Production Structure, Technological Change and Scale Economies in the Saw and Planing Mills Industry in New Brunswick, Canada

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Abstract

The translog cost function approach is employed to characterize the production structure and to estimate the rate of technical change and technical bias in the saw and planing mills industry (SPM) in the New Brunswick Province. The findings are that the production structure of the saw and planing mills in Canada is neither homothetic nor homogenous implying potential scale induced distortion in the input mix. Morishma elasticity of substitution estimates show that in the existing technology of the saw and planing mills in New Brunswick, labor can more easily be substituted by capital than capital by labor. Moreover, the amount of round wood that is required to complement labor is higher than that required to complement energy and capital, which indicates that a labor intensive technology choice in the SPM industry is more round wood consuming than the capital and energy intensive technologies. These results coupled with the increasingly stringent environmental regulations indicate that the relative use of labor compared to other inputs is likely to decline in the saw and planing mills industry. Hence, in view of their cost minimizing behavior, the saw and planing mills in New Brunswick will sooner or latter start to replace labor with energy or capital. The saw and planing mills in New Brunswick exhibited fairly high economies of scale during the period 1965-1995, but the rate of technical change has been found to be negative.

Key words: Translog cost function, Morishima elasticity of substitution, rate of technical change, input bias, scale economies.

1. Introduction

1.1 Background

The forest industry is a mainstay of New Brunswick's output and employment base – it directly contributes $1.7 billion to the New Brunswick economy, directly employs over 17,000 people in high paying jobs, and accounts for 30-40% of exports from the province. The industry has grown rapidly during the last decade – double the growth rate in the rest of the economy. The core of the forest industry has long been the pulp and paper sector. This sector has diversified in recent years by using new processes to create more advanced products. The wood products industry has taken off during the last decade – doubling its output. This sector has also diversified to include industries such as particle board, fiberboard and other byproducts (APEC, 2003).

However, given the increasing environmental awareness and the relatively longer period for forest replenishment, its contribution to the provincial GDP and employment in the industry will be at risk unless new sources of fiber can be generated to support a growing industry. Continued investment is required to maintain the international competitiveness of this sector. Being profit maximizers, firms are reluctant to invest improved technologies if there are likely to be fiber shortages in the future.

Globally, the forest industry has undergone major technological changes during the last century. However, unlike the high technology industries where change is dramatic and fast, change in forest-product technology is characterized by a rather mature and slow development. Philippou (1998) argues that the main driving forces for these changes were the resource itself, its character, availability and price, as well as product and substitute performance and prices.

In the last two decades, new aspects have been added to the above driving forces for technological improvement and changes. Most of them arise from: a) society's growing concern and demand for sustainability, material and energy conservation and environmental protection, b) the increasing consumer demand for higher quality, safety and performance of the product, and c) the increasing competitiveness in the market which is becoming more global. As a result, new technologies are being developed at a relatively rapid rate mainly by adapting the processing and management methods and technologies developed in the high-technology branches of the industry. Such technologies include biotechnology, polymers, automation, computer and electronic controls, X-rays, lasers, ultrasonic, microwaves, scanners, systems engineering, modern production systems, total quality management and marketing, telematics technologies, etc.

Given the central role it plays in the New Brunswick economy, and in particular forest dependent communities, concern over uncertainties faced by the forest sector has grown in recent years for a variety of reasons. The major causes of uncertainty are: (i) the expected decrease in world price due to increases in global supply of forest sector products from Latin America and South East Asia (these suppliers may have a comparative advantage over producers in New Brunswick due to such factors as technological advances and regional differences in timber growth rates, rotation age, labor costs and environmental regulations) (ii) increasing concern for environmental quality that may call for government intervention to reduce the Annual Allowable Cut (AAC)[1] thereby negatively impacting forest dependent communities.

More rapid technological innovation and adoption could increase the competitiveness of the forest sector in the New Brunswick province. Hence, given the important role that the forest sector plays in the New Brunswick province, in-depth studies on the rates of technological change in the different industries in the forest sector are essential for predicting the future of the industries and for informed policy decisions.

This paper therefore attempts to characterize the production structure and estimate the rate of technical change and scale economies in the saw and planing mills industry in New Brunswick.

2. Methodology and Data

2.1 Methodology

Any study that attempts to characterize the production structure of a given industry requires information about the production technology. However, as discussed in Christensen and Greene (1976) and Berndt (1991)**,** given the duality[2] between the production function and cost function, the specification of a cost function implies a particular production technology and that production relationships can be uniquely recovered from estimation of the demand equations derived from the dual cost function. Thus, the structure of production can be studied using either a production function or cost function where the choice should be made on statistical grounds. Direct estimation of the production function is attractive when output is endogenous. The use of cost function is

[1] AAC is the amount of timber that is permitted to be cut annually from a particular area; AAC is used as the basis for regulating harvest levels to ensure a sustainable supply of timber.

[2] It has been noted in the economic literature that when the objective of the firm is to minimize costs, a duality exists between the cost function and the production function (Singh and Nautiyal, 1985). Varian (1978) has shown that the cost function contains all the economic information of the production function and vice versa.

however somewhat more attractive if the output level is exogenous (Christensen and Greene, 1976).

Due to the fact that at least 50% of the forestland in New Brunswick is Crown land, the output levels of the forest industries in the province can be assumed to be quasi-fixed and are determined largely by government regulations such as the annual allowable cuts (Yigezu and Lantz, 2002). Hence, the cost function approach is deemed appropriate to model the long-run equilibrium relationships in the saw and planning mills industry in New Brunswick.

The commonly used translog cost function is adopted here for its desirable property of flexibility. Moreover, the fact that we don't know the true production or cost generating process makes the choice of functional form difficult, but previous successful applications (Christensen and Greene, 1976, Kant and Nautiyal, 1997, Martinello, 1985, Tadesse, 2005) made it an attractive choice. As discussed in (Varian, 1978), the translog cost function can be viewed as a second-order approximation to an arbitrary twice differentiable, well behaved cost function and it places no a priori restrictions on the substitution possibilities between factors of production while allowing scale economies to vary with the level of output.

2.2 The Translog Cost Function

For the purpose of this exercise, the cost items in the saw and planing mills in the New Brunswick province are broadly classified in to four categories namely: Capital (k), labor (l), round wood (m) and energy (e)[3]. Accordingly, the following translog cost function is specified for the saw and planing mills in New Brunswick, where, in addition to the input prices and output quantities, following Kant and Nautiyal (1997) and Martinello (1985),

[3] Machinery, labor and electric power are used in the saw and planning mills to convert round wood (or commonly called log) in to lumber and particle and fiber boards.

time trend is included as concomitant variable and interacted with prices and quantities of output.[4]

$$(1)\ Ln\,C = \alpha_0 + \lambda_y\, lnY + ½\, \lambda_{yy}\, [lnY]^2 + \theta_t\, T + ½\, \theta_{tt}\, T^2 + \lambda_{ty} T\, lnY$$
$$+ \lambda_{yk}\, lnY lnP_k + \lambda_{yl}\, lnY\, lnP_l + \lambda_{ye}\, lnY\, lnP_e + \lambda_{ym}\, lnY\, lnP_m + \alpha_k\, lnP_k + \alpha_l\, lnP_l$$
$$+ \alpha_e\, lnP_e + \alpha_m\, lnP_m + ½\, \beta_{kk}\, [lnP_k]^2 + \beta_{kl}\, lnP_k\, lnP_l + \beta_{ke}\, lnP_k\, lnP_e + \beta_{km}\, lnP_k\, lnP_m$$
$$+ ½\, \beta_{ll}\, [lnP_l]^2 + \beta_{le}\, lnP_l\, lnP_e + \beta_{lm}\, lnP_l\, lnP_m + ½\, \beta_{ee}[lnP_e]^2 + \beta_{em}\, lnP_e lnP_m$$
$$+ ½\, \beta_{mm}[lnP_m]^2 + \theta_{tk} T\, lnP_k + \theta_{tl}\, T\, lnP_l + \theta_{te} T\, lnP_e + \theta_{tm} T\, lnP_m + U_t$$

The cost share functions, S_i (i=k,l,m,e), which also represent the cost-minimizing demands for the respective inputs, are derived using the Shepard's Lemma[5]and are provided below:

$$(2)\ S_k = \alpha_k + \lambda_{yk}\, lnY + \beta_{kk}\, lnP_k + \beta_{kl}\, lnP_l + \beta_{km}\, lnP_m + \beta_{ke}\, lnP_e + \theta_{tk}\, lnT + V_t$$
$$(3)\ S_l = \alpha_l + \lambda_{yl}\, lnY + \beta_{kl}\, lnP_k + \beta_{ll}\, lnP_l + \beta_{lm}\, lnP_m + \beta_{le}\, lnP_e + \theta_{tl}\, lnT + W_t$$
$$(4)\ S_m = \alpha_m + \lambda_{ym} lnY + \beta_{km}\, lnP_k + \beta_{lm}\, lnP_l + \beta_{mm}\, lnP_m + \beta_{em}\, lnP_e + \theta_{tm}\, lnT + O_t$$
$$(5)\ S_e = \alpha_e + \lambda_{ye}\, lnY + \beta_{ke}\, lnP_k + \beta_{le}\, lnP_l + \beta_{em}\, lnP_m + \beta_{ee}\, lnP_e + \theta_{te}\, lnT + \mu_t$$

In the representation of the data depicted by equations 1-5, the λ's, α's, β's, and θ's are coefficients to be estimated and U_t, V_t, W_t, O_t, and μ_t are random disturbances. These equations would seem to be unrelated. However, the translog cost function being a second order approximation, there is an implied truncation error. The effects of such specification errors are passed on to the error terms of the cost share equations and lead to a seemingly unrelated error structure (SUR). In addition, imposition of restrictions on coefficient values across equations requires a system estimation approach.

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[4] The inclusion of the time variable in this way facilitates the analysis of a changing production structure over time, particularly in the computation of the rate of technical change. Alternatively, the time trend could be viewed as an index of the technology over time.

[5] The Sheppard's lemma is given by the relationship $\frac{\partial C}{\partial P_i} = q_i$, the quantity of input i $\Rightarrow$ $\frac{\partial LnC}{\partial \ln P_i} = \frac{P_i}{C}\frac{\partial C}{\partial P_i} = \frac{P_i q_i}{C} = S_i$, the share of input i in total cost.

Zelner's (1962) generalized least squares (GLS) method for seemingly unrelated regression is commonly used for solving translog models. Given the adding up condition from demand theory, the cost share variables in equations 2-4 add up to unity and the error terms add to zero across equations. This feature of the translog model results in a singular error covariance matrix and one of the share equations must be omitted in estimation. The parameters of the omitted equation can be recovered from the following restrictions. Use of a maximum likelihood estimation (MLE) procedure guarantees that the parameter estimates are invariant to the choice of the omitted equation (Barten, 1969).

Restrictions to be Imposed

1) Across-Equations

All of the coefficients in the cost share equations should be equal to their corresponding coefficients in the cost function (eg. the constant term (α_k) in equation 2 must be equal to the coefficient of lnP_k in equation 1)

2) Symmetry

$\beta_{ij} = \beta_{ji}, \forall i, j$, where in this case, the symmetry restrictions are imposed a priori on the cost function (equation 1) while they are imposed on the cost share equations (equations 2-5) by the across-equations restrictions between the cost and cost share equations (e.g. the coefficient of lnP_k in equation 3 must be equal to the coefficient of $lnP_k lnP_l$ in the first equation which also has to be equal to the coefficient of lnP_l in equation 2 which implicitly imposes the symmetric restriction that the coefficients of lnP_l in equation 2 must be equal to the coefficient of lnP_k in equation 3).

Restrictions to be Tested

1) Homotheticity

In order to be a dual to a homothetic production function which has a linear expansion path, the following restrictions need to hold in the cost function.

$\lambda_{yy} = \lambda_{ty} = 0$;

2) Homogeneity

To correspond with a well-behaved production function, a cost function must be homogeneous of degree one in the input prices. This requires the establishment of the following identities:

$$\sum_i \alpha_i = 1$$

$$\sum_j \lambda_{yj} = 0$$

$\sum_j \beta_{ij} = 0 \;\; \forall i$ (i.e., horizontal summation e.g. for $i=k$, $\beta_{kk} + \beta_{kl} + \beta_{km} + \beta_{ke} = 0$)

$\sum_i \beta_{ij} = 0 \;\; \forall j$ (i.e., vertical summation, where in our formulation, this is required only on the price of the commodity whose share equation has been dropped because on this price, no symmetry restrictions can be imposed. Whereas, for the others, the horizontal summation in the presence of the symmetry restrictions is the same as the vertical summation restrictions which makes the vertical summation restrictions redundant.

$$\sum_j \theta_{tj} = 0$$

3) Returns to Scale

The restrictions required for constant returns to scale are:

- the restrictions for homotheticity,
- $\lambda_{yj}=0 \;\; \forall j$ and $\lambda_y=0$

2.3 Elasticities of Factor Substitution

It is to be expected that the elasticities of factor substitution and their associated price elasticities vary with the relative size of share of each input in total cost. Many studies (Christensen and Greene, 1976, Singh and Nautiyal, 1985, Martinello, 1985, Kant and Nautiyal, 1997,) have used the Allen elasticities of Substitution (AES) to estimate how effectively one factor could be substituted for the other. Uzwa (1962) has shown that the Allen Partial Elasticities of Substitution (σ_{ij}^{A}) and price elasticities of demand (ϵ_{ij}) between inputs *i* and *j* can respectively be expressed as:

$$\sigma_{ij}^{A} = (\beta_{ij} + (S_i * S_j))/(S_i * S_j), \text{ for } i \neq j$$
$$\sigma_{ii}^{A} = (\beta_{ii} + (S_i^2 - S_i))/S_i^2 \text{ and}$$
$$\epsilon_{ij} = (\beta_{ij} + (S_i * S_j))/S_i \text{ for } i \neq j \text{ and}$$
$$\epsilon_{ii} = (\beta_{ii} + (S_i^2 - S_i))/S_i$$

It is possible that some of the estimates of the coefficients in the cost function could turn out to be insignificant, thus limiting the confidence in the elasticity estimates. However, methods have been developed to build confidence intervals for the estimates. The easiest and perhaps the oldest method is a confidence interval based on the Chebychev's inequality which is symmetric and requires no prior assumption about the distribution of the errors. Alternatively, Filler (1954), Anderson & Thursby (1986) and others have shown that we can compute confidence intervals for the Allen Elasticities of Substitution, making certain assumptions about the distributions. The Anderson and Thursby (1986) and the Chebychev's inequalities will be constructed and compared in this paper to build 95% confidence intervals for elasticity estimates. Then which ever provides a tighter confidence interval will be presented.

The 95% confidence interval using the Chebychev's inequality is given by:

$$\sigma_{ij}^{A} \pm 4.47*SE$$

And the confidence interval by Anderson and Thursby (1986) is given by:

$\psi_{ij} \pm A/B$

where $\psi_{ij} = 1+ (\beta_{ij}/\bar{I}_i\bar{I}_j)$, $A= Z_\alpha (V^2\psi_{ij}^2 - 2V\Omega_\beta r_1\psi_{ij} + S_\beta^2)^{1/2}$, $B= \bar{I}_i\bar{I}_j + r_{ij}\Omega_i\Omega_j/N$ *and* $\bar{I}_i$, $\bar{I}_j$, Ω_i, *and* Ω_j, are the mean and standard deviation of the sample cost shares i and j, Z_α is the critical value from the standard normal distribution $V^2 = (\bar{I}^2_i\ \Omega_j^2 + \bar{I}_j^2\ \Omega_i^2 + 2\ \bar{I}_i\ \bar{I}_j\ \Omega_i\ \Omega_j\ r_{ij} + (1+ r_{ij})\ \Omega_i^2\ \Omega_j^2\ )/N$, where N is the sample size, r_{ij} is the sample correlation between share i and share j, Ω_β is the estimated standard error of β_{ij}, r_1 is the sample correlation between β_{ij} and $\bar{I}_i\bar{I}_j$. Anderson and Thursby (1986) suggest that r_1 should be set to zero and hence the confidence interval reduces to $\psi_{ij} \pm (Z_\alpha (V^2\psi_{ij}^2 + \Omega_\beta^2\ )^{1/2}\ )/(\ \bar{I}_i\bar{I}_j + (r_{ij}\ \Omega_i\ \Omega_j)/N)$.

Kant and Nautiyal (1997) have alternatively used the Morishma Elasticity of Substitution (MES) to study the production structure of the logging industry in Canada. The MES measures the ease of substitution, and it is a sufficient statistic for assessing the effects of changes in price ratios (as a result of changes in one price dimension) on relative factor ratios. One of the main differences between the Allen (AES) and Morishma (MES) elasticities is that the AES is always symmetric (i.e, the elasticity of substitution of input *i* by input *j* is the same as the elasticity of substitution of input *j* by input *i*), while this is not the case with MES (Blackorby and Russell 1989). The Morishima elasticities of substitution are the theoretically appropriate measure of substitution when there are more than two choice variables involved in the optimization (Fleissig and Rossana 2003).

Blackorby and Russell (1989) have shown that the Morishma elasticity of substitution between inputs i and j (σ_{ij}^M) can be calculated as:

(1) $\sigma_{ij}^M = \epsilon_{ji} - \epsilon_{ii}$

(2) $\sigma_{ji}^M = \epsilon_{ij} - \epsilon_{jj}$

Given the complex nature of many production structures (with more than two inputs), a strong case can be made for using the MES estimate (over the AES estimate) as the most appropriate measure. Although this report will present both estimates, given the lack of clear interpretation of the AES, more emphasis will be given to the interpretation of the MES estimates.

2.4 Returns to Scale

From the production function perspective, returns to scale measure the response of output to changes in the use of all inputs. From the cost function side however, returns to scale measure cost responses to output changes, holding input prices constant. Scale economies exist if an increase in output, at constant input prices, leads to a less than proportional increase in total costs, causing a decline in average costs (Tadesse, 2005).

The measure of economies of scale is defined as:

$SE = \frac{1}{\eta_{cy}}$, where $\eta_{cY} = d\ln C \big/ d\ln Y$ is the output elasticity of cost.

Starting from our cost function (equation 1), the output elasticity of cost is given by:

$$(6) \qquad \eta_{CY} = \lambda_Y + \lambda_{YY}\ln Y + \lambda_{tY}\ln T + \sum_i \lambda_{Yi}\ln P_i$$

A value greater than one of *SE* means that there is a less than proportionate increase in costs associated with a given level of change in output and indicates that there is an increasing return to scale (or there are scale economies which are characterized by a relative decline in cost).

2.5 Technological Change

Technological changes are defined as changes in the production process that arise from the application of scientific knowledge (Antle and Capalbo, 1988). Different studies employ different approaches to measuring technological change, which include the primal rate of technical change, the dual measure of technical change and total factor productivity. In this paper, the dual measure of technical change is employed. Modifying the specification of the time variable (in terms of logarithms) as opposed to the levels in the production and cost functions in Antle and Capalbo (1999), the dual rate of technical change is defined as:

$$(7) \qquad -\frac{\partial \ln C}{\partial t} = \sum_{i=1}^{n} S_i \frac{d \ln P_i}{dt} + \frac{\partial \ln C}{\partial \ln Y}\frac{\partial \ln Y}{dt} - \frac{d \ln C}{dt},$$

Equation (7) shows that the dual rate equals an index of the rate of change in factor prices plus a scale effect minus the rate of change of total cost. The valuation of the right hand side of equation (7) makes the knowledge of the production function necessary. Alternatively the cost function can be used to directly estimate the value of the left hand side. For instance, given the cost function defined above (i.e., equation 1), the rate of technical change is given by:

$$(8) \qquad -\frac{\partial \ln C}{\partial t} = -(\theta_t + \theta_{tt} T + \gamma_{ty} \ln Y + \sum_i (\theta_{ti} \ln P_i)$$

This estimate of technical change is composed of three components namely (Tadesse, 2005):

a) Pure technological change which is the rate of reduction in total costs, holding constant the efficient scale of production and the shares of each of the inputs in total cost. In equation (8), -($\theta_t + \theta_{tt} \ln T$) measures the pure technical change

b) Scale-augmenting technical change (SATC) which is the rate of reduction in total cost due to technical change that accompanies the change in output is measured by -($\gamma_{ty} \ln Y$) in equation (8).

c) Input-biased (non-neutral) technological change (IBTC) which is the measure of the reduction in total cost due to the changes in input prices accompanying technical change. In equation (8), $\sum_i \varepsilon_{ti} \ln P_i$ measures IBTC.

A technological change is said to be Hicks neutral if it is expansion path preserving where homothetic[6] production functions are an example. On the other hand, a technological change is input biased if the production function doesn't preserve the expansion path without regard to the slope of the expansion path.

A dual measure of input bias in technical change is given by:

(9) IBTC$_i$ = $\frac{\partial \ln S_i}{\partial t} |_{dpi=0} = \sum_{i \neq j} S_i * B_{i,j}$ where

$\partial \ln S_i = \frac{\partial S_i}{S_i}$, and $B_{i,j}$ (Y,P,t)[7]= $\frac{\partial \ln\left(\frac{x_i}{x_j}\right)}{\partial t} = \frac{\partial \ln\left(\frac{C_i}{C_j}\right)}{\partial t}$. From equations (2-5) we have:

$$\frac{\partial LnS_i}{\partial t} = \left(\frac{\partial S_i}{S_i} \Big/ \partial t \right) = \frac{1}{S_i} * \left(\frac{\partial S_i}{\partial t} \right) \text{ where } \frac{\partial S_i}{\partial t} = \theta_{ti}$$

$$\Rightarrow IBTC_i = \frac{\theta_{ti}}{S_i},$$

This measure of input bias is useful if the cost function is homothetic. If the cost function is not homothetic (i.e., not separable in output) then we need to define the following input bias measure with a scale adjustment (IBTCA):

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[6] A production function is homothetic when the slopes of the production isoquants (i.e., the marginal rates of substitution between all pairs of inputs) remain the same as one moves across all isoquants along any ray that passes through the origin. This also implies that the input ratios remain the same along the rays passing through the origin.

[7] $B_{i,j}$ measures the % change in the ratio of input i and input j due to technical change for a given output level (Y) and input prices (P).

$$IBTCA_i = \frac{\partial \ln S_i}{\partial t} - \frac{\partial \ln S_i}{\partial \ln Y}\left(\frac{\partial \ln C}{\partial \ln Y}\right)^{-1}\left(\frac{\partial \ln C}{\partial t}\right) = \frac{\partial \ln S_i}{\partial t} - \frac{1}{S} * \frac{\partial S_i}{\partial \ln Y}\left(\frac{\partial \ln C}{\partial \ln Y}\right)^{-1}\left(\frac{\partial \ln C}{\partial t}\right)$$

$IBTC_i$ or $IBTCA_i$ value of zero indicates that the technology is neutral while values less or greater than zero indicate that the technology is input i saving or using respectively.

2.5 Data

The data used for estimating the cost function relate to the Saw and Planing Mills industry in the New Brunswick province of Canada. Annual data for volume of production of timber in the Saw and Planing Mills in New Brunswick (in m^3) were obtained from ESTAT databases Table No. 303-0009. The number of employees and costs of wages and salaries, energy and material were obtained from Stats. Can. (1965-1995), Cat. No. 25-202. The cost of fuel and electricity represent cost of energy while aggregate data on cost of materials and supplies that include not only the cost of wood but also of other supplies is incorporated. The wage index has been computed from the annual average wage, which is the ratio of wages and salaries and number of employees.

The price of wood as an input in the saw and planing mills is taken from ESTAT (2002), Table No. 330-0001 (1,2). However, the data was not available for the period prior to 1981. A linear regression equation is estimated with the price index of wood as the dependent variable and the price index of timber/lumber (which was taken from the national Timber/lumber price indices in ESTAT (2002), Table 329-0001) as the explanatory variable using the data for the period 1982-1995. Then, the regression equation is used to fill the data gap on the price of wood using the data on the price index of timber for the period prior to 1981.

Electric power is the major source of energy in the saw and planing mills, while the contribution of other possible sources of energy, like oil, is insignificant. Hence, the price index of electricity for non-residential use in New Brunswick is taken to represent the overall price index of energy. The price indices of electricity (for the period 1973-1995) were taken from Stats Can. (2001), Cat. No.62-011, and converted into the same base year as the other variables. Because there was no data for the years before 1973, a regression equation of price index of wood on price index of electricity was fitted for the period 1973-1995 and this regression was used to make backward projections for the price of electricity.

Researchers have used a variety of techniques to calculate the cost and price of capital in a given production year. The method suggested by Yigezu and Lantz (2002) is adopted here.

3. Empirical Results

Using the time series data collected from the saw and planing mills in New Brunswick for the period 1965 – 1995, equations 1-4 have been estimated as a system of equations using the SUR technique first with only the symmetry and across-equation restrictions imposed, and latter imposing the different (homotheticity and homogeneity) restrictions individually and in combination. As explained above, the energy cost share equation is omitted and its parameters have been recovered from the adding up restriction.

3.1 Characterization of the Production Structure

Likelihood ratio and Wald statistic tests rejected both the homotheticity and homogeneity restrictions. The fact that the production function is not homothetic implies that in the saw and planning mills industry in New Brunswick, any change in the output level will result in a change in the relative mix of inputs, which once again would mean that the output elasticity of cost is not constant but varies with output levels. The cost function is therefore not separable between output and input prices, indicating that the relationship among costs, output and input prices cannot be characterized globally. The estimates of the cost function corresponding to the non homothetic non homogeneous production function are provided in table 1. The model fits the data quite well with R^2 values respectively of: 0.9887, 0.9944, 0.6091 and 0.5346, for the cost function and the capital, labor and wood share equations[8].

For a further characterization of the production structure of the New Brunswick saw and planing mills industry, we have computed the own price and cross price elasticities, and the Allen and Morishima elasticities of factor substitution presented in Tables 2, 3 and 4 respectively. The own price elasticities and hence the own Allen elasticities of substitution are found to be negative at all data points which is consistent with the theoretical expectation. All of the cross price elasticities are positive showing that the inputs are all pair-wise substitutes. The positive cross price elasticities of energy and capital seem to be strange in that theoretically, we would expect capital and energy to be complements i.e., the more machines are used in the industry, the higher will be the demand for energy to run them. The counter argument could be that the newer capital is more efficient and energy saving. The cross price elasticities of labor, material (mainly logs) and energy with respect to the price of capital are small (i.e., they are not highly responsive), while on the contrary the elasticity of capital with respect to the prices of labor, logs and energy is higher showing that capital is more responsive. With regard to the Allen Elasticity of substitution, labor and capital have the highest elasticity of substitution.

The confidence intervals constructed for the Allen partial elsticities of substitution using the Chebychev's inequality are found to be tighter than those estimated using Anderson and Thursby (Table 6 in the Appendix).

One of the striking observations from the MES estimation results is that none of the pairs of factors are equally substitutable among each other (i.e., they are not symmetric). This further justifies the appropriateness of the MES as measure of factor substitution because it allows for more flexibility in cross product effects. An interesting result from the Morishima elasticity of substitution estimates is that the Morishima elasticities of

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[8] The squared correlation coefficients are considered for the cost share equations for the R^2 is not necessarily bound between 0 and 1.

substitution of labor by capital (0.513) is smaller than capital by labor (0.923). This result suggests that in the existing technology in the saw and planing mills in New Brunswick, labor can more easily be substituted for by capital than capital can be by labor. This could possibly be because the industry is characterized by a labor intensive technology on the extreme side of the isoquant mapping of the production process.

The results also show that, it is easier to substitute material by capital and labor than capital and labor by material indicating that the existing production technology is material saving. Another interesting result is that, the MES of material by capital and energy are smaller than that of material by labor and energy, showing that in the existing technology in the saw and planing mills in New Brunswick, the amount of round wood required to complement capital and energy is less than that required for labor indicating that capital and energy are round wood saving while labor is round wood using.

Over the years, forest supply is being depleted, wage rates are becoming increasingly higher and environmental regulations are becoming more stringent. On the contrary, capital is becoming cheaper and energy efficient machineries are increasingly available for which these results are to be expected.

The MES of material by energy is lower than the MES of energy by material. That is, material, which has round wood as its main component can more easily be substituted by energy than energy can be substituted for by material. This result indicates that the new machineries adopted by the saw and planing mills are energy using and wood saving.

3.2 Economies of Scale and Rate of Technical Change

The economies of scale (or returns to scale) measure, which is the reciprocal of the output elasticity of cost at the mean values of LnY, LnPk, LnPl, LnPm, and LnPe for the saw and planing mills in New Brunswick has been calculated to be 4.21 for the period 1965-1995. This shows that the saw and planing mills industry in NB has been enjoying increasing returns to scale during the study period. The values of the economies of scale (ES) measure ranged between 1.32 and 21.7 at different output levels.

The general picture from our data is that the saw and planing mills industry in the New Brunswick province enjoyed an increasing trend in the economies of scale (i.e. downward slopping average cost curve) for the period before 1985 with an average returns to scale measure of 5.8. Where as during the period between the late 60's and late 80's, the industry faced a downward slopping average cost curve with an average returns to scale measure of 2.4. For the period after late 1980's, the average cost curve once again became steeper attaining an average returns to scale measure of 4.6 until 1995 (Fig.1).

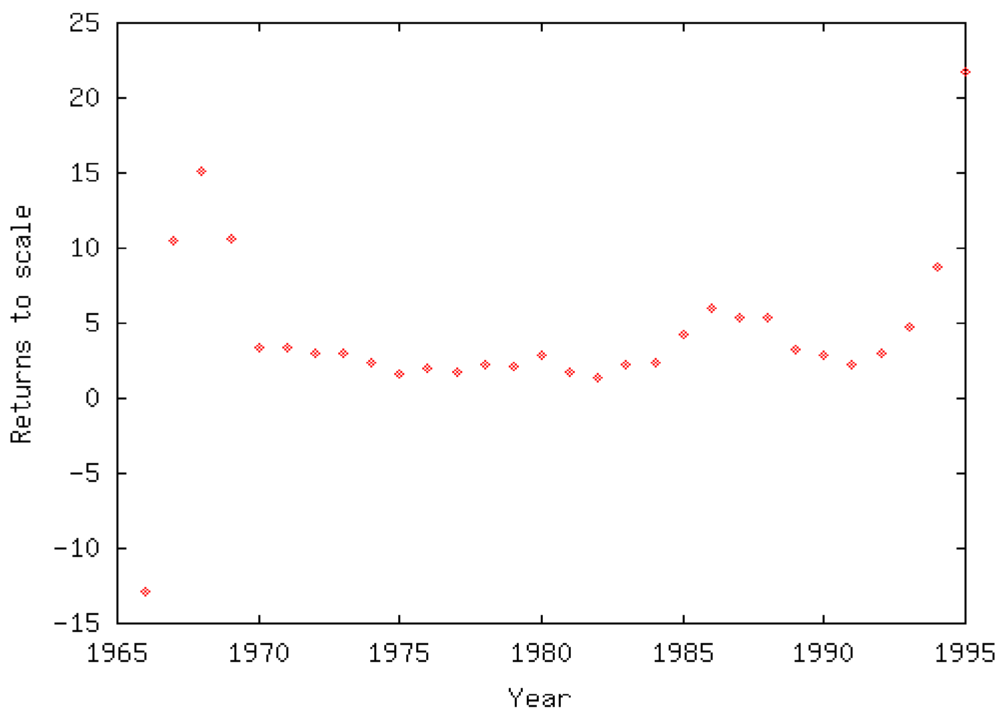

Fig.1 Scale Economies in the Saw and Planning Mills in New Brunswick

On the other hand, our estimates show that the saw and planing mills industry in New Brunswick has been experiencing a negative rate of technical change for the period 1965-1995. Our computations show that the average being -0.012 (i.e., -1.2%) the rate of technical change measures ranged between -0.02 and -0.008. An interesting phenomenon however is that the rate of technical change has shown an increasing trend especially for the period after 1970 (Fig.2). Explaining the sharp decline for the period before 1970 could possibly give an insight as to why the rate of technical change remained to be negative during the study period.

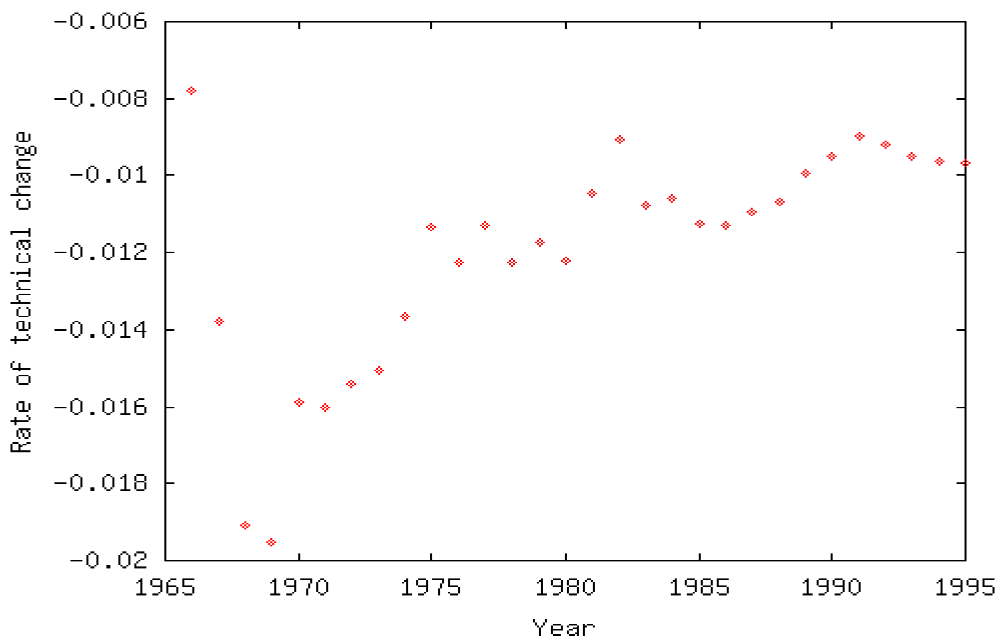

Fig.2 Rate of Technical Change in the Saw and Planning Mills in New Brunswick

The breakdown of the rate of technical change in to its constituent parts shows that the measure of pure technical change is positive (0.023) but insignificant while the scale augmenting technical change and the input biased technical change measures are negative (-0.033 and -0.0013) respectively, which are also both insignificant (Table 1).

Table 1 shows that all the constituent components of the rate of technical change are individually insignificant. On the other hand, the combined effect turned out to be significant indicating that the opposite effects from the individual components cancel out each other.

Table1 Decomposition of the Rate of Technical Change

Source of technical change	Estimate
Pure technical change	0.02299 (0.032)
Scale augmented technical change	-0.03358 (0.038)
Input biased technical change	-0.00136 (0.0025)
Rate of technical change	**-0.01196***** **(0.0029)**

NB: Figures in parentheses are standard errors.

Given that homotheticity is rejected, the scale adjusted measure of input bias has been estimated and tested. The results are consistent with the above finding that there was no bias in favor of or against any of the four inputs (Table 5 in the Appendix).

These results are consistent with Nautiyal and Singh (1986) who also used a translog cost model to study factor demands and productivity trends in the Canadian lumber industry from 1955 to 1982. They found that the lumber industry experienced increasing economies of scale over the time period but their model could not capture any significant technological progress. Baardsen (2000) also found that the rate of technical change in the Norwegian saw mill industry was –0.005 (–0.5%) p.a. for the average mill, with a standard error of 0.001. Martinello (1987) also found negative technical change and explained it by decreasing size and quality of timber, which led to more capital intensive production and increased labor productivity, and slowed but did not eliminate the decrease in output per unit of materials. Many different studies show various kinds of results for technical change (CSLS, 2003).

4. Conclusion

The production structure of the saw and planing mills in Canada is neither homothetic nor homogenous. Hence any increase in output in the future will cause a distortion in the input mix. All inputs are substitutes for each other, i.e. an increase in the price of one factor leads to the increased demand for the others.

Results from the Morishma Elasticity of substitution estimates show that in the existing technology in the saw and planing mills in New Brunswick, labor can more easily be substituted by capital than capital by labor. Moreover, the amount of round wood that is required to complement labor is relatively higher than that required to complement capital and energy, which indicates that the capital and or energy intensive technology choices in the SPM industry are more round wood saving than the labor intensive technology. These results indicate that the relative use of labor compared to other inputs is likely to decline in the saw and planing mills industry. This is because, the existing technology in the saw and planing mills in New Brunswick is labor intensive, which means the industry is operating somewhere at the extreme tail of its isoquant curve. Hence, in view of their cost minimizing behavior, the saw and planing mills in New Brunswick will sooner or latter start to replace labor with capital (i.e., with improved and more efficient machineries).

Given the increasingly stringent environmental considerations, it is likely that there will be more forest use regulations in the future thereby making wood an even more scarce input. This would once again compel firms to be in favor of wood saving inputs while reducing the wood consuming ones such as labor. The policy implication is then that, the provincial government should devise ways and means with which to absorb the labor force that may ultimately be laid off from the saw and planing mills.

The saw and planing mills in New Brunswick have exhibited fairly high economies of scale, while the rate of technical change has been found to be negative. This result is consistent with the findings of some previous studies, while it is not with others. Our findings of lower returns to scale during the period 1970-1982 as compared to latter years is also consistent with the wider gap between the annual allowable cuts and actual harvest during the period as compared to the years after 1982 (see Fig.3 in the Appendix). A closer look at this figure reveals that, if the saw and planning mills were to have advantages in expanding production (increasing returns) during the 70's, their demand for raw wood (assuming all other factors are not binding) would have been at least as high as the AAC.

The implications of our results is that the saw and planing mills industry in New Brunswick will face a huge challenge to remain competitive in the face of high rate of technological change in other areas such as British Columbia and comparative advantage in cheaper labor and conducive climate for tree growth in newly emerging supply channels. If the industry is to continue to play its central role in the New Brunswick economy, there needs to be a substantial investment on technology.

APPENDIX

Table 1 Parameter Estimates of the Cost Function

Coefficient	Estimate	Standard error	P-values
α_0	-2.8498***	0.0001	0.0000
ε_y	2.0207***	0.5787	0.0001
ε_{yy}	-0.7956***	0.2452	0.0010
ε_{yk}	-0.1049***	0.0295	0.0000
ε_{yl}	0.0199*	0.0077	0.0100
ε_{ye}	0.0820***	0.0219	0.0000
ε_{ym}	0.0030***	0.0005	0.0000
α_k	0.8283	25.2600	0.9740
α_l	0.0904	0.1514	0.5500
α_e	0.0325***	0.0001	0.0000
α_m	0.0458***	0.0001	0.0000
β_{kk}	-0.0242	0.5918	0.9670
β_{kl}	0.0134	0.0401	0.7370
β_{ke}	-0.0053***	0.0001	0.0000
β_{km}	0.0165	0.0328	0.6160
β_{ll}	0.0089**	0.0040	0.0240
β_{le}	-0.0006	0.0024	0.7910
β_{lm}	-0.0218***	0.0053	0.0000
β_{ee}	0.0079	0.0155	0.6110
β_{em}	0.0085***	0.0001	0.0000
β_{mm}	-0.0026***	0.0001	0.0000
θ_t	-2.1029***	0.0001	0.0000
θ_{tt}	0.3089***	0.0675	0.0000
θ_{tk}	0.0625	2.1910	0.9770
θ_{tl}	-0.0195***	0.0001	0.0000
θ_{te}	-0.0066***	0.0001	0.0000
θ_{tm}	-0.0361***	0.0121	0.0030
R^2	0.9887		

NB: *, ** and *** indicate that the estimates of the corresponding parameters are significant at 10%, 5% and 1% levels respectively.

Table 2. Own and Cross price elasticities of inputs

	Capital	Labor	Material	Energy
Capital	-0.3972***	0.7880***	0.7074***	0.2351***
	(0.0514)	(0.0709)	(0.0572)	(0.0692)
Labor	0.1152***	-0.8080***	0.0061	0.0449*
	(0.0188)	(0.0040)	(0.0270)	(0.0208)
Material	0.2775***	0.0135	-0.7164***	0.0518
	(0.0357)	(0.0685)	(0.0296)	(0.0590)
Energy	0.0051	0.0064	0.0029	-0.3329***
	(0.0022**)	(0.0028)	(0.0032)	(0.1154)

Table3. Allen Partial Elasticities of Substitution

	Capital	Labor	Material	Energy
Capital	-0.6294***			
	(0.1325)			
Labor	1.2284***	-8.8491***		
	(0.0259)	(1.4811)		
Material	1.1034***	0.0213	-2.9121***	
	(0.0066)	(0.2787)	(0.5089)	
Energy	0.3668***	0.4588***	0.1837	-24.0750***
	(0.1036)	(0.1501)	(0.2172)	(5.4959)

Table4. Morishma Elasticities of Substitution

	Capital	Labor	Material	Energy
Capital	0.0000	0.5123***	0.6747***	0.4023***
		(0.0685)	(0.0866)	(0.0518)
Labor	0.9232***	0.0000	0.8216***	0.8144***
	(0.0179)		(0.0682)	(0.0050)
Material	0.9940***	0.7300***	0.0000	0.7193***
	(0.0062)	(0.0433)		(0.0272)
Energy	0.3380***	0.3393***	0.3358***	0.0000
	(0.1174)	(0.1180)	(0.1183)	

Table 5: Estimates of the Scale Adjusted Measure of Input Biases

Input	Estimate*	Standard Errors
Capital	-0.18323	0.24918
Labor	-1.17240	1.29520
Material	-0.43029	0.50026
Energy	-0.02446	0.02153

*/ Note here that all the scale adjusted measures of input Biases are insignificant at α level of 0.01.

Table 6: Confidence Intervals Constructed for the Allen Partial Elasticities of Substitution Using Two Different Methods

Input		**Using Anderson and Thursby's method**				**Based on the Chebichev's inequality**			
		Capital	Labor	Material	Energy	Capital	Labor	Material	Energy
Capital	Estimated	-0.6294				-0.6294			
	Lower limit	-1.8829				-1.2217			
	Upper limit	3.7648				-0.0372			
Labor	Estimated	1.2284	-0.8109			1.2284	-0.81089		
	Lower limit	-0.0807	1.0964			1.1127	-7.43141		
	Upper limit	2.5264	2.9229			1.3441	5.809622		
Material	Estimated	0.2517	0.0077	-0.7586		0.2517	0.007681	-0.75864	
	Lower limit	0.6957	-0.3560	0.8679		0.2221	-1.23802	-3.0336	
	Upper limit	1.5083	0.5193	1.0500		0.2813	1.25338	1.516322	
Energy	Estimated	0.3668	0.4588	0.1837	-24.0750	0.3668	0.45875	0.18368	-24.075
	Lower limit	0.3484	-0.9090	1.0566	-124.4334	-0.0963	-0.21229	-0.78738	-48.6417
	Upper limit	0.4241	1.8967	1.2836	214.2359	0.8298	1.129786	1.154743	0.491673

Note: Generally, our results indicate that the Chebychev’s inequality provides a tighter confidence interval than that of Anderson and Thursby’s.

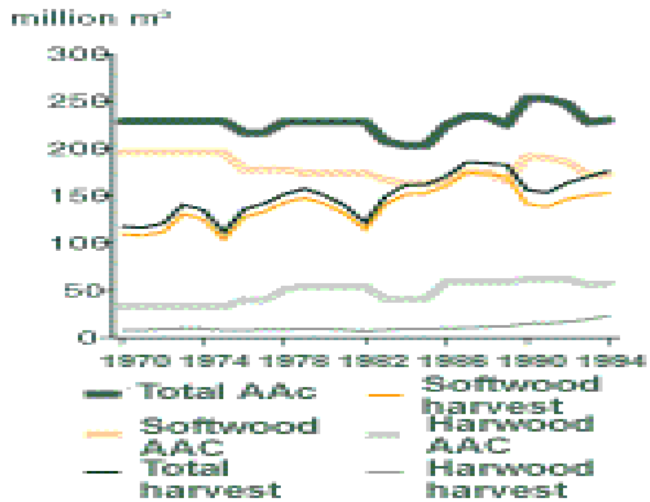

Fig.3 Annual Allowable Cuts (AAC) and harvests in Canada
Source: CCI (no date)

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