side, the rate of technological change can be measured as

$$TC = d\ln(C)/d\ln(t) \qquad (9)$$

where C is the cost of producing output Q, and t represents technology.

Another important aspect of technological change is its neutrality or bias, the latter meaning change that leads to a greater saving in one input relative to another. Production theory recognizes several definitions of technological change, of which definitions by Hicks, Harrod and Solow have been widely used (see e.g., Beckman & Sato 1969; Puu & Wibe 1980, p. 3-21). Technological change is Hicks-neutral if it does not change the marginal rate of substitution between the inputs at given factor proportions; that is, the ratio of marginal products stays constant. Harrod-neutral and Solow-neutral technological change, on the other hand, refer respectively to cases in which the ratio of marginal products remains constant when measured with respect to identical capital-output or labor-input ratios (e.g., Nadiri 1970, p. 1142-3). Definitions of labor- and capital-saving technological bias follow from the definitions of neutrality. We may define, for example, Hicks bias as

$$B_H = \frac{d(f_K K/f_L L)}{dt} \qquad \text{K/L constant} \tag{10}$$

>0 labor-using (capital-saving)
=0 neutral
<0 capital-using (labor-saving)

A distinction is made conventionally between embodied and disembodied technological change. In the first case, technological change is built into new capital goods, while in the second case, it is a function of time and independent of any changes in factor inputs. Disembodied technological change is generally attributed to improvements in the organization and management, and in techniques that enhance the productivity of old equipment along with new (Kennedy & Thirwall 1972, p. 31-39). A neoclassical production function exhibiting disembodied (neutral) technological change (progress) may be written in a general form

$$Q = f(x,t), \qquad f_t>0 \tag{11}$$

where x is the vector of factors of production, and t denotes time or level of technology at point t (see Solow 1957). The change in output over time is defined by taking the total derivative of the above equation

$$dQ/dt = \Sigma(\delta f/\delta x_i)(dx_i/dt) + \delta f/\delta t. \tag{12}$$

The first term on the right indicates the change in output due to increased inputs, and the second term on the right indicates the change in output due to disembodied technological change. Equation (11) is often expressed in factor augmenting form that may be written in a two-factor case as

$$Q = f(a(t)L, b(t)K) \quad (13)$$

where a(t)K and b(t)L can be identified as "effective" labor and capital. Technological change is said to be purely capital-saving if $\dot{a}(t)>0$ and $\dot{b}(t)=0$, whereas, it is purely labor-saving if $\dot{b}(t)>0$ and $\dot{a}(t)=0$. When $\dot{a}(t)=\dot{b}(t)>0$, technological change is neutral.

Another distinction is that between exogeneous and endogeneous (or induced) technological change. In the case of the former, technological change as such is not explained; it is just exogeneous to the economic system. In the case of endogeneous technological change, the expansion of technological possibilities is explained explicitly by economic factors such as long term changes in the relative prices of inputs, investment in education and research plus in inputs required for changing over to improved industrial methods (Kennedy & Thirwall 1972, p. 13; Heertje 1977, p. 173-4).

Total Factor Productivity, Technological Change and the Theory of Index Numbers

In recent years, the empirical analysis of production has changed its focus from explicit production function analysis to the application of total factor productivity (TFP) indices. Total factor productivity is often defined as a ratio of output to the aggregate of all factor inputs. If an aggregate index of inputs is defined as $F_t = g(x)$, where x is the input vector, total factor productivity (A_t) can be measured as the ratio

$$A_t = Q_t/F_t = Q_t/g(x). \tag{14}$$

From this equation two important conclusions can be derived. First, total factor productivity and technological change are similar concepts, because both measure that part of the output growth that cannot be accounted for by the factors of production. Second, a productivity index always implies the existence of a production function and vice versa (Diewert 1976). The implicit production function underlying the measure A_t can be expressed as

$$Q_t = P_t F_t = P_t g(x). \tag{15}$$

One of the main problems in the index approach is, how should the inputs be arranged, or in other words, what form should the (implicit) production function take. In order to be consistent, factors of production should be aggregated in such a way that would correspond to the "factual" production function

$$Q_t = f(x). \tag{16}$$

TFP index approach does not therefore free us from the choice of the production function, even if the precise form of the function does not necessarily have to be estimated directly. For example, application of Kendrick's arithmetic index (1961) implies the assumption that the "factual" production function is of CES-type (Kendrick & Sato 1963). It is evident that even if the inputs were measured properly and the weighting (index number) problem were solved, the validity of TFP measures depends greatly on how well the underlying economic theory describes the actual production relationships.

Difficulties involved in the productivity measurement have been significantly reduced by the recent developments in the index number theory and by the introduction of flexible functional forms. The modern theory of total productivity measurement is based on the explicit recognition of the connection between the theory of production and the application of the Divisia index principle (Diewert 1976, 1980, p. 443-52). Given certain conditions[3] production function can take the special form

$$Q(t) = A(t)f(x(t)) \tag{17}$$

where the multiplicative factor A(t) measures cumulatively the shifts in the production function over time (Solow 1957; Jorgenson & Griliches 1967; Diewert 1980, p. 443). If one takes the total derivative of Equation (17), and divides it by Q(t), one obtains the following equation

$$\frac{\dot{Q}(t)}{Q(t)} = \frac{\dot{A}(t)}{A(t)} + A(t)\Sigma\frac{\delta f(x(t))}{\delta x_i}\frac{\dot{x}_i(t)}{Q(t)} \tag{18}$$

where dots indicate time derivatives. Then, if inputs are being paid the value of their marginal products $(\delta f/\delta x_i)=p_i$), TFP growth can be expressed as the difference between the

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[3]The production function should be linearly homogeneous, concave and nondecreasing, and it should exhibit neutral technological change and constant returns to scale. Cost minimization is also assumed.

rate of change of output and weighted (average) rates of changes in inputs:

$$\frac{\dot{A}(t)}{A(t)} = \frac{\dot{Q}(t)}{Q(t)} - \Sigma w_i(t)\frac{\dot{x}_i(t)}{x_i(t)} \tag{19}$$

where the weights w_i are relative cost shares ($w_i = p_i x_i / Q$) at given points of time. Note that this Divisia index defines the continuous rate of total factor productivity change, but because data are available only in discrete form, Equation (19) must be approximated using a discrete index number formula.[4] Diewert (1976) has shown that if a particular form is assumed for the production function, it is possible to construct an exact discrete index of productivity change. A quantity index Q is defined to be exact for the given functional form f, if the ratios of the outputs between any two periods are equal to the index of inputs:

$$f(x_1)/f(x_0) = Q(p_0, p_1; x_0, x_1). \tag{20}$$

When measuring total factor productivity, one should choose a discrete index that is exact for the underlying production function. Because the true functional form of the production function is generally not known, one should choose from the set of all exact index numbers an index number that is exact for a flexible production function capable of providing a second-order approximation to an arbitrary twice differentiable linearly homogeneous function. Index numbers sharing this property are called superlative, because they

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[4]Given continuous data Equation 19 could be integrated to achieve the usual interval index.

are capable of providing a good approximation to any well-behaved function (Diewert 1976). An index number that approximates a superlative index to the second order is termed pseudosuperlative (Diewert 1978).

Diewert (1976) has shown, for example, that the only exact index for the translog production function is Törnqvist's (1936) discrete approximation of the continuous Divisia index. In Törnqvist's quantity index the relative changes of inputs from one period to the next are indicated by log-changes $(\ln x_1 - \ln x_0) = \ln(x_1/x_0)$, and they are weighted by the average of income (cost) shares of the input in the two adjacent periods. The relative changes in total factor productivity (A) can then be written:

$$A = \ln(A_1 - A_0) = \ln(Q_{1i}/Q_{0i}) - 0.5\Sigma[(w_{1i}/w_{0i})\ln(x_{1i}/x_{0i})] \quad (21)$$

in which Q represents output, x_i's are inputs, and w_i is the share of the ith input in total costs at a given time. Because the Törnqvist index is exact for the translog function, it is therefore also superlative.

Changes in total factor productivity can be measured with several alternative exact index formulas each of them implying a unique production function. The Vartia I quantity index is exact for the CD-function, but it has also been shown to be a pseudosuperlative index (Vartia 1976; Diewert 1978). The Vartia II index is consistent only with a CES-function (Vartia 1976; Sato 1976; Lau 1979). Fisher's index number, which employs a geometric average of the weights from both periods in a binary comparison,[5] has been shown to be a superlative index number formula (Diewert 1976). Paasche's fixed weight index, on the other hand, is exact only for the Leontief input-output production function.

TFP change with Vartia II index can be measured in the following way:

$$A = \ln(Q_1/Q_0) - \Sigma\frac{L(w_{1i},w_{0i})}{\Sigma L(w_{1i},w_{0i})}\ln(x_{1i}/x_{0i}) \qquad (22)$$

in which L denotes the logarithmic mean function introduced by Vartia (1974).[6] Note that the application of TFP indices in growth accounting allows not only the estimation of the role of total factor productivity or technological change in the growth, but also the relative contributions of all factors of production can be quantified. This is evident, because the growth of output is defined to be equal to the weighted sum of total factor productivity change and the changes in the use of individual factors of production.

In the above, several economically relevant index number formulas were briefly presented. The basic "rule" for choosing the index for empirical research is to base the choice on the consistency between the index number and the underlying production function. Because the form of the "true" production function is generally not known, and if no

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[5]That is, the geometric average of Paasche and Laspeyres weights.

[6]The logarithmic mean function is defined by $L(a,b) = (a-b)/(\ln a-\ln b)$ for $a \neq b$ and $L(a,a)=a$

attempt is made to estimate the function, it is recommended that superlative index number formulas should be used, because they are exact for flexible functional forms. The choice of the appropriate index is also made easier by the knowledge that all known superlative indices approximate each other to the second order for small changes in prices and quantities (Diewert 1978). Moreover, if weighting is based on the chain principle rather than on a fixed base, it has been demonstrated that all superlative, pseudosuperlative, Paasche and Laspeyres index numbers should coincide quite closely, the degree of coincidence being somewhat greater for the superlative and pseudosuperlative indices (Diewert 1978).

III ALTERNATIVE APPROACHES IN MEASURING CONTRIBUTIONS TO GROWTH

Production Function Approach

The contributions of individual factors of production to the output have traditionally been estimated by production functions and employing alternative regression methods. In a time series analysis it has been common to analyze production relationships with a two-factor (L, K) Cobb-Douglas production function in which technological change is represented by an exponential time trend (e.g., Tinbergen 1942; Niitamo 1958; Brown 1966; Åberg 1969, 1981, 1984; Salonen 1981). The CD-function is generally written in a multiplicative form to allow linear econometric estimation:[7]

$$Q = AL^aK^be^{gt} \quad (23)$$

and after taking logarithms

$$\ln(Q) = c + a\ln(L) + b\ln(K) + gt \quad (24)$$

where g represents the rate of disembodied neutral technological change, a and b represent output elasticities, and c=ln(A). Under perfect competition, the sum of a and b measures returns to scale. Neutral technological change can also manifest itself in the elasticity of scale, if a and b change in the same ratio. In the case of nonneutral technological change, the ratio of output elasticities

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[7]The error terms are not written here. If the error term is specified additively, computationally more difficult nonlinear estimation methods have to be used.

changes. If the sum of output elasticities is restricted to one, the effect of economies of scale is included in the estimate of technological change (g). In a time series analysis, it is practically impossible to distinguish effects of neutral technological change and returns to scale from each other (Sato 1980).

The CD-function can also be estimated in an intensive form relating output per man-hour to the capital-labor ratio:

$$\ln(Q/L) = c + b\ln(K/L) + gt. \quad (25)$$

This equation can serve to answer how much of the increase in output per man-hour is due to technological change and how much to an increase in capital deepening.

The models discussed above are based on the assumption that technological change is disembodied, but CD-functions have also been very popular in attempts to assess the role of embodied technological change in the growth process. These types of models have been applied quite extensively (e.g., Solow 1960, 1962; Nelson 1964; Intriligator 1965; Wickens 1970; You 1976), but results have been inconclusive. It seems that when more realistic models allowing simultaneously both disembodied and embodied technological change and embodiment of technological change both in labor and capital, the validity of the parameter estimates and the observed relationships become more dubious (Heertje 1977, p. 199).

The CD-production function's popularity in empirical research work is based mainly on its simple functional form, enabling the use of the ordinary least squares method, and on the general consistency of the results with some a priori notions of established economic theory. The most serious drawbacks of the CD-function are the assumptions of unitary elasticity of substitution between factors of production and of a strictly linear expansion path. These shortcomings become more obvious when one considers more than two factors of production, because these assumptions must hold for each and every pair of inputs.

The CD-function does not also allow one to study non-neutral technological change because Hicks-neutrality is assumed initially. The analysis of technological change in the growth process is also made somewhat ambiguous by the fact that technological change can change one or more of the coefficients in the CD-function (Brown 1966, p. 38-42; Heertje 1977, p. 126). From the point of view of this study's objectives, these drawbacks are not as serious as they may seem compared to the advantages of the CD-function. However, it may be concluded that for more detailed and realistic studies on the structure of the production and of technological change, some other type of production function must be used.

In the CD production function, the elasticity of substitution is compelled to take on a value of unity. The extent to which capital and labor, or any pair of inputs, can be substituted for each other is, however, an empirical question. The CES-production function - which together with the CD-function has dominated empirical work - allows σ to be estimated empirically; σ is constant but it can take on any value (Arrow et al. 1961)[8]

$$Q = \mu[\delta K^{-\alpha} + (1-\delta)L^{-\alpha}]^{-v/\alpha}. \quad (26)$$

Most of the CES-applications have been concerned mainly with the estimation of the elasticity of substitution and its effects on the relative income shares, but the CES-function is also applicable in the analysis of the role of inputs and technological change in the growth of output. Futhermore, the CES-function allows not only the estimation of the rate of neutral technological change, but also its bias can be studied under given conditions. Hicks-neutral technological change is reflected in the coefficient μ, or it may change the value of the returns to scale parameter v. Non-neutral technological change can affect the elasticity of substitution or the capital intensity parameter δ (see Brown 1966, p. 54-59).

The CES-function can be written and estimated in several alternative ways (see Nadiri 1970, p. 1151-6; Thursby 1980). For example, it may be estimated directly using nonlinear least squares regression methods, or indirectly by utilizing

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[8]Symbols are explained on p. 11.

the relationship between the average productivity of labor and the wage rate:

$$\ln(Q/L) = \ln(c) + b\ln(w) + gt. \tag{27}$$

From the point of view of this study, the type of CES-function allowing the estimation of the rate of technological change, and distinguishing variations in the efficiency of capital and labor over time is of most interest. Equation (26) can be written in a factor augmenting form with a trend factor t representing technological change (assuming constant returns to scale):

$$Q = [(a(t)L)^{-\alpha} + (b(t)K)^{-\alpha}]^{-1/\alpha} \tag{28}$$

Before statistical estimation is attempted, the type of factor augmentation needs to be specified to avoid the Diamond and McFadden "impossibility" theorem, which states that variations in individual efficiencies of inputs and σ cannot be separately identified (Nerlove 1967, p. 92-98). A common specification is to assume that factor augmentation occurs at a constant exponential rate ($a(t) = a_0e^{gt}$, $b(t) = b_0e^{gt}$). This type of models have been estimated, e.g., by David & van der Klundert (1965), Ferguson & Moroney (1969) and Kalt (1978). In this study a factor augmenting CES-type function allowing nonneutral technological change will be applied implicitly.

The main advantage of the CES-production function is its generality and flexibility compared to the CD-function. On the other hand, it has also several limitations. The estimation of the CES-function is relatively difficult, and the empirical evidence seems to indicate that its parameters are highly sensitive to slight changes in the data, measurement of the variables, and the methods of estimation (Nadiri 1970, p. 1151). This was proved to be true also in the case of the Finnish forest industries (Simula 1979, 1983). Another limitation of the CES-function is that it is difficult to apply in the case of multiple factors of production (n>2). Also, the analysis of technological change is not unambiguous, because technological change can be manifested in one or more of the coefficients (Brown 1966, p. 59-61).

Some of the limitations of the CD and CES production functions can be handled with alternative functional forms. The variable elasticity of substitution function which is a generalization of the CES-function, and the translog production function, which is a generalization of the CD-function, both allow for different σ at different input-input and input-output ranges (Intriligator 1978, p. 280). The latter function can also readily handle the problem of pairwise differing elasticities of substitution for a set of several inputs. Empirical applications of the variable elasticity of substitution production functions seem to, however, often produce results that are statistically insignificant and sometimes even economically meaningless.

Application of the widely used translog production function (or its dual) is also fraught with some difficulties. First, it is theoretically somewhat ambiguous because of its several possible interpretations (see p. 12-13). Second, the problems encountered in obtaining reliable estimates of the parameters of the function are difficult to solve. Third, in order to take advantage of the function's flexibility, one encounters numerous computational difficulties and additional data requirements (Boisvert 1982, p. 31-35). In this study the translog production function will be applied - not explicitly but implicitly in a total factor productivity index as a second-order approximation to an unknown function. In this type of application most of the criticisms raised against the translog production function do not apply because the function is not estimated statistically.

In general, the gain of realism from alternative production forms like, e.g., translog, vintage or frontier production functions, comes at the cost of additional - sometimes excessive - data requirements and computational difficulties. These complications often make the use of simpler and more manageable functions advantageous compared to more sophisticated and complex models.

Index Theoretical Approach

Total factor productivity indices have been widely used in assessing the contributions of individual factors of production to the growth of output. All the models based on this approach share the same logic: the change in output can be attributed to increasing factor inputs by weighting different inputs in some "appropriate" way, while the change in output due to increase in total factor productivity can be obtained by subtracting this aggregate input component from the actual increase in output(s). Direct estimation of a production function is unnecessary, even if every productivity index implies a particular production function. All measures of TFP are more or less based on the neoclassical framework: weighting is based on the equality of factor prices and marginal productivities, production technology exhibits constant returns to scale, etc.

In the measurement of total factor productivity, two major approaches can be distinguished, which could be called the "no-quality-change" approach and the "explain-everything" approach using Tolley's (1961) terminology (see Denison 1961).

"No-Quality-Change" Approach

In the "no-quality-change" approach only conventional factors of production are measured; i.e., inputs are not adjusted for changes in quality. The remaining residual output that cannot be explained by the increase in conventional inputs is called total factor productivity or technological change. For example, the familiar arithmetic (Abramovitz 1956, Kendrick1961) and geometric (Solow 1957) index applications belong to this category. Abramovitz's "residual index" is expressed as

$$dA/A = dQ/Q - a_0 dL/L - b_0 dK/K \tag{29}$$

where a_0 and b_0 are fixed weights. Kendrick measures total factor productivity using a distribution equation derived from a homogeneous production function and the Euler condition:

$$dA/A = \frac{K_1/Q_0}{(wL_1+rK_1)/(wL_0+rK_0)} - 1 \tag{30}$$

where the weights w (wage rate) and r (the rate of return on capital) are allowed to change from period to period. The geometric index applied by Solow is based on a linear homogeneous production function with constant returns to scale and disembodied technological change:

$$dA/A = dQ/Q - \alpha(dL/L) - \beta(dK/K) \tag{31}$$

where α and β are the shares of labor and capital.

The validity of these indices depends greatly on the way of measuring inputs and outputs and on the weighting scheme used for their aggregation. The derivation and application of these models require also several simplifying assumptions which don't necessarily apply in reality. For example, Abramovitz's index is based on the unrealistic assumption that marginal productivities are not affected by a change in capital-labor ratio (Lave 1966, p. 8). Solow's index, on the other hand, is based on the assumption that the underlying production function is of Cobb-Douglas type, while Kendrick's index implies a CES-function (Kendrick & Sato 1963, Lave 1966, p. 7-13).

Common to all these indices is also the implicit assumption that only capital and labor are important factors of production; material inputs and energy are excluded. In recent years, it has become more common to measure TFP change in gross-output framework applying, e.g., the Törnqvist index presented earlier in this study. The development in the economic index number theory has also led to the use of more flexible indices concerning the underlying production function which have replaced the "traditional" indices in empirical work (see Chapter II). Also these indices could be applied without making any quality adjustments and measuring output with value added, but most often they are applied in a more "ambitious" way.

"Explain-Everything" Approach

All the indices where inputs are measured conventionally share the same major limitation: they cannot be used to "explain" economic growth, because the resulting measure of technological or total factor productivity change includes all the possible factors that could shift the production function, e.g., economies of scale, improved quality of labor and capital, more efficient management, measurement errors, etc. Therefore, even if the contribution of TFP to the growth can be estimated, the sources of that growth - which are of most interest to policy makers and firm managers - remain unknown. Dissatisfaction with models that left much of the growth unexplained[9] led to the new approach that tried to narrow the residual, and thus reduce our ignorance concerning sources of economic growth.

The works of Denison (1962, 1967, 1974) and Jorgenson with several colloborators - Griliches (1967), Christensen (1969), Gollop (1977), and Fraumeni (1980) - are the most important studies that employ this approach. Denison uses the production function (similar to CD) as an organizing device or accounting format to decompose the residual into economies of scale, improvements in resource allocation, and finally advances of knowledge (Nadiri 1970, p. 1165-6). Denison sought to narrow the residual by adjusting labor for changes in quality due mainly to more education, changes in the composition by sex and age and shorter working hours. After quantifying the contributions to growth of all major factors, he was left with a "final residual", which he called advances in knowledge. The underlying relation between growth of output and various explanatory factors in Denison's model is:

$$dQ = \mu(\Sigma\alpha_i dx_i + \Sigma y_j + J) \qquad (32)$$

where dQ is the growth rate of output, μ is a measure of economies of scale, α_i represents the income share of the factor represented by dx_i, y_{ij} refers to the growth rates of

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[9]For example, in Solow's (1957) study the residual amounted to almost 90 percent.

various disequilibrium factors, and J is the final residual (Nadiri 1970, p. 1166).

Because Denison adjusted only labor for changes in quality and left capital unadjusted, his approach could be called a "partial-quality-change" approach. Jorgenson and Griliches (1967), on the other hand, tried to explain away the very existence of total factor productivity by adjusting total output and input data for errors of aggregation, errors in investment goods prices, and errors of utilization of capital and labor. The rate of TFP growth is calculated using Törnqvist's discrete approximation of the Divisia index and assuming producer's equilibrium, constant returns to scale and perfect competition:

$$\dot{A}/A = \dot{Q}/Q - \dot{x}/x = \Sigma w_i \frac{Q_1}{Q_0} - \Sigma w_j \frac{X_1}{X_0} \qquad (33)$$

where w_i is the relative share of the value of the ith output in the value of total output, and w_j is the value of the jth input in the value of total input. Maybe the most significant difference between this approach and Denison's approach is in the measurement of capital: Denison uses capital stocks (excluding depreciation) while Jorgenson & Griliches measure capital input by flows of capital services.

Attempts to reduce the magnitude of the residual or explain away its existence are necessary to obtain a deeper understanding of the growth process, and to identify the major variables for decision makers. Unfortunately, this approach can be time consuming and very expensive because of its great demand for data. In fact, the lack of data often precludes the application of this type of approach. The results are also sensitive to the classification of the sources growth and the assumed causal relationships, and especially to the choice of conventions for measuring real factor inputs (Nadiri 1970, p. 1167-9).

In summary, given certain assumptions TFP indices allow the estimation of the contributions of various factors to the growth of output without explicitly specifying the form of the aggregate production function. They are also easy to apply in the case of multiple factors of production. On the other hand, they cannot be used for testing the associated hypotheses, e.g., the type of the production function or technological change, and moreover, the parameters of the production function reflecting, e.g., changes in the individual efficiencies of inputs that underlie the total productivity change, are left unknown.

In this study both the production function and index theoretical approach are used. Before the models to be applied in this study are presented, an important question concerning the proper way of measuring the output is briefly discussed.

Value Added vs. Gross Output Measurement

Most analyses of productivity growth and technological change have measured output in terms of real value added (real gross output less real intermediate inputs). In such studies output (Q_{va}) is a function only of labor, capital and time:

$$Q_{va} = f(L,K,t) \tag{34}$$

On the economy level, working with a value added model of production is correct when dealing with a closed economy, or with an open economy where imports are considered as final goods or as being separable from primary factors of production (Denny & May 1977). A value added technology at the economy-wide level also seems intuitively a reasonable concept, because when the production accounts of all industries are aggregated, inter-industry flows of intermediate inputs cancel out (no fear of double counting).

At the subsector or industry level the relevancy of value added as an output measure can, however, be strongly questioned. In 1970's the restrictions of the value added approach were formally presented, and attempts were made to test the existence of a real value added function (Sims 1969, Arrow 1972, Berndt & Wood 1975, Humprey & Moroney 1975, Denny & May 1977, Bruno 1978).

Sims (1969) and Arrow (1972) demonstrated that <u>at the industry level</u> (real) value added is an economically meaningful concept only given weak separability between the primary inputs (L,K) and intermediate inputs. A production function is defined to be weakly separable with respect to the grouping of factors of production, if the marginal rate of substitution between pairs of factors in the separated group are independent of the levels of factors outside that group, or alternatively, if the Allen partial elasticities of substitution between a factor in the separable group and some factors outside the group are equal for all factors in the group (Berndt & Christensen 1973).

Thus, only when the marginal rate of substitition between capital and labor is independent of the quantity of intermediate inputs M (including energy), can value added (Q_{va}) be separated from the original function

$$Q_{gv} = F(L,K,M,t) \tag{35}$$

and it can be written as a sub-function of F:

$$Q_{gv} = F(f(L,K,t),M) \tag{36}$$

$$Q_{va} = f(L,K,t) \tag{37}$$

In the value added model of production quite strict assumptions have to be made on the nature of the production process that reduce the generality of the model and often cause bias in the results. The value added approach at the subsector or industry level has also been criticized for implying irrational producer behavior because producers are not allowed to equate the prices of intermediate inputs to the respective values of marginal products as required by the profit maximization assumption. This again creates restrictions on the production technology in terms of substitution possibilities.

Moreover, from Equation 37 it can be seen that technological change is allowed to affect output only through function f, which leaves no room for intermediate inputs as a source of productivity growth or decline (see Hulten 1978).

In the case of forest industries these restrictions mean that producers would not (necessarily) respond to changing relative stumpage or energy prices by substitution or increasing the efficiency of wood utilization (see Bengston & Strees 1986). It can also be asked how relevant it is to describe, e.g., lumber production with a production function where roundwood is not entered as an input.

The calculation of real value added is also problematic. In many countries (not in the U.S. or Finland), the method used to calculate real value added is the double deflation procedure. This requires price and quantity data on intermediate inputs at a disaggregated level, or reliable deflators (at purchaser's prices). Double deflation is also likely to produce biased real value added measures unless one of the following conditions is satisfied (Bruno 1978):

1) The volume ratio of intermediate inputs to outputs remains constant (regardless of the price of intermediate inputs)

2) The relative price of intermediate input (P_m/P_{Qgv}) remains constant

3) Production technology is separable with respect to primary inputs and intermediate inputs

The Divisia quantity index of sectoral value added can then be derived from Equation 36 by logarithmic differentiation with respect to time and assuming constant returns to scale, perfect competition and producer's equilibrium:

$$d\ln(Q_{va}/dt) = (d\ln(Q_{gv}/dt) - w_m(d\ln M/dt))/w_{va}, \qquad (38)$$

where w_m and w_{va} are value shares of intermediate inputs and value added respectively (Sims 1969).

As a result of the difficulties involved in the application of the value added approach, it can be concluded that if possible, it is preferable to use gross output measures for industry studies. Value added measures can be reliably used only if certain conditions are met, and even if these conditions were satisfied, the problem of calculating the <u>real</u> value added would still remain, because there is not any observable price for value added.

In this study the real intermediate input, and consequently real value added can be calculated only in the pulp and paper industries. This allows the comparison of estimates of technological change with alternative output measures. The existence of the value added production function is not, however, <u>econometrically</u> tested because it is very probable that the result of testing will be more dependent on the way of measuring variables and the quality of data than on the actual form of the production technology. The lack of suitable data precludes similar kind of analysis for the mechanical forest industries.

IV MODELS AND VARIABLES USED

Models

Four basic models are applied to study the contributions of various factors to the growth of output in the Finnish and U.S. forest industries. The first two models are simple production functions that are estimated by the ordinary least squares method. The third model is based on a combination of production function estimation and economic index number theory. The first three models are estimated in a value added framework. The fourth model - that is perhaps the most interesting - represents the total factor productivity approach where production is measured by gross output; raw materials and energy are included as separate inputs.

Cobb-Douglas Production Function

The Cobb-Douglas (CD) production function is estimated both in the unrestricted form (Equation 38), where the sum of output elasticities is not restricted to one, and in the strictly neoclassical form (Equations 39 and 40):

$$d\ln(Q) = g + a d\ln(L) + b d\ln(K) \tag{38}$$

$$d\ln(Q/L) = g + b d\ln(K/L) \tag{39}$$

$$d\ln(Q/K) = g + a d\ln(L/K) \tag{40}$$

where g represents the rate of disembodied neutral technical change, a and b stand for output elasticities, and d is a difference operator.

Model 38 will be estimated to test the nature and extent of returns to scale. A priori, one could expect the rate of technological change to be smaller in Equation 38, because in Equations 39 and 40 technological change term g includes both the "pure" technological change and returns to scale effects. Equation 39 is the often-applied labor-intensive specification of the Cobb-Douglas production function, and correspondingly Equation 40 could be called the capital-intensive formulation. From these equations the contributions of capital-deepening and technological change to the change in labor (capital) productivity can be easily calculated. Models 39 and 40 avoid the problem of multicollinearity making the interpretation of the results easier and more reliable.

Modified Cobb-Douglas Function

The measurement of capital is troubled with both theoretical and empirical problems that often reduce the reliability of production function estimations. Åberg (1984) has derived a CD-model that partly avoids the problems caused by the difficulties in the measurement of capital. In his model capital is measured indirectly by assuming that the real capital income is dependent on the utilized capital stock, and that the real return requirement on capital stays (statistically) constant during the study period. In that case, the real capital income can be used as a proxy for capital services. The model to be estimated is:

$$d\ln(Q/L) = g + b d\ln(s) \tag{41}$$

where Q/L is average labor productivity, b is capital elasticity, s is R/L, and g represents the rate of technological change. R is the real capital income, and given certain conditions it can be used to measure capital services (see Appendix B).

The relative contributions of technological change and capital deepening (s) to the growth (decrease) in labor productivity can be computed (mechanically) by dividing both the estimate of g and the average capital intensity factor s multiplied by capital elasticity by the average relative change in labor productivity.

To gain knowledge about a possible change in the rate of technological change during the study period, and to make the assumption about a constant real return requirement on capital more realistic, the following model with a dummy (D) will also be estimated:

$$d\ln(Q/L) = g_i + b d\ln(s) \tag{42}$$

where $g_i = g + \pi D_i$ (D = 0,when $i \leq 1970$, and 1 when $i > 1970$. The year 1970 was chosen because it divides the study period into two subperiods of equal length.

Compared to the CD-models, the model derived by Åberg can be considered as an improvement, if capital data are of poor quality, or if one wants to measure capital services, but relevant data on capital are missing. The derivation of this model and its estimation require however some restrictive assumptions, of which the assumption of constant real return on capital is the most serious one. A detailed derivation of this model and its underlying assumptions are presented in Appendix B.

Factor Augmenting CES Production Function

The estimation of a factor augmenting type of production function gives more detailed information about factors underlying TFP change. In the factor augmenting formulation with two factors of production $Q = f(a(t)L, b(t)K)$, $a(t)$ and $b(t)$ stand for the input augmenting factors or the "efficiencies" of labor and capital, respectively. The problem is that when technological change is factor augmenting, estimates for the rates of efficiencies of labor and capital cannot be uniquely determined unless the form of the production function is known a priori (Diamond & McFadden 1966, Sato & Beckman 1968).

When differentiating the above equation with respect to time and assuming constant returns to scale we get

$$\dot{Q} = \alpha(\dot{L} + \dot{a}) + \beta(\dot{K} + \dot{b}) \tag{43}$$

where $\alpha = (\delta f/\delta L)(L/Q)$, $\beta = (1-\alpha) = (\delta f/\delta K)(K/Q)$, and the dot refers to rate of change over time. If we write $x = L/K$ then

$$(Q/\dot{L}) = \alpha\dot{a} + \beta\dot{b} - \beta\dot{x} \tag{44}$$

Estimation of the efficiencies of capital and labor from Equation (44) is not possible because we have two unknowns and one equation. Sato and Beckman (1968) solved this problem by deriving the following two equations using the definition of the elasticity of substitution (σ)

$$\dot{w} = \dot{a} - (\beta/\sigma)(\dot{a} - \dot{b} + \dot{x}) \tag{45}$$

$$\dot{r} = \dot{b} + (\alpha/\sigma)(\dot{a} - \dot{b} + \dot{x}) \tag{46}$$

where r and w stand for input prices of capital and labor. By solving Equations 45 and 46, and using Equation 44, we get the fundamental relationships for estimating $\dot{a}$ and $\dot{b}$:

$$\dot{a} = (\sigma\dot{w} - (\dot{Q/L})/(\sigma-1), \qquad \sigma \neq 1 \tag{47}$$

$$\dot{b} = (\sigma\dot{r} - (\dot{Q/K})/(\sigma-1), \qquad \sigma \neq 1 \tag{48}$$

To estimate a and b we have to assume that the underlying production function is a CES function, i.e., σ is constant. Elasticity of substitution is solved by fitting regression Equations 45 and 46 assuming at this point that a(t) = b(t). The coefficients of $\dot{x}$ in the estimated equations are respectively equal to the averages of $-\beta/\sigma$ and α/σ, from which we get two estimates for σ. The best estimate of σ is then used in Equations 47 and 48 to estimate labor and capital efficiencies.

The index of technological change or productivity can be computed by aggregating the resulting labor and and capital efficiencies by appropriate weights. Because the underlying production function is a CES function, the theoretically valid index is the Vartia II index, because it is exact for the CES function (see p. 21).

The stability of σ is tested with a dummy model. Also, sensitivity analysis is carried out to study the effects of alternative sizes of σ on the labor and capital efficiencies and on the TFP index.

Translog Total Factor Productivity Index

The rate of TFP change is measured by Törnqvist's discrete approximation of the Divisia index that is exact for the translog production function (see p. 20):

$$TFP = \ln(Q_1/Q_0) - 0.5\Sigma[(w_{1i}/w_{0i})\ln(x_{1i}/x_{0i})] \qquad (49)$$

TFP change is thus calculated by subtracting a Törnqvist index of annual relative changes in labor, capital, material inputs and energy from the annual relative change in the real gross output. Logarithmic changes in inputs are weighted by the arithmetic averages of respective income (cost) shares between two adjacent years.

TFP index is first computed without any quality adjustments, i.e., the components of the capital stock and labor are aggregated directly. The resulting TFP measure includes then all the effects that could shift the production function. To account for at least part of the unexplained output growth, i.e., to reduce the size of the residual, capital and labor are adjusted for changes in composition.

Capital stocks are aggregated by asset type using implicit rental prices as weights (Jorgenson & Griliches 1967). The derivation of rental prices and capital services is explained on p. 53-54. Labor input is adjusted by weighting production and nonproduction worker hours by their respective cost in the total labor compensation.

In both adjustments the Törnqvist index is used in the aggregation. The differences between weighted and unweighted capital and labor measures can be regarded as proxies for quality changes in capital and labor.

Estimation of Models

The production functions are estimated by the ordinary least squares method. The goodness of the models is evaluated using economic theory, goodness of fit, and significance of parameter estimates as criteria.

The goodness of fit of an equation is measured by multiple correlation coefficient adjusted by degrees of freedom, $\bar{R}^2$ (e.g., Pindyck & Rubinfeld 1981, p. 79-81). The F-statistic is used in the multiple regression models to test the significance of the $\bar{R}^2$ statistic. The significance of individual parameter estimates is measured by the the t-statistic. In the empirical estimates presented below t-values are reported in the parentheses below the parameter estimates.

Multicollinearity is often a serious problem in time series analysis. Multicollinearity is present when two or more variables are correlated with each other, which makes it difficult to obtain precise estimates of the separate effects of the variables involved (Pindyck & Rubinfeld 1981, p. 88). The problem is to decide when multicollinearity is harmful. In this study multicollinearity is deemed harmful, if the simple correlation between two explanatory variables, is greater than $\bar{R}^2$ (Farrar & Glauber 1967).

Another common problem in time series analysis is autocorrelation, i.e., correlation between stochastic disturbance terms corresponding to different observations. Autocorrelation does not affect unbiasedness or consistency of the ordinary least squares regression estimators, but it makes $\bar{R}^2$ too high, and more important, it leads to an estimate of the error variance that is smaller than the true error variance. Here autocorrelation is tested by the Durbin-Watson (D-W) statistic (see e.g., Intriligator 1978, p. 161-165). When present, regression models are corrected for autocorrelation using the Hildreth-Lu estimator.

Measurement of Variables and Sources of Data

The primary sources of quantity and cost data for inputs and outputs were Industrial Statistics published annually by Central Statistical Office of Finland, and the Censuses of Manufactures and Annual Survey of Manufactures (ASM's) for the U.S. Deflators were mainly obtained from the Statistical Yearbook of Finland and from the Handbook of Labor Statistics 1985, U.S. Department of Labor, Bureau of Labor Statistics. Other central sources of data were U.S. Timber Production, Trade, Consumption, and Price Statistics 1950-83 of the U.S. Department of Agriculture, and Statistics of Paper and

Paperboard issued by American Paper Institute, Inc. The central data are in Appendices C and D.[10]

Output in the production function models was measured by real value added. In Finland the real value added index is computed by the Central Statistical Office by assuming that the volume of value added changes at the same rate as real gross output. This implies an (unrealistic) assumption of constant relationship between real gross output and real intermediate inputs, which is likely to cause downward bias in the real value added index. The use of Palgrave's price index in the calculation of this index has also been shown to overestimate the price development and thus underestimate the volume of value added (see Parkkinen 1982, p. 56, 70-73).

For the U.S. forest industries the output index series calculated by Bureau of Labor Statistics was used for measuring real value added (Handbook of Labor Statistics 1985). Output of the industry "Structural Wood Members, N.E.C." had to be included in veneer and plywood production, because no separate output index for this industry existed. The error is not significant because of the small importance of the industry in question. The extent of bias in the BLS output series is not known, but most likely they are a considerably better approximation of the real value added

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[10]Complete data available by request from the Dept. of Social Economics of Forestry, Univ. of Helsinki, Unionink. 40B, 00170 Helsinki, Finland.

than the often used value added series deflated by corresponding wholesale price indices.

In the TFP analysis of the pulp and paper industry the measure of output was gross value of production in Finland, and the value of shipments plus changes in finished goods inventories in the U. S. Real gross output was obtained by deflating the output by corresponding producer price indices (PPI). For Finland, the PPI for the P & P industry was calculated using the knowledge that the value added volume index actually describes the development of real gross output. In the case of the United States, if the share of secondary products was greater than 5 percent, secondary products were deflated separately from the primary products.

The gross output measure for the P & P industry includes a significant amount of double counting in the Finnish statistics. For example, in 1981-1983 the value of output exclusive of such duplication was 73 percent of the reported gross output. For 1975-82 corrected output figures were provided by Indufor Ky (1986), but for the preceding years output had to be adjusted by subtracting the value of pulp used for own production. Similar kinds of adjustment had to be carried out for the cost of materials. No adjustment was made for the U.S. output figures because the amount of duplication in cost of materials and value of shipments was not so significant and because reliable annual data for such adjustments were not available.

The measure of labor input in both countries was total hours paid. In both countries, data on nonproduction worker hours are missing - in Finland for the period 1958-1973, and in the U.S. for the whole study period. For Finland nonproduction worker hours estimated by Simula (1979) were used to build up the total man-hour series. The American nonproduction workers were assumed to work 1,880 hours annually (Productivity Analysis in ... 1970, p. 14). In the production function models the production and nonproduction worker hours were aggregated directly, but in the TFP analysis also a share-weighted labor index was constructed to approximate quality change in the aggregate labor input. The total number of workers was used as an alternative labor input measure.

Labor input in both countries is most likely biased upwards, because labor is measured in terms of hours paid, and not in terms of hours worked, which is the correct measure of labor flow. According to a BLS study the ratio of hours worked to hours paid in 1982 was about 0.93 in the U.S. lumber and wood products industry and 0.89 in the paper industry (Monthly Labor Review 1984, p. 3-7). In Finland this ratio is most likely smaller. If the annual decreases (or increases) in this ratio were known, the effects on the rate of TFP change of these changes could be estimated by multiplying the percentage change in this ratio by labor's share of income. Data on the development of this ratio, however, are lacking. If there is no trend in the ratio hours worked to hours paid over the study period, results will not be affected.

Simula (1979, p. 102-3) has commented on other possible sources of bias in the labor input data for the Finnish forest industries. These errors are not likely to have a significant effect on the labor input index and productivity measures in the type of time series analysis used here.

The real wage rate was calculated by dividing total payroll including supplemental benefits by aggregate man-hours of employment, and then deflating these series with the consumer price index (CPI). For the Finnish forest industries supplemental benefits (indirect labor costs) were estimated for 1958-1973 using data from an unpublished study (Ennakkotietoja ETLA:n ... 1987). The data on indirect labor costs for 1974-1982 reported in the Industrial Statistics were slightly adjusted to make the total labor compensation series consistent for the whole period. Supplemental labor cost for the mechanical and P & P industry in the U.S. were calculated using supplemental labor cost shares (percent of wages and salaries in Lumber & Wood Products and Paper & Allied Products) derived from the National Income & Product Accounts of the United States, 1929-76, Statistical Tables, and from the July issues of the Survey of Current Business for subsequent years.

Capital was measured by the gross capital stock in constant prices in the production function models and partial productivity calculations and by capital services and gross capital stock in the TFP analysis. In Finland the current gross capital stock is measured as the total replacement value of buildings, machinery and equipment represented by the fire insurance values in the Industrial Statistics. Because these values are reported at the end of a year, average values of two adjacent years were used. Capital assets were deflated by respective wholesale price and construction cost indices. Because inventory data are not available for the whole study period inventories were excluded from the Finnish capital stock measures.

The quality of Finnish capital series is reduced by changes in capital valuation, and by the exclusion of working capital. It is also possible that fire insurance values don't represent pure gross capital stocks, but they are a mixture of gross and net capital (Koskenkylä 1979, p. 20, 27).

Fixed (gross) capital stock series in current and constant prices calculated by U. S. Department of Commerce, Office of Business Analysis, combined with stocks of inventories, were used to measure capital input for the U.S. forest industries. Capital assets were measured as annual averages as in the case of Finland. The Census provides information on the inventories and their composition for the census years. For the intermediate years only ASM data on the current value of inventories are available, so the composition for these years was estimated using the information from the census years. In the mechanical forest industry the current value of inventories was deflated by a weighted index consisting of the wholesale price index and the PPI for lumber and wood products. In the P & P industry the material component of the inventories was deflated by the implicit material price index derived in this study.

Capital services were assumed to be proportional to the average stock of capital. The annual quantity of capital input was computed as a translog index: the logarithmic annual changes in the individual assets were weighted by the arithmetic averages of respective implicit rental prices (user costs) between two years (Jorgenson & Griliches 1967). This weighting procedure is based on the neoclassical principle that inputs should be aggregated using weights that reflect their marginal products. The price of capital services for each asset i is defined by

$$p^i_{KS} = p_K(r + d^i - p^i_K) \qquad (50)$$

where p_K is the price of asset, p_K is real capital gains, r is the rate of return and d is the rate of depreciation computed by a declining balance formula. Depreciation was calculated on fixed assets by asset type assuming the following service lives: buildings and constructions, 40 years; and machinery and equipment, 15 years (Profitability, Productivity, and ... 1987).

The rate of return required in Equation 50 was solved by assuming that it is the same for each asset, and by setting the products of the rental prices and real capital stock equal to the capital income:

$$r = [CI - \Sigma K^i (p_K^i d^i - \dot{p}_K^i)]/\Sigma p_K^i \qquad (51)$$

where CI is nominal capital income (see e.g., Gollop & Jorgenson 1977). Capital services are also calculated without capital gains to test if the inclusion or exclusion of capital gains (losses) affects TFP measures.

The <u>real rate of return</u> was computed by dividing the real profit by real capital. Real profit was calculated in two alternative ways: 1) nominal gross profit (value added less total labor compensation) deflated by the CPI, and 2) value added and total labor compensation deflated separately by their own deflators.

The computation of the implicit rate of return in the user cost calculations and the two measures of the real rate of return all depend on the assumption of constant returns to scale. If increasing returns to scale exist these rates of return will be biased upwards.

A measure of <u>material input</u> in current and constant prices is essential when measuring productivity in a gross output framework, so considerable attention was given to the construction of the real material input index in both countries. Obtaining the nominal material input series was easy (except for the problem of double counting) because these data are available in the Industrial Statistics, Censuses of Manufactures and ASM's. The derivation of material input series in constant prices was a much more complex task, the most serious problems being lack of detailed price and quantity data and lack of reliable deflators at purchaser's prices. The detailed derivation of the real material input series for the Finnish and U.S. P & P industries is described in Appendix E.

The energy input includes purchased fuels and electric energy. For Finland, the total value (cost) and quantity data of purchased fuels, energy and steam are available in the Industrial Statistics. In Finland some of the steam and electricity generated by P & P mills is also included in these figures. Because energy data are not reported in a commensurable measure, conversion factors to gigajoules reported in the Industrial Statistics had to be used in building up the quantity index. For the years 1958-64 quantity data on purchased steam does not exist, so it was assumed that purchased unit steam consumption developed at the same rate with purchased unit electricity consumption. In 1982 the classification of energy inputs changed, so it was assumed that no change had taken place in purchased unit energy consumption between 1981 and 1982.

The resulting energy input series is biased upwards for two reasons: 1) The P & P industry sells forward a small part of the energy it has purchased, and 2) Because integrated pulp and paper mill complexes are not reported separately, some of the purchased energy reported in the Industrial Statistics is in fact bought from itself.

For the U.S. P & P industry, energy was measured in British thermal units (BTU's). Detailed quantity data were available for the census years and for 1972-82 (excl. 73-74). For those years when data on total purchased fuels and electric energy in BTU's didn't exist, quantities of distillate and residual fuel oil, coal, natural gas, etc. were converted to BTU's. For the intermediate years the quantity of energy in BTU's was estimated by first computing energy-output ratios for the census years, and then interpolating this ratio between these years.

Total energy cost data in a detailed level is reported in the different volumes of the Census of Manufactures and ASMs for most years. For 1959-62, 1964-66 and 1968-70 cost data had to be estimated using existing data for the SIC subindustries 2622 and 2661, and the detailed data from the census years.

V TRENDS IN THE USE OF FACTORS OF PRODUCTION AND THEIR PARTIAL PRODUCTIVITIES

Mechanical Forest Industry

Partial productivity ratios relate output to each major input when both outputs and inputs are measured in physical volumes or in constant prices. For the mechanical forest industry only labor and capital productivity ratios were computed; for the P & P industry also material and energy productivity measures were furnished. Measurement of variables is explained in Chapter IV.

Between 1958 and 1982 the output (real value added) of the Finnish mechanical forest industry increased at an average annual rate of 2.7 percent. There was strong growth early in the period and in the latter half of the 1970's (over 5 percent annually), but because of the setback caused by the "oil recession" in 1974-5, the production peak of 1973 was not exceeded until in 1980. In 1982 the production declined to the same level as in 1969.

Over the same period employee hours declined slightly and capital input increased almost fivefold (Figure 2). This development together with changes in output more than doubled labor productivity over the study period, but simultaneously capital productivity declined at an annual rate of 4.3 percent. The increase in labor productivity averaged 3.3 percent a year from 1958 to 1982, and even between 1971 and 1982 when output declined by an average of 0.9 percent a year, labor productivity grew annually 1.8 percent because employee hours decreased even faster than output. In 1975 labor productivity dropped to its lowest level since 1959, then increased by an average annual rate of 5.2 percent reaching the highest point in 1982 (Figure 3, Appendix F).

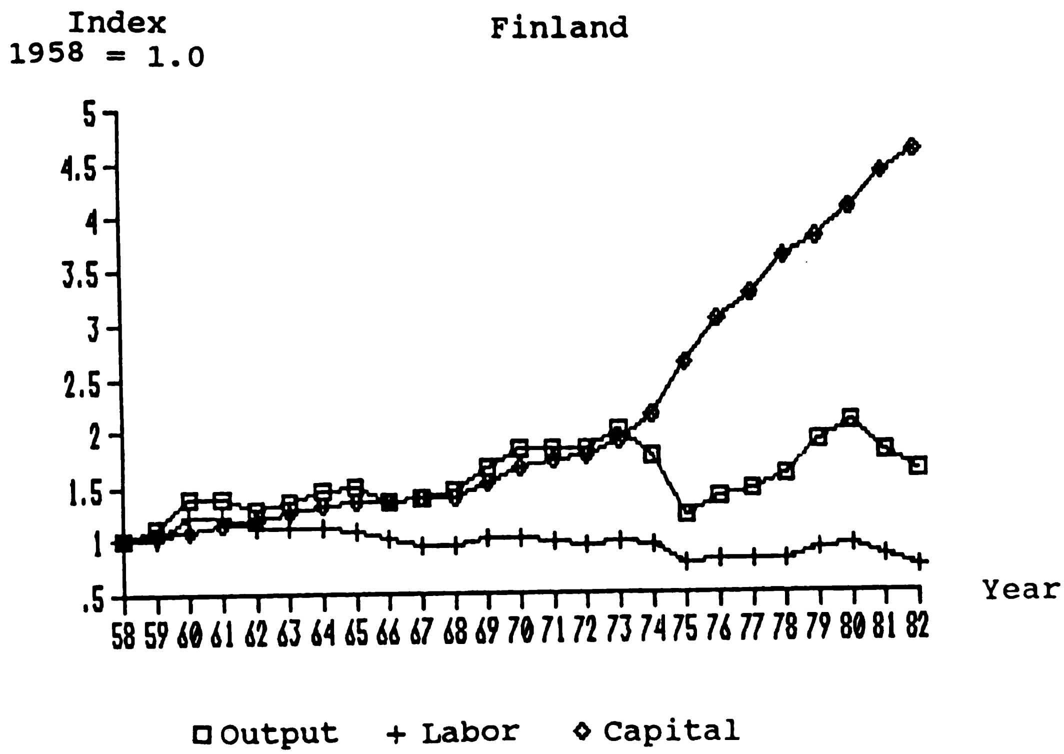

Figure 2. Output and Input Development in the Finnish Mechanical Forest Industry.

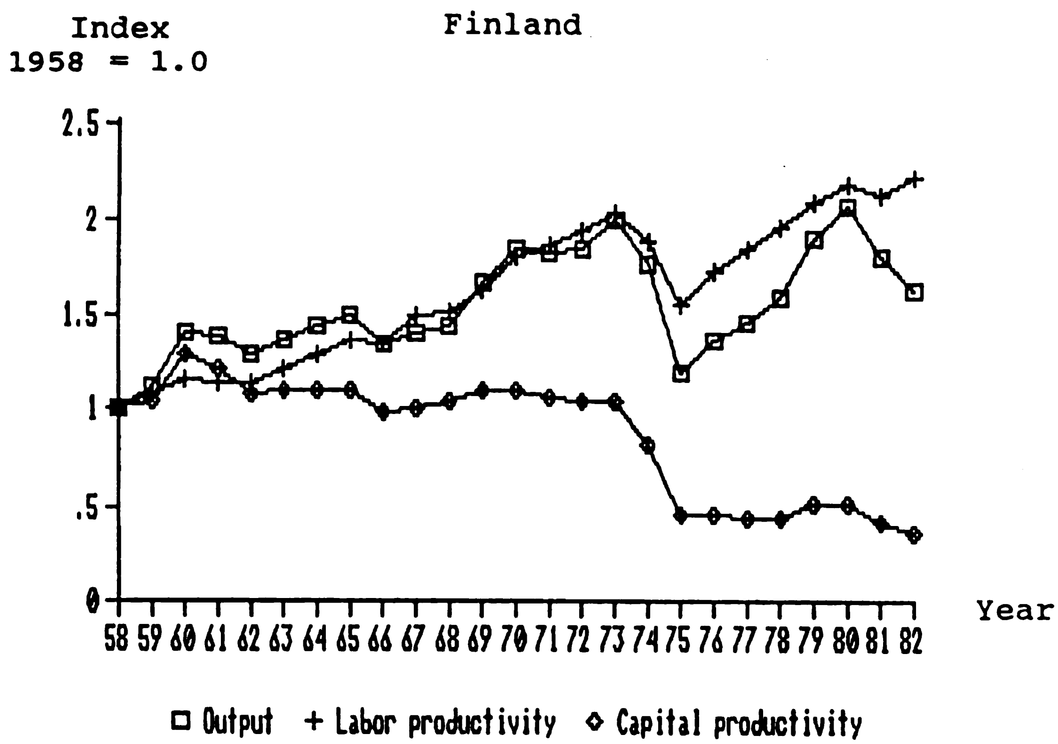

Figure 3. Labor and Capital Productivity in the Finnish Mechanical Forest Industry.

Output in the U.S. mechanical forest industry increased at less than half the rate of Finland's industry, averaging 1.4 percent a year in 1958-82. The biggest difference in the growth rates appeared after the oil crisis: between 1976 and 1982 annual output decreased very slightly while in the Finnish mechanical forest industry output grew at an average rate of 4.4 percent. Capital investment increased almost linearly, but at a significantly lower rate than in Finland. Employee hours have fluctuated together with changes in output, but the trend has been clearly downwards (Figure 4, Appendix F).

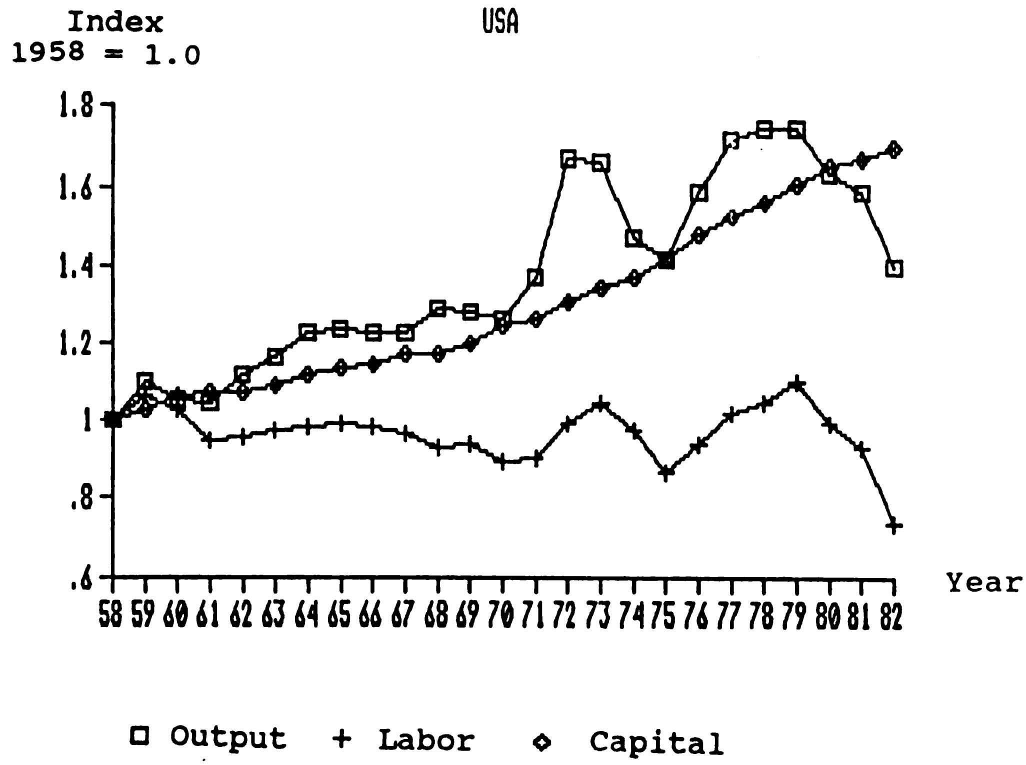

Figure 4. Output and Input Development in the U.S. Mechanical Forest Industry.

The productivity development in the U.S. mechanical forest industry is characterized by an increase in labor productivity (2.7 percent a year) and a slight decline in capital productivity (0.8 percent a year). The growth in labor productivity has been quite steady over the study period but the decline in capital productivity has been fastest at the end of the period (Figure 5, Appendix F).

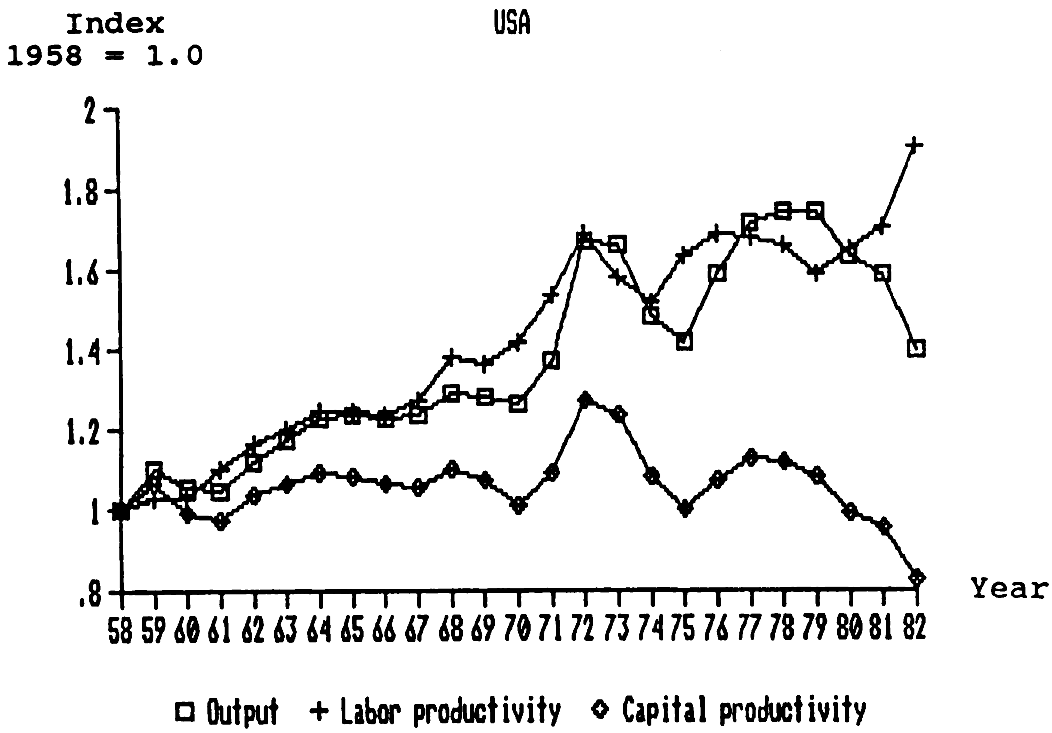

Figure 5. Labor and Capital Productivity in the U.S. Mechanical Forest Industry.

When the partial productivity ratios in the Finnish and U.S. mechanical forest industries are compared with each other the following conclusions can be advanced. Labor productivity increased more in Finland than in the U.S. between 1958 and 1982. The difference in the average growth rates is not great (0.6 percent a year), but what is significant is the difference in productivity growth after the mid-70's: in 1976-82 labor productivity in the Finnish mechanical forest industry grew at the annual rate of 5.2 percent when the corresponding rate in the U.S. was 2.8 percent (Figure 6). On the other hand, capital productivity declined clearly faster in Finland than in the U.S., becoming a considerable problem to the industry.

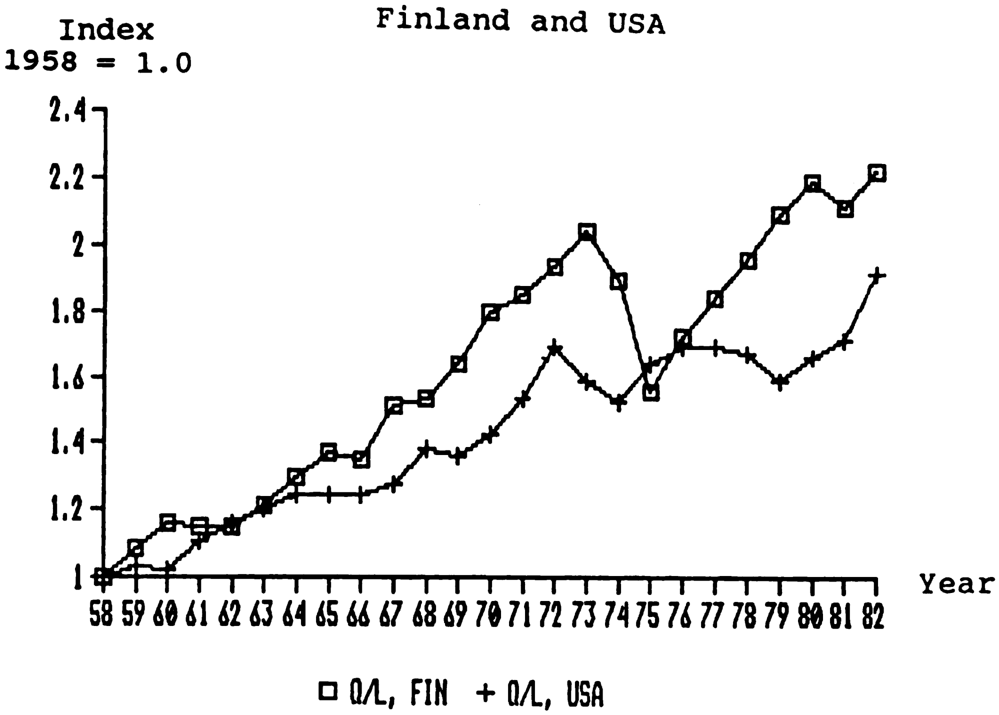

Figure 6. Labor Productivity in the Finnish and U.S. Mechanical Forest Industries

Pulp and Paper Industry

The output of the Finnish P & P industry tripled during the study period. The growth rate has fluctuated in response to changes in demand, but the trend has been clearly upwards: from 1958 to 1982 output growth averaged 4.6 percent a year. At the same time employee hours have stayed constant with slight cyclical fluctuation, material and energy inputs have about doubled, and capital has increased fivefold (Figure 7).

During the same period output of the U.S. P & P forest industry grew annually 2.9 percent the growth being faster during the early years. In 1958-82 employee hours declined slightly and capital more than doubled. In 1982 the amount of purchased materials and energy was 1.9 and 1.4 times more than in 1958, respectively (Figure 8).

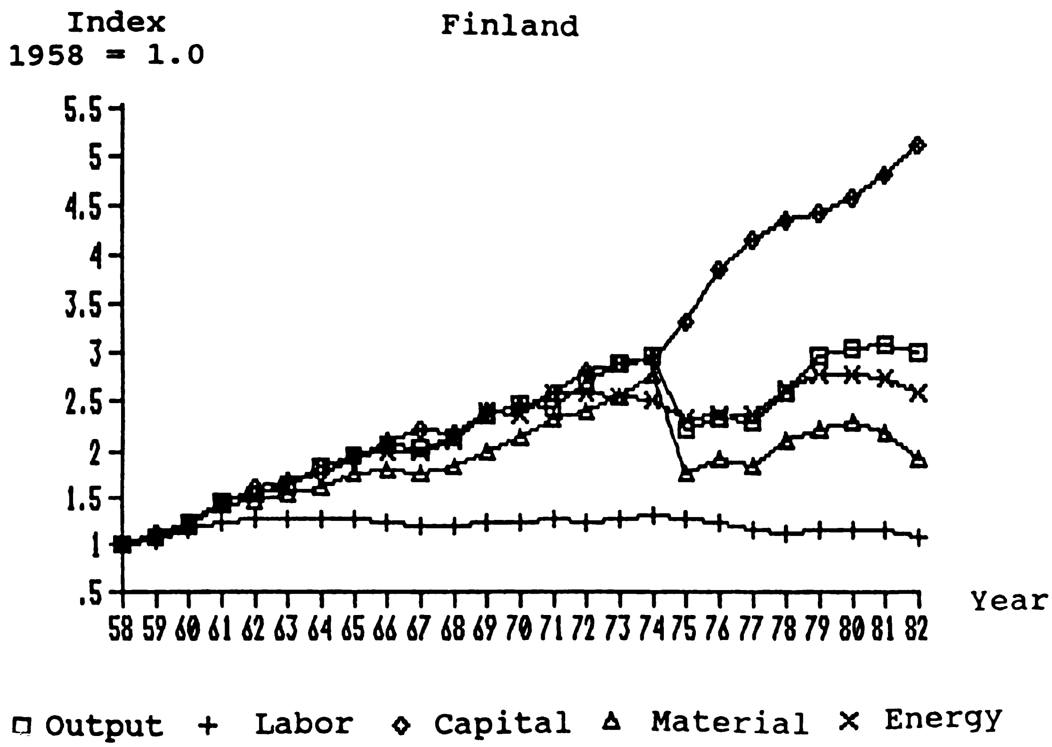

Figure 7. Output and Input Development in the Finnish P & P Industry.

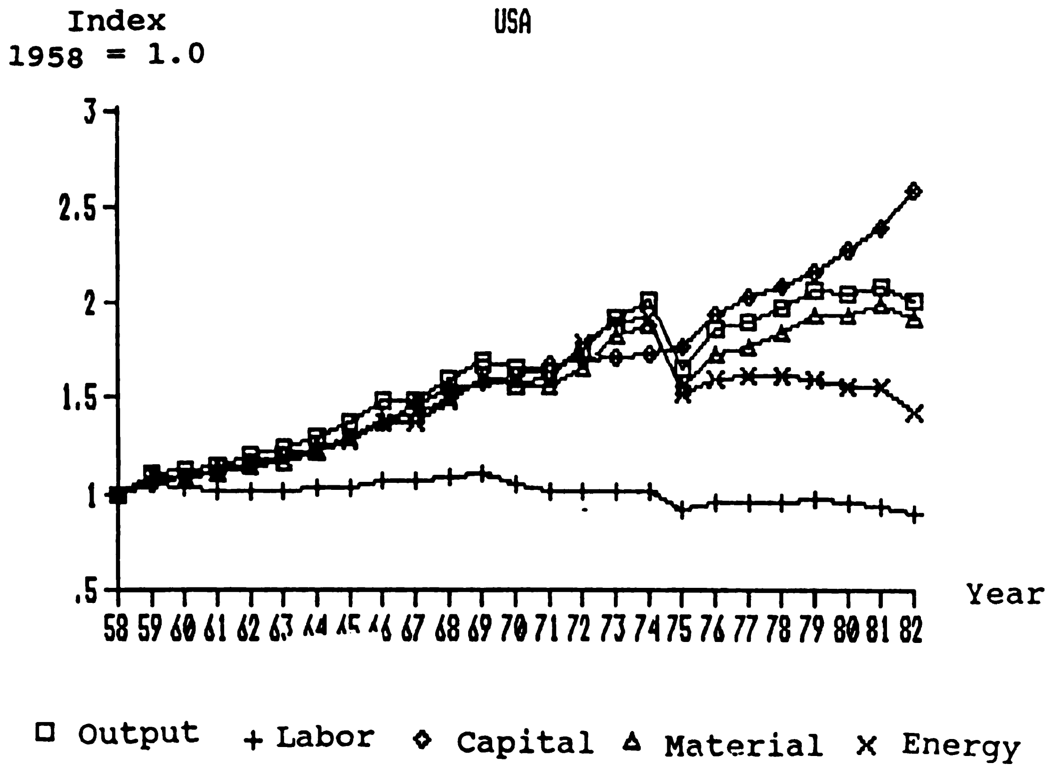

Figure 8. Output and Input Development in the U.S. P & P Industry.

When partial productivity ratios in the Finnish and U.S. P & P industries are studied, it can be concluded that labor and material productivity development has been more favorable for Finland than for the U.S, but the opposite holds for capital and energy productivities. Over the study period labor, material and energy productivities in Finland grew annually 4.3, 1.9 and 0.6 percent, respectively, while capital productivity declined at an average rate of 2.2 percent a year. The corresponding figures for the U.S. are 3.3 percent, 0.2 percent, 1.4 percent and -1.0 percent. During the last years these differences increased: between

1976 and 1982 labor productivity in Finland grew 6.8 percent and material productivity 3.4 percent a year when the corresponding rates in the U.S. were 3.0 percent and -0.3 percent. It also appears that during the latter part of the study period the decline in capital productivity slowed down in Finland and increased in the U.S. (Figures 9, 10, 11, Appendix F)

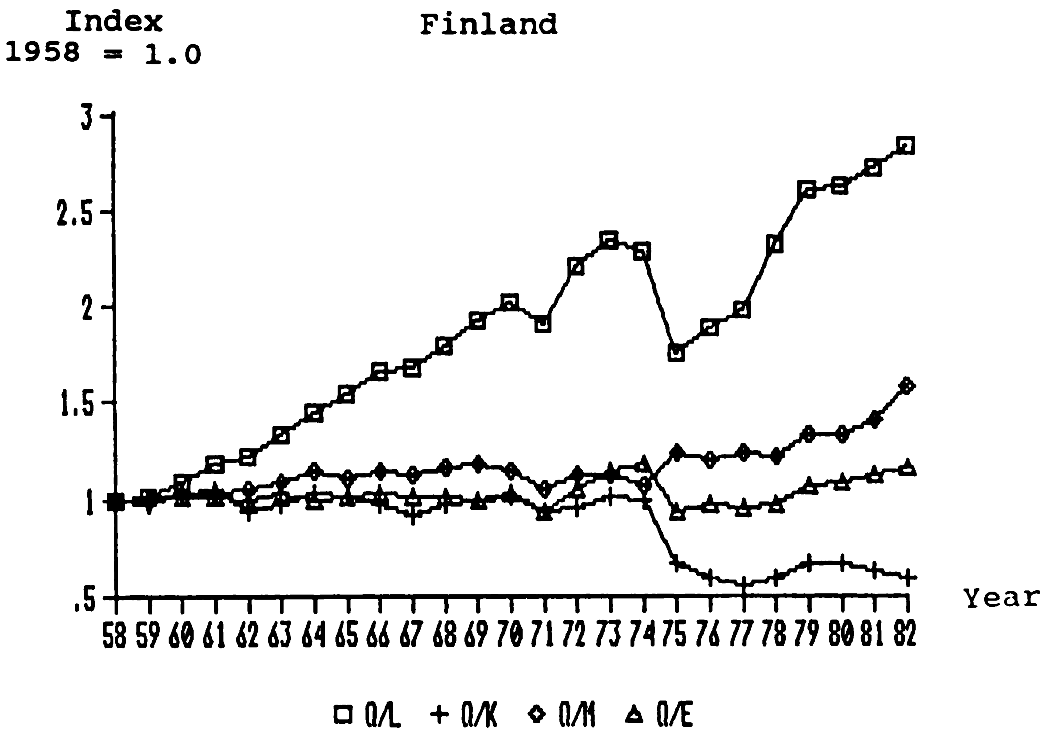

Figure 9. Partial Productivities in the Finnish P & P Industry.

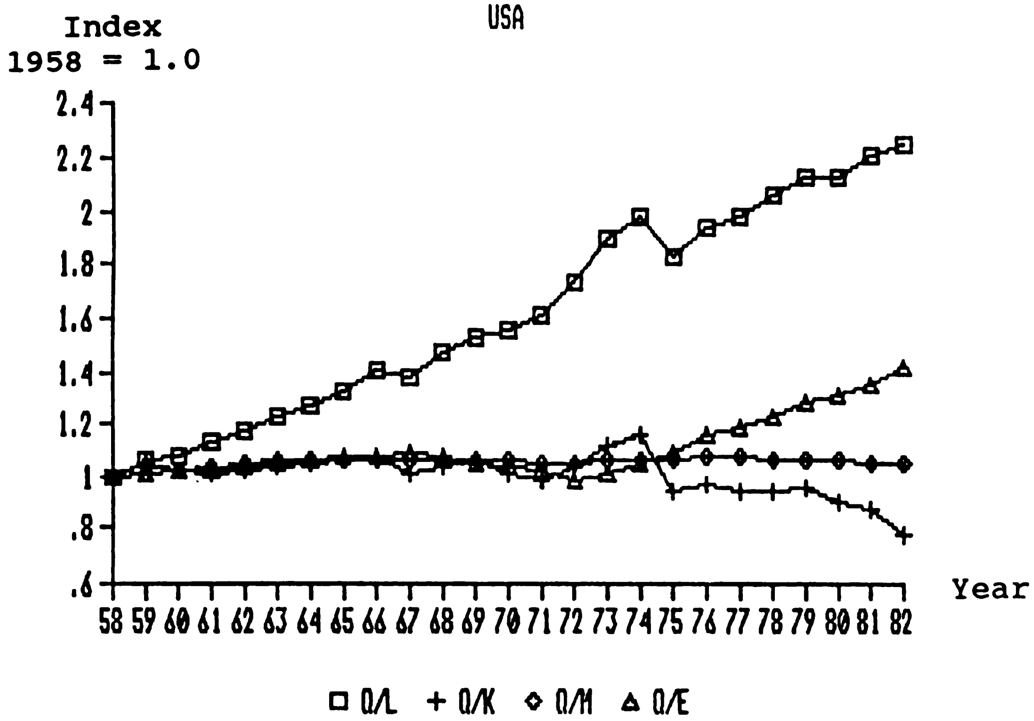

Figure 10. Partial Productivities in the U.S. P & P Industry.

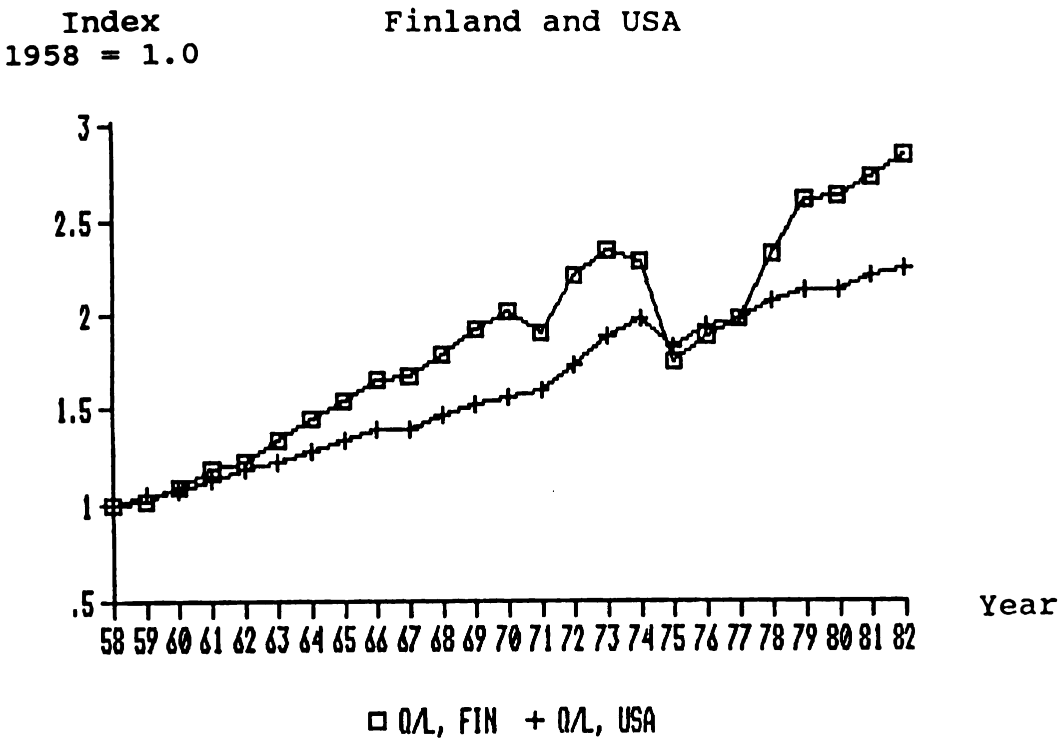

Figure 11. Labor Productivity Development in the Finnish and U.S. P & P Industries.

Discussion

In both countries labor productivity has been increasing steadily while capital productivity shows a downward trend. Both in the mechanical and P & P industry labor productivity advanced more in Finland than in the U.S., the opposite being true for capital productivity. Material productivity in P & P industry has grew almost 60 percent in Finland when it has stayed practically constant in the U.S. during the study period. On the other hand, growth in energy productivity was greater in the U.S. than in Finland. Based on these results it can be stated that labor productivity development has been favorable in both countries, but the continuing decline in capital productivity has become a considerable problem to the forest industries in both countries.

Based on an inter-industry comparison it can be stated that labor productivity increased more in the P & P industry than in the mechanical forest industry in both countries. In Finland capital productivity in the mechanical forest industry declined twice as fast as in the P & P industry while in the U.S. there was no difference between these rates. Inter-industry comparison is however not fully reliable because of the difference in measuring output.

There are many possible explanations for the partial productivity differences between Finland and the U.S. and also between different industry aggregates. One very plausible partial explanation for the differences in labor and capital productivity development in Finland and the U.S. is the difference in the capital intensity of production. Over the study period capital intensity grew much faster in the Finnish forest industries than in the U.S. (Figures 12 and 13). This may have increased labor productivity more in Finland than in the U.S., but simultaneously capital productivity has declined faster due to the "law of diminishing returns".

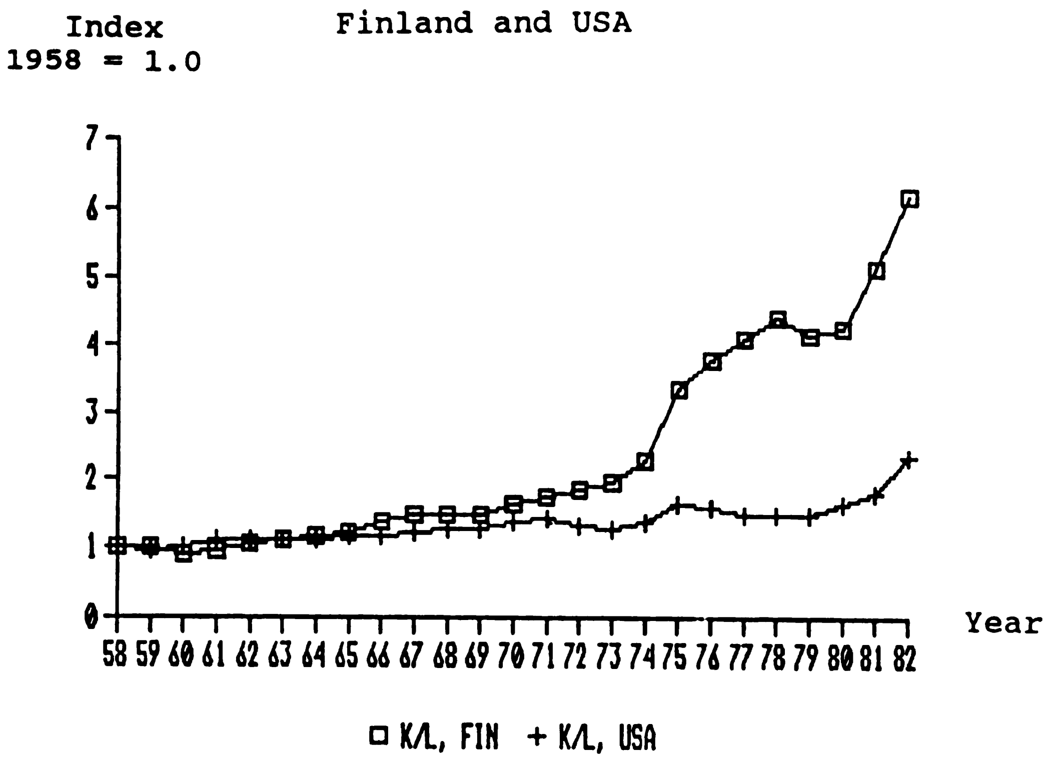

Figure 12. Capital-Labor Ratios in the Finnish and U.S. Mechanical Forest Industries.

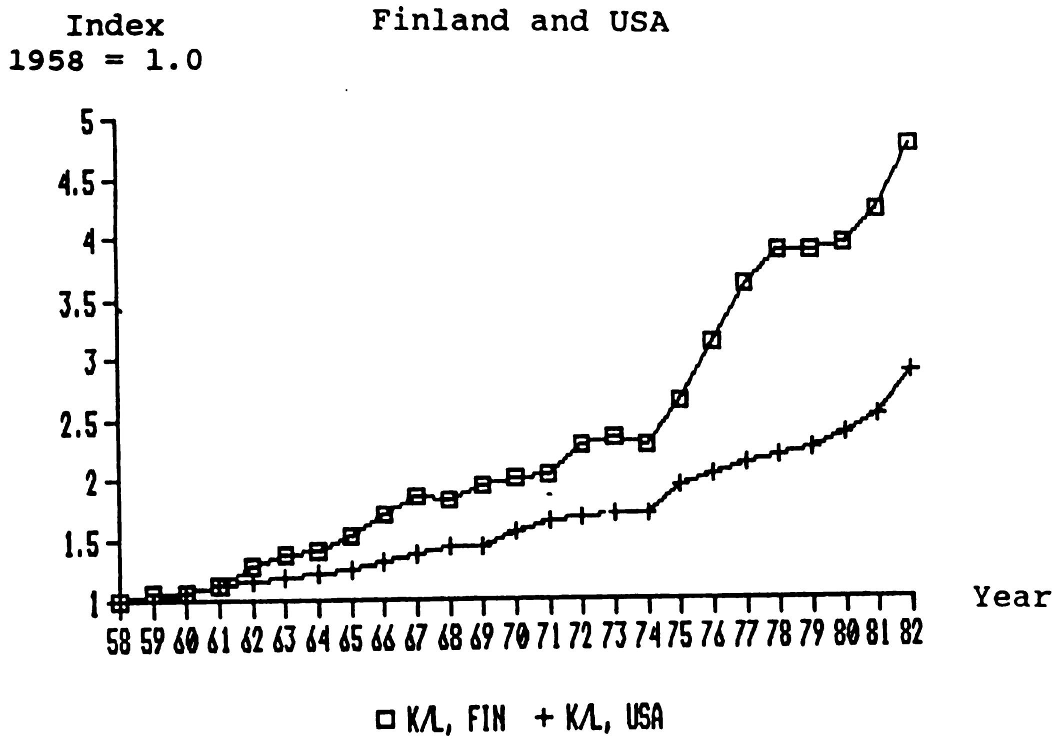

Figure 13. Capital-Labor Ratios in the Finnish and U.S. P & P Industries.

The differences in labor and capital productivity may also be due to differences in rates of capacity utilization (explains annual variation), disembodied technological change, returns to scale, differences in the quality of outputs and inputs, structural change within the industry, etc. The verification and quantification of the causal links between growth (decline) in labor (capital) productivity and the factors contributing to it requires, however, empirical testing, before the analysis amounts to more than only inferential assessment (see e.g., Simula 1983).

When inferring partial productivity ratios, one should not make far reaching conclusions. Especially, increases in individual factor productivities should not be given too much significance, because changes in the partial productivities are often strongly interrelated through complementary relationships between factors of production. Also, an increase in an industry's labor productivity doesn't necessarily mean that new more efficient technology has been introduced, or that the quality of labor force has improved. Improvement in labor productivity may also be brought about by a reorganization of the industry: small, often inefficient mills may have gone out of business as economic conditions have changed, raising thus the (average) labor productivity ratio of the industry. This type of reorganization has taken place especially in the U.S. lumber and wood products industry, and also in the Finnish sawmilling industry.

It must also be noted that even if partial productivity measures can provide useful information about the performance of an industry (e.g., increased labor productivity may very well reflect technological change), we are more interested in the overall increase in productivity than in changes in individual factor productivities.

VI COMPARISON OF THE SOURCES OF GROWTH IN THE FINNISH AND U.S. FOREST INDUSTRIES

Mechanical Forest Industries

Cobb-Douglas production functions performed poorly both for the Finnish and U.S. mechanical forest industries from the viewpoint of the objectives of this study. The poor performance applies to the estimation of unrestricted and restricted formulations (models 38, 39, 40) and also to different ways of measuring capital and labor input. Autocorrelation and multicollinearity did not affect the interpretation of the estimated equations. The equations are presented in Appendix G.

The fitted regressions explained the variation in output levels and in labor and capital productivities reasonably well - at least in the Finnish mechanical forest industry where $\bar{R}^2$ was 0.83 in the unrestricted function, and 0.40 and 0.89 in labor and capital intensive formulations, respectively. The estimated models for Finland give indication of a relatively high rate of technological change (the parameter estimate of the trend term g was about 6.7 percent and it was significant in all the models) and decreasing returns to scale, but not too much weight should be given to these results because of wrong signs occurring in the estimated equations (negative output elasticities).

In the U.S. models $\bar{R}$-squares ranged from 0.11 in the labor intensive equation to 0.62 in the capital intensive and unrestricted formulations. The parameter estimates for the trend term g representing technological change (1.9 and 2.6 percent a year) were not statistically significant implying no technological progress. The output elasticity parameter b (for capital) also had a wrong sign in the unrestricted regression equation. Hence, the estimate of returns to scale (the sum of a and b) that appeared to indicate decreasing returns to scale is unreliable. The parameter estimates for the rate of technological change were lower for the U.S. mechanical forest industries than for Finland, but because of the above mentioned problems the estimates in absolute terms are not reliable.

CD models were also estimated using periodical dummy variables for the rate of technological change to relax the assumption of constant rate of technological change. Several period divisions were tried but parameters didn't obtain consistently significant values and right signs, even if models in some cases improved otherwise, e.g., adjusted R^2's increased and wrong signs disappeared. Also, no significant improvement took place when models were estimated using only machinery and equipment or lagged capital as capital measures. The use of employee numbers instead of employee hours had no significant effect on the results. These estimated regression equations are not reported in this study.

The poor performance of the CD models is most likely caused by an unrealistic assumption of constant elasticity of substitution equalling one over the whole study period. Another source of error is simultanaeity bias in estimation. Also, errors in capital data are very possible because the modified CD functions with no explicit capital input performed well.

Åberg's modified CD function, which took changes in capacity utilization rates indirectly into account, was estimated for the whole study period, and also for the years 1958-70 and 1971-82 using a period dummy. Other period divisions were also tried but the loss of degrees of freedom made it difficult to get significant parameter estimates. The models were originally estimated also in levels, but because of multicollinearity and autocorrelation problems analysis was carried out in a difference form both for the mechanical and P & P industries. Estimation of the models yielded statistically significant estimates of technological change and high multiple coefficients of correlation. The estimated equations are presented in Appendix H.

According to this model the average annual rate of technological change was 3.3 percent in Finland and 1.2 percent in the U.S. Over the period, technological change was the major source of labor productivity growth in the Finnish mechanical forest industry, while in the U.S. increased capital intensity and technological change had about equal contributions. Towards the end of the study period the importance of technological change as a source of labor productivity growth grew in Finland and declined in the U.S. (Table 1). However, the period dummy was significant only for the U.S. mechanical forest industry. In 1971-82 capital deepening had a negative contribution to labor productivity's growth in Finland mainly due to the severe recession in the mid-70's. Although the contributions are here reported separately, they should not be interpreted as being independent from each other.

Table 1. Sources of Labor Productivity Growth in the Finnish and U.S. Mechanical Forest Industries (percent).

	Year	Labor Productivity Q/L	Capital Deepening b(s)		Technological Change g	
Finland	1959-82	3.4	0.1	(2.9)	3.3	(97.1)
	1959-70	4.9	0.6	(12.2)	4.3	(87.8)
	1971-82	1.7	-0.5	(-29.4)	2.2	(129.4)
USA	1959-82	2.7	1.5	(55.6)	1.2	(44.4)
	1959-70	2.9	1.4	(48.3)	1.5	(51.7)
	1971-82	2.4	1.6	(66.7)	0.8	(33.3)

(Changes in variables are expressed in average log-percentages. Numbers in parentheses are relative contributions.)

Labor productivity estimates obtained through the estimation of the dummy models corresponded well with the actual computed average rates of productivity change (see Appendix F), and they also had improved statistical properties, which increases the reliability of the results.

Experiments with other period divisions demonstrated, however, that results are to a small extent sensitive to period division. The parameter estimates in the basic model cannot be regarded fully reliable because the underlying assumption of no clear trend in the real rate of return was found not fully realistic after testing.

The <u>factor augmenting production function</u> approach allowed a more detailed study on the sources of output growth. Application of this model required estimates for the elasticity of substitution in the Finnish and U.S. forest industries. Equations 45 and 46 were first fitted assuming equality between labor and capital augmentation to allow the estimation of σ. Equation 46 was fitted with two alternative measures of real rates of return (see p. 54). The results presented here are based on rates of return where real profit was defined as nominal profit deflated by consumer's price index, because the use of this profit measure provided statistically better estimates of σ[11]. Based on these equations it could be concluded that the underlying production functions were not CD functions, and that technological change had been nonneutral in both countries (constants in Equations 45 and 46 differed statistically from each other). Estimated equations and derivations of σ are presented in Appendix I.

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[11]However, for the Finnish mechanical forest industry an estimate of σ (0.16) based on the estimation of Equation 47 with the alternative rate of return measure was used.

The values chosen for σ in the Finnish and U.S. mechanical forest industries were 0.16 and 0.21, respectively. Given these estimates of σ, the annual rates of change in the technological augmentation (efficiency) of labor and capital, that is a(t) and b(t), could be calculated through the use of Equations 47 and 48. In both countries the efficiency of labor rose steadily and that of capital decreased over the period. In Finland the average annual increase in labor's efficiency was 3.1 percent a year; the corresponding rate in the U.S. was 2.9 percent. The decline in capital's efficiency was considerably faster in the Finnish mechanical forest industry than in the U.S.: the rate of decline was 3.8 percent in Finland and only 0.3 percent in the U.S. (Appendix J).

The knowledge of the changes in labor and capital inputs and their relative efficiencies permitted the estimation of the sources of growth[12]. The relative importances of these contributions are presented in Table 2, where changes are expressed as log-percentages.

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[12]The contributions to output growth were estimated using relationship $\dot{Q}/Q=\alpha(\dot{K}/K)+\beta(\dot{L}/L)+\alpha(\dot{a}/a)+\beta(\dot{b}/b)$.

Table 2. Contributions to Output Growth in the Finnish and U.S. Mechanical Forest Industries, 1959-82.

	Finland		USA	
Source	Change	Relative contribution to output (%)	Change	Relative contribution to output (%)
$\alpha\dot{L}/L$	-0.0088	-43.0	-0.0079	-45.7
$\beta K/K$	0.0196	95.6	0.0085	49.1
$\alpha(\dot{a}/a)$	0.0217	105.9	0.0180	104.0
$\beta(\dot{b}/b)$	-0.0120	-58.5	-0.0013	-7.5

(Changes in variables are expressed in average log-percentages.)

Increases in labor's efficiency contributed the most to the growth of output in both countries while labor input in itself had a large negative contribution. The large negative contribution of capital efficiency in the Finnish industry follows directly from capital efficiency's decline over the study period. Although the contributions are reported separately here, they should not be interpreted as being independent of each other.

The index of productivity or technological change was calculated by aggregating annual labor and capital efficiencies with Vartia II weights. Over the period this productivity index grew slightly faster in the U.S. than in Finland; annual growth rates were 1.8 and 1.3 percent, respectively. In 1958-72 productivity grew more rapidly in Finland than in the U.S., but due to the effects of the oil shock there was a very steep decline in productivity in the Finnish mechanical forest industries in 1974-5, after which

Finland started catching up with the U.S. The index of technological change in both countries is presented graphically in Figure 14 and numerically in Appendix J.

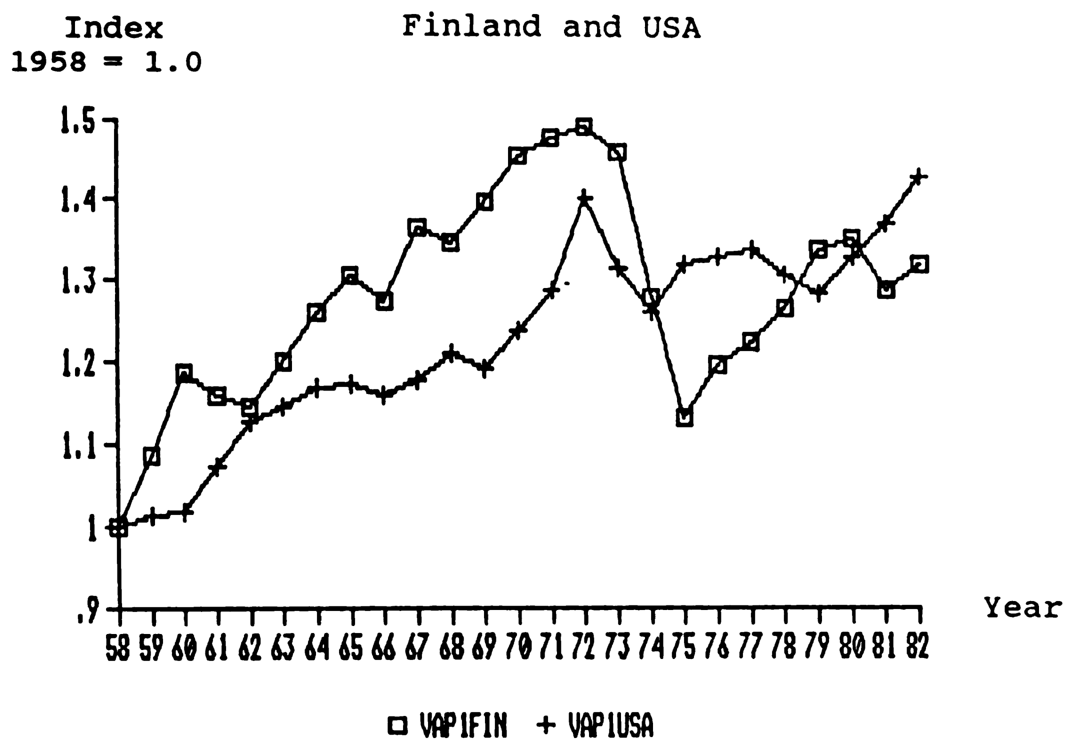

Figure 14. CES Indices of Technological Change in the Finnish and U.S. Mechanical Forest Industries.

Because estimates of technological change are dependent on the size of σ, and the obtained estimates of σ cannot be considered fully reliable, sensitivity analysis was carried out with respect to increases in the size of σ. The analysis showed that average growth in productivity decreased slightly in Finland as the value of σ increased. In the U.S. there was a noticeable, but small increase in productivity in response to greater σ's (within reasonable ranges).

Because it was reasonable to assume that over this long study period the elasticity of substitution may have changed (decreased), the constancy of σ was tested with a dummy model for period divisions 1959-70, 1971-82 and 1959-1975, 1976-1982. Dummies did not, however, obtain significant values. If σ has decreased over time, as one might a priori anticipate, this would lead to overstatement of productivity estimates in the Finnish mechanical forest industry during the early years and understatement at the end of the period, the opposite being true for the U.S.

Pulp and Paper Industry

Production Function Models

The performance of CD functions in explaining changes in output and in labor and capital productivity improved for the U.S. P & P industry compared to estimations for the mechanical forest industry, but for Finland no conclusive results could be obtained. The reliability of the estimated models was again reduced by wrong signs (contradictory with a priori economic theory) as in the mechanical forest industries. Autocorrelation and multicollinearity were not present to such an extent that they would have affected the interpretation of the models. The estimated regression equations are presented in Appendix K.

The parameter estimates for technological change (g) in the Finnish P & P industry were 5.6 and 6.2 percent and significant in most regression equations. The sum of output elasticities was less than one, but the parameter estimate for output elasticity of capital was not significant it had a wrong sign. The estimated equations had a very low explanatory power: $\bar{R}^2$'s ranged from negative to 3.7 percent.

The unrestricted CD function for the U.S. P & P industry gives indication of increasing returns to scale (the sum of output elasticities a and b was greater than one) and of technological progress. When the estimate of technological change (3.2 percent a year) in this equation is compared to an estimate produced by the capital intensive formulation (5.1 percent a year), further evidence is given for the existence of returns to scale. This would also mean that the estimates of g in the estimated labor- and capital-intensive equations overestimate the rate of technological change. However, it should be remembered that these estimates of technological change and returns to scale were not simultaneously determined. The R^2's corrected for degrees of freedom were 0.72 for the unrestricted, and 0.08 and 0.66 for labor- and capital-intensive CD functions, respectively. In the last two equations, the estimated parameter for output elasticity of capital had a wrong sign.

Estimations with dummies, and with different input measures, in a similar vein to what was done in the mechanical forest industries did not produce new, relevant results. The comparison of rates of technological change between Finland and the U.S. was not reasonable because of the quality of Finnish results. The poor performance of CD functions is most likely caused by a combination of unrealistic assumptions, simultaneity error in estimation, and errors in capital data as in the mechanical forest industries.

Estimation of modified CD production functions gave statistically reliable parameter estimates for technological change. The estimated equations also explained well variations in labor productivity changes (growth): the adjusted multiple correlation coefficients ranged from 0.94 to 0.96 (Appendix H). The estimates of technological change showed that the relative importance of technological progress in the growth process increased in the course of time in both countries. The rate of technological change over the study period was estimated to average 2.5 percent a year in Finland and 1.0 percent in the U.S. In Finland technological progress was the major source of labor productivity growth, in the U.S. capital deepening had the greatest relative contribution (Table 3). The U.S. labor productivity estimates differed slightly from the actual computed average annual rates of change (compare to Appendix F).

Table 3. Sources of Labor Productivity Growth in the Finnish and U.S. P & P Industries (percent).

	Year	Labor Productivity Q/L	Capital Deepening b(s)	Technological Change g
Finland	1959-82	4.3	1.8 (41.9)	2.5 (58.1)
	1959-70	5.8	2.8 (48.3)	3.0 (51.7)
	1971-82	2.8	0.7 (25.0)	2.1 (75.0)
USA	1959-82	3.8	2.8 (73.9)	1.0 (26.1)
	1959-70	4.4	3.5 (79.5)	0.9 (20.5)
	1971-82	3.0	2.1 (70.0)	0.9 (30.0)

(Changes in variables are expressed in average log-percentages. Numbers in parentheses are relative contributions.)

The estimation of TFP (technological) change and various contributions to output growth through the use of a <u>factor augmenting production function</u> was carried out in a similar way to that done for the mechanical forest industries. Estimation of Equations 43 and 44 showed that technological change had been nonneutral in both countries. The estimates for σ were 0.11 and 0.17 for the Finnish and U.S. P & P industries, respectively (Appendix L). The efficiency of labor grew steadily in both countries: the average annual increase was 4.3 percent in Finland and 4.0 percent in the U.S. Like in the mechanical forest industries, capital efficiency declined more rapidly in the Finnish P & P industry than in the U.S. The average annual decline was 1.9 percent in Finland and 0.5 percent in the U.S. (Appendix M). In both countries the decline in capital efficiency accelerated towards the end of the period. The contributions of individual factor efficiencies and inputs to output growth are presented in the following table.

Table 4. Contributions to Output Growth in the Finnish and U.S. P & P Industries, 1959-82.

Source	Finland Change	Finland Relative Contribution to output (%)	USA Change	USA Relative contribution to output (%)
$\alpha\dot{L}/L$	0.0013	2.8	-0.0022	-6.3
$\beta\dot{K}/K$	0.0327	69.6	0.0211	60.8
$\alpha(\dot{a}/a)$	0.0222	47.2	0.0184	53.0
$\beta(\dot{b}/b)$	-0.0092	-19.6	-0.0026	-7.5

(Changes in variables are presented in average log-percentages.)

Sources of output growth in both countries were surprisingly similar; increases in capital investment and in labor's efficiency were the largest contributors. Capital efficiencies had negative contributions, as in the mechanical forest industries.

The rate of technological change, that is, the weighted sum of labor and capital efficiencies, increased at the same pace in both countries (1.6 percent a year), but Finland experienced more ups and downs than the U.S. After the oil crisis the Finnish P & P industry experienced noticeably higher rates of technological change. However, in 1982 the indices of technological change were at the same level (Figure 15, Appendix M). The sensitivity analysis with respect to a possibility of greater σ revealed that estimates of average technological change in both countries are quite robust to small changes in σ. The constancy of σ was tested with a dummy model for the same period divisions as in the mechanical forest industries. Dummies didn't obtain significant values.

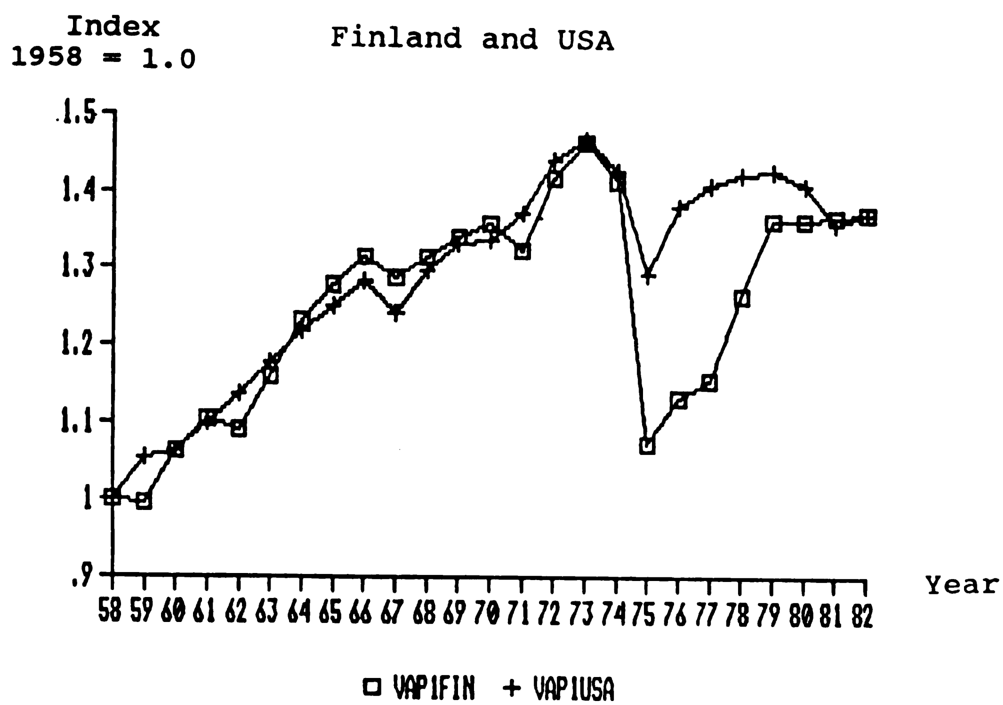

Figure 15. CES Indices of Technological Change in the Finnish and U.S. P & P Industries.

Total Factor Productivity Index

Estimation of all the above models as well as the computation of partial productivity measures were carried out in a value added framework. In the application of a translog total factor productivity index, productivity was interpreted in a gross output framework with labor, capital, materials and energy as inputs. The inputs were aggregated using

Törnqvist's index formula with arithmetic averages of cost (income) shares between the adjacent years as weights. The output and input quantity series are presented in Tables C and D. Value shares used in weighting are in Appendix N.

Three alternative measures of total factor productivity were computed both for the Finnish and U.S. P & P industries. In TFP1 all inputs were aggregated directly, i.e., inputs were not adjusted for quality (composition) changes, in TFP2 and TFP3 labor and capital were adjusted for changes in quality, but in TFP3 capital services included also capital gains (losses). In addition, two value added productivity measures were computed: one based on real value added used in the production function estimations (VAP), and the second based on double deflated value added (DVAP). In double deflating, Equation 38 presented in Chapter III was used.

Annual log-changes in total factor productivity are presented in Appendix O; in the following these changes are reported as averages for five year periods (the first period is only 4 years) and for the whole study period.

Table 5. Alternative Measures of Annual TFP Change in the Finnish and U.S. P & P Industries (percent).

	Finland				USA			
	TFP1	TFP2	TFP3	VAP	TFP1	TFP2	TFP3	VAP
59-62	1.26	1.24	1.24	1.54	1.67	1.61	1.62	3.02
63-67	1.88	1.75	1.77	3.42	0.90	0.87	0.86	1.85
68-72	1.23	1.18	1.17	3.10	0.92	0.90	0.90	3.16
73-77	-1.35	-1.42	-1.40	-5.36	0.62	0.58	0.60	-0.11
78-82	4.34	4.33	4.35	4.50	0.15	-0.19	-0.19	-1.23
59-82	1.48	1.42	1.43	1.44	0.76	0.72	0.72	1.27

The unadjusted productivity version of total factor productivity (TFP1) indicates that prior to the mid-70's productivity rose at stable rates in both countries, the rate of productivity increase being greater in the Finnish P & P industry than in the U.S. The annual productivity increase was about 1.5 percent a year in Finland and about 1 percent in the U.S. During the mid-70's both countries experienced a severe decline in production and total factor productivity. The Finnish P & P industry was especially hurt by the recession, but the recovery from this setback was much stronger in Finland than in the U.S. During the last five year period the average annual growth in TFP1 was 4.3 percent in Finland while the U.S. experienced only very slight productivity growth (0.15 percent a year). Over the study period TFP1 growth averaged approximately 1.5 percent a year in Finland and about 0.8 percent a year in the U.S.

Figure 16 shows the cumulated sum of annual log-changes in TFP1 for both countries. Inspection of this graph reveals clearly the general rising trend in total factor productivity and the sharp decline in the mid-70's that was discussed above. It can also be seen that up until 1975 productivity in both countries developed approximately at same average rate, but there was much more fluctuation in the Finnish P & P industry than in the U.S. After the mid-70's setback TFP growth was very fast in Finland. During 1978 the former peak in productivity from 1973 was surpassed, and in 1982 total productivity reached its highest level; the level of TFP1 in 1982 was about 40 percent higher compared to the base year. In the U.S. total factor productivity in 1982 was slightly above the level in 1972 indicating stagnation during the last ten years. The same information is presented graphically in Figure 17 using a moving average method to emphasize long-run changes in total factor productivity instead of year-to-year fluctuations, which largely reflect changes in the level of demand.

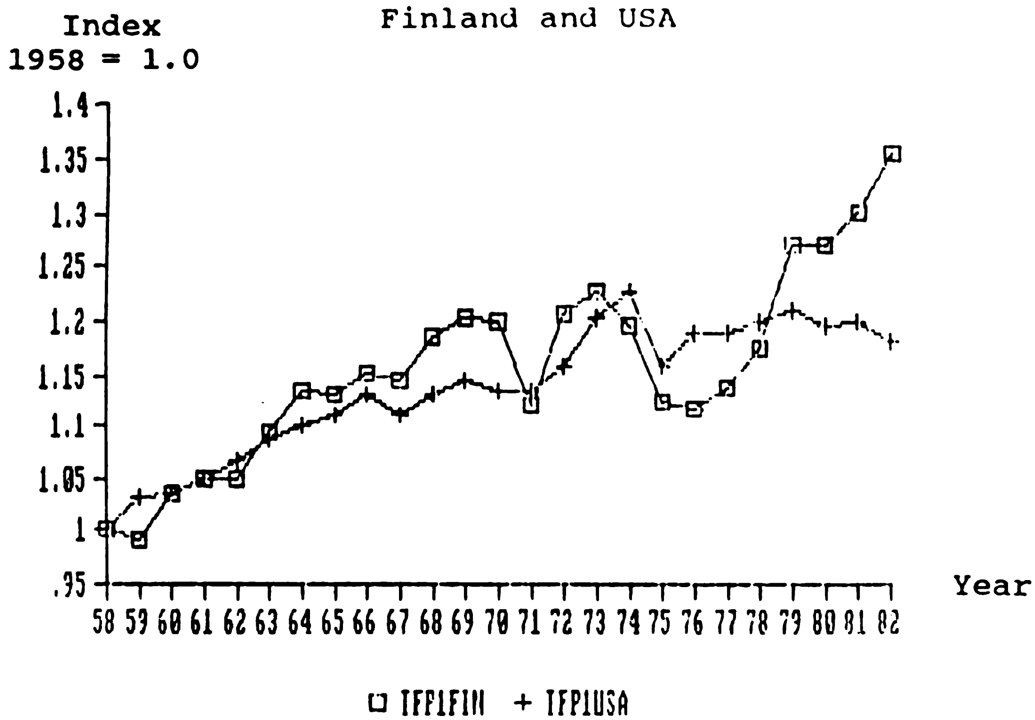

Figure 16. Total Factor Productivity (TFP1) in the Finnish and U.S. P & P Industries.

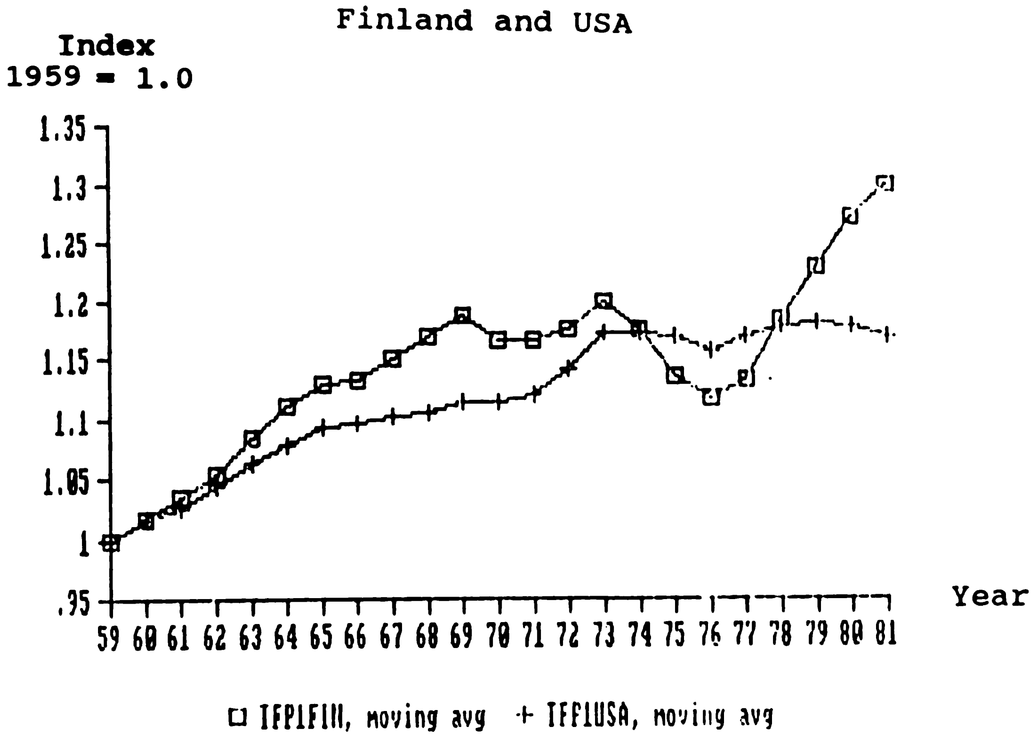

Figure 17. Total Factor Productivity (TFP1) in the Finnish and U.S. P & P Industries, Moving Average.

A more detailed analysis of sources of output growth is presented in Tables 6 and 7, where contributions of labor (L), capital (K), materials (M), energy (E) and total factor productivity (TFP1) to the growth of output (Q) are presented in (weighted) logarithmic percentages. The growth of output is equal to the sum of weighted growth rates of these factors.

Table 6. Contributions to Output Growth in the Finnish P & P Industry (percent).

Year	Q	L	K	M	E	TFP1
59-62	10.41	0.82	2.04	4.84	1.44	1.26
63-67	5.64	-0.16	0.82	2.44	0.66	1.88
68-72	6.07	0.11	0.96	3.27	0.49	1.23
73-77	-3.51	-0.35	1.01	-2.61	-0.21	-1.34
78-82	5.50	-0.30	0.69	0.59	0.18	4.34
59-82	4.59	0.00	1.07	1.58	0.47	1.46

Table 7. Contributions to Output Growth in the U.S. P & P Industry (percent).

Year	Q	L	K	M	E	TFP1
59-62	4.53	0.11	1.03	1.52	0.20	1.67
63-67	4.93	0.25	1.23	1.86	0.18	0.90
68-72	3.25	-0.30	0.71	1.59	0.33	0.92
73-77	1.69	-0.17	0.88	0.59	-0.23	0.62
78-82	1.05	-0.29	1.07	0.75	-0.33	-0.15
59-82	2.93	-0.09	0.98	1.25	0.02	0.76

Examination of these two tables reveals that over the study period TFP growth accounted for about one third and one fourth of the output growth in Finland and the U.S., respectively. The importance of TFP growth for the formation of output in the Finnish P & P industry increased over time- during the last five year period it "explained" almost 80 percent of output growth - while in the U.S. its relative importance has stayed constant. Increased use of materials (mainly wood and chemicals) and capital appear to have become more central to the growth process in the U.S. P & P industry, in Finland their relative importance decreased towards the end of the study period. These results suggest that the growth processes in the Finnish and U.S. P & P industry differ in nature: growth in Finland after the mid-70's has been intensive, in the U.S. it has been extensive.

Productivity measures TFP2 and TFP3 were computed to make an attempt to "explain" changes in total factor productivity, that is, to reduce the remaining residual. Comparison of productivity measures TFP2 and TFP3 showed that TFP measures are insensitive to the inclusion or exclusion of capital gains and losses (Appendix O).

The analysis revealed that the changes in TFP1, TFP2 and TFP3 follow each other very closely (Appendix O). This should not be interpreted as an indication that quality changes in labor and capital inputs have not contributed to TFP growth, because in this study no attempt was made to measure directly the quality of these inputs. It is concluded that the composition changes have not affected the aggregate labor and capital input to such an extent that would have had a significant effect on the TFP measures during the study period, and that - the way they were measured here - they are not good proxies for quality changes.

Comparison of the Finnish gross output (TFP1) and value added (VAP) productivity measures revealed that the use of value added as an output measure overestimated total productivity growth during most of the time between 1959 and 1982 (Figure 18). On theoretical grounds overestimation should have been more clearly pronounced over the whole study period, but on the other hand, the applied value-added measure is not theoretically correct either. Exaggeration of annual productivity changes was also characteristic to the use of value added framework. Similar kind of overestimation of productivity growth was found in the U.S. P & P industry where two different real value added measures were used (Figure 19). This finding means that the results based on value added models should be interpreted conservatively to avoid overestimating the rate of productivity growth.

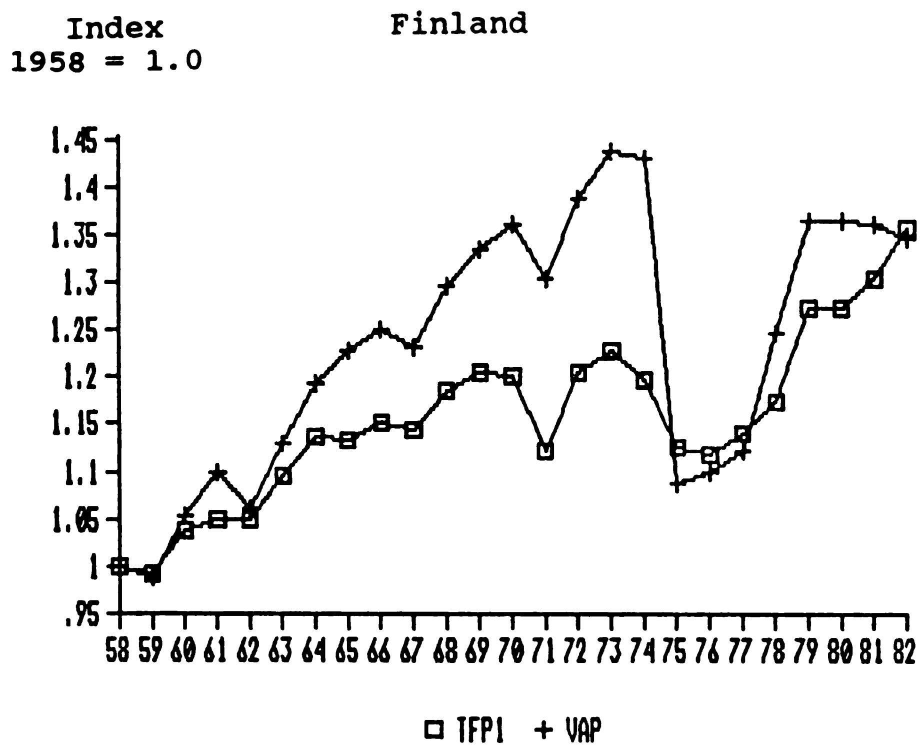

Figure 18. Total and Value Added Productivities in the Finnish P & P Industry.

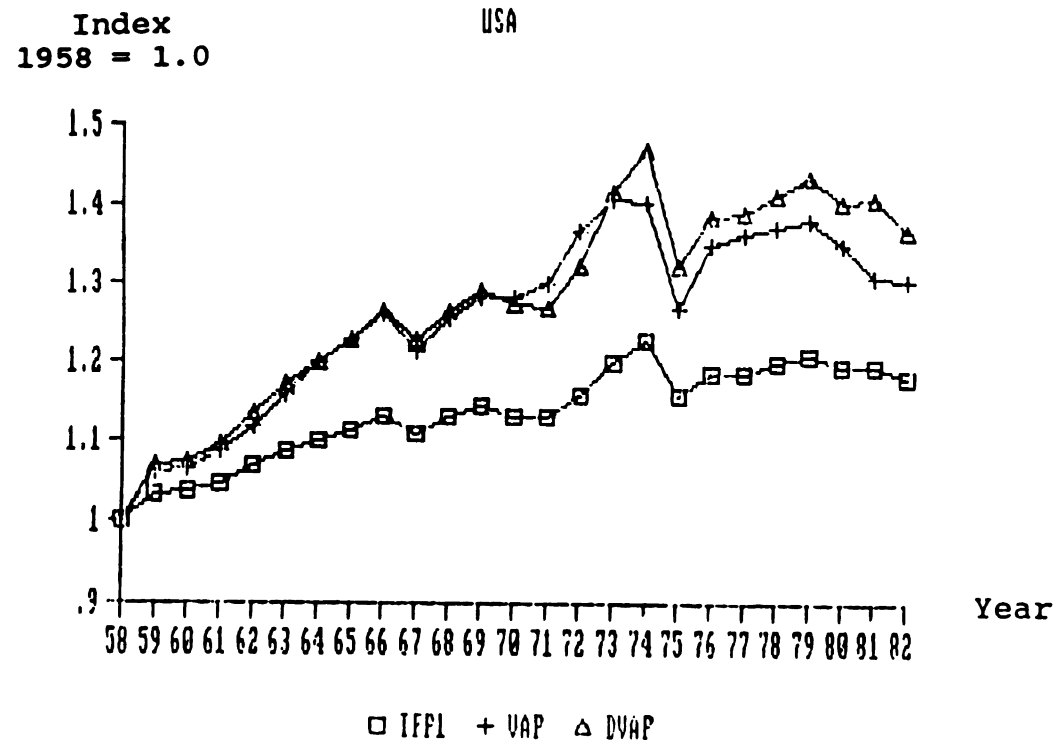

Figure 19. Total and Value Added Productivities in the U.S. P & P Industry.

The computation of the real intermediate input needed for TFP calculations made the calculation of double deflated value added possible that was then used in assessing the reliability of value added measures used in the production function and partial productivity analyses. Before double deflation was carried out using Equation 38, the conditions for unbiased deflation procedure, i.e., separability requirements had to be tested (see p. 38-39).

In the Finnish P & P industry neither the ratio of intermediate inputs to outputs or the relative price of intermediate inputs had stayed constant over the study period, so the existence of a value added function can be questioned. Because it appears that production technology in the Finnish P & P industry was not separable with respect to to primary inputs and intermediate inputs, the calculated double deflated value added is biased and cannot be used as a measure of real output. It also seems that if one for whatever reason is required to use real value added as a measure of output in the Finnish P & P industry, the inappropriately calculated value added volume index, in spite of its biasedness, is as good and maybe even a better measure of real value added than the theoretically preferred double deflated measure.

A similar kind of simple separability test for the U.S. P & P industry indicated separability between intermediate and primary inputs. Therefore, double deflated value added could be used to measure real value added. Comparison of the double deflated and real value added measures used earlier in the study showed that the output indices computed by BLS describe well the development of real value added, which increases the reliability of production function estimations and partial productivity ratios (Appendix P).

The calculated TFP1 indices were also used in providing an explanation to changes in labor productivity in the Finnish and U.S. P & P industries. Using the familiar Törnqvist's TFP index formula with L, K, M and E as inputs, and a labor productivity measure Q/L, the rate of growth of labor productivity could be expressed as the sum of the rate of growth of TFP and weighted capital-, material-, and energy-deepening (see May & Denny 1979b)[13]. These calculations demonstrated the importance of TFP in contributing to labor productivity growth over the study period in the Finnish P & P industry: during the last five year period the relative contribution of TFP was 61.6 percent while in 1959-62 it was only 25.9 percent. It must be noted that the role of productivity in a gross output framework is smaller compared to value added labor productivity calculations. In the U.S., the contribution of TFP growth decreased over time, and during the last ten years labor productivity increase was almost totally due to material and capital deepening (Appendix Q).

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[13] $\dot{Q/L} = TFP + w_k(\dot{K}-\dot{L}) + w_m(\dot{M}-\dot{L}) + w_e(\dot{E}-\dot{L})$

VII DISCUSSION AND CONCLUSIONS

The nature of the growth process in the Finnish and U.S. forest industries was examined here using two approaches containing four different basic models for the pulp and paper industries and three for the mechanical forest industries. Regardless of some data problems and restrictive assumptions underlying the models discussed in earlier chapters, study results can be used in interpreting differences in the sources of growth in the forest industries.

Differences and Similarities Between Countries and Industries

Analysis of sources of output growth showed that the growth processes in the Finnish and U.S. mechanical forest and P & P industries differ in nature, the differences being most apparent after the mid-70's. Growth in Finland has become more intensive over time, emphasizing the role of technological change or total factor productivity; in the U.S., it has been more of the extensive type emphasizing the role of capital deepening. Total factor productivity analysis in a gross output framework with a translog productivity index showed that capital and increased use of wood, chemicals and other material inputs have become more central to the growth process in the U.S. P & P industry, while in Finland their relative importance decreased towards the end of the study period.

All the models except the CD production function for the mechanical and P & P industries and CES function for the P & P industries showed that even before the mid-70's the role of total productivity in the growth process has been greater in the Finnish forest industries than in the U.S. Estimations of the factor augmenting CES production function showed no significant difference in the sources of output growth in the Finnish and U.S. P & P industries during 1958-75. But they do show technological change as a major contributor to output growth in the U.S. mechanical forest industries[14]. Estimated CD production functions, on the other hand, could not be used for reliable comparison because of their poor quality, caused most likely by a combination of restrictive assumptions underlying CD functions, simultaneity errors, and deficiencies in (capital) data.

Inter-industry performance comparison based on the estimates of rates of technological change revealed that the mechanical forest industries are not less progressive than the P & P industries, opposite to conventional belief (see also Risbrudt 1979). When interpreting estimates of technological change, it should be remembered that the use of value added framework overstates the importance of technological change; this was demonstrated here for the pulp and paper industries, but it has been shown to be true also

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[14]Greber and White (1982) obtained the same result in their study on the U.S. lumber and wood products industry for a slightly different period.

for mechanical forest industries (Bengston & Strees 1986). Therefore, one should interpret carefully (conservatively) the results of value added models.

Comparison of total factor productivity (technological change) measures developed in this study to technological change in other industries (see e.g., Gollop & Jorgenson 1977, Fraumeni & Jorgenson 1980, Wyatt 1983, Karhu & Vainionmäki 1985) indicates that productivity has increased slowly both in the Finnish and U.S. forest industries. This gap can be interpreted as a signal that technological opportunities may be open to the forest industries for increasing the role of TFP in the growth process. Reliable comparison of the rates of productivity growth between different industries would, however, require the use of similar kind of methods and data for approximately the same period.

Conclusions and Implications

Although the results of this study emphasize the importance of productivity, the role of capital in the growth process should not be ignored: investment makes the application of new, more efficient technology possible, and the creation of this new technology through R & D efforts is not costless either. For instance, more efficient use of wood fibre input required large investments (and disinvestments) to change pulping methods from sulphite to sulphate. Also, although nothing conclusive could be said about the nature and degree of economies of scale in this study, it is known that some of the technological change is scale-related.

A growth characteristic in both countries is the rapid increase in the capital intensity of production, with increase in the K/L-ratio over three times faster in Finland than in the U.S. since the early 1970's. This suggests that capital intensity of production is one of the major factors explaining the differences in the role of productivity. Examination of numerical data and Figures 12, 13, and 17 showed that increases in TFP and capital-intensity are related. This is, naturally, only inferential, descriptive analysis. The relationship between capital intensity and labor and total factor productivity in the Finnish forest industries found in this study is supported econometrically by Simula (1979, 1983).

Compared to the Finnish forest industries the United States forest industries have underinvested during the 1970's and early 1980's. It appears that if the U.S. forest industries are to increase their productivity, investment rates should be increased. Where investments are most likely to provide the greatest benefits is discussed later on.

The type of complementary role of capital and productivity in contributing to growth discussed above is likely to apply to other inputs, too. For instance, application of a new, more efficient pulping process may require increased energy intensity and new technical skills, which again require new investments. The problem lies in establishing these relationships in a quantitative form.

It must be noted that in the late 1960's and early 1970's K/L -ratios were increased by significant investment for environmental protection. During those years TFP measures are to a small extent affected negatively by these investments.

Increased capital intensity of production may have been important in raising productivity but it has also created problems. Increased amounts of fixed capital together with limited substitution possibilities make forest industries more vulnerable to fluctuations in demand for forestry products. This is a very serious problem for the Finnish P & P industry because of its high capital intensity and almost complete dependency on export markets, and also for the U.S. mechanical forest industries that suffer from fluctuations in housing starts.

Examination of the changes in the levels of output and productivity revealed clearly their close relationship. The adverse effects of decreases in demand were strongly demonstrated in 1975 when there was almost a thirty percent drop in Finnish P & P production, and an almost ten percent decline in total factor productivity. The differences in output increases after 1975 in the Finnish and U.S. forest industries provide a very plausible explanation of the differences in productivity development between 1975 and 1982. During those years both output and productivity in the mechanical and P & P industries grew significantly faster in Finland than in the U.S. The close relationship between TFP and changes in output has been shown in other studies (Simula 1979, 1983, Berndt & Watkins 1981, Martinello 1985).

Changes in the demand and limited substitution possibilities also explain the negative efficiencies of labor and capital during several years shown by the factor augmenting CES production function. Negative labor efficiency is due to labor's quasi-fixed nature: it has not been possible to reduce labor input as much as needed when output has contracted. As a result labor productivity has decreased, and simultaneously wages have risen. Negative capital efficiency is due to capital's fixity and increased capital intensity in production.

Increased capital intensity means that less labor is needed relative to capital to produce one unit of output, which has important implications for the demand for labor. The K/L-ratio can have changed either through the substitution process or through labor-saving technological change. According to this study, substitution possibilities are small, so increases in K/L ratios must be due to biased technological change that may have been induced by relatively greater changes in wages than in the price of capital. In Chapter V in connection with a factor augmenting CES function, technological change was shown to be nonneutral. Additional analysis following Sato (1970) revealed technological change to be labor saving and capital using (according to Hick's definition). Similar results have been reported by Stier (1980a) and Greber and White (1982). If this development continues in the future, not even significant increases in output will increase the demand for labor.

Material and energy using/saving technological change was not tested econometrically in this study, and in the mechanical forest industries intermediate inputs were totally excluded from the analysis because of data problems. However, some conclusions concerning the role of material and energy input in the Finnish and U.S. P & P industry can be made.

In the Finnish P & P industries, increased material productivity was an important source of output and TFP growth during the last years of the study period. If the growth of output and TFP is to continue, attention must be paid to maintaining favorable material productivity development because of the wood input's cost importance and limited possibilities for increasing its use. This is going to mean increased use of chemicals and changes in the product mix towards products where wood costs are relatively less important. It is also possible that substitution possibilities between labor and wood exist; e.g., allocation of additional labor to improving maintenance of existing equipment could increase output, at least in the mechanical forest industries.

The U.S. P & P industry hasn't been able to adapt smoothly to increases in relative timber prices. The use of material inputs, mainly pulpwood, during the study period increased faster than the use of any other input, and material productivity stayed practically constant over the study period. This development offers a partial explanation of the slowdown in TFP in the U.S. P & P industries after the mid-70's. Inability to respond to changes in relative factor input prices through substitution or through (material-saving) technological change means higher production costs and reduced profits and investment, which finally may result in stagnation. Slow material productivity development and large material cost share imply that to increase the rate of productivity, more should be invested on increasing material productivity.

Material input's large value share in the gross output suggests a need for a more detailed look at the components of material input and their productivity development. That was not possible in this study because of the difficulties in getting reliable, disaggregated annual price and quantity data.

In both countries energy productivity increased only slightly over the 1958-74 period, with most of the increase taking place after 1975 as a response to sharp increases in energy prices. In Finland, the high growth rates of output even with increases in energy productivity have meant increased use of energy. Because the forest industry is already now a major consumer of energy, the economic scarcity (rising prices) of energy may become a factor limiting new investments and growth.

In the preceding discussion some explanations for changes in TFP and productivity differentials between the Finnish and U.S. forest industries were offered. These explanations can also be understood as suggestions where research and data improvement efforts should be directed to learn more about the factors affecting growth. In this study an attempt was made to account for changes in TFP in the pulp and paper industries by adjusting labor and capital for quality changes, but the amount of unexplained output growth was not reduced noticeably (Chapter VI). The "explanation" (reduction) of the residual would seem to require better data on changes in the quality of inputs (e.g., vintage data on capital), or possibly a different analytical approach. It is also possible that a significant part of the reported TFP change has been disembodied, and/or some central variables have been left out from the analysis, e.g., economies of scale, R & D expenditures and management input. It is also evident that a part of TFP change is "explainable" by errors in data and by market imperfections.

Fluctuations in demand for forest products combined with the high capital intensity of production emphasize the importance of good management, especially in investment planning. Management is also central in effective organization planning and direction of R & D efforts. Although the role of management in increasing productivity is recognized, management as an input has not really been quantitatively studied, mainly because of the concept's complexity and intangibility.

Since the efficiency with which an industry converts resources into outputs affects the level of profits and subsequent capital investment, total factor productivity is an important determinant of an industry's performance and eventually of it's rise or decline. In Finland, the forest industry's performance has great repercussions on social well-being because of its central importance in the economy. To maintain the relatively favorable productivity development, more attention must be paid to supporting research, education and labor training, and to creating a positive environment for investments. At the firm level, attention should be paid to investment planningandto management of technology diffusion.

The above recommendations are quite general. More concrete recommendations would require a separate study where factors affecting total factor productivity development would be examined in detail. Because of the nature of the concept, total factor productivity studies can provide only little guidance for policy formulation unless causal, quantitative relationships between policy instruments and productivity development are established. The problem in explaining total factor productivity is that behind productivity lie all the dynamic forces of economic life, and it is very difficult to account for these factors. Nevertheless, the linking of quantitative knowledge of production relationships to policy instruments and objectives should be attempted.

APPENDICES

APPENDIX A. Related Research.

Empirical research on the sources of economic growth and technological change at national level is extensive. Studies on the forest industry and its subindustries are, however, less common.

In Finland, Simula (1979, 1983) has studied productivity in the forest industries using production functions and total factor productivity (TFP) indices. His first study examined factors affecting productivity in individual branches using time-series data and several alternative models and ways of measuring inputs and outputs. In the latter study, cross-section data were used in analyzing the suitability of TFP indices and alternative production functions for explaining productivity differences in individual branches and at the aggregate level. The study revealed that in most cases productivity variation is best explained by differences in the capital-labor ratio and plant size. The study also demonstrated the importance of output quality and the level of output for total productivity.

Katila (1983) has analyzed the role and nature of technological change in the growth of output in the Finnish pulp and paper (P & P) industry. The study attributed most of the growth to the increased use of capital, and the rate of technological change was found to be quite slow. Wyatt (1983)

APPENDIX A. (cont'd.).

compared sectoral total factor productivity growth in the Finnish and Swedish industries using a TFP index. The study demonstrated that total factor productivity growth in the Finnish forest industries has been slow and below the corresponding growth rates in Sweden. The reliability of Wyatt's conclusion's can, however, be questioned because of problems with the Finnish real material data. Karhu & Vainionmäki (1985) used the same data in their work on TFP measurement in the Finnish economy.

In the United States, Robinson (1975) has applied Solow's (1957) residual model to the U.S. mechanical wood industry. The study indicated that increased use of capital had a greater impact on labor productivity than technological change. Manning and Thornburn (1971) applied the same method to the Canadian P & P industry but with opposite results. Risbrudt (1979) has examined the rate of technological change in the U.S. forest industry using five alternative models. He attempted also to analyze qualitatively the factors underlying technological change. The validity of the assumptions underlying the alternative models was not assessed in the study.

Stier (1980a, 1980b) has applied dual cost functions in studying the structure and role of technological change in the U.S. forest industry. Greber and White (1982) applied

APPENDIX A. (cont'd.).

Sato's (1970) method to study the role of technological change in the U.S. lumber and wood products industry. In their study, most of the growth was attributed to technological change. Martinello (1985) has estimated the rate of technological change and returns to scale in the Canadian forest industries, using cost functions. Bengston and Strees (1986) have emphasized the need to analyze technological change in a gross output framework. They found out that the use of value added output measures overestimated considerably the rate of technological change in the U.S. lumber and wood products industry.

Two Swedish studies must also be acknowledged. Wohlin (1970) applied Salter's (1960) approach in his study on structural change, expansion possibilities and technological change in the Swedish forest industries. Forsund et al. (1978) have analyzed technological and structural change in the Swedish pulp industry using plant-level cross-section data and frontier production functions.

APPENDIX B. Derivation of Åberg's Model.

The starting point is a CD-production function with constant returns to scale:

$$Q = AL^{\alpha}K^{\beta}c^{\Phi}e^{gt} \quad (1)$$

where Q is the real value added, α and β stand for output elasticities, c is the rate of capacity utilization, Φ is the elasticity with respect to c, and g represents the rate of technological change. It is assumed that firms have a constant real return requirement (r) on capital, and they try to equate the marginal product of capital with this rate ($f_K = r$). If the "true" rate of return is assumed to be proportional to the rate of capacity utilization we can write

$$Q = Kcr + Lw \quad (2)$$

where Kc represents the utilized capital stock. This equation can be rewritten

$$R = Kcr = Q - Lw \quad (3)$$

where R is the real capital income. From this, c can be reformulated as $c = R/Kr$. In empirical analysis the ratio R/K can thus be used as a measure of the utilization rate. Equation 1 can then be expressed by

$$Q = B\, R^{\beta}L^{\alpha}e^{gt} \quad (4)$$

where B is equal to $Ar^{-\beta}$ (for simplicity's sake $\Phi = \beta$). Given constant returns to scale Equation 3 can be written in labor intensive form

$$\ln(Q/L) = \ln B + \beta \ln(R/L) + gt \quad (5)$$

APPENDIX B. (cont'd.).

In order to be able to include r in the constant factor B, the assumption of the constant real return requirement on capital is crucial. However, it doesn't necessarily have to be fully constant, but it is enough if there's no clear trend in r during the period in question, so that the technological change term g is not affected. Another requirement is that the share of capital income (R/Q) is not constant during the period of estimation.

APPENDIX C. Data for the Finnish Forest Industries.

Table C1. Data for the Finnish Mechanical Forest Industry.

Finland

Year	QVA	K	L	w	r1	r2	α	β
1958	.5446	.5968	.9789	.5819	.8257	.8492	.6360	.3640
59	.6061	.6313	1.0057	.6079	.7024	.9473	.6758	.3242
60	.7618	.6457	1.1851	.6223	1.1469	1.2367	.6001	.3999
61	.7508	.6778	1.1785	.6656	.9446	1.0328	.6494	.3506
62	.7032	.7127	1.1023	.7145	.8415	.8077	.7732	.2268
63	.7422	.7379	1.0966	.7252	.5226	.8971	.7571	.2429
64	.7872	.7803	1.0869	.7397	.5372	.9763	.7435	.2565
65	.8173	.8058	1.0702	.7785	.5096	.9846	.7541	.2459
66	.7399	.8181	.9808	.8247	.3322	.7769	.8181	.1819
67	.7629	.8332	.9082	.8692	.3877	.8675	.7870	.2130
68	.7900	.8311	.9290	.8758	.8091	.9075	.6466	.3534
69	.9148	.9025	1.0030	.9348	1.0942	.9755	.5894	.4106
70	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	.6019	.3981
71	.9974	1.0320	.9661	1.1094	.6874	.8574	.6955	.3045
72	1.0047	1.0595	.9330	1.1907	.7424	.7967	.6810	.3190
73	1.0833	1.1338	.9544	1.2644	1.6913	.7908	.4875	.5125
74	.9614	1.2833	.9142	1.3830	1.4371	.3923	.5089	.4911
75	.6567	1.5583	.7612	1.3905	.0006	.0316	.9994	.0006
76	.7482	1.8083	.7800	1.4994	.2671	.0615	.7855	.2145
77	.7966	1.9577	.7790	1.5043	.4187	.1171	.6837	.3163
78	.8712	2.1519	.7987	1.5204	.4476	.1639	.6558	.3442
79	1.0393	2.2516	.8915	1.5614	.6986	.2248	.5723	.4277
80	1.1337	2.4129	.9304	1.6092	.9069	.2422	.5084	.4916
81	.9854	2.6252	.8344	1.6323	.3771	.1585	.6753	.3247
82	.8933	2.7501	.7219	1.6518	.1775	.1604	.7869	.2131
Avg.							.6829	.3171

Note: All monetary variables are in constant prices. Base year is 1970. QVA=value added, K=total capital, L=total labor hours, w=wage rate, r1, r2 are alternative real rates of return, α=labor's value added income share, β=capital's value added income share. Construction of time series is explained in Chapter IV.

APPENDIX C. (cont'd.).

Table C2. Data for the Finnish P & P Industry.

Finland

Year	QGV	QVA	M	E	K	L	w	r1	r2	α	β
1958	.4065	.4065	.4674	.4200	.4083	.8185	.5463	.9282	.9358	.4814	.5186
59	.4315	.4315	.5002	.4440	.4478	.8546	.6088	.7636	.8441	.4518	.5482
60	.5040	.5040	.5605	.5149	.4918	.9321	.5971	.8403	.9604	.4594	.5406
61	.5937	.5937	.6626	.6050	.5721	1.0139	.6345	.8385	.9854	.4676	.5324
62	.6164	.6164	.6709	.6366	.6550	1.0214	.6721	.5514	.8766	.4770	.5230
63	.6729	.6729	.7072	.6796	.6865	1.0170	.6928	.6015	.9524	.4687	.5313
64	.7431	.7431	.7490	.7716	.7220	1.0340	.7213	.5650	1.0269	.4581	.5419
65	.7980	.7980	.8236	.8142	.7857	1.0382	.7590	.4517	1.0234	.4512	.5488
66	.8360	.8360	.8453	.8371	.8572	1.0161	.8034	.3546	.9891	.4463	.5537
67	.8173	.8173	.8270	.8406	.9010	.9752	.8374	.3800	.9075	.4721	.5279
68	.8693	.8693	.8526	.8828	.8922	.9807	.8594	.7723	.9923	.4812	.5188
69	.9616	.9616	.9296	1.0052	.9735	1.0051	.9103	.8998	1.0167	.4866	.5134
70	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	.5017	.4983
71	.9902	.9902	1.0827	1.0851	1.0532	1.0441	1.0802	.5941	.8614	.5343	.4657
72	1.1069	1.1069	1.1200	1.0842	1.1517	1.0121	1.1807	.5402	.9151	.5174	.4826
73	1.1802	1.1802	1.1991	1.0701	1.1800	1.0167	1.2821	.6225	.9372	.4825	.5175
74	1.2009	1.2009	1.2937	1.0491	1.2034	1.0545	1.3332	1.0662	.8954	.4031	.5969
75	.8966	.8966	.8264	.9821	1.3557	1.0237	1.4514	.5229	.3995	.4334	.5666
76	.9393	.9393	.8918	.9963	1.5657	1.0062	1.4650	.1627	.3942	.4362	.5638
77	.9287	.9287	.8536	.9979	1.6896	.9392	1.4674	.1788	.3894	.4668	.5332
78	1.0572	1.0572	.9879	1.1095	1.7774	.9158	1.4701	.3775	.4968	.4682	.5318
79	1.2060	1.2060	1.0338	1.1684	1.8063	.9289	1.5603	.5798	.5865	.4453	.5547
80	1.2376	1.2376	1.0683	1.1709	1.8658	.9474	1.6506	.5371	.5580	.4607	.5393
81	1.2554	1.2554	1.0216	1.1586	1.9653	.9310	1.6724	.4740	.5463	.4534	.5466
82	1.2230	1.2230	.8877	1.0838	2.0765	.8696	1.7003	.3193	.5148	.4759	.5241
Avg.										.4672	.5328

Note: All monetary variables are in constant prices. Base year is 1970. QGV=gross value of production, QVA=value added, M=material input, E=energy, K=total capital, L=total labor hours, w=wage rate, r1, r2 are alternative rates of return, α=labor's value added income share, β=capital's value added income share. Construction of time series is explained in Chapter IV.

APPENDIX D. Data for the U.S. Forest Industries.

Table D1. Data for the U.S. Mechanical Forest Industry.

USA

Year	QVA	K	L	w	r1	r2	α	β
1958	.7881	.7994	1.1222	.7370	.9370	.8913	.6817	.3183
59	.8653	.8221	1.1999	.7748	1.2443	.9004	.6381	.3619
60	.8319	.8517	1.1554	.7650	.8715	.8583	.6979	.3021
61	.8251	.8619	1.0627	.7879	.8522	.9297	.6886	.3114
62	.8792	.8607	1.0750	.8038	.9634	1.0556	.6690	.3310
63	.9218	.8755	1.0898	.8520	1.0955	1.0383	.6526	.3474
64	.9660	.8962	1.1060	.9067	1.1478	.9985	.6542	.3458
65	.9740	.9107	1.1160	.8934	1.0681	1.0213	.6654	.3346
66	.9656	.9182	1.1067	.8979	1.1427	.9921	.6475	.3525
67	.9726	.9379	1.0851	.9051	1.1224	1.0171	.6441	.3559
68	1.0167	.9385	1.0460	.9883	1.5866	1.0482	.5739	.4261
69	1.0146	.9589	1.0571	1.0023	1.5211	.9670	.5850	.4150
70	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	.6599	.3401
71	1.0869	1.0138	1.0076	1.0499	1.4129	1.1277	.5890	.4110
72	1.3242	1.0512	1.1116	1.1257	1.9040	1.3944	.5481	.4519
73	1.3132	1.0789	1.1777	1.1095	2.3301	1.2290	.5021	.4979
74	1.1668	1.0965	1.0956	1.0739	1.5287	1.0469	.5766	.4234
75	1.1175	1.1327	.9695	1.0948	1.0777	1.0829	.6278	.3722
76	1.2543	1.1897	1.0562	1.1319	1.5896	1.1503	.5509	.4491
77	1.3554	1.2229	1.1424	1.1755	1.7897	1.1282	.5434	.4566
78	1.3796	1.2494	1.1775	1.2140	2.0112	1.0269	.5246	.4754
79	1.3763	1.2873	1.2319	1.1579	1.6948	.9935	.5592	.4408
80	1.2933	1.3229	1.1127	1.0983	1.0244	1.0820	.6363	.3637
81	1.2576	1.3369	1.0438	1.0695	.7953	1.1457	.6707	.3293
82	1.1073	1.3607	.8249	1.1635	.5130	1.0241	.7274	.2726
Avg.							.6206	.3794

Note: All monetary variables are in constant prices. Base year is 1970. QVA=value added, K=total capital, L=total labor hours, w=wage rate, r1, r2 are alternative real rates of return, α=labor's value added income share, β=capital's value added income share. Construction of time series is explained in Chapter IV.

APPENDIX D. (cont'd.).

Table D2. Data for the U.S. P & P Industry.

USA

Year	QGV	QVA	M	E	K	L	w	r1	r2	α	β
1958	.6044	.5650	.6400	.6290	.6132	.9430	.7542	1.2584	.6813	.4814	.5186
59	.6719	.6300	.7031	.6925	.6464	.9902	.7695	1.4406	.7691	.4518	.5482
60	.6765	.6440	.6994	.6904	.6687	.9811	.7882	1.3705	.7684	.4594	.5406
61	.6911	.6640	.7060	.6984	.6960	.9512	.8095	1.2685	.8008	.4676	.5324
62	.7247	.7000	.7312	.7250	.7175	.9618	.8393	1.2422	.8251	.4770	.5230
63	.7520	.7370	.7494	.7448	.7349	.9591	.8654	1.2892	.8754	.4687	.5313
64	.7879	.7840	.7847	.7722	.7566	.9679	.8859	1.3503	.9385	.4581	.5419
65	.8333	.8300	.8296	.8082	.7964	.9775	.8995	1.3520	.9799	.4512	.5488
66	.9013	.8940	.8968	.8650	.8427	1.0036	.9246	1.3756	1.0203	.4463	.5537
67	.9043	.8920	.8994	.8586	.9021	1.0174	.9449	1.2001	.9114	.4721	.5279
68	.9719	.9590	.9684	.9392	.9448	1.0286	.9618	1.1368	.9828	.4812	.5188
69	1.0249	1.0090	1.0231	1.0077	.9713	1.0451	.9764	1.1160	1.0270	.4866	.5134
70	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	.5017	.4983
71	.9951	1.0110	.9969	1.0119	1.0242	.9636	1.0349	.8548	1.0006	.5343	.4657
72	1.0641	1.0900	1.0679	1.1298	1.0450	.9564	1.0953	.9417	1.0839	.5174	.4826
73	1.1668	1.1410	1.1660	1.1978	1.0563	.9596	1.1137	1.0930	1.1491	.4825	.5175
74	1.2201	1.1360	1.2139	1.2098	1.0603	.9574	1.1097	1.4944	1.1413	.4031	.5969
75	1.0057	.9650	.9962	.9618	1.0898	.8570	1.1467	1.1872	.8691	.4334	.5666
76	1.1302	1.1230	1.1146	1.0081	1.1894	.9050	1.2056	1.1939	.9713	.4362	.5638
77	1.1579	1.1750	1.1369	1.0180	1.2497	.9104	1.2616	1.0572	.9615	.4668	.5332
78	1.1980	1.2030	1.1836	1.0153	1.2904	.9032	1.2834	1.0275	.9665	.4682	.5318
79	1.2521	1.2460	1.2446	1.0102	1.3375	.9150	1.2720	1.0914	.9935	.4453	.5547
80	1.2451	1.2370	1.2453	.9900	1.4076	.9098	1.2444	.9484	.9538	.4607	.5393
81	1.2681	1.2030	1.2759	.9800	1.4712	.8927	1.2367	.9114	.8855	.4534	.5466
82	1.2201	1.2120	1.2351	.8970	1.5847	.8428	1.2707	.7494	.8544	.4759	.5241
Avg.										.5168	.4832

Note: All monetary variables are in constant prices. Base year is 1970. QGV=gross value of production, QVA=value added, M=material input, E=energy, K=total capital, L=total labor hours, w=wage rate, r1, r2 are alternative rates of return, α=labor's value added income share, β=capital's value added income share. Construction of time series is explained in Chapter IV.

APPENDIX E. Derivation of the Real Material Input Series

For the U.S. P & P industry detailed annual price and quantity data on materials consumed were not available, so data from census years were used in constructing the real material input index. Different items comprising the aggregate cost of materials, supplies, etc. reported in the Census of Manufactures were deflated respectively by their wholesale/producer price indices. These real costs were used in computing material input-output ratios for the census years. The real material input for the intermediate years was obtained by estimating input-output ratios for these years by linear interpolation, and then multiplying the corresponding real outputs by these ratios. To improve the interpolation procedure an attempt was made to relate changes in input-output ratios to changes in capacity utilization rates, but no clear relationship was found using the data from the census years. In the following the cost items and their deflators are presented. The correctness of some of the deflators can be questioned, but the best existing deflator was always chosen. In some cases a deflator was constructed combining several price series with "consumption" or cost shares as weights.

Cost of Resales: Deflated by a product's price index. (Resales should have been excluded from both the gross output

APPENDIX E. (cont'd.).

and material input, but it was not possible, because of lack of data).

Contract Work: Deflated by an index with following weights: 0.5*(wage index in metal industries) + 0.5*(PPI for machinery and equipment).

Materials and Supplies:

- Different pulpwood species and chips were deflated using price indices from U.S. Timber Production, Trade.... 1984. Southern pine and mixed hardwoods were deflated by an average of Midsouth, Southeastern & Louisiana pine and hardwood pulpwood prices, respectively. Item "Other hardwoods" was deflated by the average of these two price indices. Cost of stumpage cut was deflated by an index with following weights: 0.7*(Southern pine) + 0.1*(Southern hardwoods) + 0.1*(Wisconsin spruce) + 0.1*(Wisconsin hemlock).
- Chemicals: Deflated by PPI for industrial chemicals.
- Woodpulp: Deflated by PPI for woodpulp.
- Wastepaper: Deflated by a price index from Bureau of Labor Statistics (BLS).
- Paperboard boxes: Deflated by a price index from BLS.
- All other materials and supplies were deflated by PPI for intermediate materials and supplies.

APPENDIX E. (cont'd.).

For the Finnish P & P industry the real material input was constructed using annual data reported in Industrial Statistics Parts I and II. Nominal material costs were deflated with various indices and procedures to make these costs represent physical material input.

Raw materials and semifinished products: This was the largest cost item reported in Industrial Statistics Part I. To deflate it, it was necessary to divide this aggregate cost group into three sub-groups, pulpwood, chemicals and others, using detailed value and quantity data reported in Industrial Statistics Part II. The prices of different pulpwood species, chips, etc. were calculated using the reported value and quantity data, but in the construction of the real wood input quantity data reported in Yearbook of Forest Statistics were used. The total real cost of chemicals was obtained by summing up all chemicals product by product, and deflating this aggregate by WPI for chemicals. The value of "others" was computed as a residual that remained after the value of pulpwood, chemicals and own pulp was deducted from the total cost. The resulting residual was deflated by WPI. The deduction of own pulp was necessary to avoid (reduce) double counting of material costs. These three subaggregates were then added together to get the real raw

APPENDIX E. (cont'd.).

material and semifinished products. This procedure was carried out for years 1958-74; from 1975 to 1982 price index for <u>raw materials</u> provided by Indufor Ky, Helsinki was used for deflating. This index is based on detailed data and computations, and can be considered to be a reliable deflator for raw materials. The use of two different deflating procedures causes error in the material input index, but the difference between these two ways of deflating is not great because wood raw material was the major cost item in this cost aggregate, and wholesale prices for all products and chemicals developed similarly enough with this "correct" index between 1975 and 1982. The effect on TFP measures is probably small except during 1975 when the change in the deflator takes place. The material input and TFP measures for this year are also of suspect because of the change in the correction procedure for double counting.

<u>Packaging mat.</u>: Deflated by WPI for paper and paperboard.

<u>Lubricants</u>: Deflated by WPI for mineral fuels and lubricants.

<u>Other auxiliary materials and accessories</u>: Deflated by WPI for machinery and equipment.

APPENDIX E. (cont'd.).

Contract work: Deflated by an index with following weights: 0.4*(wage index in P & P industry) + 0.6*(WPI for machinery and equipment).

Repairs: Deflated by an index with following weights: 0.5*(wage index in metal industries) + 0.5*(WPI for machinery and equipment).

APPENDIX F. Output and Partial Productivity Changes for the Finnish and U.S. Forest Industries

Table F1. Output and Partial Productivity Changes in the Mechanical Forest Industries.

Mechanical Forest Industries

Year	Finland Q	Finland Q/L	Finland Q/K (percent)	USA Q	USA Q/L	USA Q/K
1959-82	0.0206	0.0333	-0.0430	0.0142	0.0270	-0.0080
1959-70	0.0506	0.0489	0.0076	0.0198	0.0295	0.0012
1971-82	-0.0094	0.0178	-0.0937	0.0085	0.0245	-0.0172
1976-82	0.0440	0.0515	-0.0372	-0.0013	0.0218	-0.0275

Table F2. Output and Partial Productivity Changes in the P & P Industries.

Pulp and Paper Industries

Finland (percent)

Year	Q	Q/L	Q/K	Q/M	Q/E
1959-82	0.0459	0.0434	-0.0219	0.0192	0.0064
1959-70	0.0750	0.0583	0.0004	0.0116	0.0027
1971-82	0.0168	0.0284	-0.0441	0.0267	0.0101
1976-82	0.0444	0.0677	-0.0166	0.0341	0.0303

USA (percent)

Year	Q	Q/L	Q/K	Q/M	Q/E
1959-82	0.0293	0.0339	-0.0103	0.0019	0.0145
1959-70	0.0420	0.0371	0.0012	0.0048	0.0033
1971-82	0.0166	0.0308	-0.0218	-0.0010	0.0256
1976-82	0.0277	0.0300	-0.0259	-0.0031	0.0376

APPENDIX G. Estimated C-D Production Functions in the Finnish and U.S. Mechanical Forest Industries

Finnish Mechanical Forest Industry, 1959-82

$$\text{dln}(Q) = \underset{(3.6331)}{0.0679} + \underset{(9.7611)}{1.4307}\ \text{dln}(L) - \underset{(-1.8495)}{0.4573}\ \text{dln}(K)^{1}$$

$\bar{R}^2 = 0.8315$ F = 57.7500 D-W = 2.1444

$$\text{dln}(Q/L) = \underset{(5.0462)}{0.0668} - \underset{(-4.0753)}{0.4386}\ \text{dln}(K/L)$$

$\bar{R}^2 = 0.4043$ F = 16.6078 D-W = 2.1304

$$\text{dln}(Q/K) = \underset{(5.0480)}{0.0668} + \underset{(13.3674)}{1.4386}\ \text{dln}(L/K)$$

$\bar{R}^2 = 0.8854$ F = 178.6880 D-W = 2.1296

U.S. Mechanical Forest Industry, 1959-82

$$\text{dln}(Q) = \underset{(1.3193)}{0.0264} + \underset{(6.1112)}{0.7638}\ \text{dln}(L) - \underset{(-0.1389)}{0.1088}\ \text{dln}(K)$$

$\bar{R}^2 = 0.6186$ F = 19.6527 D-W = 1.8043

$$\text{dln}(Q/L) = \underset{(1.8817)}{0.0186} + \underset{(1.9729)}{0.2412}\ \text{dln}(K/L)$$

$\bar{R}^2 = 0.1117$ F = 3.8922 D-W = 1.7869

$$\text{dln}(Q/K) = \underset{(1.8831)}{0.0186} + \underset{(6.2092)}{0.7590}\ \text{dln}(L/K)$$

$\bar{R}^2 = 0.6202$ F = 38.5544 D-W = 1.7864

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[1] T-values are in the parentheses.

APPENDIX H. Estimated Modified C-D Functions in the Finnish and U.S. Forest Industries

Finnish Mechanical Forest Industry, 1959-82

$$d\ln(Q/L) = \underset{(5.6787)}{0.0325} + \underset{(10.2324)}{0.1121}\, d\ln(s)$$ [1]

$\bar{R}^2 = 0.8185 \quad F = 104.703 \quad D\text{-}W = 2.0212$

$$d\ln(Q/L) = \underset{(5.5661)}{0.0428} - \underset{(-1.8840)}{0.0205D} + \underset{(10.5907)}{0.1103}\, d\ln(s)$$

$\bar{R}^2 = 0.8373 \quad F = 60.1929 \quad D\text{-}W = 2.2857$

U.S. Mechanical Forest Industry, 1959-82

$$d\ln(Q/L) = \underset{(2.0202)}{0.0120} + \underset{(6.7643)}{0.3686}\, d\ln(s)$$

$\bar{R}^2 = 0.6605 \quad F = 45.7558 \quad D\text{-}W = 1.6261$

$$d\ln(Q/L) = \underset{(1.8975)}{0.0155} - \underset{(-0.6343)}{0.0071D} + \underset{(6.6874)}{0.3696}\, d\ln(s)$$

$\bar{R}^2 = 0.6511 \quad F = 22.4576 \quad D\text{-}W = 1.6924$

Finnish Pulp and Paper Industry, 1959-82

$$d\ln(Q/L) = \underset{(7.4905)}{0.0254} + \underset{(23.1761)}{0.4441}\, d\ln(s)$$

$\bar{R}^2 = 0.9589 \quad F = 537.130 \quad D\text{-}W = 1.8967$

$$d\ln(Q/L) = \underset{(6.4407)}{0.0304} - \underset{(-1.4663)}{0.0095D} + \underset{(23.3630)}{0.4404}\, d\ln(s)$$

$\bar{R}^2 = 0.9609 \quad F = 238.680 \quad D\text{-}W = 1.9902$

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[1] T-values are in the parentheses.

APPENDIX H. (cont'd.).

U.S. Pulp and Paper Industry, 1959-82

$$d\ln(Q/L)^{*} = \underset{(3.0077)}{0.0099} + \underset{(19.5133)}{0.5175}\, d\ln(s)$$

$\bar{R}^2 = 0.9452$ F =380.771   D-W = 1.5824

$$d\ln(Q/L)^{*} = \underset{(2.1216)}{0.0088} + \underset{(0.2509)}{0.0013}D + \underset{(18.3244)}{0.5218}\, d\ln(s)$$

$\bar{R}^2 = 0.9385$ F = 168.800   D-W = 1.5298

* Hildreth-Lu correction for autocorrelation

APPENDIX I. Estimated CES Functions for the Finnish and U.S. Mechanical Forest Industries.

Finnish Mechanical Forest Industry, 1959-82

$$\dot{w}/w = \underset{(5.6169)}{0.0441} + \underset{(0.1278)}{0.0082}\,(\dot{x}/x)^{1}$$

$\bar{R}^2 = -0.0447$
$F = 0.0163$
$D\text{-}W = 1.6441$

$\sigma = 0.387/0.0082 = 47.1951$, not sign., wrong sign

$$\dot{r}/r^{*} = \underset{(1.8130)}{0.6130} + \underset{(2.9088)}{8.7107}\,(\dot{x}/x)$$

$\bar{R}^2 = 0.2533$
$F = 8.4612$
$D\text{-}W = 2.2421$

$\sigma = 0.6829/8.7107 = 0.0780$, significant

$$\dot{r}/r = \underset{(2.3467)}{0.2625} + \underset{(4.7802)}{4.3470}\,(\dot{x}/x)$$

$\bar{R}^2 = 0.4872$
$F = 22.8503$
$D\text{-}W = 1.8010$

$\sigma = 0.6829/4.3470 = 0.1571$, significant

U.S. Mechanical Forest Industry, 1959-82

$$\dot{w}/w = \underset{(2.2550)}{0.0206} + \underset{(0.3952)}{0.0447}\,(\dot{x}/x)$$

$\bar{R}^2 = -0.0381$
$F = 0.1562$
$D\text{-}W = 1.6523$

$\sigma = 0.3794/0.0447 = 8.4877$, wrong sign

$$\dot{r}/r = \underset{(1.9473)}{0.0783} + \underset{(5.9321)}{2.9538}\,(\dot{x}/x)$$

$\bar{R}^2 = 0.5978$
$F = 35.1898$
$D\text{-}W = 2.1849$

$\sigma = 0.6206/2.9538 = 0.2101$, significant

*Hildreth-Lu correction for autocorrelation

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[1] T-values are in the parentheses.

APPENDIX J. Rates of Change in Factor Efficiencies and Indices of Technological Change for the Mechanical Forest Industries.

Table J1. Rates of Change in Factor Efficiencies and Indices of Technological Change for the Finnish Mechanical Forest Industries.

FINLAND

Year	b1	b2	b3	a1	a2	a3	VAP1	VAP2	VAP3
1958							1.0000	1.0000	1.0000
59	.0913	.1703	.3694	.0868	.1002	.1341	1.0883	1.1243	1.2150
60	.1520	.0462	-.2202	.0723	.0876	.1262	1.1894	1.1970	1.2161
61	-.0381	.0106	.1334	-.0235	-.0519	-.1233	1.1604	1.1685	1.1890
62	-.0129	.1882	.6948	-.0118	-.0377	-.1029	1.1483	1.1954	1.3143
63	.0107	-.0060	-.0481	.0676	.0841	.1257	1.2026	1.2584	1.3992
64	-.0017	-.0109	-.0341	.0768	.0946	.1396	1.2598	1.3267	1.4954
65	.0165	.0382	.0929	.0534	.0541	.0559	1.3039	1.3768	1.5605
66	-.0551	.0614	.3549	-.0255	-.0515	-.1171	1.2721	1.3493	1.5439
67	-.0148	-.0677	-.2010	.1180	.1384	.1900	1.3639	1.4471	1.6568
68	-.0955	-.3552	-1.0098	.0131	.0148	.0191	1.3466	1.3584	1.3882
69	.0191	-.0693	-.2919	.0711	.0729	.0776	1.3978	1.3770	1.3247
70	.0010	.0294	.1010	.0967	.1058	.1289	1.4558	1.4519	1.4423
71	.0308	.1575	.4770	.0181	-.0087	-.0762	1.4783	1.5014	1.5599
72	-.0373	-.0729	-.1629	.0368	.0261	-.0007	1.4920	1.4966	1.5087
73	-.1478	-.4513	-1.2161	.0512	.0484	.0415	1.4609	1.3384	1.0302
74	-.2585	-.2884	-.3637	-.1079	-.1696	-.3252	1.2774	1.1092	.6857
75	.7833	3.4370	10.1241	-.2368	-.3125	-.5033	1.1339	1.1395	1.1540
76	-1.1695	-3.4178	-9.0837	.1119	.1234	.1522	1.1954	1.1235	.9427
77	-.1055	-.2790	-.7162	.0756	.0981	.1551	1.2233	1.1223	.8684
78	-.0187	-.0454	-.1127	.0749	.0950	.1456	1.2673	1.1709	.9287
79	.0713	-.0455	-.3399	.0740	.0888	.1261	1.3402	1.2079	.8752
80	-.0285	-.1190	-.3470	.0470	.0522	.0655	1.3525	1.1814	.7511
81	-.1001	.1429	.7552	-.0401	-.0571	-.1000	1.2880	1.2056	.9986
82	-.0287	.1977	.7683	.0534	.0664	.0992	1.3196	1.3070	1.2760
Avg.	-.0390	-.0312	-.0115	.0314	.0276	.0181			

Note: Numbers 1, 2, and 3 refer to alternative elasticities of substitution (0.16, 0.36, 0.60, respectively). Symbols a and b represent labor and capital efficiencies. VAP's represent value added productivity indices.

APPENDIX J. (cont'd.).

Table J2. Rates of Change in Factor Efficiencies and Indices of Technological Change for the U.S. Mechanical Forest Industries.

USA

Year	b1	b2	b3	a1	a2	a3	VAP1	VAP2	VAP3
1958							1.0000	1.0000	1.0000
59	.0075	-.0860	-.2613	.0202	.0101	-.0089	1.0159	.9775	.9053
60	.0000	.1207	.3471	.0015	.0063	.0153	1.0169	1.0217	1.0306
61	-.0195	-.0186	-.0168	.0876	.1073	.1442	1.0716	1.0904	1.1255
62	.0497	.0249	-.0215	.0606	.0744	.1003	1.1287	1.1489	1.1866
63	.0041	-.0380	-.1170	.0272	.0167	-.0031	1.1481	1.1470	1.1449
64	.0174	.0076	-.0108	.0241	.0112	-.0131	1.1699	1.1569	1.1326
65	.0096	.0373	.0893	.0033	.0094	.0208	1.1753	1.1758	1.1767
66	-.0398	-.0763	-.1449	-.0021	-.0045	-.0090	1.1602	1.1466	1.1210
67	-.0129	-.0112	-.0079	.0319	.0400	.0553	1.1762	1.1685	1.1539
68	-.0366	-.1663	-.4097	.0793	.0764	.0709	1.2102	1.1501	1.0371
69	-.0188	-.0108	.0041	-.0198	-.0313	-.0529	1.1908	1.1274	1.0081
70	.0401	.1959	.4881	.0526	.0713	.1062	1.2387	1.2456	1.2583
71	-.0037	-.1221	-.3443	.0830	.0946	.1165	1.2892	1.2589	1.2019
72	.1247	.0659	-.0446	.1072	.1199	.1437	1.4039	1.3555	1.2644
73	-.0971	-.1984	-.3885	-.0798	-.1020	-.1435	1.3159	1.2078	1.0046
74	-.0581	.0650	.2959	-.0494	-.0551	-.0659	1.2625	1.2080	1.1054
75	-.0028	.1148	.3354	.0951	.1208	.1691	1.3187	1.3264	1.3406
76	-.0193	-.1576	-.4170	.0289	.0274	.0245	1.3278	1.2779	1.1840
77	.0317	.0023	-.0531	-.0113	-.0280	-.0592	1.3360	1.2636	1.1276
78	-.0357	-.0873	-.1842	-.0244	-.0436	-.0796	1.3064	1.1997	.9993
79	.0046	.0642	.1761	-.0477	-.0478	-.0481	1.2827	1.2032	1.0539
80	.0204	.1979	.5309	.0642	.1038	.1782	1.3293	1.3448	1.3738
81	.0186	.1108	.2839	.0525	.0793	.1297	1.3701	1.4350	1.5569
82	-.0667	.0594	.2961	.1144	.1246	.1438	1.4301	1.5400	1.7465
Avg.	-.0034	.0039	.0177	.0291	.0326	.0390			

Note: Numbers 1, 2, and 3 refer to alternative elasticities of substitution (0.21, 0.41, 0.60, respectively). Symbols a and b represent efficiencies of labor and capital. VAP's represent value added productivity indices.

APPENDIX K. Estimated CD Functions for the Finnish and U.S. Pulp and Paper Industries.

Finnish Pulp and Paper Industry, 1959-82

$$dln(Q) = \underset{(1.9060)}{0.0621} + \underset{(2.4786)}{1.0912}\, dln(L) - \underset{(-0.6775)}{0.2798}\, dln(K)$$ [1]

$\bar{R}^2 = 0.1570 \quad F = 3.1420 \quad D\text{-}W = 1.8421$

$$dln(Q/L) = \underset{(2.1298)}{0.0559} - \underset{(-0.6156)}{0.1925}\, dln(K/L)$$

$\bar{R}^2 = -0.0277 \quad F = 0.3790 \quad D\text{-}W = 1.8276$

$$dln(Q/K) = \underset{(2.1301)}{0.0559} + \underset{(3.8142)}{1.1923}\, dln(L/K)$$

$\bar{R}^2 = 0.3707 \quad F = 14.5487 \quad D\text{-}W = 1.8274$

U.S. Pulp and Paper Industry, 1959-82

$$dln(Q) = \underset{(2.1032)}{0.0315} + \underset{(7.4031)}{1.4276}\, dln(L) + \underset{(0.5246)}{0.1768}\, dln(K)$$

$\bar{R}^2 = 0.7239 \quad F = 31.1485 \quad D\text{-}W = 1.6900$

$$dln(Q/L) = \underset{(4.7401)}{0.0510} - \underset{(-1.6972)}{0.3289}\, dln(K/L)$$

$\bar{R}^2 = 0.0756 \quad F = 2.8806 \quad D\text{-}W = 1.9635$

$$dln(Q/K) = \underset{(4.7358)}{0.0510} + \underset{(6.8549)}{1.3286}\, dln(L/K)$$

$\bar{R}^2 = 0.6666 \quad F = 46.9896 \quad D\text{-}W = 1.9622$

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[1] T-values are in the parentheses.

APPENDIX L. Estimated CES Functions for the Finnish and U.S. Pulp and Paper Industries.

Finnish Pulp and Paper Industry, 1959-82

$$\dot{w}/w = 0.0508 + 0.0535\ (\dot{x}/x)^{1} \qquad \bar{R}^2 = -0.0374$$
$$\quad (4.6694) \quad (0.4129) \qquad F = 0.1705, \quad D\text{-}W = 1.7955$$

$\sigma = 0.4832/0.0535 = 9.032$, not sign., wrong sign

$$\dot{r}/r = 0.2766 + 4.9208\ (\dot{x}/x) \qquad \bar{R}^2 = 0.3561$$
$$\quad (2.4789) \quad (3.7037) \qquad F = 13.7174, \quad D\text{-}W = 1.7187$$

$\sigma = 0.5168/4.9208 = 0.1050$, significant

U.S. Pulp and Paper Industry, 1959-82

$$\dot{w}/w^{*} = 0.0170 - 0.0993\ (\dot{x}/x) \qquad \bar{R}^2 = 0.0079$$
$$\quad (2.0595) \quad (-1.0838) \qquad F = 1.1747, \quad D\text{-}W = 1.3662$$

$\sigma = 0.5328/0.0933 = 5.7106$, not sign.

$$\dot{r}/r = 0.1031 + 2.8191\ (\dot{x}/x) \qquad \bar{R}^2 = 0.6189$$
$$\quad (4.0765) \quad (6.1928) \qquad F = 38.3506, \quad D\text{-}W = 1.4050$$

$\sigma = 0.4672/2.8191 = 0.1657$, significant

* Hildreth-Lu correction for autocorrelation

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[1]T-values are in the parentheses.

APPENDIX M. Rates of Change in Factor Efficiencies, and Indices of Technological Change for the P & P Industries.

Table M1. Rates of Change in Factor Efficiencies, and Indices of Technological Change for the Finnish P & P Industries.

FINLAND

Year	b1	b2	b3	a1	a2	a3	VAP1	VAP2	VAP3
1958							1.0000	1.0000	1.0000
59	-.0129	.0102	.0751	.0051	-.0079	-.0448	.9952	1.0216	1.2150
60	.0575	.0527	.0392	.0793	.0917	.1269	1.0625	1.1031	1.2163
61	.0143	.0164	.0223	.0820	.0847	.0923	1.1099	1.1623	1.1834
62	-.0580	-.0123	.1167	.0267	.0228	.0118	1.0915	1.2381	1.3317
63	.0349	.0283	.0096	.0997	.1085	.1333	1.1664	1.3296	1.4447
64	.0627	.0786	.1235	.0878	.0938	.1108	1.2547	1.4852	1.5837
65	.0126	.0425	.1266	.0693	.0717	.0782	1.3096	1.6339	1.6868
66	-.0156	.0131	.0940	.0694	.0710	.0754	1.3554	1.7693	1.6588
67	-.0900	-.1102	-.1671	.0157	.0124	.0032	1.3199	1.6556	1.8461
68	-.0073	-.0980	-.3536	.0598	.0641	.0762	1.3551	1.4309	1.3502
69	-.0035	-.0233	-.0791	.0786	.0813	.0888	1.3955	1.4150	1.2645
70	.0008	-.0124	-.0496	.0380	.0310	.0110	1.4164	1.3775	1.4132
71	-.0049	.0604	.2445	-.0691	-.0876	-.1398	1.3688	1.4774	1.5794
72	.0364	.0530	.0997	.1491	.1567	.1782	1.5003	1.6860	1.4985
73	.0272	.0128	-.0280	.0568	.0535	.0444	1.5645	1.7030	.7815
74	-.0690	-.1459	-.3627	-.0263	-.0346	-.0579	1.4870	1.3224	.5123
75	-.3742	-.3313	-.2106	-.3056	-.3550	-.4943	.9794	.8649	.7521
76	.0350	.1874	.6169	.0704	.0782	.1000	1.0370	1.0971	.5932
77	-.1105	-.1368	-.2111	.0645	.0725	.0949	1.0595	1.1191	.5491
78	-.0034	-.0983	-.3656	.1737	.1955	.2568	1.1767	1.1583	.5822
79	.0768	.0322	-.0934	.1245	.1328	.1559	1.2952	1.1948	.5511
80	.0022	.0122	.0405	-.0001	-.0072	-.0274	1.2966	1.2050	.4827
81	-.0270	-.0146	.0202	.0341	.0368	.0443	1.3007	1.2437	.6022
82	-.0422	.0025	.1285	.0451	.0488	.0589	1.3068	1.3570	.7692
Avg.	-.0191	-.0159	-.0068	.0429	.0423	.0407			

Note: Numbers 1, 2, and 3 refer to alternative elasticities of substitution (0.11, 0.21, 0.40, respectively). Symbols a and b represent efficiencies of labor and capital. VAP's represent value added productivity indices.

APPENDIX M. (cont'd.).

Table M2. Rates of Change in Factor Efficiencies, and Indices of Technological Change for the U.S. P & P Industries.

				USA					
Year	b1	b2	b3	a1	a2	a3	VAP1	VAP2	VAP3
1958							1.0000	1.0000	1.0000
59	.0400	.0270	.0035	.0682	.0748	.0866	1.0532	1.0423	.9053
60	-.0043	.0019	.0131	.0328	.0340	.0362	1.0665	1.0669	1.0187
61	.0045	.0157	.0359	.0686	.0744	.0848	1.1029	1.1293	1.1154
62	.0313	.0385	.0513	.0428	.0437	.0454	1.1434	1.1841	1.1836
63	.0254	.0237	.0208	.0592	.0631	.0701	1.1906	1.2363	1.1342
64	.0301	.0278	.0239	.0587	.0635	.0722	1.2422	1.2935	1.1203
65	.0066	.0073	.0086	.0538	.0590	.0685	1.2770	1.3400	1.1697
66	.0179	.0180	.0182	.0521	.0554	.0614	1.3194	1.3904	1.1045
67	-.0567	-.0458	-.0262	-.0236	-.0298	-.0410	1.2646	1.3445	1.1408
68	.0427	.0559	.0798	.0705	.0777	.0907	1.3353	1.4588	1.0076
69	.0316	.0384	.0507	.0391	.0424	.0483	1.3823	1.5310	.9784
70	-.0234	-.0116	.0096	.0374	.0392	.0426	1.3914	1.5706	1.2232
71	.0166	.0404	.0832	.0508	.0531	.0571	1.4392	1.6801	1.1542
72	.0466	.0397	.0273	.0881	.0925	.1002	1.5376	1.7903	1.2263
73	.0117	-.0071	-.0409	.0477	.0519	.0595	1.5833	1.8070	.9077
74	-.0739	-.1269	-.2221	-.0018	-.0015	-.0011	1.5168	1.5824	.9992
75	-.1825	-.1760	-.1643	-.0697	-.0838	-.1090	1.3114	1.3589	1.2342
76	.0762	.0858	.1032	.1068	.1146	.1286	1.4288	1.5141	1.0410
77	.0198	.0392	.0741	.0379	.0369	.0351	1.4688	1.5997	.9822
78	-.0044	-.0011	.0048	.0345	.0369	.0412	1.4891	1.6345	.8562
79	-.0132	-.0233	-.0414	.0286	.0337	.0430	1.4978	1.6298	.9030
80	-.0414	-.0277	-.0032	.0026	.0059	.0119	1.4656	1.6357	1.1918
81	-.0787	-.0841	-.0937	-.0095	-.0099	-.0107	1.3966	1.5444	1.4101
82	-.0406	-.0194	.0187	.0726	.0789	.0901	1.4134	1.6245	1.6774
Avg.	-.0049	-.0027	.0015	.0395	.0419	.0463			

Note: Numbers 1, 2, and 3 refer to alternative elasticities of substitution (0.17, 0.27, 0.40, respectively). Symbols a and b represent efficiencies of labor and capital. VAP's represent value added productivity indices.

APPENDIX N. Factor Input Shares in Gross Value of Production.

Table N. Factor Input Shares in Gross Value of Production.

	Finland				USA			
Year	w_L	w_K	w_M	w_E	w_L	w_K	w_M	w_E
1958	.1369	.1927	.5305	.1399	.2316	.2495	.4623	.0566
1959	.1557	.1700	.5292	.1451	.2239	.2717	.4514	.0530
1960	.1457	.1796	.5307	.1439	.2285	.2689	.4486	.0541
1961	.1443	.1787	.5512	.1257	.2301	.2620	.4517	.0561
1962	.1589	.1387	.5732	.1292	.2325	.2549	.4564	.0562
1963	.1571	.1528	.5657	.1245	.2326	.2637	.4478	.0559
1964	.1576	.1430	.5847	.1147	.2285	.2704	.4466	.0546
1965	.1619	.1211	.6071	.1099	.2244	.2730	.4484	.0542
1966	.1690	.1044	.6162	.1104	.2214	.2746	.4520	.0520
1967	.1738	.1209	.5994	.1059	.2335	.2611	.4511	.0542
1968	.1612	.2189	.5287	.0912	.2333	.2515	.4616	.0535
1969	.1488	.2365	.5193	.0954	.2332	.2460	.4682	.0527
1970	.1455	.2415	.5227	.0993	.2380	.2363	.4680	.0577
1971	.1630	.1501	.5769	.1100	.2432	.2120	.4769	.0679
1972	.1671	.1445	.5749	.1135	.2418	.2256	.4637	.0689
1973	.1684	.1575	.5667	.1074	.2232	.2394	.4693	.0681
1974	.1393	.2111	.5154	.1342	.1808	.2676	.4632	.0884
1975	.1987	.1574	.4971	.1469	.1901	.2485	.4567	.1047
1976	.2179	.0624	.5549	.1648	.1899	.2454	.4609	.1037
1977	.2208	.0805	.5367	.1620	.2008	.2293	.4557	.1142
1978	.1937	.1604	.4961	.1499	.2039	.3216	.4515	.1131
1979	.1804	.2165	.4621	.1411	.1939	.2416	.4481	.1164
1980	.1875	.1994	.4423	.1709	.1881	.2201	.4658	.1260
1981	.1837	.1825	.4411	.1926	.1831	.2208	.4614	.1347
1982	.1917	.1427	.4536	.2120	.1950	.2147	.4523	.1379

APPENDIX O. Annual Changes in Total Factor Productivity in the Finnish and U.S. P & P Industries.

Table O. Annual Changes in Total Factor Productivity in the Finnish and U.S. P & P Industries.

	FIN			USA		
Year	TFP1	TFP2	TFP3	TFP1	TFP2	TFP3
59	-.0073	-.0076	-.0078	.0327	.0319	.0323
60	.0441	.0448	.0448	.0022	.0011	.0012
61	.0122	.0120	.0120	.0131	.0124	.0124
62	.0014	.0003	.0004	.0189	.0189	.0189
63	.0433	.0421	.0423	.0188	.0186	.0186
64	.0410	.0394	.0401	.0141	.0143	.0143
65	-.0031	-.0041	-.0041	.0126	.0117	.0117
66	.0213	.0203	.0202	.0184	.0182	.0181
67	-.0084	-.0099	-.0100	-.0189	-.0194	-.0195
68	.0404	.0401	.0401	.0191	.0195	.0196
69	.0198	.0193	.0189	.0132	.0129	.0129
70	-.0041	-.0046	-.0047	-.0101	-.0110	-.0111
71	-.0785	-.0796	-.0797	-.0006	-.0012	-.0013
72	.0840	.0839	.0841	.0245	.0247	.0248
73	.0222	.0209	.0210	.0439	.0438	.0438
74	-.0305	-.0302	-.0304	.0246	.0242	.0237
75	-.0730	-.0743	-.0727	-.0668	-.0680	-.0687
76	-.0080	-.0090	-.0092	.0283	.0287	.0301
77	.0219	.0216	.0215	.0012	.0006	.0013
78	.0368	.0370	.0376	.0103	.0097	.0097
79	.0967	.0965	.0964	.0110	.0106	.0107
80	.0003	-.0005	-.0003	-.0141	-.0143	-.0145
81	.0293	.0297	.0297	.0020	.0021	.0019
82	.0540	.0539	.0539	-.0169	-.0175	-.0173
Avg.	.014823	.014241	.014343	.007571	.007185	.007236

Note: TFP1 - no quality adjustments
TFP2 - quality adjustments, capital gains excl.
TFP3 - quality adjustments, capital gains incl.

APPENDIX P. Development of Alternative Real Value Added Measures in the U.S. P & P Industry.

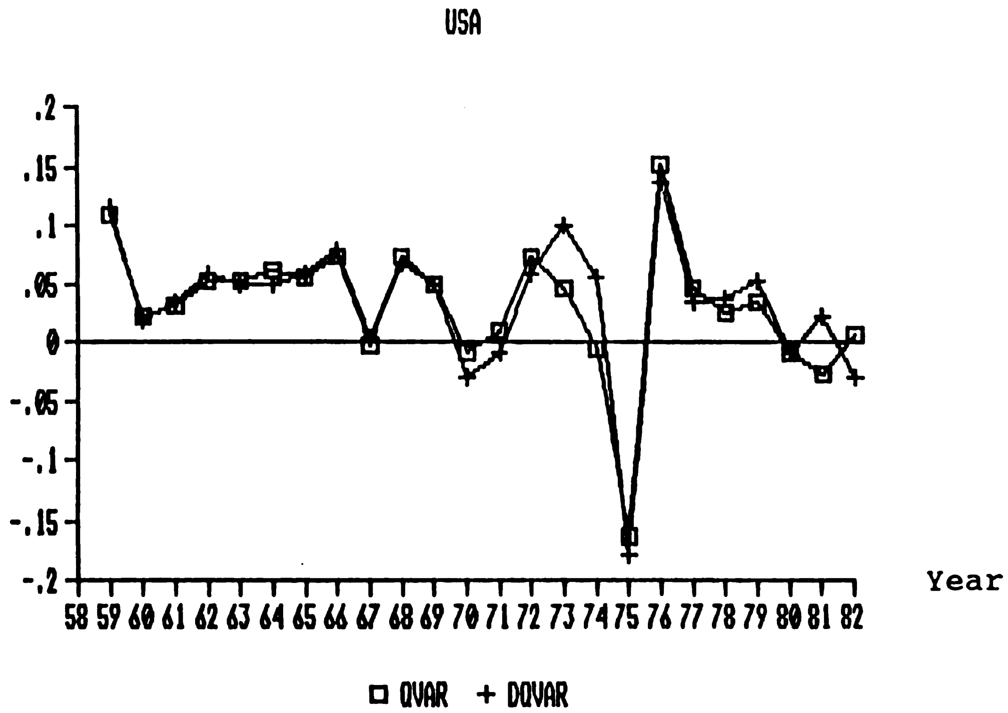

Figure P. Development of Alternative Real Value Added Measures in the U.S. P & P Industry.

Note: QVAR is based on the output indices calculated by the Bureau of Labor Statistics. DQVAR is the double deflated real value added.

APPENDIX Q. Contributions of Capital, Material and Energy Deepening and TFP1 to Labor Productivity Growth.

Table Q1. Contributions to Labor Productivity Growth in the Finnish P & P Industry (percent).

Year	$\dot{Q}/L$	$w_k(\dot{K}-\dot{L})$	$w_m(\dot{M}-\dot{L})$	$w_e(\dot{E}-\dot{L})$	TFP1
1959-82	**4.34**	**0.95**	**1.43**	**0.47**	**1.48**
		(21.9)	**(32.9)**	**(10.8)**	**(34.1)**
1959-62	4.87	1.06	1.88	0.66	1.26
		(21.8)	(38.6)	(13.5)	(25.9)
1963-67	6.57	0.91	3.02	0.76	1.88
		(13.8)	(46.0)	(11.57)	(28.6)
1968-72	5.32	0.77	2.89	0.34	1.23
		(14.5)	(54.3)	(8.1)	(23.1)
1973-77	-2.01	1.11	-1.82	0.05	-1.35
		(55.2)	(-90.5)	(2.5)	(-67.2)
1978-82	7.04	0.91	1.30	0.49	4.34
		(12.9)	(18.5)	(7.0)	(61.6)

Table Q2. Contributions to Labor Productivity Growth in the U.S. P & P Industry (percent).

Year	$\dot{Q}/L$	$w_k(\dot{K}-\dot{L})$	$w_m(\dot{M}-\dot{L})$	$w_e(\dot{E}-\dot{L})$	TFP1
1959-82	**3.39**	**1.08**	**1.47**	**0.08**	**0.76**
		(31.8)	**(43.4)**	**(2.3)**	**(22.4)**
1959-62	4.04	0.91	1.28	0.17	1.67
		(22.5)	(31.7)	(4.2)	(41.3)
1963-67	3.30	0.93	1.35	0.12	0.90
		(28.2)	(40.9)	(3.6)	27.3)
1968-72	4.49	0.99	2.18	0.40	0.92
		(22.0)	(48.5)	(8.9)	(20.5)
1973-77	2.67	1.15	1.04	-0.14	0.62
		(43.1)	(38.9)	(-5.2)	(23.2)
1978-82	2.59	1.41	1.46	-0.12	-0.15
		(54.4)	(56.4)	(-4.6)	(-5.8)

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