ESSAYS ON FORESTRY PRODUCTS INDUSTRY: SAWMILL PRODUCTIVITY

AND INDUSTRIAL TIMBERLAND OWNERSHIP

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ESSAYS ON FORESTRY PRODUCTS INDUSTRY: SAWMILL PRODUCTIVITY AND INDUSTRIAL TIMBERLAND OWNERSHIP

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ESSAYS ON FORESTRY PRODUCTS INDUSTRY: SAWMILL PRODUCTIVITY

AND INDUSTRIAL TIMBERLAND OWNERSHIP

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DISSERTATION ABSTRACT

ESSAYS ON FORESTRY PRODUCTS INDUSTRY: PRODUCTIVITY

AND INDUSTRIAL TIMBERLAND OWNERSHIP

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In this dissertation, two topics of forest products industry were investigated: inter-regional productivity comparison of sawmilling industries in the North America, and the relationship between industrial timberland ownership and corporate financial performance in the U.S.

The first study used nonparametric programming approach to estimate technical efficiency and total factor productivity (TFP) growth of sawmill industries in the U.S. and Canada between 1963 and 2001 The results showed that the U.S. sawmill industry was more likely to be on the industry frontier than Canada during 1990-2001 although the Canadian sawmill industry was shown more efficient compared to the U.S. counterpart during 1963-1989. The weighted annual productivity growth of sawmill industry was 2.5% for the U.S. and 1.3% for Canada. Regional differences in technical efficiency and

TFP growth existed. All regions were shown to have a trend of moving towards the industry frontier. Assumption of Hicks neutrality in production was rejected for both countries. Bootstrap results suggested that both countries experienced statistically significant productivity growth and the U.S. had a higher rate of growth during the whole study period although the estimates may be sensitive to outliers.

The second study presented an empirical analysis of the relationship between industrial timberland ownership and financial performance of forestry products companies in the U.S. A three stage least square (3SLS) model system was used for estimation. The results showed that generally timberland holding may improve a forest products company's profitability in terms of return on asset (ROA) and return on equity (ROE) as well as its ability of response of rate of returns to uncertainty. However, higher capital expense and debt/asset ratio were shown associated with timberland holding. Forest product companies may divest some of their timberland to ease the financial burden.

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I. INTRODUCTION

This dissertation addresses two issues related to forest products industries in the US. Productivity comparisons in the North American sawmilling industries have been of concern for decades as they play an important role in regional resource allocation and relative competitiveness among regional counterparts. Although costs of inputs affect relative competitiveness in the short run, competitiveness in the long run will be determined by technical efficiency and productivity growth. Chapter II presents a study of productivity analysis of sawmill industries in the U.S. and Canada by using non-parametric programming method or Data Envelope Analysis approach.

The second issue concerns industrial timberland ownership of forest products companies in the US. forest products company restructuring involves decisions about industrial timberland holdings. However, the patterns of timberland holdings are far from uniform. There have been quite a few theories explaining timberland holding behavior of forest products companies have been proposed, favorable return and financial success among them. However, there has been no empirical analysis of this hypothesis. To fill this gap, an econometric analysis of timberland ownership and corporate financial performance is performed using cross-sectional data for 36 publicly-traded U.S. forest products companies from 1988 to 2003. Results are reported in Chapter III.

II. PRODUCTIVITY IN THE SAWMILLING INDUSTRIES OF THE UNITED STATES AND CANADA: A NONPARAMETRIC ANALYSIS

INTRODUCTION

Productivity measures the efficiency with which inputs are transformed into outputs. Higher productivity occurs when larger quantities of outputs are produced with given inputs. Among various techniques to estimate the performance of industries, total factor productivity (TFP) provides a simple yet comprehensive measurement. TFP, the ratio of an index of aggregate output to an index of aggregate input, is a measure taking into account the contribution of all inputs.

Productivity comparisons in the North American sawmilling industries have been of concern for decades as they play an important role in regional resource allocation and relative competitiveness among regional counterparts. Although costs of inputs affect relative competitiveness in the short run, competitiveness in the long run will be determined by technical efficiency and productivity growth. In the ongoing U.S.-Canada softwood lumber dispute, the Canadian industry uses relatively higher productivity as an argument to explain their increasing share of the U.S. lumber market. However, this argument is refuted by the U.S. lumber industry. While many studies have been devoted to the productivity growth of the sawmill industry in the U.S and Canada, the results are mixed. Some studies suggest that there has been little or no technical progress in Canada, and productivity growth in the Canadian sawmill industry is lower than the U.S. counterpart (Constantino and Haley 1989, Ghebremichael et al. 1990, Abt et al. 1994, Nagubadi and Zhang 2004). At one extreme, Meil and Nautiyal (1988) reported negative TFP growth for all four Canadian regions over 1950-1983. On the other hand, Gu and Ho (2000) estimated that TFP growth of lumber & wood products industry increased by 0.62% per year in Canada while decreasing by 0.21% annually in the U.S. between 1961 and 1995.

Different approaches adopted by these studies may contribute to the differences in the results. Often, either an index approach or an econometric model is used to estimate productivity growth and technical change. Both approaches assume that all firms in the industries operate efficiently, which may not be the case in the reality, and some specific forms of cost or profit functions have to be assumed for econometric analysis.

As a more flexible approach, a nonparametric programming approach (or called data envelopment analysis) has been used recently in the area of agricultural and industrial productivity analysis (e.g., Färe et al. 1994, Granderson and Linvill 1997, Preckel et al. 1997, Arnade 1998, Yin 1998, 1999, 2000, Hailu and Veeman 2001, Nin, Arndt, and Preckel 2003, Nin, Arndt, Hertel, and Preckel 2003, Umetsu et al. 2003). This method, proposed by Färe et al. (1994) involves estimating an input or output based Malmquist index (Caves et al. 1982). Compared to other methods, the nonparametric programming approach has the advantage of imposing no *a priori* restrictions on the functional form of the underlying technology and allowing for inefficiency in production (Varian 1984, Färe et al. 1994). This approach is also capable of decomposing productivity growth into changes in technical efficiency over time and shifts in technology over time. Requiring only quantity data, the nonparametric programming approach may avoid distortions due to estimated errors in price data and fluctuations in exchange rate. Until recently, however, the nonparametric programming approach has rarely been used in sawmill productivity analysis. Nyrud and Baardsen's (2003) analysis of Norwegian sawmill productivity is one of the few exceptions.

This study attempts to expand the analytic scope of the technical efficiency and productivity trends of sawmill industries in the North America by using the nonparametric programming approach. In doing so, it answers the following questions: Which state/province, region or country is on average the most efficient in sawmill production in the North America? What is the pattern of TFP growth for each state/province, region or country? Decomposition of productivity growth can also shed light on the sources of the growth as a shift in the production frontier or movement towards or away from the production frontier, and bias in technical change: input or output oriented, which assists policy makers and managers make decisions. Are estimates from the nonparametric estimation different from those obtained by using other estimation methods?

In this chapter, distance functions and the nonparametric Malmquist index will be reviewed. Then, the data will be described followed by the results. Comparisons between the results from this study and other previous relevant studies as well as the results using other approach (Törnqvist-Theil index approach) are made. Finally, conclusions and suggestions for future research will be presented.

METHODOLOGY: DISTANCE FUNCTION AND THE MALMQUIST PRODUCTIVITY INDICES

As in Caves et al. (1982), the productivity change of the sawmilling industry over time is estimated as the geometric mean of two output-based Malmquist productivity indices, developed based on distance functions. Suppose that for each time period $t = 1,...,T$ the feasible production set of the industry is:

$$S^t = \{(\mathbf{x}^t, \mathbf{y}^t): \mathbf{x}^t \text{ can produce } \mathbf{y}^t\} \qquad [2.1]$$

Where, $\mathbf{x}^t \in \mathbb{R}_+^N$ and $\mathbf{y}^t \in \mathbb{R}_+^M$ are input and output quantity vectors from N and M dimensional real number spaces; and N and M are the total number of inputs and outputs. S^t is assumed to be closed, bounded, convex and to satisfy strong disposability[1] of outputs and inputs.

Following Shepherd (1970), the output-based distance function at t is defined as the reciprocal of the maximum proportional expansion of output vector $\mathbf{y}^t$ given input $\mathbf{x}^t$:

$$D_0^t(\mathbf{x}^t, \mathbf{y}^t) = \inf\left\{\theta : (\mathbf{x}^t, \frac{\mathbf{y}^t}{\theta}) \in S^t\right\}$$

$$= (\sup\{\theta : (\mathbf{x}^t, \theta\mathbf{y}^t) \in S^t\})^{-1}. \qquad [2.2]$$

The distance function measures how far the production function of interest is from the frontier of the whole industry in period t.

Figure 2.1 shows the case of two outputs (y_1 and y_2). The frontier at t is developed by production unit B, C, and D. For production unit A, the distance function at t can be

[1] Which means if $(\mathbf{x}^t, \mathbf{y}^t) \in S^t$, then $(\tilde{\mathbf{x}}^t, \tilde{\mathbf{y}}^t) \in S^t$ for all $(\tilde{\mathbf{x}}^t, \tilde{\mathbf{y}}^t)$ such that $\tilde{\mathbf{x}}^t \geq \mathbf{x}^t$ and $\tilde{\mathbf{y}}^t \geq \mathbf{y}^t$.

expressed $D_0^t(\mathbf{x}^t, \mathbf{y}^t) = \frac{OA^t}{OP^t}$. And its distance function at t+1 is $\frac{OA^{t+1}}{OP^{t+1}}$. $D_0^t(\mathbf{x}^t, \mathbf{y}^t)$ equals 1 when production unit is on the frontier, or technically efficient. On the other hand, $D_0^t(\mathbf{x}^t, \mathbf{y}^t)$ is less than 1 when production is technically inefficient. The greater its value is, the closer is the production unit to the efficient production frontier. The distance function provides a complete characterization of the production technology.

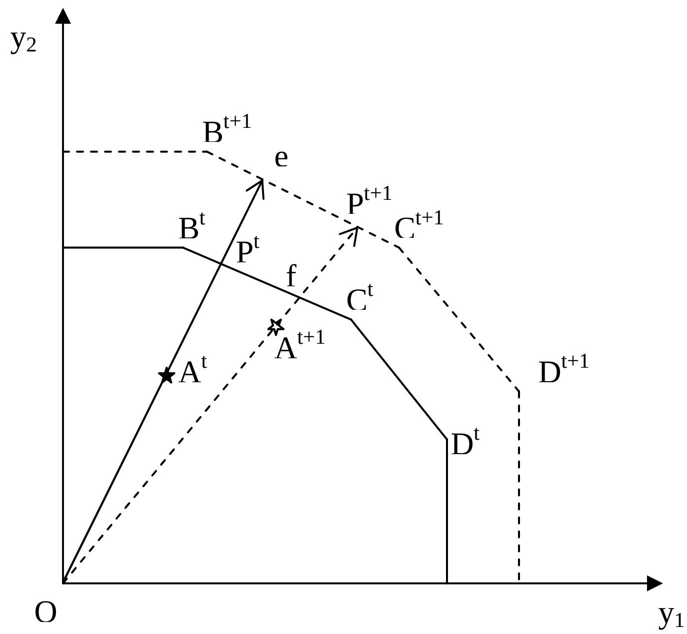

Figure 2.1. Output distance functions in two periods

$D_0^t(\mathbf{x}^t, \mathbf{y}^t)$ can be obtained by solving the following linear programming model:

$$\underset{\lambda_k, \theta_{k^*}}{Maximize}\ (D_0^t(\mathbf{x}^t, \mathbf{y}^t))^{-1} = \theta_{k^*}^t$$

Subject to:

$$\sum_{k=1}^{K} \lambda_k y_{km}^t \geq y_{k^*m}^t \theta_{k^*}^t \qquad m=1,\ldots,M$$

$$\sum_{k=1}^{K} \lambda_k x_{kn}^t \leq x_{k^*n}^t \qquad n=1,\ldots,N \qquad [2.3]$$

$$\lambda_k \geq 0 \qquad k=1,\ldots,K$$

where *m* indexes outputs; *n* indexes inputs; *k* indexes production regions (k^* is a particular region of interest); λ_k is the weight on the *k*th region data; $\theta_{k^*}^t$ is the efficiency index, or the reciprocal of the distance function for region k^*. The inequalities for inputs and outputs make free disposability possible. Non-negativity of λ_k allows the model to exhibit constant returns to scale.

In the same way, the distance from the production point in *t* relative to the frontier in *t*+1 can be defined as $D_0^{t+1}(\mathbf{x}^t, \mathbf{y}^t)$ ($\frac{OA^t}{Oe}$ in Figure 2.1). Two simple Malmquist indices can be defined depending on the technology reference of time periods by using distance functions. Using the technology at *t* as the reference, the period *t*-based Malmquist index is defined as:

$$M_0^t = \frac{D_0^t(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})}{D_0^t(\mathbf{x}^t, \mathbf{y}^t)} \qquad [2.4]$$

Using the technology at *t*+1 as the reference, the period *t*+1-based Malmquist index is:

$$M_0^{t+1} = \frac{D_0^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})}{D_0^{t+1}(\mathbf{x}^t, \mathbf{y}^t)} \qquad [2.5]$$

In Figure 2.1, for production unit *A*, M_0^t is $\frac{OA^{t+1}}{Of} \Big/ \frac{OA^t}{OP^t}$, and M_0^{t+1} is $\frac{OA^{t+1}}{OP^{t+1}} \Big/ \frac{OA^t}{Oe}$. A Malmquist index of greater than 1 implies positive productivity growth, or technical progress. As Färe et al. (1997) noted, however, these two measures may not provide consistent results in some cases. The estimate of productivity growth may vary depending on the choice of Malmquist indices. Based on Caves et al. (1982), Färe et al. (1994) suggested the use of a geometric mean of M_0^t and M_0^{t+1} as the output-based Malmquist index (M_0). That is:

$$M_0 = [M_0^t \times M_0^{t+1}]^{\frac{1}{2}} = \left[\frac{D_0^t(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})}{D_0^t(\mathbf{x}^t, \mathbf{y}^t)} \times \frac{D_0^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})}{D_0^{t+1}(\mathbf{x}^t, \mathbf{y}^t)} \right]^{\frac{1}{2}} \qquad [2.6]$$

Improvement in productivity yields a Färe Malmquist index value greater than 1 while deterioration in performance over time is associated with an index value less than 1. Furthermore, Färe et al. (1994) show that M_0 can be decomposed into an efficiency change component and a technical change component. Thus, Equation [2.6] is equivalent to:

$$M_0 = \frac{D_0^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})}{D_0^t(\mathbf{x}^t, \mathbf{y}^t)} \times \left[\frac{D_0^t(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})}{D_0^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})} \times \frac{D_0^t(\mathbf{x}^t, \mathbf{y}^t)}{D_0^{t+1}(\mathbf{x}^t, \mathbf{y}^t)} \right]^{\frac{1}{2}} \qquad [2.7]$$

where, the first part on the right hand side is defined as efficiency change (*EFFCH*) or "catch up", which measures the change in how far the observed production unit is from the potential production frontier between period *t* and period *t*+1. The second part is defined as technical change (*TECH*) or "innovation", which captures the shift in technology between two periods. In Figure 2.1, *EFFCH* is $\frac{OA^{t+1}}{OP^{t+1}} \Big/ \frac{OA^t}{OP^t}$, and *TECH* is $\frac{OP^{t+1}}{Of} \Big/ \frac{Oe}{OP^t}$ for *A*.

Nin, Arndt, and Preckel (2003) show that these three Malmquist indices (M_0^t, M_0^{t+1} and M_0) have the same efficiency change. The potential differences stem from the estimate of technical change. When technical change is biased (either input or output biased) the estimates of technical change from the three indices will be different. Färe et al. (1997) decompose the technical change component of M_0 into three parts: output-biased technical change (*OBTECH*), input-biased technical change (*IBTECH*), and the magnitude of technical change under input and output neutrality (*MATECH*).

$$TECH = \left[\frac{D_0^t(\mathbf{x}^{t+1},\mathbf{y}^{t+1})}{D_0^{t+1}(\mathbf{x}^{t+1},\mathbf{y}^{t+1})} \times \frac{D_0^t(\mathbf{x}^t,\mathbf{y}^t)}{D_0^{t+1}(\mathbf{x}^t,\mathbf{y}^t)} \right]^{\frac{1}{2}}$$

$$= \underbrace{\left[\frac{D_0^t(\mathbf{x}^{t+1},\mathbf{y}^{t+1})}{D_0^{t+1}(\mathbf{x}^{t+1},\mathbf{y}^{t+1})} \Big/ \frac{D_0^t(\mathbf{x}^{t+1},\mathbf{y}^t)}{D_0^{t+1}(\mathbf{x}^{t+1},\mathbf{y}^t)} \right]^{\frac{1}{2}}}_{OBTECH} \times \underbrace{\left[\frac{D_0^t(\mathbf{x}^{t+1},\mathbf{y}^t)}{D_0^{t+1}(\mathbf{x}^{t+1},\mathbf{y}^t)} \Big/ \frac{D_0^t(\mathbf{x}^t,\mathbf{y}^t)}{D_0^{t+1}(\mathbf{x}^t,\mathbf{y}^t)} \right]^{\frac{1}{2}}}_{IBTECH} \times \underbrace{\frac{D_0^t(\mathbf{x}^t,\mathbf{y}^t)}{D_0^{t+1}(\mathbf{x}^t,\mathbf{y}^t)}}_{MATECH} \quad [2.8]$$

It should be noted that this decomposition is valid only under constant returns to scale (CRS) (Färe et al. 1997). *OBTECH* measures the output bias of technical change by the ratio of the magnitude of technical change along a ray through $\mathbf{y}^{t+1}$ to the magnitude of technical change along a ray through $\mathbf{y}^t$ holding input vector fixed at $\mathbf{x}^{t+1}$. *IBTECH* captures the input bias of technical change by providing the ratio of the magnitude of technical change along a ray through $\mathbf{x}^{t+1}$ to the magnitude of technical change along a ray through $\mathbf{x}^t$ holding output vector fixed at $\mathbf{y}^t$. *MATECH* measures the magnitude of technical change along a ray through period *t*. *OBTECH*=1 implies neutral output technical change, and *IBTECH*=1 is associated with neutral input technical change.

DATA

A time-series dataset of sawmills and planing mills[2] covering 1963-2001 for 26 states in the U.S. [3] and 8 provinces[4] in Canada is used. The selection of state/province is mainly based on data availability and each state's share in national lumber production. In 2001, selected states accounted for 96.8% of softwood lumber production and 93.2% of hardwood lumber production in the U.S. And selected Canadian provinces accounted for about 99% of both national softwood and hardwood lumber production. Since state-level lumber production data prior to 1963 are not available, the study period was selected from 1963-2001. For purpose of regional comparison, selected states of the U.S. were classified into three regions (West, South, North). Canadian provinces were classified into British Columbia, Ontario, Quebec and Others mainly based on their shares of lumber production.

Main data sources for the U.S are the Annual Survey of Manufactures (ASM) and the Census of Manufacturing (CM). Data for Canada are from the Annual Census of Manufactures (ACM), principal statistics from the Canadian Forest Service, and the CANSIM II database. In 1997, the new industry classification system, North American Classification System (NAICS), was introduced and replaced the Standard Industrial Classification (SIC) system. For this study, we used the industry definition based on the

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[2] 1987 Standard Industry Classification (SIC) System 242 for U.S. and 251 for Canada, concordances between SIC and NAICS are made to assemble the data after 1996.

[3] Selected U.S. western states: California (CA), Idaho (ID), Montana (MT), Oregon (OR), Washington (WA). Selected U.S. northern states: Indiana (IN), Maine (ME), Michigan (MI), Missouri (MO), New York (NY), Ohio (OH), Pennsylvania (PA), Wisconsin (WI), West Virginia (WV). Selected U.S. southern states: Alabama (AL), Arkansas (AR), Florida (FL), Georgia (GA), Kentucky (KY), Louisiana (LA), Mississippi (MS), North Carolina (NC), South Carolina (SC), Tennessee (TN), Texas (TX), Virginia (VA).

[4] Alberta (AB), British Columbia (BC), Manitoba (MB), New Brunswick (NB), Nova Scotia (NS), Ontario (ON), Quebec (QC) and Saskatchewan (SK).

1987 SIC system. A bridge between SIC and NAICS was constructed based on value of shipments, number of employees, and annual payrolls in 1997. All principal production data[5] in NAICS were converted based on Table 2.1. For example, the sum of 85% of value of shipments under 3211 and 19% under 3219 are estimated as the value of shipment for 242. Canadian series were merged using average proportions developed from data reported for the same years 1990-1997 under NAICS and SIC classifications.

Table 2.1. Concordance between SIC242 and NAICS for the U.S. used in this study

NAICS	Value of Shipment (%)	# of Employee (%)	Annual Payroll (%)
3211	85	91	91
3219	19	16	15

Five inputs and three outputs were used to estimate the Malmquist index. The construction of each variable is described as follows.

LABOR INPUTS

This study used two types of labor input: production labor and non-production labor. Manufacturing-related labor is measured in terms of hours worked for the American states and in terms of hours-paid for the Canadian provinces, which includes paid vacation. Abt et al. (1994) suggested that this may lead to a slight downward bias of the productivity estimate for the Canadian industry. Labor not related to manufacturing is measured in terms of the number of employees who are not production workers.

[5] Employee number, production hours and production worker number are converted based on the concordance of # of employee. Employee wages and production worker wages are converted based on the concordance of annual payroll. All others are converted based on the concordance of value of shipment.

CAPITAL INPUT

Capital stock in 1997 constant U.S. dollars is estimated using the perpetual inventory method (PIM). As in Ahn and Abt (2003) investment on plants and structures was depreciated over 28 years, and machinery and equipment was depreciated over 16 years. Annual capital stock estimates for different asset types were aggregated as a total capital stock for each state/province. Estimate of capital stock for any given state/province *s* at the end of year *t* is calculated as:

$$K_{s,t} = \sum_{\tau=0}^{\infty} \phi_{\tau} I_{s,t-\tau} \qquad [2.9]$$

where, τ is age of asset; ϕ_{τ} is the relative efficiency function at age τ; and I is investment. The hyperbolic efficiency function is:

$$\phi_{\tau} = \begin{cases} (L-\tau)/(L-\rho\tau) & 0 < \tau < L \\ 0 & otherwise \end{cases}, \qquad [2.10]$$

where L is the service life of asset and ρ is the decay parameter which determines the method of depreciation. Following Bureau of Labor Statistics (1983), we chose ρ equal to 0.5 for equipment, and 0.75 for structure.

The U.S. We retrieved the end of year investment data on different assets by state from CM and ASM to year 1954. Since PIM requires the investment data since 1935 which are not available, we estimated the investment data of SIC 242 prior to 1954 by using estimates of national non-residential fixed assets by types from Bureau of Economic Analysis for SIC 24, the average proportion of capital investment of SIC 242 in SIC 24, and each state's average share in total national capital investment in SIC 242 during 1954-1957.

Canada. Annual capital and repair expenditure data are available for three provinces (QC, ON, and BC) during 1970-2001. Other provinces' investment during the same period were estimated by national sawmill industry flows and stocks of fixed non-residential capital, and each province's average share of national industry added value. For all provinces, capital investment data for 1935-1969 were constructed by multiplying national industry fixed capital flows and each province's average share of national industry added value from 1961 to 2001.

ENERGY INPUT

The U.S. Since energy quantity data are not available, approximations are made using energy cost and a weighted aggregate energy price index. Cost of energy includes purchased fuels and electricity assembled from ASM, CM, and the U.S. Census Bureau's publication, "Fuels and electric Energy Consumed". Since state-level energy data are not available for most years, national industry consumption and each state's share in the nearest available year were used for estimation purpose. Since data are not available for 1963-1967, upper level SIC 24 energy cost data were multiplied by the energy cost proportion of SIC 242 in the succeeding year to estimate the cost. Annual energy cost for each state was estimated by material costs, and the share of energy cost in total material costs at the national level. Weighted fuel prices (46% of #2 diesel fuel oil, 23% of gasoline, and 31% of natural gas) and electricity prices in terms of $/British thermal units (*Btu*) were weighted by their shares in total energy cost to construct the aggregate price index. State industry energy consumption quantity was derived by dividing annual energy cost by the aggregate price. Energy input is in trillion *Btu*.

Canada. Quantities of purchased fuels and electricity are from Catalogues 35-204, 35-250, and Catalogue 57-208 for years 1963-1984. They were converted to units of trillion *Btu*. For years 1985-2001, provincial industry energy cost is available from the Canadian Forest Service. A weighted energy price index was constructed by using the similar approach used for the U.S. based on the data of 1963-1984, and extended to 2001 by using percent change in non-residential electric power selling price index at national level. Energy includes gasoline, fuel, liquid petroleum gas (LPG), natural gas, and purchased electricity. These prices were weighted by their shares in total energy cost. Energy quantity data were derived by dividing energy cost by the weighted energy price index and converted to trillion *Btu*.

WOOD INPUT

The U.S. Quantities of wood inputs were derived by non-energy material costs and the weighted price of delivered hardwood and softwood sawtimber. Softwood and hardwood sawtimber prices by states for the South over 1977-2001 were collected from Timber Mart South. Southern region average prices were used to estimate prices for the states in the West and the North. The sum of southern-pine sawlog selling price by Louisiana private owners and logging and haul cost was used to estimate industry delivered softwood log price for 1963-1976[6]. (Ulrich 1988) The sum of oak sawlog selling price by Louisiana private owners and logging and haul cost was used to estimate industry delivered hardwood log price for 1963-1976. Softwood and hardwood delivered

[6] Average prices for sawlog sold by private owners in Louisiana, and logging and haul cost were from Ulrich (1988). The original price was in dollars per MBF, Doyle log scale. The conversion factor of 1 Scribner log scale = 1.39 Doyle log scale was used to convert the prices in Doyle log rule to prices in Scribner log rule.

sawtimber prices were aggregated by using state softwood and hardwood production as weights to estimate the weighted price index of wood input.

Canada. Quantities of wood materials were collected from Statistics Canada, Catalogues 35-204, 35-250, and Catalogue 57-208, for the years 1963 to1984. Softwood and hardwood sawtimber were treated as homogeneous, and aggregated by volume in terms of thousand board feet, Scribner. For years thereafter, the quantities were estimated by provincial industry materials cost and a price index. The price index was based on the price data of 1963-1984 and extended to the following years by using industry raw materials price index from Statistics Canada, CANSIM, table 330-0006 and Catalogue no. 62-011-XPB.

SOFTWOOD AND HARDWOOD LUMBER OUTPUTS

For the U.S., softwood and hardwood lumber production for each state was collected from lumber production and the mill stock section of current industrial reports by the census annually. For Canada, production data from 1963-1984 were collected from Canadian Forestry Statistics. Missing data were interpolated by using the average growth rate of state/province production in the previous 5 years.

WOODCHIPS

The U.S. The quantity of woodchips was estimated based on annual value of shipments and average chip price. Annual state level value of shipment data for woodchips were constructed by the product of industry value of shipments and the share of woodchips in total value of shipments at the national level. Chip price was approximated by the average value of softwood chips exported from four customs districts provided by the Pacific Northwest Research Station.[7]

Canada. The quantity of woodchips for five provinces (NS, NB, QC, ON and BC) over 1963-1980 is available from Canadian Forestry Statistics. Missing data for each province were estimated by annual national woodchips quantity, and annual proportion of woodchips in the industry value of shipments for total products.

RESULTS AND DISCUSSIONS

The non-parametric programming method is applied to the time-series dataset obtained above to construct cross-sectional best-practice frontiers year by year. Outputs or inputs from different states/provinces under the same category were assumed to be homogeneous. Also, each state/province was treated as a production unit as a whole. Technology is assumed to be constant return to scale for the Malmquist index estimation and further decompositions.

TECHNICAL EFFICIENCY

Values assigned by the distance function in this study are a measure of the technical efficiency of the production unit. A value of unity implies that the production unit is on the industry-wide frontier, or efficient, in respective years. Values greater than unity imply that the production unit is off the frontier, or inefficient, in the given year.

Figure 2.2 shows the percentage of time on the industry-wide frontier for each production unit over 1963-2001. Over the 39 years, some states/provinces stayed on the frontier more often than others, especially for BC, SK in Canada and ID, MT, OR, and WV in the U.S. (80% or more of time). Among them, Oregon was the only state which

[7] The Seattle, Columbia-Snake, San Francisco, and Anchorage.

remained on the frontier during the whole period. However, other states/provinces such as NS, AR, NC, TN, and TX were on the frontier for less than 20% of time. Interestingly, they are all southern states. Among them, North Carolina was the only state which had been on the frontier less than 5% of the whole study period.

There are some apparent geographic patterns of distribution of efficient units. The weighted arithmetic means (WAM[8]) of the percentage of time for each region and country on the industry frontier were calculated. Compared to the U.S., the Canadian sawmill industry is more likely to be efficient. During 1963-2001, Canadian sawmills stayed on the industry frontier 74% of time while American sawmills stayed on the frontier 56% of time. Over the whole study period, the U.S. West (81% of the time) and the North (47%) were more likely to be on the frontier than the U.S. South (30%).

It should be noted that the technical efficiency performance for the selected states/provinces varied with different periods of time. Table 2.2 presents the percentage of time on the industry-wide frontier for each production unit for the period 1963-2001 and four sub-periods. Appendix A provides the whole set of distance function values by year obtained from the study. Some states/provinces performed efficiently during most of time during the early periods but the performance gradually deteriorated in the later periods, such as BC, MB, NB in Canada, and GA, MI, PA, WI in the U.S. Some other states/provinces were off the efficiency frontier most of time in the early periods but the performance gradually improved in the later periods, such as AB and ON in Canada, and AL, FL, IN, LA, ME, MS, TX, WA in the U.S., most of which are in the U.S. South. In the latest ten years, Canadian province AB as well as American states FL, ID, ME, MT,

[8] Since each state/province has different share in lumber production, weighted average is a better estimate for regional and national estimate than simple average.

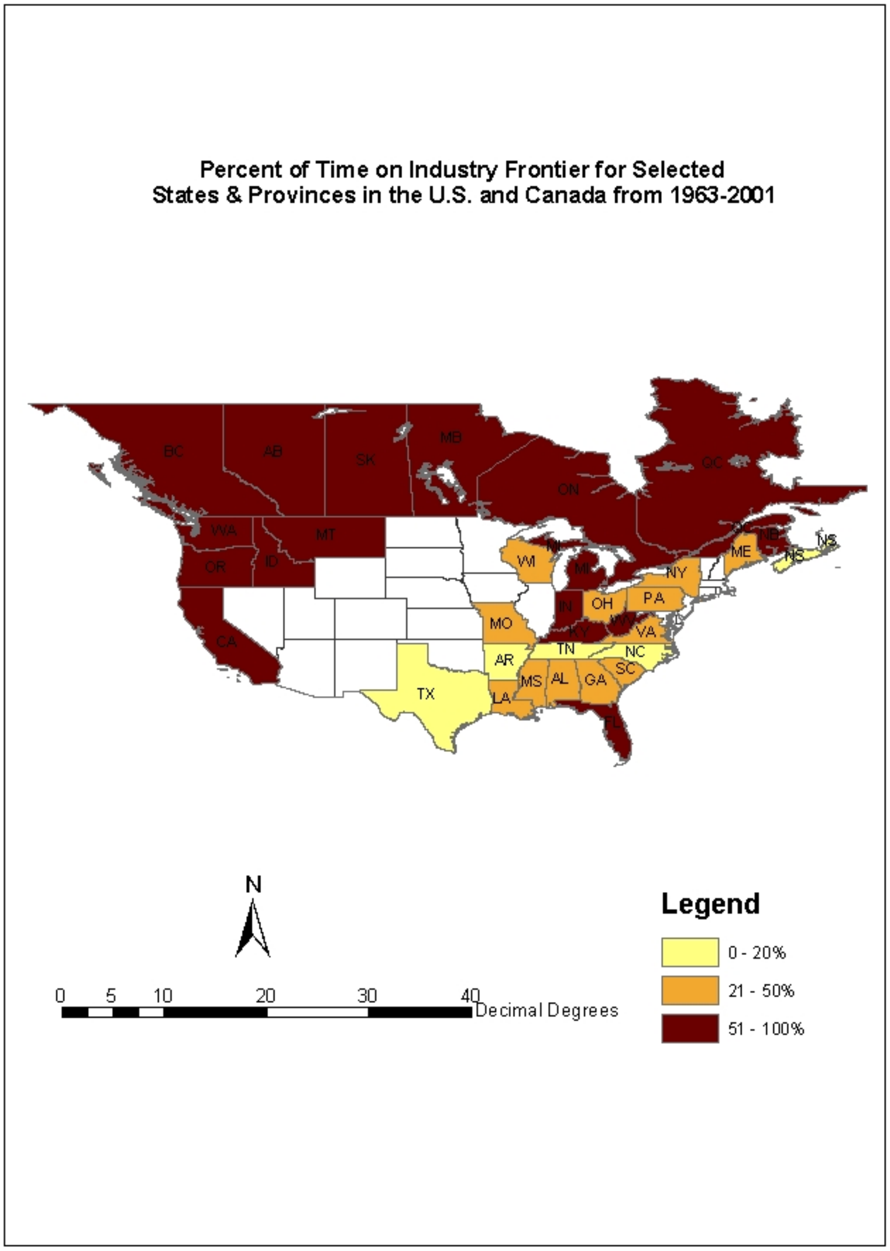

Figure 2.2. Percentage of time on industry frontier for selected states/provinces in the U.S. and Canada over 1963-2001

OR, and WV formed the “best practice” frontier. Although most other western states remained on the frontier, CA apparently moved off from the frontier after the late 1980s, which is coincident with the period of logging restriction to protect the California Spotted Owl. Logging restrictions directly influenced the price and availability of primary materials for sawmilling industries. Some inputs can be adjusted according to outputs. However, some fixed inputs such as capital and labor can not be adjusted in the short run. These inflexibilities may lead to inefficient sawmilling in California.

For most Canadian provinces, the 1980s were a period with the highest rate of technical efficiency. However, on the other hand, the 1990s was a period during which most of Canadian provinces moved off the industry frontier, especially for BC and Quebec, the largest two softwood production provinces in Canada. Interestingly, this period was coincident with the period of the U.S.-Canada softwood lumber dispute. Apparently, restrictions on exports of Canadian softwood lumber led to inefficient use of inputs for Canadian sawmills. Especially, the 1996-2001 Softwood Lumber Agreement constrained softwood lumber export from the four Canadian provinces (BC, AB, ON and QC), thus impairing their production efficiency to some degree.

Meanwhile, more and more the U.S. southern states moved towards and stayed on the efficient production frontier, especially in the latest 10 years. Both imposing environmental restrictions on northwestern sawmills in the U.S. and the dispute on softwood lumber between the U.S. and Canada may contribute to this phenomena.

It should be noted that being more efficient does not imply higher well-being. It only means that states/provinces with higher efficiency scores have exploited their resources relatively better than others in the sample with similar proportional combinations of inputs.

Table 2.2. Percentage of time on the industry frontier over different periods

Province/State	1963-1969	1970-1979	1980-1989	1990-2001	1963-2001
Canada:	85	69	99	60	74
British Columbia	100	90	100	58	85
Ontario	14	40	100	83	64
Quebec	71	0	100	50	54
Others	56	65	88	66	65
Alberta	29	50	100	92	72
Manitoba	100	100	60	58	77
New Brunswick	100	100	90	33	77
Nova Scotia	14	20	30	0	15
Saskatchewan	86	80	90	83	85
United States:	53	60	59	62	56
the North	51	55	36	50	47
Indiana	14	70	100	50	62
Maine	29	0	30	92	41
Michigan	86	60	20	58	54
Missouri	71	10	50	42	41
New York	43	40	10	33	31
Ohio	29	60	10	33	33
Pennsylvania	57	50	10	0	26
Wisconsin	57	70	20	33	44
West Virginia	57	100	100	100	92
the South	30	15	26	50	30
Alabama	0	0	50	50	28
Arkansas	14	0	10	33	15
Florida	14	50	60	100	62
Georgia	100	10	20	58	44
Kentucky	100	80	60	83	79
Louisiana	29	20	20	75	38
Mississippi	14	20	30	67	36
North Carolina	0	0	0	8	3
South Carolina	29	50	20	50	38
Tennessee	29	30	30	8	23
Texas	0	0	20	33	15
Virginia	57	0	40	58	38
the West	66	88	87	79	81
California	29	80	90	25	56

Table 2.2. Percentage of time on the industry frontier over different periods (continued)

Province/State	1963-1969	1970-1979	1980-1989	1990-2001	1963-2001
Idaho	100	90	100	100	97
Montana	71	100	100	100	95
Oregon	100	100	100	100	100
Washington	29	70	50	67	56

FÄRE MALMQUIST PRODUCTIVITY INDEX AND COMPONENTS

Table 2.3 provides a summary of the Färe productivity growth index and its decomposition into efficiency and technological change for 1964-2001. An index less (greater) than 1 represents regress (progress).

Most of these states/provinces experienced progress in productivity during the period. The weighted arithmetic means[9] were estimated for each region and country. During 1964-2001, the weighted annual productivity growth of sawmill industry for the U.S. was 2.5%, indicating modest progress. During the same period, the Canadian sawmilling industry was shown to have a lower growth rate, 1.3%. In the U.S., all regions experienced comparable productivity growth (around 2.5% annually). Michigan was the only U.S. state experiencing regress during the whole period. Most Canadian provinces experienced progress over 1964-2001, Quebec being an exception.

All regions were shown to have positive efficiency change, indicating a trend of moving towards the industry frontier. Differences in productivity growth is mainly attributable to the difference in technical change for Canada and the U.S. during the

[9] Since each state/province has different share in lumber production, weighted average is a better estimate for regional and national productivity growth than simple average. See Färe and Zelenyuk (2003) for detailed discussion on this point. Volume of lumber production (sum of softwood and hardwood) is used as weight. In this study, simple averages reports greater productivity progress for both Canada and the U.S.

whole study period (1.2% for Canada and 2.4% for the U.S.). Most southern U.S. states experienced both positive efficiency change and technical change, indicating a trend of moving towards the industry frontier as well as frontier extension. On the other hand, most of the northern U.S. states experienced either progress in technical change or efficiency change. Moving away from the industry frontier was the main reason contributing to California's relative low rate of productivity growth. Most of the sawmill industry in Canada experienced both technical and efficiency progress during the period. Regress in technical change was shown to contribute to the regress in productivity growth for Quebec.

Table 2.3. Färe Productivity Index, Efficiency Change, and Technical Change for 1964-2001

Province/State	Färe Index (M_0)	Efficiency Change (EFFCH)	Technical Change (TECH)
Canada:	1.013	1.001	1.012
British Columbia	1.014	1.001	1.012
Ontario	1.016	1.002	1.016
Quebec	0.996	1.001	0.999
Others	1.028	1.004	1.025
Alberta	1.051	1.001	1.048
Manitoba	1.004	0.990	1.009
New Brunswick	1.009	0.999	1.009
Nova Scotia	1.013	1.022	1.005
Saskatchewan	1.024	1.002	1.020
United States:	1.025	1.001	1.024
North	1.026	1.000	1.027
Indiana	1.009	0.988	1.018
Maine	1.037	1.011	1.027
Michigan	0.996	1.000	0.998
Missouri	1.024	1.002	1.021
New York	1.055	1.007	1.040
Ohio	1.051	0.993	1.061
Pennsylvania	1.008	0.997	1.013
Wisconsin	1.006	0.994	1.022
West Virginia	1.043	1.004	1.041
South	1.025	1.002	1.022
Alabama	1.026	1.004	1.020
Arkansas	1.035	1.004	1.028
Florida	1.034	1.003	1.030
Georgia	1.009	0.999	1.010
Kentucky	1.050	1.002	1.043

Table 2.3. Färe Productivity Index, Efficiency Change, and Technical Change for 1964-2001 (Continued)

Province/State	Färe Index (M_0)	Efficiency Change (EFFCH)	Technical Change (TECH)
Louisiana	1.027	1.003	1.021
Mississippi	1.021	1.002	1.021
North Carolina	1.032	1.003	1.028
South Carolina	1.029	1.003	1.026
Tennessee	1.040	1.003	1.034
Texas	1.003	0.999	1.006
Virginia	1.021	1.002	1.020
West	1.025	0.999	1.025
California	1.021	0.995	1.028
Idaho	1.023	1.000	1.023
Montana	1.025	1.000	1.024
Oregon	1.030	1.000	1.030
Washington	1.019	1.001	1.017

Table 2.4 compares the estimates of the Färe index for the period 1964-2001 with the estimates of the same index for four subperiods. Sawmill productivity growth was up and down in the subperiods for both countries and all regions. Most regions experienced regress during the 1970s and progress during other decades. Before the 1980s, Canada possessed a higher rate of growth (or lower rate of regress) than the U.S. However, the U.S. outperformed Canada after the 1980s (annual rate of growth was 5.0% for the U.S. vs. 2.2% for Canada during 1980s, and 3.2% for the U.S. vs. 0.4% for Canada during 1990s). The U.S. South experienced the highest annual growth rate during the 1980s (6.1%), which contributed to the country’s growth significantly. Although the North possessed the highest growth rate during 1960s, the growth rate declined during the subsequent periods. As for Canada, Ontario was the only province which experienced productivity progress during all four time periods. On the other hand, Quebec experienced regress during most of period except the 1980s.

Table 2.4. Färe productivity index in different periods

Province/State	1964-1969	1970-1979	1980-1989	1990-2001	1964-2001
Canada:	1.036	0.996	1.022	1.004	1.013
British Columbia	1.038	0.996	1.025	1.006	1.014
Ontario	1.056	1.011	1.001	1.010	1.016
Quebec	0.984	0.990	1.010	0.998	0.996
Others	1.085	0.995	1.043	1.005	1.028
Alberta	1.154	1.004	1.083	0.999	1.051
Manitoba	1.041	0.932	1.006	1.044	1.004
New Brunswick	1.095	0.975	0.991	1.002	1.009
Nova Scotia	0.981	1.033	1.022	1.007	1.013
Saskatchewan	1.056	0.987	1.020	1.041	1.024
United States:	1.024	0.992	1.050	1.032	1.025
North	1.068	0.974	1.048	1.026	1.026
Indiana	1.146	0.977	1.031	0.932	1.009
Maine	1.042	0.997	1.042	1.066	1.037
Michigan	1.028	0.955	1.029	0.984	0.996
Missouri	1.040	0.945	1.091	1.026	1.024
New York	1.117	1.028	1.060	1.037	1.055
Ohio	1.060	0.945	1.056	1.139	1.051
Pennsylvania	1.018	0.951	1.034	1.027	1.008
Wisconsin	1.072	0.961	1.034	0.978	1.006
West Virginia	1.089	1.007	1.050	1.041	1.043
South	1.027	0.983	1.061	1.027	1.025
Alabama	1.031	0.983	1.072	1.019	1.026
Arkansas	1.050	0.985	1.050	1.056	1.035
Florida	1.070	0.972	1.076	1.029	1.034
Georgia	0.985	0.971	1.046	1.025	1.009
Kentucky	0.995	1.004	1.127	1.060	1.050
Louisiana	1.008	0.993	1.089	1.013	1.027
Mississippi	1.030	0.984	1.038	1.033	1.021
North Carolina	1.047	0.979	1.087	1.020	1.032
South Carolina	1.048	0.999	1.038	1.036	1.029
Tennessee	1.017	0.978	1.081	1.075	1.040
Texas	1.033	1.005	1.010	0.977	1.003
Virginia	1.021	0.960	1.102	1.003	1.021
West	1.017	0.999	1.043	1.037	1.025
California	1.031	1.006	1.041	1.011	1.021
Idaho	1.032	0.990	1.050	1.022	1.023
Montana	1.043	0.993	1.045	1.024	1.025
Oregon	1.010	1.003	1.044	1.055	1.030
Washington	0.996	0.990	1.040	1.041	1.019

Figure 2.3 shows the trend in annual Färe index values for the U.S. and Canada during 1964-2001. Generally, the productivity change for the Canadian sawmilling industry was relatively small until the mid-1980s. For the U.S., productivity change was the most variant during the 1970s and early 1980s.

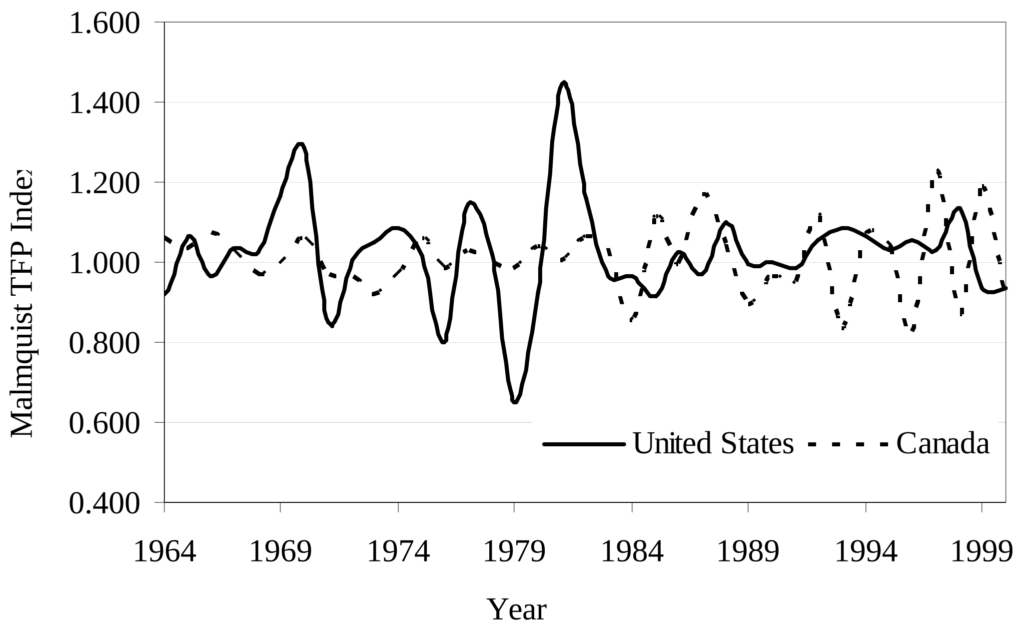

Figure 2.3. Annual Färe Productivity Indices for
the U.S. and Canada, 1964-2001

Figure 2.4 shows the cumulated Färe index for the U.S. and Canada during the same period using 1963 as the base year. The cumulated index was calculated as sequential multiplicative sums of weighted annual Färe index values. Apparently, the gap in TFP growth between the U.S. and Canada has widened wider since the 1990s.

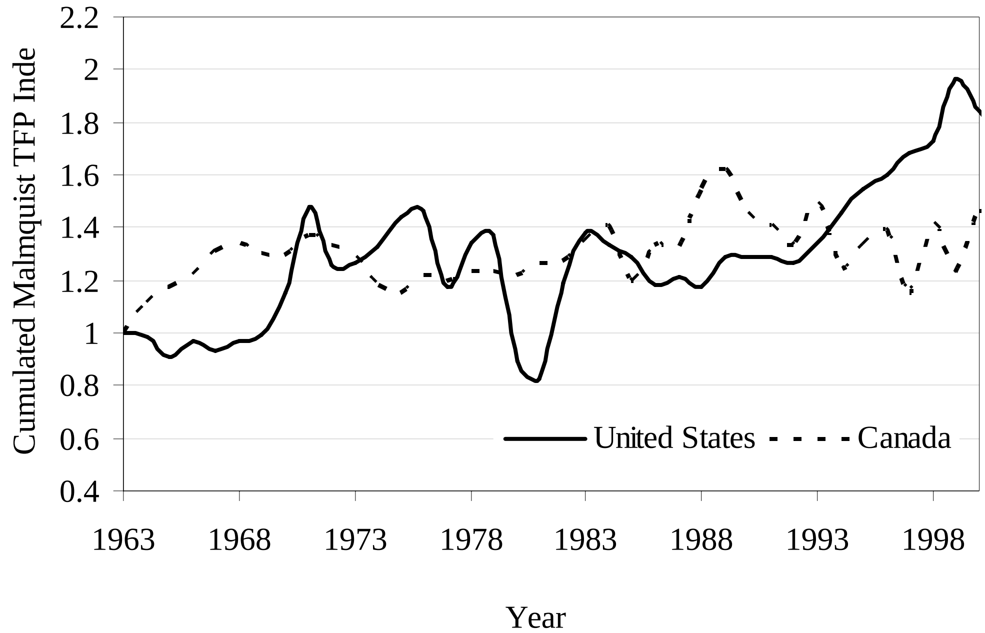

Figure 2.4. Cumulated Färe productivity indices
for the U.S. and Canada, 1963-2001 (Base=1963)

BIAS COMPONENTS OF TECHNICAL CHANGE

The results of technical change decomposition into input biased, output biased and neutral components are presented in Table 2.5. As discussed earlier, *MATECH* equals the technical change under joint Hicks neutrality, when *IBTECH* an *OBTECH* are simultaneously equal to one. The results show that *IBTECH* increased by 7.0% annually for the U.S., and 5.5% for Canada over the 38-year period. *OBTECH* increased by 2.7% for the U.S. and 3.8% for Canada annually. The results suggest that technical change regressed by 5.0% and 6.9% annually for the U.S and Canada respectively, if the technical change is Hicks neutral.

Table 2.5. Annual Biased Technical Change, 1964-2001

Province/State	Input-Biased Technical Change (IBTECH)	Output-Biased Technical Change (IBTECH)	Neutral Technical Change (MTECH)
Canada:	1.055	1.038	0.931
British Columbia	1.048	1.045	0.929
Ontario	1.053	1.018	0.954
Quebec	1.043	1.029	0.938
Others	1.102	1.037	0.915
Alberta	1.140	1.046	0.901
Manitoba	1.105	1.057	0.876
New Brunswick	1.106	1.039	0.895
Nova Scotia	1.014	1.005	0.993
Saskatchewan	1.079	1.041	0.916
United States:	1.070	1.027	0.950
The North	1.087	1.031	0.936
Indiana	1.058	1.033	0.938
Maine	1.025	1.022	0.986
Michigan	1.077	1.029	0.910
Missouri	1.045	1.015	0.968
New York	1.086	1.037	0.941
Ohio	1.146	1.034	0.940
Pennsylvania	1.094	1.015	0.950
Wisconsin	1.058	1.024	0.953
West Virginia	1.195	1.067	0.839
The South	1.037	1.017	0.982
Alabama	1.028	1.010	0.986
Arkansas	1.021	1.007	1.003
Florida	1.052	1.045	0.943
Georgia	1.037	1.018	0.961
Kentucky	1.112	1.039	1.043
Louisiana	1.038	1.032	0.963
Mississippi	1.027	1.016	0.980
North Carolina	1.015	1.005	1.011
South Carolina	1.040	1.024	0.969
Tennessee	1.040	1.012	0.989
Texas	1.022	1.016	0.970
Virginia	1.089	1.021	0.951
The West	1.094	1.035	0.925
California	1.038	1.017	0.979
Idaho	1.078	1.054	0.904
Montana	1.112	1.044	0.889
Oregon	1.135	1.045	0.903
Washington	1.070	1.022	0.940

Figure 2.5 and 2.6 show the annual decomposed biased technical change effects for each country. The results show that both input and output biased technical change index were not 1, which suggests that sawmill production in the U.S. and Canada experienced neither Hicks input-neutral nor output-neutral technical change. This indicates that the normal assumption of Hicks neutrality of technical change in traditional TFP growth studies was rejected for sawmill industries in both the U.S. and Canada. In other words, the traditional treatment of representing the state of technology by a scalar adopted by other studies in TFP growth estimation may yield biased results. Technological changes were biased on the inputs side much more than on the outputs side for both countries since *IBTECH* is larger than *OBTECH*, reflecting more input efficient use than output capability increase.

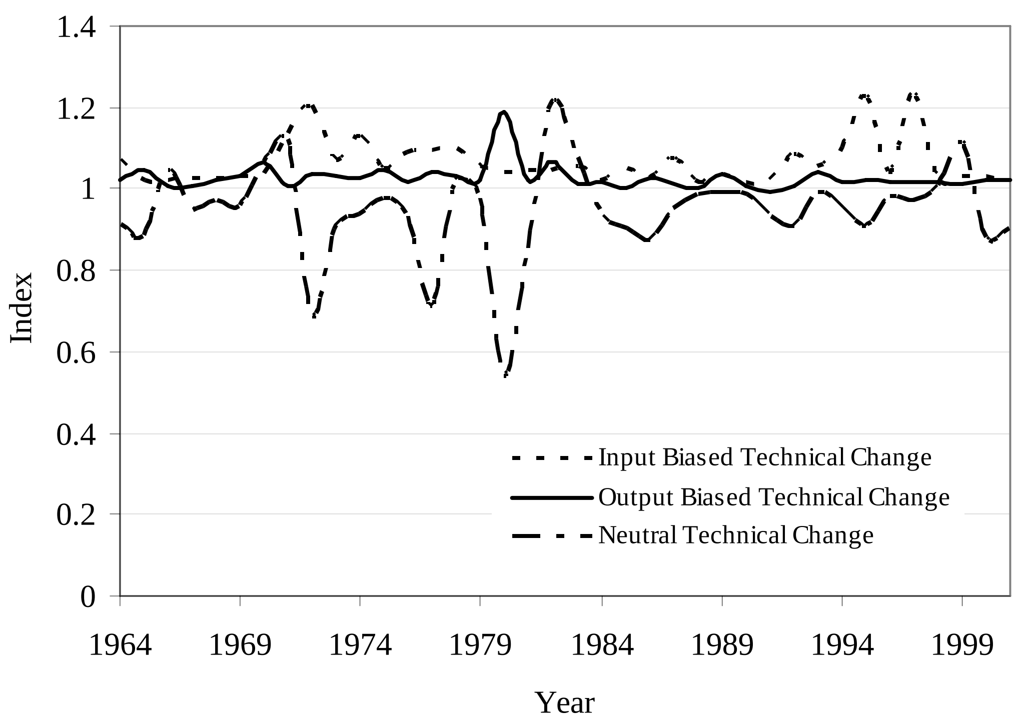

Figure 2.5. Annual biased technical change effects, the U.S.

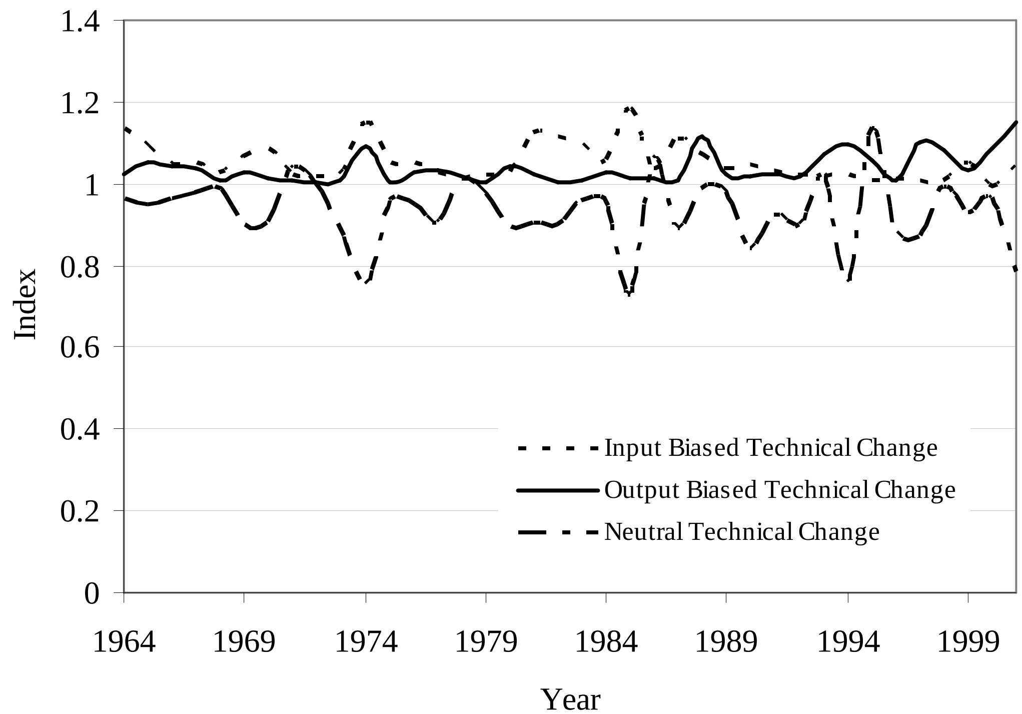

Figure 2.6. Annual biased technical change effects, Canada

COMPARISON WITH THE TÖRNQVIST-THEIL INDEX APPROACH AND OTHER STUDIES

We applied the Törnqvist-Theil index approach to the same dataset to calculate the TFP growth for both countries. To increase comparability, TFP growth was calculated for each state/province first. Then, weighted arithmetic means were calculated for each country using share of total lumber production as weights. Annual TFP growth was calculated as:

$$\frac{TFP_t}{TFP_{t-1}} = \exp\left\{\sum_{m=1}^{M}\frac{1}{2}(r_{m,t} + r_{m,t-1})\ln\left(\frac{q_{m,t}}{q_{m,t-1}}\right) - \sum_{n=1}^{N}\frac{1}{2}(s_{n,t} + s_{n,t-1})\ln\left(\frac{x_{n,t}}{x_{n,t-1}}\right)\right\} \quad [2.11]$$

where $r_{m,t} = \frac{p_{m,t} q_{m,t}}{\sum_{m=1}^{M} p_{m,t} q_{m,t}}$ is the share of output *m* in total revenues in period *t*;

$s_{j,t} = \frac{c_{n,t} x_{n,t}}{\sum_{n=1}^{N} c_{n,t} x_{n,t}}$ is the share of input *n* in total costs in period *t*; $p_{m,t}$ and $q_{m,t}$ are the price and quantity of output *m* in period *t*; $c_{n,t}$ and $x_{n,t}$ are the price and quantity of input *n* in period *t*, respectively. The results show that the annual weighted TFP growth of the sawmill and planing industry for the U.S. and Canada is 0.39% and 0.56%, respectively. Since we used the same set of data, the difference between the results from these two approaches probably lies mainly in the techniques applied. Comparable results may be obtained if there is no inefficiency in production. As suggested by Färe et al. (1994), multilateral comparison may be another contributing explanation for the difference. The results may vary with selection of production units (countries in this case). Another reason may be due to the fact that the Törnqvist-Theil index approach involves the price factor by calculating the shares while the nonparametric approach does not. Also, the Törnqvist-Theil index approach considers the shares of each input or output in the total values and uses them as weights while the nonparametric approach treats each input or output equivalently.

The results of this study are consistent with most previous studies in that both countries are shown to have experienced progress in TFP over the study period. This study also found negative annual growth in TFP in the 1970s for U.S. sawmills, which is in agreement with Abt et al. (1994), and Ahn and Abt (2003). The estimation of annual average growth rate of TFP for Canada is comparable to the results from Ghebremichael et al. (1990) and Nagubadi and Zhang (2004). The estimation of annual TFP growth rate for the U.S. is comparable to the findings of Ahn and Abt (2003). This study showed that the U.S. had relatively higher rate of TFP growth than Canada in the study period. Similar to Nagubadi and Zhang (2004), this study suggested that there was a trend of gap-widening between the two countries' productivity growth during the later part of the study period. Some of the difference in estimation may be due in part, to different time periods of analysis, subjects (national vs. state/province) and estimation of some inputs and outputs, or to different estimation techniques applied. The results from this study can provide important complementary information to other traditional approaches of productivity analysis. The estimates from traditional approaches may be distorted by invalid assumption on production efficiency or involving fluctuations from other factors such as prices and exchange rate. Policy makers have to be cautious in making decisions not solely based on estimates from them.

Sensitivity Analysis

It should be noted that estimation the results reported above are based on a nonparametric programming approach, which treats all variables equally. A unit being efficient in lumber production will appear equally efficient to a unit being efficient in its production of chips, even though chips and residues are secondary products with much less value (Nyrud and Baardsen 2003). In most cases, chip value accounts for less than 15% of the total output value. A sensitivity analysis was conducted to check for changes in the Färe productivity index and its components when only softwood and hardwood were considered in the output.

Table 2.6 presents the estimation results without wood chips. Compared to the estimation results reported in Table 2.3, annual productivity growth decreased to 2.0% annually for the U.S. and increased to 1.7% for Canada annually. It is mainly due to different estimation in technical change. Regardless, the general conclusion we drew above still stands.

Table 2.6. Färe Productivity Index, Efficiency Change, and Technical Change for 1964-2001 (without wood chips)

Province/State	Färe Index (M_0)	Efficiency Change (EFFCH)	Technical Change (TECH)
Canada:	1.017	1.005	1.018
British Columbia	1.015	1.002	1.017
Ontario	1.020	1.013	1.018
Quebec	1.006	0.999	1.011
Others	1.042	1.018	1.028
Alberta	1.057	1.005	1.048
Manitoba	1.016	0.999	1.015
New Brunswick	1.014	1.005	1.015
Nova Scotia	1.068	1.079	1.008
Saskatchewan	1.036	1.014	1.021
United States:	1.020	1.005	1.021
North	1.037	1.026	1.028
Indiana	1.000	1.006	1.011
Maine	1.046	1.028	1.026
Michigan	0.997	1.002	1.008
Missouri	1.117	1.131	1.009
New York	1.090	1.042	1.041
Ohio	1.042	1.006	1.076
Pennsylvania	1.007	1.012	1.017
Wisconsin	0.997	1.000	1.025
West Virginia	1.039	1.008	1.039
South	1.021	1.008	1.019
Alabama	1.019	1.002	1.017
Arkansas	1.029	1.012	1.022
Florida	1.023	1.014	1.015
Georgia	1.012	1.002	1.020
Kentucky	1.048	1.028	1.030
Louisiana	1.038	1.015	1.026
Mississippi	1.010	1.008	1.011
North Carolina	1.010	0.999	1.018
South Carolina	1.022	0.999	1.027
Tennessee	1.055	1.035	1.025
Texas	1.009	1.004	1.008
Virginia	1.013	1.005	1.015
West	1.017	0.998	1.021
California	0.998	0.985	1.018
Idaho	1.018	1.000	1.019
Montana	1.023	1.001	1.022
Oregon	1.029	1.001	1.028
Washington	1.011	1.002	1.013

However, the results derived from the nonparametric programming approach inevitably suffer from the inherent weakness of the frontier analysis method: the sensitivity to outliers (Koop et al. 1999). Distance functions (or nonparametric linear-programming based efficiency measures) were assumed to be deterministic. *Estimates* and *true* frontiers were not distinguished. Yet, as Simar and Wilson (2000) noted, if the observed data are viewed as generated from the true production set, then estimates of efficiency from the frontier model are subject to uncertainty due to sampling variation. Statistical analysis is desirable to check the sensitivity of the results obtained above.

A bootstrap procedure is currently the most popular and handy method to estimate confidence intervals for distance functions (and Malmquist productivity indices after some data manipulation). The method has been applied by others (e.g. Simar and Wilson 1998, 1999, 2000, Henderson and Zelenyuk 2004). In this study, a bootstrap approach was used to provide statistical inference of our estimates above.

Bootstrapping generates an appropriately large number of pseudosamples from the feasible production set

$$S^* = \{(\mathbf{x}^*_{lt}, \mathbf{y}^*_{lt}) \mid l = 1, \ldots, L;\ t = 1,\ 2)\,. \qquad [2.12]$$

where, L is the size of the pseudosamples, l is the index of the element in it. For each bootstrap replication, Equation [2.3] was used to measure the distance from each observation in the original sample to the frontier formed by the pseudosamples.[10] Consequently, Malmquist indices, Färe productivity indices, and their components were

[10] Please refer to Davison and Hinkley (1997) for more on bootstrapping.

obtained based on the distance functions described in Equation [2.4] to [2.7]. R[11] and two other software packages were used for simulation. One of them is FEAR developed by Wilson (2005) for Data Envelopment Analysis, the other is Boot developed by Canty (2002) for bootstrapping. Since FEAR only deals with sensitivity analysis of a single time period distance function, a R-program was created to do bootstrapping for the indices in this study based on multiple time periods. Replication of bootstrapping was set to 1000. Confidence intervals for the indices were obtained by applying a normal approximation method to bootstrap results. The index is significantly different from unity (indicating no change in productivity or efficiency) if the interval does not include unity.

Table 2.7 presents the Färe productivity indices for each state or province by year. A single asterisk (*) indicates that the index is significantly different from 1 at the 10% level, and a double asterisks (**) indicate the significance at the 5% level. Lack of asterisk indicates that the index is not statistically significantly different from 1.

Sixty-nine percent of the estimates shown in the table are significantly different from 1 at the 10% level, and 63.4% show significance at the 5% level. The significance varied with periods. Seventy one percent of the estimates in 1990s were shown to be significant at the 10% level while 67.5% of the estimates in 1970s were significant at the same level. Appendix B and C present the bootstrap results for efficiency changes and technical changes by year. It showed that efficiency changes were very sensitive to the selection of the frontier. Only 19.3% of the efficiency change estimates were shown to be significant at the 10% level. Technical change estimates were better, with 46.75% of estimates being

[11] R is a language and environment for statistical computing and graphics. It is a GNU project which was developed at Bell Laboratories by John Chambers and colleagues.

significant. The bootstrap results indicated the estimates of the productivity growth index and the technical change index were generally reliable, while the estimates of efficiency changes should be interpreted cautiously.

The 95% confidence interval of the WAM of annual Färe productivity indices for the U.S. was [1.015, 1.034], and the 95% Confidence Interval for Canada was [1.002, 1.024]. This indicats that the estimates of annual productivity growth rate may vary depending on the selection of the sample. However, both countries experienced statistically significant productivity growth during the whole study period (CI does not include 1).

Table 2.7. Bootstrap results of Färe productivity index by year

State/Province	1963/1964	1964/1965	1965/1966	1966/1967	1967/1968	1968/1969	1969/1970	1970/1971	1971/1972	1972/1973
Alberta	2.67	0.38**	0.91**	0.91**	1.06**	1.05**	1.08**	1.38**	0.77**	1.16**
British Columbia	1.06**	1.12**	1.07**	1.10**	1.02**	0.95*	0.95	1.05*	0.99	0.97**
Manitoba	0.73**	0.85**	1.18**	1.04	1.08**	1.04**	1.36**	0.80**	1.00	0.67**
New Brunswick	0.92	1.25**	1.08*	1.01	1.05**	1.12**	1.22**	1.14**	0.82**	0.94**
Nova Scotia	0.83**	0.97	0.94**	1.04	0.86**	1.14**	1.11**	0.93**	1.13**	0.35**
Ontario	1.07**	1.04**	1.05**	1.02	0.96	0.99	1.27**	0.99	1.05	0.93**
Quebec	1.01	0.88**	0.93	1.05	1.06*	0.99	0.97	1.07*	0.92	0.99
Saskatchewan	0.91*	1.38**	0.81	1.06	1.05**	1.01	1.18	1.04	0.97	0.80**
Alabama	1.08**	1.00	1.07**	0.86**	1.01	1.07**	1.13**	1.26**	0.82**	0.94**
Arkansas	1.06**	1.00	1.00	0.90**	1.05**	1.09**	1.25**	1.35**	0.75**	0.91**
California	1.00	0.86**	1.07**	0.96**	1.11**	1.04	1.18**	1.29**	0.93*	1.03**
Florida	1.05**	0.97	1.22**	0.92	1.07**	1.04**	1.23**	1.21**	0.83**	0.91**
Georgia	0.95**	0.93**	1.00	1.03	0.99	0.97	1.03	1.27**	0.86**	0.86**
Idaho	1.04**	0.94	1.02	0.96**	1.04*	1.01	1.21**	1.23**	0.88**	0.99
Indiana	1.11**	0.89**	1.74**	0.72**	1.06**	1.07**	1.44**	1.21**	0.88**	0.93**
Kentucky	0.92**	0.86**	1.01	0.97	1.02	1.08*	1.11**	1.23**	0.79**	0.94**
Louisiana	1.01*	0.92**	1.05**	0.83**	1.03**	1.08**	1.12**	1.45**	0.74**	0.88**
Maine	1.22	0.83**	1.20**	0.64**	1.06**	1.06**	1.28**	1.24**	0.80**	0.90**
Michigan	1.05	1.00	1.04	1.05	1.02	0.85**	1.19**	1.25**	0.77**	0.97
Missouri	1.03	0.72**	0.91*	0.97	1.06**	1.18**	1.41**	1.15**	0.76**	1.03
Mississippi	0.99	0.93**	1.05	0.95**	1.05**	1.15**	1.10**	1.19**	0.88**	1.00
Montana	1.00	0.90**	1.17**	0.99	1.13**	0.98	1.12**	1.34**	0.77**	1.09
North Carolina	1.00	0.84**	1.10**	1.00	1.07**	1.11**	1.20**	1.30**	0.94	0.96**
New York	1.05**	0.79**	2.23**	1.04**	0.58**	1.06**	1.06	1.42**	0.72**	1.75*
Ohio	0.90**	0.89**	1.19**	0.83*	1.04**	1.13	1.44**	1.21**	0.78**	0.90**
Oregon	1.03*	0.93**	1.05**	1.01	0.99	0.97	1.11**	1.24**	0.91**	1.01
Pennsylvania	0.43**	1.00	1.04	1.16**	1.04**	0.86**	1.59**	1.45*	0.51**	1.05
South Carolina	0.99	1.00	1.10**	1.12**	1.03**	0.94*	1.16**	1.48**	0.74**	1.09
Tennessee	1.11**	0.82**	1.00	0.91**	1.06**	1.06*	1.15**	1.26**	1.01	0.92**
Texas	1.04**	0.88**	1.02	0.99	1.09**	1.11**	1.10**	1.41**	0.77**	0.83**
Virginia	0.99	1.02	1.03	0.93*	1.06**	1.06	1.07	1.21**	0.80**	0.90**
Washington	0.80**	0.86**	1.02	0.94**	1.09**	1.05*	1.22**	1.35**	0.80**	1.13*
Wisconsin	1.22**	1.04**	1.07**	1.01	1.02	1.00	1.16**	1.14**	0.87**	0.99
West Virginia	1.11	1.47*	1.07*	0.82**	0.96**	1.02	1.17**	1.18**	0.80**	1.05**

Note: * denotes significant difference from unity at the 10% level; ** denotes significant difference from unity at the 5% level.

Table 2.7. Bootstrap results of Färe productivity index by year (Continued)

State/Province	1973/1974	1974/1975	1975/1976	1976/1977	1977/1978	1978/1979	1979/1980	1980/1981	1981/1982	1982/1983
Alberta	0.81**	0.90**	0.91**	1.02	1.05**	0.94**	1.10**	1.12*	1.05**	1.25**
British Columbia	0.95	0.99	1.09**	0.96**	1.00	0.98**	0.98	1.07*	0.99	1.10**
Manitoba	1.10	0.84**	1.03	0.91**	0.97	1.07**	0.93**	0.91**	1.15**	0.96**
New Brunswick	0.95	0.75**	0.86**	0.95**	1.35**	1.13**	0.87**	0.83**	0.98	0.99
Nova Scotia	1.91*	0.91*	1.17**	0.92**	1.03*	1.02	0.97	0.96**	1.10**	1.14**
Ontario	0.94	0.96	1.14**	0.98	1.12**	1.01	1.00	1.00	1.02	1.03
Quebec	0.78**	0.97	0.96	1.09**	1.07**	1.05**	1.00	0.97**	1.03	0.92**
Saskatchewan	0.93	0.91**	1.29**	1.03**	0.97	0.86**	1.05	1.23**	0.87*	1.08*
Alabama	1.09	1.10**	1.06**	0.78**	1.10**	1.02	0.66**	0.96	1.68**	1.15**
Arkansas	0.96	1.11**	1.05**	0.83**	1.22**	1.02	0.65**	0.83**	1.56**	1.17**
California	1.08**	1.14**	1.07**	0.73**	1.12**	1.04**	0.62**	0.89**	1.43**	1.16**
Florida	1.16**	1.14**	0.94**	0.81**	1.12**	0.97	0.64**	1.12**	1.46**	1.27**
Georgia	1.03	1.16**	0.98	0.84**	1.13**	1.00	0.58**	1.11	1.40**	1.16**
Idaho	1.04	1.12**	1.13**	0.68**	1.22**	0.94*	0.68**	0.93**	1.38**	1.26**
Indiana	1.23**	1.20**	1.09**	0.62**	1.08**	0.97	0.56**	0.98	1.50**	1.01
Kentucky	0.97	1.02	0.98	0.96	0.95	1.17**	1.02	0.68**	1.88**	1.09**
Louisiana	1.10**	1.24**	0.94**	0.91**	0.98	1.09*	0.60**	0.92**	1.50**	1.12**
Maine	1.17**	1.18**	0.94**	0.80**	1.13**	1.06*	0.76**	1.19**	1.26**	1.14*
Michigan	0.98	1.09**	0.89**	0.97	1.03	0.89*	0.71**	1.00	1.16*	1.05**
Missouri	1.02	1.15**	0.99	0.77**	1.02**	1.05**	0.51**	1.00	1.83**	1.02
Mississippi	0.95	1.12**	1.05**	0.90**	1.17**	1.07**	0.52**	1.03	1.26**	1.11**
Montana	0.90	1.03	1.17**	0.93	1.00	0.97	0.72**	0.88**	1.34**	1.23**
North Carolina	1.16**	1.04	0.97	0.78**	0.99	1.11**	0.54**	0.95**	1.97**	1.02**
New York	0.87	1.41**	1.02	0.58**	0.85**	0.98	0.68**	1.14*	1.33**	1.01
Ohio	1.09	1.10	0.89**	0.81**	0.80**	1.08**	0.80**	1.05	1.40**	1.10**
Oregon	1.17**	0.99	1.06**	0.73**	1.22**	1.02	0.67**	0.92**	1.41**	1.23**
Pennsylvania	0.96	1.15**	0.97	0.83*	0.93*	0.99*	0.69**	1.04	1.25**	1.10
South Carolina	0.90	1.29**	0.79**	0.84**	1.13**	0.93*	0.80**	0.87**	1.53**	1.09**
Tennessee	1.13*	1.08	0.84**	0.90	0.97	1.10**	0.57**	0.89*	1.89**	1.11**
Texas	0.88	1.13**	1.19**	0.85**	1.19**	0.92	0.88**	0.88**	1.44**	1.03
Virginia	1.05	1.04	0.98	0.86**	1.08**	1.09**	0.60**	0.99	1.41**	1.12**
Washington	0.91	1.08	0.85	0.90	1.29**	1.00	0.58**	0.80**	1.49**	1.19**
Wisconsin	1.00	0.91	1.14**	1.01	0.76**	1.05*	0.73**	0.98	1.17**	1.06**
West Virginia	1.08	1.25*	0.97	0.83	0.81**	1.32**	0.77**	0.98	1.06	1.14**

Note: * denotes significant difference from unity at the 10% level; ** denotes significant difference from unity at the 5% level.

Table 2.7. Bootstrap results of Färe productivity index by year (Continued)

State/Province	1983/1984	1984/1985	1985/1986	1986/1987	1987/1988	1988/1989	1989/1990	1990/1991	1991/1992	1992/1993
Alberta	1.05*	1.00	1.20**	1.14	1.23	0.88	0.90**	1.01	0.94**	0.98
British Columbia	0.97**	0.92**	1.13**	0.99	1.13	1.03**	0.93**	0.98	0.92**	1.08
Manitoba	1.11**	0.78**	0.97	1.08	0.94	1.30**	0.85**	0.89**	1.08**	1.49**
New Brunswick	1.33**	0.63**	1.06**	0.96**	0.81**	1.56**	0.77**	0.80**	1.00	1.28**
Nova Scotia	1.27**	0.52**	1.01	0.91**	1.00	1.50**	0.82**	1.03	1.04	1.07**
Ontario	1.09**	0.71**	1.12**	0.99	1.17**	1.02**	0.87**	0.91**	1.07**	1.16**
Quebec	1.17**	0.70**	1.08**	0.97**	1.35**	1.08**	0.83**	0.97**	0.97*	1.26**
Saskatchewan	1.07**	0.91**	1.09**	0.97	1.00	1.10**	0.88**	1.01	1.00	1.10**
Alabama	0.99	0.94**	0.88**	1.01	1.02	1.08**	1.01	0.94**	1.22	0.87
Arkansas	1.01	0.99	0.85**	1.04**	0.91**	1.16**	0.98	1.02**	1.09**	1.13**
California	0.94**	0.98	0.91**	1.03	1.01	1.11**	0.95**	1.06**	1.01	1.05**
Florida	0.97	0.93**	0.89**	1.02	0.94**	1.10**	1.07**	1.01	1.04**	1.19**
Georgia	0.88**	0.91**	0.89**	1.01	0.97	1.04**	1.10**	1.00	1.01	1.09**
Idaho	0.92**	0.99	1.01	1.10	0.96**	0.96	0.98	1.04	1.01	0.96*
Indiana	1.35**	1.06*	0.88**	0.76**	0.94**	0.92	0.91**	1.14**	0.95	1.08*
Kentucky	1.01	0.94**	0.93	0.97	0.97	1.76	1.04	N.A	N.A	1.27**
Louisiana	0.93**	0.88**	0.99	0.94**	1.04	1.10**	1.48	0.67**	0.86**	1.14**
Maine	0.95	0.92**	0.89**	0.96**	0.88**	1.19**	1.04**	1.02*	1.06**	1.09**
Michigan	0.93**	1.00	0.93	1.04**	0.89*	1.29**	1.01	0.82**	0.93**	0.93**
Missouri	1.11**	1.05*	1.04	0.98	0.95	0.89	1.05	0.78**	1.12**	1.04
Mississippi	0.94**	0.96**	0.91**	1.12**	0.91**	1.09**	1.06**	1.03	1.02	1.10**
Montana	1.18	1.07*	0.96	0.90	0.94**	1.01	0.95**	0.97	0.96	1.00
North Carolina	1.04**	0.96**	0.89**	1.01	0.90**	1.17**	0.97**	1.08**	0.91**	0.95**
New York	0.97**	0.97**	0.95**	1.02**	0.96	1.28**	0.95	1.27**	0.86**	1.15**
Ohio	1.01	0.94*	0.94	1.04	0.93**	1.14**	1.00	1.06*	0.96	3.40
Oregon	0.93**	0.97	0.95	1.04	1.00	1.07**	0.94**	1.00	1.02	0.95**
Pennsylvania	0.87**	1.05**	0.92**	1.02	0.88**	1.24**	0.96*	0.98	0.93**	1.05**
South Carolina	1.02	0.92**	0.91**	1.00	1.05**	1.01	0.98**	0.92**	1.18**	1.01
Tennessee	1.02	0.97**	0.92**	1.10**	0.93**	1.05**	0.93**	1.01	0.98	1.85**
Texas	1.02	0.93**	0.82*	1.10**	0.85**	1.02	1.00	0.90**	1.01	1.08**
Virginia	1.10	0.96**	0.95*	1.03	1.05*	1.24	1.16	1.31	0.41**	1.02
Washington	0.91**	0.96**	0.89*	1.04	0.96**	1.17**	0.97	1.04	0.98**	1.01
Wisconsin	1.08**	0.85**	0.94**	0.92**	1.08**	1.13**	1.14**	1.06**	0.91**	1.11**
West Virginia	1.47**	0.88**	0.95	0.88**	1.25**	0.97	0.92**	1.02**	0.97	1.08*

Note: * denotes significant difference from unity at the 10% level; ** denotes significant difference from unity at the 5% level.

Table 2.7. Bootstrap results of Färe productivity index by year (Continued)

State/Province	1993/1994	1994/1995	1995/1996	1996/1997	1997/1998	1998/1999	1999/2000	2000/2001
Alberta	0.86**	1.25**	0.83**	0.94**	0.96**	1.15**	0.96	1.09**
British Columbia	0.86**	1.01	1.09	0.81**	1.36**	0.78**	1.33**	0.86**
Manitoba	0.83**	1.35**	0.76**	0.95**	1.01	1.71**	0.49**	0.93**
New Brunswick	0.83**	1.50**	0.85**	1.07**	0.90**	0.89**	0.93**	0.98
Nova Scotia	0.91**	1.26**	0.89**	1.09**	1.07**	0.87**	0.85**	1.00
Ontario	0.86**	1.47**	0.72**	0.91**	0.89**	1.12**	1.09*	0.90**
Quebec	0.76**	0.89**	1.19**	0.73**	1.31**	0.78**	1.18*	0.94
Saskatchewan	0.95	1.15*	0.89**	1.05**	0.96*	1.21**	0.78**	1.34**
Alabama	1.12**	0.96**	0.98	1.18**	1.05**	1.15**	0.89**	0.85**
Arkansas	1.10**	0.95**	1.10**	1.25**	1.06**	1.17**	0.89**	0.85**
California	1.06**	0.94**	0.98*	1.09**	1.05**	1.02**	0.93**	0.91**
Florida	0.91**	1.07*	0.98	1.10	1.00	1.09**	0.96	0.94**
Georgia	0.97	1.02	1.03	1.09**	1.07**	1.16**	0.89**	0.95**
Idaho	1.20**	1.01	1.05	1.00	1.03	1.22**	0.91**	0.81**
Indiana	0.89**	0.93**	0.93**	0.69**	0.98	1.05	0.87**	0.73**
Kentucky	0.91**	1.03	1.28**	1.00	1.03**	1.07	0.99	0.95
Louisiana	0.98	1.16**	0.98	1.19**	1.07**	1.06**	1.01	1.00
Maine	0.92**	1.06**	1.16**	1.15**	1.07**	1.15**	0.98	1.07
Michigan	1.21**	1.10**	1.19**	1.00	0.85**	0.88**	1.07**	0.84**
Missouri	1.10**	0.98	0.91*	1.43**	0.92**	1.02	1.08**	0.90**
Mississippi	1.06**	0.97*	0.94**	1.24**	1.04**	1.11**	0.92**	0.93**
Montana	1.02	1.01	0.94**	1.45**	0.98	1.08	0.95	0.91**
North Carolina	1.14**	0.95**	1.02	1.16**	1.01	1.11**	0.93**	0.96**
New York	0.92**	1.09**	1.00	1.21**	0.99	1.08**	0.91**	0.93**
Ohio	0.33**	1.02*	1.09**	0.74**	1.06	1.20**	0.84**	0.83**
Oregon	1.33**	1.56	1.06**	0.51**	1.06**	1.15**	0.96	1.00
Pennsylvania	1.04**	1.11**	1.09**	1.10**	0.97	1.16**	0.92**	0.96**
South Carolina	1.11**	0.95**	1.03*	1.24**	1.02**	1.11**	0.94**	0.89**
Tennessee	0.63**	1.08**	1.05	1.08	0.86**	1.21**	1.04	1.02
Texas	1.05	0.92**	1.05*	0.88**	0.83**	1.14**	0.92**	0.96
Virginia	1.02	0.96	0.98	1.11**	1.05**	1.13**	1.10**	0.92**
Washington	1.11**	0.95**	1.03**	1.17**	1.09**	1.20**	0.92**	0.96**
Wisconsin	1.00	0.94*	1.00	0.73**	1.03	1.13**	0.85**	0.97
West Virginia	0.94	1.05	1.07**	1.17**	1.02	1.33	0.72**	1.08

Note: * denotes significant difference from unity at the 10% level; ** denotes significant difference from unity at the 5% level.

CONCLUSIONS

This study used nonparametric programming approach to estimate technical performance and productivity trends of sawmill industries in North America, the first time this has been performed. The results showed that the U.S. sawmill industry was more likely to be on the industry frontier than the Canadian counterpart during 1990-2001 although the Canadian sawmill industries were more likely to be efficient than the U.S. counterpart before 1990. This suggests that alleged higher productivity by Canada may not be true for 1990-2001. Efficiency means that the state/province with higher efficiency has exploited their resources relatively better than others in the sample with similar proportional inputs. Over the whole study period, the U.S. West and North were more likely to be on the frontier than the U.S. South. However, the technical efficiency performances for the selected states/provinces varied with different periods of time. There was a slight trend of frontier moving towards the South, especially in the latest 10 years.

The results also show that logging restriction in the U.S. Northwest and the softwood lumber dispute between the U.S. and Canada affected the performance of sawmilling industries differently across the regions. This may affect the competitiveness and performance of the sawmilling industries in the long run as well.

During 1964-2001, the weighted annual productivity growth of sawmill industry for the U.S. was 2.5%, indicating progress. During the same period, Canadian sawmill industry was shown to have a lower growth rate of 1.3%. All regions except the U.S. west had a trend of moving towards the industry frontier. Difference in productivity growth was mainly due to the difference in technical change. Compared to Canada, the U.S. had a higher rate of frontier expansion. Sensitivity analysis indicated that the estimates of annual productivity growth rate may vary depending on the selection of the sample. However, both countries experienced statistically significant productivity growth and the U.S. had a higher growth rate during the whole study period The results of biased technical change analysis suggest that the technical change associated with sawmill industry in the North America over the 38-year period was not Hicks neutral, and the adoption of traditional neutrality assumption should be cautious in the productivity growth analysis for the U.S. and Canada sawmill industries.

This study suggests that there was a trend of gap-widening between two countries' productivity growth during the late part of the study period. The large difference in annual rate of TFP growth between the U.S. and Canadian sawmilling industries after 1990 led to this widening gap.

The comparison with the results by using Törnqvist-Theil approach suggests that the estimation may vary with the selection of approaches. Assumption of efficiency in production, selection of production units, and involvement of price factors may all result in the difference in the results.

It should be noted that this study did not consider the quality difference in inputs and outputs across states and provinces. In other words, homogenous inputs and outputs were assumed during the whole study. However, this may not be the case. Constantino and Haley (1989) discuss the difference in wood inputs across production units and the impact on measure of technical change. Meanwhile, there is difference in outputs combinations between the U.S. and Canada. The U.S. has larger proportion of hardwood in total lumber production than Canada. However, the DEA method used in this study did not consider this inherent difference between these two countries as well as among regions. Also, constant return to scale was assumed in this study for convenience of the estimation of TFP growth and further decomposition. This assumption may not be suitable in some cases.

III. AN EMPIRICAL ANALYSIS OF TIMBERLAND OWNERSHIP AND CORPORATE FINANCIAL PERFORMANCE FOR THE US FORESTRY INDUSTRIES IN THE U.S.

INTRODUCTION

Forest products firms in the U.S. own 13% of U.S. timberland (27 million ha), which generated approximately 29% of timber supply for them in 2001 (Smith et al. 2003). The past 15 years have witnessed a gradual decrease in the total area of industrial timberland holdings in the U.S. Compared to the peak which occurred during the mid-1980s, the total area of industrial timberland in 2002 has decreased by around 7% or approximately 2 million ha.

The on-going forest industry corporate restructures involve industrial timberland holdings. However, patterns are far from uniform. Lately, some forest products firms such as Georgia-Pacific (GP) and Boise Cascade Corporation (BC) divested some or all of their timberland. Timberland Investment Management Organizations (TIMOs) have acquired most of the industrial timberland on the market in recent years (Yin et al. 2000). On the other hand, International Paper (IP) has consolidated its timberland holdings after terminating its IP limited timberland partnership in the last few years.

Empirically there are various degrees of timberland ownership by forest industry firms. At one extreme, Alabama River Inc., a privately held company, does not own any timberland. At the other extreme, Weyerhaeuser Company and International Paper own millions of hectares of timberland.

Theoretically, there are several justifications for industrial timberland ownership, including favorable returns on timberland, earning stabilization or cost control, leverage on open stumpage market, tax advantages, price volatility and risk reduction, and supply assurance (Hungerford 1969, Carlton 1979, O'Laughlin and Ellefson 1982, Ellefson and Stone 1984, Zinkhan 1988, Zinkhan et al. 1992, Yin et al. 1998). Unfortunately, some of them provide inconsistent even controversial explanations and predictions.

Based on a survey of 87 forest products companies, Clephane and Carroll (1981) suggest that industrial timberland ownership is critical to a firm's profitability and valuation. A recent study by Yin et al. (2000) indicated that holding timberland can enhance the ability of forest products companies to make decisions that can result in financial success in the long term by using a numerical simulation. However, no previous empirical study has analyzed the relationship between industrial timberland ownership and corporate financial performance.

The purpose of this chapter is to empirically examine the relationship between timberland ownership and the financial performance of forest products companies in the U.S controlling for other factors. Since corporate performance is multidimensional, it is reflected not only in rates of return (economic performance) but also in its response of security of returns to the turbulent economic environment and risks. Thus, a variety of performance measures are used to represent different attributes of performance. Specifically, this study intends to answer questions as follows:

1. Do timber-owning companies perform economically better than non-timber-owning companies in the industry?
2. If so, how much is the extent to which industrial timberland ownership can explain corporate economic performance for the U.S. forestry products firms?
3. What is the role of timberland ownership in firm risk management? Does timberland ownership reduce the level of systematic risk?

The results may provide insights into forestry product companies' timberland investment behavior. It can also be useful in estimating the future trend of U.S. industrial timberland holdings, which have both important market and environmental implications. To control the impact of 1986 federal tax reform, which put industrial timberland and other timberland in the same tax category, the study period will be from 1988 to the present. The scope of this research is to examine all publicly trade companies in the lumber and wood products sector, and the paper and allied products sector.

In this chapter, the current situation of industrial timberland holdings by U.S. forest products companies is reviewed. Then a literature review on industrial timberland holding and relevant financial analysis is provided. After that, the data and methodology used in this study are presented, followed by the results obtained from the analysis. Finally, conclusions are provided.

CURRENT SITUATION OF INDUSTRIAL TIMBERLAND HOLDINGS

This section provides an overview of the industrial timberland ownership situation in the U.S. during the past 15 years. Industry-level statistics can give a picture of overall situation and trend of development while corporate-level data can present internal differences of timberland holding patterns across companies within the industry.

Table 3.1 shows the timberland holding situation in the U.S. forest products and paper industries from 1977-2002. During the period of late 1980s to mid-1990s, the industry experienced a decrease in timberland holdings. The area of industrial timberland decreased from 1987's 28.5 millions ha to 1997's 27.0 million ha at an annual rate of 0.5%. The rate of decrease diminished to 0.3% annually from 1997 to 2002.

Table 3.1. Industrial timberland area by region and year

	1977		1987		1997		2002	
	Area	%	Area	%	Area	%	Area	%
U.S. Total	27,897	100	28,468	100	27,056	100	26,546	100
North	7,063	25	6,854	24	5,986	22	5,928	22
South	14,917	53	15,373	54	14,988	55	14,535	55
Rocky Mountain	848	3	1,199	4	1,184	4	1,184	4
Pacific Coast	5,070	18	5,042	18	4,898	18	4,899	18

Source: Smith et al. (2003).
Note: Area in thousand ha.

The U.S. South is the largest region of industrial timberland. It has experienced different degrees of growth until the mid-1980s but a slight shrink age occurred since then. The share of southern industrial timberland as of the nation's total remained almost the same, around 54%. The North is the second largest region in terms of industrial timberland area. In 1977, northern industrial timberland accounted for about 25% of the U.S. total. Since then, this percentage has decreased gradually. As of 2002, the North accounted for 22% of total industrial timberland in the U.S. The pacific coast is the third largest region in terms of industrial timberland area. During the past 50 years, both absolute and relative amounts of industrial timberland holdings remained almost constant across regions. The Rocky Mountain region only accommodates an insignificant level of industrial timberland (less than 5% of the U.S. total). Table 3.2 presents selected large company timberland ownership by region. Consistent with the regional trend of overall industrial timberland ownership, most of these selected forest products companies increased their timberland holdings in the South, and decreased their ownership in the North and the West over the past twenty years.

Table 3.2. Trend of selected forest product company timberland ownership by region (in thousand ha)

Forest Product Company	North		South		West		Total	
	1979	2000	1979	2000	1979	2000	1979	2000
Boise Cascade	1,211	1,011	1,985	3,763	207	121	3,403	4,895
Bowater	0	582	0	1,798	0	833	0	3,213
Champion	0	0	1,247	1,532	1,150	793	2,397	2,325
Deltic Timber	282	125	206	285	580	529	1,068	939
Georgia Pacific	0	0	292	737	142	153	434	891
International Paper	246	608	295	238	0	0	540	846
Kimberly-Clark	32	0	103	452	87	247	222	699
Longview Fibre	0	0	0	686	0	0	0	686
Louisiana-Pacific	100	137	221	202	210	272	531	611
Mead	235	94	259	443	0	0	494	537
Plum Creek	19	3	56	358	271	22	346	383
Potlatch	0	0	0	324	0	0	0	324
Rayonier	0	0	0	0	165	231	165	231
Temple-Inland	176	0	577	0	465	0	1,217	0
Union Camp	509	0	991	0	321	0	1,821	0
Westvaco	79	0	227	0	0	0	306	0
Weyerhaeuser	0	0	697	0	0	0	697	0
Willamette	0	0	0	161	0	0	0	161

Source: Sampson et al. (2000).

Even though some general trends are observed, the differences in industrial timberland holding decisions across forest companies are obvious. Table 3.3 lists timberland owned and controlled by the 50 largest wood-based corporations in 1981, 1994, and 2003. Following the classification of Clephane and Carroll (1982) and Yin (1998), U.S. forest products companies are divided into three categories: 1) Major companies, primarily Fortune 500 companies with major interests in forest products and paper and allied products; 2) Diversified Companies, companies with forest products as their diversified interest; and 3) Other Companies, smaller forest products companies.

Table 3.3. Industrial timberland holdings by corporate and year (in thousand ha)

Forest Products Companies	Owned				Controlled		
	1981[1]	1994[1]	2003[2]		1994[1]	2003[2]	
			U.S	Other Countries		U.S	Other Countries
Major Companies							
Weyerhaeuser	2,400	2,261	2,434	350	7,608	319	12,118
Georgia-Pacific	1,867	2,428	0	0	0	0	0
International Paper	2,793	2,388	3,359	607	81	0	318
Champion International[3]	1,242	1,818	-	-	234	-	-
Boise Cascade	1,239	1,097	828	0	1,350	0	0
Scott Paper[4]	1,152	676	-	-	142	-	-
Louisiana-Pacific	372	651	0	0	157	52	17,806
Union Camp[5]	699	618	-	-	13	-	-
Westvaco/MeadWestvaco	516	588	898	52	569	42	0
Kimberly-Clark	270	162	0	405	1,902	0	1,983
Potlatch	573	607	607	0	6	7	0
Mead[6]	638	503	808	0	43	43	0
Willamette[7]	225	500	-	-	0	-	-
Chesapeake Corp.	147	133	0	0	0	0	0
Longview Fiber Co.	195	299	231	0	0	0	0
Federal Paper bord[8]	154	230	-	-	50	-	-
Pacific Lumber Co.[4]	68	76	-	-	0	-	-
St. Regis Paper[4]	1,301	-	-	-	0	-	-
Great Northern Nekoosa[4]	1,126	-	-	-	0	-	-
Sierra Pacific Industries[9]	211	373	607	0	0	0	0
Prentiss & Carlisle[10]	283	283	344	0	0	0	0
Deltic Timber	0	126	176	0	0	0	0
Bowater[11]	1,089	1,497	121	405	0	40	12,869
Stone Container Corp.	0	136	0	405	5,301	0	0
Subtotal	18,560	17,449	10,413	2,223	17,456	504	45,094
Other Companies							
James River[12]	78	170	-	-	1,125	-	-
Temple-Inland	630	769	716	0	0	93	0
Consolidated Papers[4]	269	272	-	-	0	-	-
Mosinee Paper Co.[13]	36	35	-	-	0	-	-
P.H. Glatfelter	41	45	36	0	0	0	0
Sonoco Products Co.	7	32	0	0	0	0	0
Wausau Paper Mills	17	18	49	0	0	0	0
Grief Bros.	128	129	113	16	0	0	0
Stimson Lumber	28	28	202	0	0	0	0
The Collins Co.[13]	53	53	121	0	0	0	0
Pope Resources[14]	53	30	47	0	0	0	0
Crown Zellerbach[15]	801	-	-	-	-	-	-
Subtotal	2,141	1,528	1,284	16	1,125	93	0

Table 3.3. Industrial timberland holdings by corporate and year (Continued)
(in thousand ha)

Forest Products Companies	Owned				Controlled		
	1981[1]	1994[1]	2003[2]		1994	2003[2]	
			U.S	Other Countries		U.S	Other Countries
Diversified Companies							
ITT Rayonier	476	415	701	31	158	104	17
Tenneco Inc.[4]	179	74	-	-	332	-	-
Manville	238	220	0	0	2	0	0
Jefferson-Smurfit[16]	348	307	-	-	91	-	-
Plum Creek Timber Co.	609	809	3,278	0	0	0	0
Seven Islands Land	688	405	395	0	0	0	0
J.D. Irving	162	132	612	0	0	0	0
Proctor & Gamble[17]	421	-	-	-	-	-	-
Subtotal	2,882	2,142	4,985	31	581	104	17
Total	23,583	21,171	16,682	2,270	19,163	702	45,111

Notes:

1. From Yin et al. (1998).
2. From company annual reports (10-k).
3. International Paper acquired Champion International on Jun. 20, 2000.
4. Inactive in 2003.
5. International Paper acquired Union Camp on Nov. 24, 1998.
6. Mead merged into MeadWestvaco Corp. on Jan. 29, 2002.
7. Willamette was acquired by Weyerhaeuser Company on Mar. 24, 2002.
8. Federal Paper Board merged with International Paper on Mar. 12, 1996.
9. Source: http://www.endgame.org/spi.html.
10. From Kingsley et al. (2004). Ownership information in 1979 was used as an approximation of 1984, and that of 2000 was used as an approximation of 2003.
11. Bowater was classified into Diversified Companies by Yin et al. (1998) and Clephane & Carroll (1982).
12. It became Fort James in 1997. Georgia-Pacific bought Fort James in 1999.
13. Mosinee Paper merged with Wausau Paper Mills Co. on Dec. 18, 1997.
14. Pope and Talbot in 1981.
15. It was taken over by James River in 1986.
16. It was acquired by stone container Corp in 1994.
17. Proctor & Gamble divested its pulp business in 1992.

Consistent with the trend of timberland holding changes observed by Yin et al. (1998), Diversified Companies continued to increase their timberland holdings while

Major Companies and Other Companies continued to decrease their holdings in the U.S. from 1994-2003 except with even higher rates of change. During the decade, industrial timberland held by selected major companies decreased by 35% from 15.9 million ha to 10.3 million ha. During the same period, Other Companies divested around 244 thousand ha of timberland, a 16% decline from 1994. However, timberland held by selected diversified companies increased from 3.6 million ha to 5.1 million ha, a 40% increase from 1994.

At the same time, there was a notable trend of increasing amounts of controlled timberland among forest companies, especially for the Major Companies group. There are several forms of timberland control, including leasing, contracting, cutting rights arrangements, and cooperation (Yin et al. 1998). The area of timberland controlled by Major Companies increased by 87% from 17.5 million ha to 32.2 million ha during 1994 to 2003. Meanwhile, some major companies also increased their timberland investment overseas by ownership or control. In 2003, the area of foreign timberland control of Major Companies was about as three times the area of domestic industrial timberland holdings. The vast majority of controlled timberland is located in Canada. For example, Louisiana-Pacific Corporation has 17.8 million ha of timberland under license agreement in Canada. Weyerhaeuser holds long-term licenses on 12.1 million ha of publicly owned timberland in Canada. And Bowater Company has cutting rights on approximately 12.1 million ha of timberland in Canada. Some companies also control timberland in other foreign countries other than Canada, such as New Zealand, Brazil and Russia. For example, International Paper controls timberland in New Zealand and has a cutting agreement in Brazil. These alternatives may all contribute to some extent to the decline of industrial timberland fee ownership in the U.S.

Table 3.4 presents the concentration ratio of timberland fee ownership of forest products companies in the U.S. for selected years. A slight increase of the ratio was observed in the past decades. The three largest timber land holding companies (Plum Creek Timber Co., International Paper, and Weyerhaeuser) accounted for about 32% of all industrial timberland in 2003.[12] The three largest timberland holding companies held about 26% of all acreage in 1994. However, the percentage of the largest ten remained almost the same. About 50% of the total industrial timberland is held by the largest ten.

[12] Since total industrial acreages are not available for 1994 and 2003, constant rate of growth approach was used to interpolate.

Table 3.4. The U.S. industrial timberland concentration ratio for 1981, 1994, and 2003

Rank	Forest Products Companies	1981	Forest Products Companies	1994	Forest Products Companies	2003
1	International Paper	10%	Georgia-Pacific	9%	Plum Creek Timber Co.	12%
2	Weyerhaeuser	18%	International Paper	18%	International Paper	23%
3	Georgia-Pacific	25%	Weyerhaeuser	26%	Weyerhaeuser	32%
4	St. Regis Paper	30%	Champion International	32%	Westvaco/MeadWestvaco	35%
5	Champion International	34%	Bowater	38%	Boise Cascade	38%
6	Boise Cascade	39%	Boise Cascade	42%	Temple-Inland	41%
7	Scott Paper	43%	Plum Creek Timber Co.	45%	ITT Rayonier	44%
8	Great Northern Nekoosa	47%	Temple-Inland	48%	Potlatch	47%
9	Bowater	51%	Scott Paper	50%	Sierra Pacific Industries	51%
10	Crown Zellerbach	53%	Louisiana-Pacific	52%	Prentiss & Carlisle	53%

Since supply assurance is one of the major arguments for timberland holding, it is interesting to see the change in the self-sufficiency rate among companies in the past decades. The self-sufficiency rate is defined as the percentage of wood taken from fee land to the total wood consumed. Table 3.5 presents the self-sufficiency rates for selected companies. Some companies have experienced a significant decline in self-sufficiency in recent years (e.g. International Paper, Louisiana Pacific). Some others remained almost the same (e.g. Boise Cascade).

Table 3.5. Selected wood self-sufficiency rate

Company	1994[a]	2003[b]
International Paper	35	25
Boise Cascade	47	47
Potlatch	35	21
Louisiana-Pacific	25	5
Temple Inland Inc.	42	50[c]
Crown Pacific Partners L P	44	57
P.H. Glatfelter	22	21[d]
Kimberly-Clark	-	40

Notes:

a. From Yin et al. (1998).
b. From company annual reports (10-k).
c. From fee and lease forest land.
d. Calculated from information available.

From the analysis above, we can see that the patterns of timberland holdings across companies are far from uniform although there do exist some general trends for the group as a whole.

LITERATURE REVIEW

To investigate the relationship between industrial timberland ownership and corporate financial performance, it is important to understand the benefits and costs associated with industrial timberland holding. The first part of this section reviews previous studies on the rationale for industrial timberland holdings. The second part reviews studies on factors affecting a company's financial performance.

INDUSTRIAL TIMBERLAND HOLDINGS: BENEFITS AND COSTS

In the context of industrial organization, timberland ownerships by forest products companies can be treated as a case of partial upstream vertical integration. The determinants of upstream vertical integration can be roughly classified into four categories: imperfect competition, incomplete information, transactional economies, and other factors (Perry 1989). The advantages of industrial timberland holdings may come from these sources.

Imperfect competition in input markets provides several incentives for a firm to integrate upstream into the production of the input (Perry 1989). Due to production technology, land use patterns, and the relatively high ratio of transport costs to product value, stumpage markets are often characterized as monoposony or oligoposony. Monoposonistic or oligoposonistic rent can be generated if firms own timberland close to its manufacturing facilities and use it to reduce the price of timber in open markets. This is a leverage theory of vertical integration. Murray (1995) showed this in the context of U.S. pulpwood markets.

Timberland ownership by a forest products firm can also create an entry barrier for potential competitors. Bain (1956) argued that vertical integration creates a capital barrier to entry by forcing potential entrants to contemplate entry at two stages of production rather than just one. Similarly, upstream vertical integration can also raise a rival's cost by leaving the open market thin (Salop and Scheffman 1983). The leverage theory was mentioned in the Hungerford (1969) survey and by O'Laughlin and Ellefson (1982).

Uncertainty and incomplete information is another motivation for industrial timberland ownership. Supply assurance, diversification of returns, earnings stabilization, and risk reduction of price volatility can be all classified into this category.

Actually, assurance of input supply is one of the most frequently alleged reasons for industrial timberland holdings (Hungerford 1969). Carlton (1979) provided a rationing model of backward vertical integration to assure input supply. In his model, retailers are rationed by the manufacturer. Demand variability makes input supplies unreliable, which creates a risk of inefficiency. Carlton (1979) stated that firms integrate backward to satisfy their high probability demand and use the market to satisfy their low probability demand. Although supply security has been mentioned as an incentive for industrial timberland holdings in many studies, we still lack a specific theoretical model.

Industrial timberland holdings also can reduce risk. One argument is based on portfolio theory in the finance literature. Because timberland and manufacturing of forest products occur on different business cycles and have different levels of risk, owning both can reduce the risk level of the firm and thus smooth the flow of returns. When exogenous factors cause changes that are not perfectly positively correlated in the two markets, integration can reduce the risk of the firm as a whole (Blair and Kaserman 1983). Some other studies provided additional insights into this incentive. Helfat and Teece (1987) suggested that two factors determine the level of systematic risk facing a company: the degree of uncertainty associated with potential economic events, and the responses of security returns to those events. Although vertical integration may not reduce uncertainty, it may reduce risk by reducing a firm's response to uncertainty (secondary uncertainty) through internal organization.

Zinkhan et al. (1992) indicated that timberland holdings can be a way of achieving earning stabilization in the context of overall business operations for forest products and paper companies. When forest products prices are high (thus timber prices are high) firms can use more of their own timber, and when forest products prices are low, firms can buy timber from the open market. This can alleviate financial burdens on firms during downtime. Another possibility on the contrary is that when the timber prices are low (usually associated with low forest products prices), industrial firms buy more from their own land in order to generate more revenues and to stabilize their earnings. Binkley et al. (1996) suggested that this strategy will lead to more timber on the market during economic downturns and thus exacerbates declines in timberland profitability.

Transaction cost theory provides another perspective to view the advantage of industrial timberland ownership. An alternative of timberland ownership is timberland control by contracts between forest products companies and timber landowners. All justifications above under the framework of neoclassic economics can also be realized by timberland control such as lease, cutting rights arrangement and so on. Then why do forest products companies choose to own the fee land instead of engaging long-term or short-term contracts? Coase (1937) argued that the cost of exchange is the key to understanding vertical integration.

According to Williamson (1975, 1986) and Klein et al. (1978), vertical integration stems from a small number bargaining problem. Under that circumstance, incentive of opportunism to extract the quasi-rents from the other party arises. The hold-up cost depends on the extent of asset specificity. Yin et al. (1998) suggested a high degree of asset specificity as a characteristic of the forest products industry. Long-term contracts can be used to avoid opportunistic behavior when future contingencies can be specified and estimated. However, the governance cost on opportunistic behavior may be very high. Also, sometimes it is too costly and impossible to outline every future contingency. Internalization of the exchange will be more efficient in that case. Thus, vertical integration may be a preferable choice over contracts.

Industrial timberland ownership may also be motivated by other reasons, such as tax advantages and strategic considerations. Before 1986, the capital gains tax rate on timberland is 30% rather than a 48% of regular income tax rate, which made owning timberland lucrative. If a corporation owns timberland and grows and processes its own timber, the preferred capital gains rate applies and, in effect, becomes a public subsidy that provides industry with significant capital (Sunley 1976). However, this favorable capital gains tax treatment was terminated after 1986. This reason may not be appropriate to explain recent trends in timberland ownership. Holding timberland also may help meet the strategic objective of the overall business. Ellefson and Stone (1984) showed a case of International Paper's timberland holding to keep a competitor from intruding into its territory.

It should be noted that all theories above can be fit into one framework by using the concept of transaction cost. A firm can be treated as a cost minimizing unit, where cost is the sum of production costs and transaction costs. Production costs are the direct costs incurred in the physical production and exchange of the item subject to the transaction. Transaction costs include costs of negotiating, writing, monitoring, enforcing, and possibly also bonding to the terms of the organizational arrangement (Collis and Montgomery 1997).

Thus far, the studies reviewed here highlight the benefits derived from industrial timberland ownership in the form of increased profit or strategic advantages. However, significant costs are also associated with timberland ownership for forest products companies. High opportunity costs due to capital investment tied by timberland were argued by some scholars (Ellefson and Stone 1984, Yin et al. 1998).

> As an asset, timberland ties up large amounts of capital for long periods of time. If active timber management is pursued on the land, positive returns can result only after the timber has been sold or processed. Until that time, all cask flows (interest on borrowed capital, property taxes, administration, forest practices) are negative. To compound the problem, the timber being grown is subject to the risk of destruction by insects, disease, and fire. Like all commodity markets, timber markets may be depressed at the time timber is made available for sale. (Ellefson and Stone 1984, p. 250)

Also, the 1990s witnessed a trend of accelerating institutional ownership of timberland in the U.S. (Browne 2001). Yin et al. (1998) suggested that increased institutional ownership will result in appreciation of timberland values, thus higher opportunity costs of holding land. Additionally, agency costs and bureaucratic hierarchy costs may occur. Since timberland owning and forest products are two strategically different businesses, costs will occur if managing them under the same framework. Most of the companies focused on supplying their mills rather than managing timberland as a profitable enterprise.

Considering the advantages and disadvantages associated with industrial timberland ownership, the net impact of industrial timberland ownership on corporate financial performance and market evaluation is undetermined.

STUDIES ON DETERMINANTS OF COMPANIES' FINANCIAL PERFORMANCE

Many studies have addressed determinants of corporate financial performance other than timberland ownership in either forest products sectors or other sectors (e.g. Rumelt 1986, Lu and Beamish 2001, Li and Greenwood 2004, Booth and Vertinsky 1990, Phillips 1997, Bjorkman et al. 1997). Product diversification, geographic diversification, capital expenditure, research and development (R&D) investment, size of the firm, major business may all play a role.

Booth and Vertinsky (1990) showed that unrelated product diversification and geographic diversification resulted in a decrease in return on assets (ROA) of North American forest products companies. It was argued that such diversification brought high "learning costs" associated with managing and operating new types of business for which it may have not the required competence. Rumelt (1986), however, indicated that performance differences were more closely linked to the way in which the firm related new business to old than to overall diversity by an empirical study on firms in a variety of industries. The highest levels of profitability were shown in the case of having a strategy of diversifying primarily into areas that drew on common core skills or resources. It was found that firms with vertical integration structure were more likely to have low profitability.

Geographic diversification can also affect firm performance. Specifically, this refers to geographic diversification across countries and regions. Some researchers empirically observed that higher levels of international diversification lead to better firm performance (e.g. Daniels and Bracker 1989, Grant 1987, Kim et al. 1993, Tallman and Li 1996) while others find that performance experienced a S-shaped curve (Lu and Beamish 2001, Hitt et al. 1997). Multinational firms can gain economic benefits from the exploitation of various assets across international markets, such as a competitively priced labor force (Kogut 1985), and access to critical resources (Deeds and Hill 1998). On the other hand, different costs are associated with international operations including a “liability of foreignness” (Hymer 1976) and increasing transaction and coordinating costs (Tallman and Li 1996).

Some studies show that R&D intensity is positively related to firm economic performance (e.g. Booth and Vertinsky 1990, Lu and Beamish 2001). Size is also related to profitability (Fama and French 1993). Some studies show that firm size had positive impacts on firm performance (e.g. Li and Greenwood 2004) while some others indicated no significant impact (e.g. Booth and Vertinsky 1990, Lu and Beamish 2001).

Ben-Zion and Shalit (1975) showed that systematic risk is negatively related to a firm’s size and dividend record, and positively related to its financial leverage. Impacts of real economic growth and inflation on the systematic risk of individual firms were found not significant. Unrelated product diversification and geographic diversification were shown by Booth and Vertinsky (1990) to reduce risk of North American forest products companies. R&D intensity was shown to be positively related to systematic risk in the stock market (e.g. Lu and Beamish 2001, Booth and Vertinsky 1990, Ho et al. 2004). Since R&D intensive firms are high growth firms (Titman and Wessels 1988), a large portion of their market value will be generated from future investment opportunities. As a result, R&D intensive firms will bear greater risk (Ho et al. 2004).

DATA AND METHODOLOGY

Firms analyzed in this study consisted of U.S. companies whose primary business was in forestry products during the study period (1988-2003). Due to mergers and acquisitions in the sector, not all firms operated continuously during the whole study period. Some firms were dropped from the list due to lack of information on some variables or some years. The full list of the firms chosen for this study is in Appendix D.

Data for this study were collected from various sources: monthly security returns data from the Center for Research in Security Prices (CRSP), [13] annual financial accounting data from Compustat,[14] Mergent Online[15] as well as annual 10-k's reports, annual information on industrial timberland holding from annual reports via EDGAR.[16]

It should be noted that choosing firms based on data availability may result in sample bias. That is, the sample is biased in favor of large firms and those that have been in existence for a long time. Thus, we should be cautious about extending the conclusions from this study to the whole population of forestry products firms.

DEPENDENT VARIABLES

A variety of measures representing different attributes of firm performance were used as dependent variables in this study. Specifically, rate of return on equity (ROE), rate of return after tax on assets (ROA), price earnings ratios (PE), and systematic risk ratio Beta (β).

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[13] Center for Research in Security Prices, Graduate School of Business, University of Chicago.
[14] Standard and Poor's Compustat Services Inc.
[15] Mergent Inc.
[16] U.S. Securities and Exchange Commission Filings & Forms (http://www.sec.gov/edgar.shtml)

ROA is defined as the ratio of earnings before interest and taxes divided by total assets. It is a pure measure of the efficiency of a company in generating returns from its assets, without being affected by management financing decisions.

ROE is defined as the ratio of earnings before interest and taxes divided by total equity. It is a basic test of how effectively a company's management uses investors' money. It encompasses the three main "levers" by which management can poke and prod the corporation -- profitability, asset management, and financial leverage. By perceiving return on equity as a composite that represents the executive team's ability to balance these three pillars of corporate management, investors can not only get a good sense of whether they will receive a decent return on equity but also assess management's ability to get the job done.

PE is the ratio of current share price to per share earnings. It shows how much investors are willing to pay per dollar of earnings. It is useful for comparing the performance of firms in the same industry.

In this study, equity Beta was used to capture the systematic risk of firms. The Beta can be estimated empirically as regression coefficients of an individual stock return on the market’s return using the Capital Asset Pricing Model:

$$R_{ih} - R_{fh} = \alpha_i + \beta_i (R_{mh} - R_{fh}) + \varepsilon_{ih} \quad [3.1]$$

where

R_{ih} = the rate of security return for stock *i* for month *h*.

R_{fh} = the risk free rate of return (measured by the yield on US T-bills)

R_{mh} = the rate of return of the value-weighted market portfolio for month *h*.

α_i = regression parameters

β_i = equity beta for stock *i*

This measure has been widely used in the modern finance literature. These estimated Betas reflect the systematic risk associated with the firm's stock market equity. Annual equity betas in this study are calculated for each firm using the previous 60 months of stock market data if available. If it was not available, at least previous 20 months data were used.

These performance measures together provided a profile of the economic performance of each firm in my sample.

INDEPENDENT VARIABLES

Since my goal is to estimate the relationship between industrial timberland ownership and forest products company financial performance, the key independent variable concerns about industrial timberland ownership. The most widely available variable documented is the size of industrial timberland holdings for each company annually. To increase comparability across firms of different sizes, the area of timberland owning in the U.S. was normalized by annual sales in this study.

Other independent variables used to help explain financial performance included:

Firm size. Firm size was measured by logarithm of its market equity (ME) in 1988 constant dollars, rather than its total assets, largely because the latter is in book value that may not represent its actual value. ME is calculated as the product of a stock's price and the number of shares outstanding.

Business category. As in Booth and Vertinsky (1990), final products were classified into four categories: wood products, paper and paperboard, specialty products, and other products. Originally, the share of each product in total annual sales was intended to be the indicator of the firm's business category. However, high correlations among each pair of product shares were found (-0.74 for paper share and wood product share, and -0.41 for paper share and other wood products share). So main business dummies were used instead. Since most companies in the sample are either in the wood industry or in the paper industry, the special product category was dropped to avoid multicollinearity.

Product diversification. The entropy measure was used here. It was originally proposed by Berry and Colleague (Berry 1974, Jacquemin and Berry 1979) and has proved to be a valid measure of a firm's product diversification (Hoskisson et al. 1993). It has become the standard for research into the link between diversification and performance (Hill et al. 1992, Hitt et al. 1997, Palepu 1985, Li and Greenwood 2004). The entropy measure permits decomposition of total diversification into different types of diversification. Total entropy (*TD*) is given by:

$$TD = \sum_{j=1}^{J} P_j \ln(1/P_j) \qquad [3.2]$$

where P_j is the proportion of business activity (sales) in segment *j*, for a firm with *J* different industry segments.

Unrelated entropy (*UD*) is computed in a similar fashion using group of segment data:

$$UD = \sum_{g=1}^{G} P_g \ln(1/P_g) \qquad [3.3]$$

where P_g is the proportion of business activity (sales) in the group of segment *g*, for a firm with *G* different groups of industry segments ($G \leq J$).

Related entropy (*RD*) therefore can be estimated as:

$RD = TD - UD$. [3.4]

In this study, the industry segments are defined as:

A. Printing and writing paper, paper pulp, newsprint.

B. Paperboard products and packaging.

C. Distribution activities.

D. Specialty products and consumer products, including tissue and other specialized products.

E. Wood products, consisting of lumber and plywood and other solid wood products.

F. All other non-forest products and services.

Segments *A*-*B* were classified as the group of paper and packaging products production, *C*-*D* as the group of specialty products, *E* as wood products production, and *F* as the group of non-forest products production and service.

Geographic diversification was also used as a control variable. The percentage of U.S. domestic sales in total sales was calculated first. Then it was classified into three categories based on 3 percentiles (33%, 67%, and 100%). Finally two geographic diversification dummies were created (high geographic diversification, and low geographic diversification) to avoid multicollinearity. Annual rate of growth in net sales was used as an indicator of opportunities for a company to adapt to market and environmental change. The compound growth rate of sales in 1988 dollars was used as the measure.

Since volatility of stumpage prices may affect systematic risks and timberland owning decision, variables measuring sawtimber and pulpwood stumpage price volatilities were used in the estimation of these two models. In this study, the price volatility measures are the coefficient of variation (COV) % of real prices, which is 100 times the ratio of standard deviation (SD) and the average of real stumpage prices. Quarterly softwood sawtimber and pulpwood prices in 1988 constant dollars were used to generate yearly SD, and SD was divided by the year average price to obtain COV. The price information is from Timber Mart-South (1988-2003). Since timberland holding decisions were made based on previous year's price volatility, 1-year Lagged COVs for sawtimber and pulpwood prices were used in this study. Since a high correlation exists between sawtimber and pulpwood price volatility (r=0.49), sawtimber price volatility was dropped to avoid multicollinearity.

As mentioned in section II, timberland performance may affect forest industries' timberland ownership decisions. NCREIF Timberland index (NCREIF-T), was used in this study to account for the effect. It is a quarterly database created by the National Council of Real Estate Investment Fiduciaries. As discussed in Section II, timberland under other forms of control may have a substitution effect on industrial timberland owning. Area of timberland in other forms of control was normalized by each firm's annual sales to control for the effect of firm size.

Companies' financial performance is expected to be affected by sawtimber and pulpwood prices too. In addition, annual capital expenditure intensity, and R&D

investment intensity were also used as control variables for the models. To control for the effect of inflation, real values in 1988 constant dollars were used for these variables. The Debt/Asset ratio of the previous year was used to in the Beta and timberland holding model.

EMPIRICAL MODEL

A regression model estimates the relationship between industrial timberland ownership and different aspects of company performance. Since timberland ownership decisions are presumably, based on a variety of internal factors and can affect a firm's performance, the ownership decision was treated as an endogenous variable in the system of model equations. Since different performance measures describe different aspects of the same firm, the disturbances in the functions of different performance measures may include common factors, in other words, they may be correlated. Considerable efficiencies can be gained by estimating these equations jointly as a three-stage least squares (3SLS) model (see Greene 2003, pp. 405).

The full system of equations is

$$\begin{bmatrix} \mathbf{y}_1 \\ \mathbf{y}_2 \\ \mathbf{y}_3 \\ \mathbf{y}_4 \\ \mathbf{y}_5 \end{bmatrix} = \begin{bmatrix} \mathbf{X}_1 & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{X}_2 & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{X}_3 & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{X}_4 & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{X}_5 \end{bmatrix} \times \begin{bmatrix} \boldsymbol{\delta}_1 \\ \boldsymbol{\delta}_2 \\ \boldsymbol{\delta}_3 \\ \boldsymbol{\delta}_4 \\ \boldsymbol{\delta}_5 \end{bmatrix} + \begin{bmatrix} \boldsymbol{\varepsilon}_1 \\ \boldsymbol{\varepsilon}_2 \\ \boldsymbol{\varepsilon}_3 \\ \boldsymbol{\varepsilon}_4 \\ \boldsymbol{\varepsilon}_5 \end{bmatrix} \qquad [3.5]$$

or $\mathbf{y} = \mathbf{X}\boldsymbol{\delta} + \boldsymbol{\varepsilon}$,

where, $E[\boldsymbol{\varepsilon}|\mathbf{X}] = \mathbf{0}$, and $E[\boldsymbol{\varepsilon}\boldsymbol{\varepsilon}'|\mathbf{X}] = \boldsymbol{\Sigma} \otimes \mathbf{I}$. [3.6]

Let index *k=1, 2, 3, 4, 5* denote estimation functions for ROA, ROE, β, PE, or timberland owning in the U.S. to sales ratio respectively. $\mathbf{y}_k$ is a vector of dependent variables for estimation function *k*, $\mathbf{X}_k$ is the matrix of explanatory variables for estimation function *k*, $\boldsymbol{\delta}_k$ is the vector of coefficients associated with explanatory variables $\mathbf{X}_k$, and $\boldsymbol{\varepsilon}_k$ is the vector of disturbance.

The estimator is a GLS (generalized least square) estimator

$$\hat{\boldsymbol{\delta}}_{3SLS} = [\hat{\mathbf{X}}'(\boldsymbol{\Sigma}^{-1} \otimes \mathbf{I})\hat{\mathbf{X}}]^{-1}\hat{\mathbf{X}}'(\boldsymbol{\Sigma}^{-1} \otimes \mathbf{I})\mathbf{y} . \qquad [3.7]$$

DATA ANALYSIS AND RESULTS

DESCRIPTIVE STATISTICS

The study period was divided into three sub-periods to examine rough trends in the variables. Table 3.6 presents the descriptive statistics for the dependent variables including the mean, SD, minimum value, and maximum value. Table 3.7 presents the descriptive statistics of selected independent variables of the sample.

Table 3.6. Descriptive statistics of the sample: Dependent variables

Period Sample size	1988-1992 154	1993-1997 163	1998-2003 166
ROE (%)			
Mean	11.04	8.50	5.53
SD	9.94	26.49	13.16
Min	-27.35	-94.91	-76.44
Max	46.20	282.85	47.33
ROA (%)			
Mean	5.49	4.05	2.65
SD	6.18	5.58	4.72
Min	-39.92	-18.17	-8.36
Max	17.22	19.97	18.26

Table 3.6. Descriptive statistics of the sample: Dependent variables (Continued)

Period	1988-1992	1993-1997	1998-2003
PE			
Mean	23.33	0.81	20.95
SD	57.36	190.72	157.79
Min	-87.17	-2356.50	-973.67
Max	445.83	271.38	1109.38
Beta			
Mean	1.23	0.94	0.80
SD	0.51	0.53	0.39
Min	0.12	-0.45	-0.52
Max	3.38	3.21	1.80
Timberland owning intensity [a]			
Mean	20.84	19.82	16.94
SD	23.81	28.98	30.19
Min	0.00	0.00	0.00
Max	189.98	173.56	167.99

Note: a. Measured by 100 times the ratio of timberland area (in ha) to annual sales.

Table 3.7. Descriptive statistics of the sample: Independent variables

Period	1988-1992	1993-1997	1998-2003
Sample size	154	163	166
ln(ME) [a]			
Mean	6.71	6.53	6.40
SD	1.77	1.81	2.08
Min	0.55	0.52	-0.17
Max	9.18	9.97	10.13
R&D intensity [b]			
Mean	6.33	5.40	4.61
SD	8.98	7.17	6.01
Min	0.10	0.10	0.10
Max	97.67	75.07	45.20
Capital intensity [c]			
Mean	11.94	9.29	9.37
SD	7.84	5.04	19.27
Min	1.39	1.05	1.02
Max	53.42	34.39	225.07
Debt/Asset			
Mean	0.55	0.58	0.64
SD	0.14	0.17	0.11
Min	0.03	0.05	0.33
Max	0.85	1.04	0.90

Table 3.7. Descriptive statistics of the sample: Independent variables (Continued)

Period	1988-1992	1993-1997	1998-2003
Paper share (%) [d]			
Mean	64.89	56.83	53.21
SD	31.25	33.16	34.89
Min	0.00	0.00	0.00
Max	100.00	100.00	100.00
Wood share (%) [e]			
Mean	14.46	18.27	17.10
SD	22.26	25.36	22.66
Min	0.00	0.00	0.00
Max	91.58	96.63	88.05
Non-forest share (%) [f]			
Mean	3.10	3.57	5.55
SD	6.71	6.95	9.96
Min	0.00	0.00	0.00
Max	40.18	35.03	45.85
US. Sales share (%) [g]			
Mean	84.10	83.52	74.38
SD	20.35	21.59	26.61
Min	0.95	0.00	0.00
Max	100.00	100.00	100.00

Notes:

a. ME in millions of 1988 constant dollars.
b. Measured by 1000 times the ratio of annual R&D expenditure to annual sales.
c. Measured by 100 times the ratio of annual capital expenditure to annual sales.
d. Measured by the percentage of sales from pulp, paper, paperboard and packaging to total sales.
e. Measured by the percentage of sales from wood products (lumber and plywood) to total sales.
f. Measured by the percentage of sales from all non forestry product business to total sales.
g. Measured by the percentage of domestic sales to total sales.

A decreasing ratio of timberland ownership to sales over time was observed. The mean of the ratio was 208.4 ha per million dollar sales during 1988-1992. It decreased to 198.2 ha per million dollars during 1993-1997 and 169.4 ha per million dollar sales. However, the large standard deviation suggests high variability in the ratio among firms. The means of Beta, ranging from 0.80 to 1.23, did not deviate much from 1, indicating that the sample firms were not riskier than the market average risk level. However, the large standard deviations suggested considerable variances among the systematic risks of the firms.

The high value of mean paper shares indicates that the main business of most of the firms in the sample was pulp and paper, or paperboard. U.S. domestic sales share, ranging from 84.1% during 1988-1992 to 74.38% during 1998-2003, indicated that domestic sales still dominate although there was a trend of increasing oversea sales. Notice also that the Debt/Asset ratio increased over the study period, from 0.55 to 0.64.

Table 3.8 presents the comparison of selected economic performance of the sample firms with and without timberland ownership. ANOVA tests were conducted on each variable to test the difference in means across these two groups. The results suggest that there were no significant differences in ROE and PE between the firms with and without timberland ownership. However, there were significant differences in ROA and Beta between these two groups. Compared to the group without timberland ownership (β=1.09), the group owning timberland had a relative lower systematic risk (β=0.95). However, return on assets was sacrificed. The sample firms owning timberland had a relative lower ROA (ROA=3.57%) than the firms without timberland (ROA=5.55%).

Table 3.8. Comparison of financial performance among firms owning timberland and owning no timberland

	Own timberland	Own no timberland
ROE		
Mean	8.01	9.23
SD	18.81	16.09
ROA**		
Mean	3.57	5.55
SD	5.12	6.83
PE		
Mean	15.75	12.11
SD	166.97	46.22
Beta**		
Mean	0.95	1.09
SD	0.39	0.79
Number of observations	371	112

** significant at the 5% level in the ANOVA group mean difference test.

ECONOMETRIC MODEL

Equation system (3.5) was estimated for the sample firms. Table 3.9 shows the cross model correlation of the system. The high correlation across models suggested that efficiencies may be gained by estimating the models jointly, and 3SLS is appropriate for this study.

Table 3.9. Cross Model Correlation

	ROE	ROA	PE	Beta	Timberland intensity
ROE	1.00	0.53	0.05	-0.23	-0.30
ROA		1.00	0.10	-0.50	-0.73
PE			1.00	-0.05	-0.14
Beta				1.00	0.68
Timberland intensity					1.00

Table 3.10 presents the regression results for the system. The estimated models of ROE and ROA indicated that timberland holding is positively related to a firm's profitability, resulting in a net increase in ROA and ROE. At the same time, the significant negative coefficient of timberland holding in the Beta model suggested that timberland holding can decrease a firm's systematic risk.

Table 3.10. Estimated Results of the System of Equations

	ROE	ROA	PE	Beta	Timberland
Intercept	9.607	1.411	-40.553	2.378**	49.617*
Timberland to sales ratio (%)	0.191**	0.189**	0.761	-0.017**	
Unrelated diversification index	-0.097**	-0.064**	-0.540**	0.004**	0.238**
Related diversification index	-0.082*	-0.045**	0.402	0.000	-0.073
Firm size	2.636**	0.893**	4.017	0.039**	-0.146
Paper	6.932*	3.790**	16.620	-0.689**	-22.702**
Wood	2.107	2.803**	-4.576	-0.478**	-16.315**
Capital expense intensity	-0.211**	-0.145**	-0.394	0.009**	0.402**
Geographic diversification high	2.505	1.201**	-29.610*	0.052	
Geographic diversification medium	0.226	1.467**	-10.105	-0.002	
Growth rate in sales (%)	0.014	0.005	0.059	0.001**	
R&D intensity	-0.005	-0.010**	-0.006	-0.001	
Pulpwood price	-0.192	-0.032	0.419	-0.001	0.100
Sawtimber price	-60.079**	-23.419**	244.082	-6.369**	20.129
Debt/Asset ratio (lagged)				-0.312	-60.076**
Pulpwood price volatility					-0.121
NCREIF timberland index (lagged)					-0.052
Other Forms of Timberland Control					-0.036**
System weighted MSE			1.37		
Degree of freedom			2330		
System weighted R-square			0.28		

* significant at the 10% level, ** significant at the 5% level.

Consistent with Booth and Vertinsky (1990), the present results suggest both unrelated and related diversification in the forestry products industry had a negative relationship with ROE and ROA. Unrelated diversification may increase a firm's systematic risk. However, the effect of related diversification on a firm's systematic risk was not shown significantly. Firm size was shown to be positively related to ROE, ROA, and Beta. In other words, large firms were more likely to perform better in terms of ROE and ROA at the expense of higher systematic risk. This result contradicts Ben-Zion and

Shalit (1975), which indicated negative relationship between a firm's size and its systematic risk. However, the result echoes a recent study of Daves et al. (1999). They found that after 1980s large firms tend to be riskier than small firms because large firms have added relatively riskier projects than have small firms.

Mainly operating in wood products and paper business may result in a net increase in ROE and ROA as well as a decrease in the firm's systematic risk. Significant negative coefficients on capital expense intensity in the ROE and ROA models suggest that capital expense intensity may increase a firm's costs and thus reduce its profitability. At the same time, the significant positive coefficient on high capital expense intensity in the Beta model suggests that it also increases a firm's systematic risk.

Geographic diversification is shown to result in higher returns in terms of ROA. Meanwhile, geographic diversification was shown to be negatively related to PE. However, its effect on all other financial performance indicators was not shown significantly. Growth in sales was shown to be positively associated with Beta, indicating high growth companies may have higher systematic risk. R&D expenditure intensity was shown to be negatively related to a firm's ROA. However, its impact on other performance indicators was not shown significantly. Sawtimber price was shown to have a negative relationship to a firm's ROE, ROA and Beta. However, the impact of pulpwood price on a firm's financial performance was not shown significantly.

Most of the coefficients in the PE model were not significant except the unrelated diversification index and geographic diversification. This affected the whole system's R-Square. The significant negative coefficient of the variable suggests that unrelated diversification may deteriorate a firm's PE.

The timberland model fits well. Most of the independent variables were shown significant. A firm's unrelated diversification is positively associated with its industrial timberland holding. The previous year's financial leverage is negatively related to current year's industrial timberland holding. In other words, it empirically supports the popular argument that forest product companies divest some of their timberland to ease their financial stress. As expected, other forms of industrial timberland control have a substitution effect on forest products companies' fee land ownership decisions. The significant positive coefficient on capital expense intensity suggests a positive relationship between industrial timberland ownership and capital expenditure. Unexpectedly, neither pulpwood price nor its volatility was shown to have significant impact on a firm's timberland ownership. The coefficient of previous year's NCREIF timberland index was not shown significantly different from zero although it indicated a negative relationship between the performance of timberland in the market and a firm's timberland holding decision. When the market return is high, forest product companies tend to sell their timberland holdings.

DISCUSSIONS AND CONCLUSIONS

The present study is designed to empirically test the relationship between timberland ownership and the financial performance of forest products companies in the U.S. The results confirmed that timberland holding can enhance a forestry products company's profitability in terms of return of assets and return of equity. Moreover, timberland ownership is shown to decrease companies' systematic risk as well. In other words, timberland holding improves a firm's ability of relative response of security returns to uncertainty. The results also show that industrial timberland ownership is associated with high capital expense and a high debt/asset ratio, which may bring financial burdens and affect a forest products company's operation in the short run and long run. Forest products companies may divest some of their timberland to ease the financial burden. When the return of timberland is high, forestry product firms are inclined to decrease their timberland holdings. These findings appear to justify the timberland investment/divestment behavior of most forest products companies in the U.S. in recent years. Actually, paying down debt and focusing on core business were two common alleged reasons for forest products companies to divest timberland. (e.g. International Paper, Georgia Pacific)

On the other hand, an increasing debt/asset ratio occurs for the sample companies in the past 15 years and it will not be surprising if the trend of divesting industrial timberland continues.

The results show that there were significant differences in ROA and Beta between the firms with timberland and the firms without. Compared to the group without timberland ownership, the firms owning timberland had a relative lower systematic risk and lower return on asset. However, the difference in ROE and PE between these two groups was not shown significant.

Although my goal in this chapter was to investigate the relationship between timberland ownership and forest products company financial performance, some other findings are also interesting. The results showed that product diversification into unrelated and related product lines may deteriorate a firm's profitability. Unrelated diversification may increase fluctuations in rates of return and increase the firm's systematic risk. Large firms were shown to be more likely to have higher ROE and ROA at the expense of higher systematic risk than that of small firms. Investment on relatively riskier projects by large firms may increase their systematic risk. The results also suggested that high-growth companies may have higher systematic risk. Surprisingly, the effect of pulpwood price volatility on forest products companies' timberland ownership was not shown significant.

However, the results of this study need to be interpreted with caution. As mentioned, the sample firms in this study were chosen among public companies and based on data availability. An inherent problem associated with sampling method is sample bias. Thus, care should be taken when the conclusions are extended to a wider range of the population.

Due to data availability, measures of timberland ownership were mainly based on the area of industrial timberland. Thus, future studies may be improved if more detailed data on industrial timberland (e.g. timberland values, self-sufficiency, distribution of timberland) are available.

IV. SUMMARY

In this dissertation, I have made an attempt to analyze two issues related to forest products industries.

In the first essay, a nonparametric programming approach was used to estimate the technical performance and productivity trends of sawmill industries in North America for the first time. The results showed that the U.S. sawmill industry was more likely to be on the industry frontier than Canada during 1990-2001 although the Canadian sawmill industry was shown more efficient compared to the U.S. counterpart during 1963-1989. During 1964-2001, the weighted annual productivity growth of sawmill industry for the U.S. was 2.5%, indicating moderate progress. During the same period, the Canadian sawmill industry was shown to have a lower growth rate of 1.3%. All regions except the U.S. west have a trend of moving towards the industry frontier. The results of biased technical change analysis suggested that the technical change associated with the sawmill industry in North America over the 38-year period was not Hicks neutral. My findings also indicate that there was a trend of gap-widening between the two countries' productivity growth during the late part of the study period.

In the second essay, an empirical analysis of the relationship between timberland ownership and the financial performance of forest products companies in the U.S. was conducted. The results showed that timberland holding is positively related to a forestry products company’s profitability in terms of ROA and ROE. And timberland holding can improve a firm’s ability of relative response of security returns to uncertainty. However, higher capital expense and debt/asset ratio were shown associated with timberland holding. Forest product companies may divest some of their timberland to ease the financial burden.

The results also showed that product diversification into unrelated and related product lines may deteriorate a firm’s profitability. Unrelated diversification may increase fluctuations in rates of return and increase the firm’s systematic risk. Large firms were shown to be more likely have higher ROE and ROA at the expense of higher systematic risk than that of small firms. The companies with higher growth rate had higher systematic risk.

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Appendix A: Value of distance function by year

Province/State	1963	1964	1965	1966	1967	1968	1969
Canada:							
British Columbia	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ontario	0.983	0.973	1.000	0.939	0.920	0.944	0.881
Quebec	1.000	1.000	1.000	0.935	1.000	1.000	0.938
Others							
Alberta	1.000	1.000	0.897	0.932	0.872	0.888	0.894
Manitoba	1.000	1.000	1.000	1.000	1.000	1.000	1.000
New Brunswick	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Nova Scotia	1.000	0.928	0.912	0.931	0.972	0.791	0.864
Saskatchewan	1.000	0.781	1.000	1.000	1.000	1.000	1.000
United States:							
the North							
Inidiana	0.870	0.967	0.840	1.000	0.774	0.791	0.833
Maine	0.805	1.000	0.949	1.000	0.649	0.658	0.679
Michigan	0.896	1.000	1.000	1.000	1.000	1.000	1.000
Missouri	1.000	1.000	1.000	0.949	0.975	1.000	1.000
New York	0.779	1.000	0.746	1.000	1.000	0.864	0.914
Ohio	1.000	1.000	0.876	0.954	0.751	0.843	0.902
Pennsylvania	1.000	1.000	0.920	0.846	0.988	1.000	1.000
Wisconsin	0.916	1.000	1.000	0.698	0.669	1.000	1.000
West Virginia	0.901	1.000	1.000	1.000	0.817	0.993	1.000
the South							
Alabama	0.828	0.882	0.953	0.964	0.848	0.823	0.806
Arkansas	0.873	0.923	1.000	0.908	0.801	0.807	0.824
Florida	0.935	0.980	0.987	1.000	0.951	0.992	0.976
Georgia	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Kentucky	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Louisiana	1.000	1.000	0.973	0.983	0.835	0.844	0.865
Mississippi	0.979	0.959	0.928	0.904	0.923	0.945	1.000
North Carolina	0.979	0.956	0.802	0.779	0.802	0.833	0.862
South Carolina	0.918	0.889	0.887	0.850	0.999	1.000	1.000
Tennessee	0.873	0.992	1.000	1.000	0.897	0.929	0.833
Texas	0.993	0.994	0.884	0.843	0.931	0.965	0.996
Virginia	1.000	1.000	1.000	0.999	0.901	0.939	1.000
the West							
California	0.993	1.000	0.919	0.923	0.926	0.982	1.000
Idaho	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Montana	1.000	0.965	0.879	1.000	1.000	1.000	1.000
Oregon	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Washington	1.000	1.000	0.985	0.909	0.886	0.929	0.928

Appendix A: Value of distance function by year (continued)

Province/State	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Canada:										
British Columbia	1.000	1.000	0.937	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ontario	0.878	0.843	0.929	1.000	0.922	0.799	1.000	1.000	1.000	0.981
Quebec	0.903	0.905	0.883	0.978	0.829	0.761	0.824	0.974	0.902	0.901
Others										
Alberta	1.000	1.000	1.000	1.000	1.000	0.934	0.815	0.891	0.911	0.871
Manitoba	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
New Brunswick	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Nova Scotia	0.922	0.853	1.000	0.329	0.817	0.751	1.000	0.983	0.822	0.805
Saskatchewan	1.000	1.000	1.000	1.000	1.000	0.890	1.000	1.000	1.000	0.982
United States:										
the North										
Inidiana	0.972	1.000	0.970	0.905	1.000	1.000	1.000	1.000	1.000	1.000
Maine	0.741	0.744	0.740	0.744	0.780	0.909	0.844	0.802	0.798	0.756
Michigan	1.000	1.000	1.000	1.000	1.000	0.987	0.899	0.916	1.000	0.833
Missouri	1.000	0.990	0.889	0.923	0.906	0.873	0.903	0.970	0.787	0.817
New York	0.787	0.890	0.846	1.000	1.000	1.000	1.000	0.919	0.801	0.708
Ohio	1.000	1.000	1.000	1.000	1.000	1.000	0.903	0.882	0.699	0.659
Pennsylvania	1.000	1.000	0.932	1.000	0.951	1.000	1.000	0.906	0.873	0.744
Wisconsin	1.000	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.878	0.775
West Virginia	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
the South										
Alabama	0.786	0.740	0.766	0.803	0.770	0.812	0.835	0.817	0.801	0.758
Arkansas	0.911	0.943	0.896	0.901	0.769	0.840	0.875	0.885	0.944	0.866
Florida	1.000	1.000	1.000	0.887	1.000	1.000	0.968	0.940	0.932	0.847
Georgia	0.998	0.986	1.000	0.885	0.818	0.871	0.843	0.877	0.868	0.822
Kentucky	1.000	1.000	1.000	1.000	1.000	1.000	0.972	0.959	1.000	1.000
Louisiana	0.874	1.000	0.890	0.812	0.836	0.931	0.878	1.000	0.868	0.839
Mississippi	0.977	0.875	0.975	0.979	0.832	0.847	0.879	0.980	1.000	1.000
North Carolina	0.860	0.851	0.980	0.898	0.965	0.888	0.858	0.823	0.702	0.701
South Carolina	1.000	1.000	1.000	1.000	0.957	1.000	0.897	0.844	0.895	0.798
Tennessee	0.831	0.834	1.000	0.946	1.000	1.000	0.845	0.933	0.931	0.907
Texas	0.897	0.874	0.897	0.814	0.632	0.761	0.880	0.816	0.926	0.858
Virginia	0.963	0.870	0.915	0.880	0.899	0.887	0.863	0.898	0.882	0.833
the West										
California	0.973	1.000	0.997	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Idaho	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.986	1.000	1.000
Montana	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Oregon	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Washington	0.898	0.969	0.915	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Appendix A: Value of distance function by year (continued)

Province/State	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Canada:										
British Columbia	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ontario	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Quebec	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Others										
Alberta	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Manitoba	1.000	0.993	1.000	1.000	0.983	1.000	0.990	1.000	0.932	1.000
New Brunswick	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.713	1.000
Nova Scotia	0.932	1.000	0.894	1.000	1.000	0.901	0.894	0.834	0.746	0.975
Saskatchewan	1.000	1.000	1.000	0.995	1.000	1.000	1.000	1.000	1.000	1.000
United States:										
the North										
Inidiana	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Maine	0.784	1.000	0.990	1.000	1.000	0.971	0.994	0.907	0.796	0.847
Michigan	0.825	0.838	0.955	1.000	0.920	0.945	0.950	0.941	0.815	1.000
Missouri	0.795	0.833	0.973	0.941	1.000	1.000	1.000	1.000	1.000	0.950
New York	0.634	0.747	0.972	1.000	0.963	0.965	0.989	0.882	0.807	0.976
Ohio	0.682	0.702	1.000	0.984	0.838	0.806	0.776	0.944	0.798	0.965
Pennsylvania	0.700	0.778	0.908	1.000	0.874	0.961	0.948	0.863	0.717	0.996
Wisconsin	0.706	0.736	0.966	1.000	1.000	0.974	0.983	0.837	0.848	0.936
West Virginia	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
the South										
Alabama	0.708	0.739	0.929	0.982	0.975	1.000	1.000	1.000	1.000	1.000
Arkansas	0.801	0.736	0.903	0.956	0.997	1.000	0.955	0.940	0.791	0.832
Florida	0.803	0.981	1.000	1.000	1.000	1.000	1.000	1.000	0.956	0.922
Georgia	0.770	0.927	0.974	1.000	0.920	0.914	0.932	0.955	0.900	1.000
Kentucky	1.000	0.771	0.996	1.000	1.000	1.000	1.000	0.936	0.898	1.000
Louisiana	0.693	0.723	0.947	1.000	0.877	0.897	0.947	0.857	0.855	1.000
Mississippi	0.913	1.000	1.000	1.000	0.964	0.966	0.969	0.978	0.907	0.902
North Carolina	0.582	0.593	0.888	0.834	0.881	0.902	0.906	0.900	0.763	0.853
South Carolina	0.847	0.806	0.905	0.907	0.927	0.952	0.941	0.955	1.000	1.000
Tennessee	0.860	0.795	0.983	1.000	1.000	0.998	1.000	0.952	0.868	0.794
Texas	0.952	0.918	1.000	0.957	0.869	0.923	0.831	0.959	0.895	1.000
Virginia	0.737	0.815	0.929	0.941	1.000	1.000	1.000	0.912	0.952	1.000
the West										
California	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.991
Idaho	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Montana	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Oregon	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Washington	1.000	0.956	1.000	1.000	1.000	0.999	0.971	0.996	0.960	1.000

Appendix A: Value of distance function by year (continued)

Province/State	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Canada:												
British Columbia	1.000	1.000	1.000	1.000	0.989	0.856	1.000	0.873	1.000	0.838	1.000	0.963
Ontario	0.992	0.968	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Quebec	1.000	1.000	1.000	1.000	1.000	0.763	1.000	0.694	0.858	0.669	0.820	0.804
Others												
Alberta	1.000	1.000	1.000	1.000	0.957	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Manitoba	1.000	1.000	1.000	1.000	1.000	1.000	0.887	0.873	0.870	1.000	0.684	0.636
New Brunswick	0.920	0.736	0.828	0.966	0.912	1.000	1.000	1.000	1.000	0.796	0.785	0.797
Nova Scotia	0.842	0.879	0.943	0.827	0.813	0.868	0.857	0.740	0.780	0.642	0.596	0.643
Saskatchewan	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.969	1.000	0.890	1.000
United States:												
the North												
Inidiana	1.000	1.000	1.000	1.000	1.000	1.000	0.982	0.601	0.555	0.590	0.572	0.444
Maine	0.965	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Michigan	1.000	1.000	1.000	0.876	1.000	1.000	1.000	1.000	0.900	0.692	0.822	0.775
Missouri	1.000	0.900	0.969	0.923	1.000	0.992	0.829	1.000	1.000	0.872	1.000	0.975
New York	0.845	1.000	1.000	1.000	0.958	1.000	0.944	0.925	0.850	0.752	0.755	0.741
Ohio	0.985	1.000	0.991	1.000	1.000	1.000	0.972	0.641	0.616	0.643	0.627	0.568
Pennsylvania	0.904	0.932	0.894	0.884	0.905	0.949	0.925	0.854	0.874	0.768	0.825	0.747
Wisconsin	1.000	1.000	1.000	1.000	0.988	0.910	0.853	0.536	0.542	0.537	0.520	0.526
West Virginia	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
the South												
Alabama	1.000	0.997	1.000	0.908	1.000	1.000	1.000	0.984	0.983	1.000	0.974	0.912
Arkansas	0.885	0.935	0.991	0.933	1.000	0.953	0.933	1.000	1.000	1.000	0.995	0.912
Florida	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Georgia	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.878	0.882	0.903	0.879	0.923
Kentucky	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.912	1.000	0.976
Louisiana	1.000	1.000	0.969	1.000	0.993	1.000	1.000	1.000	1.000	1.000	1.000	0.984
Mississippi	0.958	0.989	1.000	0.921	1.000	1.000	0.941	1.000	1.000	1.000	1.000	1.000
North Carolina	0.821	1.000	0.890	0.737	0.914	0.814	0.803	0.845	0.808	0.752	0.760	0.832
South Carolina	0.921	0.886	1.000	1.000	1.000	0.963	1.000	1.000	1.000	0.950	0.974	0.952
Tennessee	0.760	0.880	0.818	1.000	0.907	0.926	0.841	0.777	0.717	0.683	0.796	0.840
Texas	1.000	1.000	0.947	0.946	1.000	0.962	1.000	0.871	0.727	0.775	0.764	0.815
Virginia	1.000	1.000	1.000	1.000	1.000	0.933	0.845	0.925	0.883	0.864	1.000	1.000
the West												
California	0.867	1.000	1.000	0.986	1.000	0.939	0.969	0.845	0.839	0.756	0.775	0.777
Idaho	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Montana	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Oregon	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Washington	0.955	1.000	1.000	0.944	0.989	1.000	1.000	0.995	1.000	1.000	1.000	1.000

Appendix B: Bootstrap Results of Technical Change by Year

State/Province	1963/1964	1964/1965	1965/1966	1966/1967	1967/1968	1968/1969	1969/1970	1970/1971	1971/1972	1972/1973
Alberta	2.67**	0.43	0.88**	0.97	1.05	1.05	0.97	1.38**	0.77**	1.16
British Columbia	1.06**	1.12*	1.07	1.10	1.02	0.95	0.95	1.05	1.05	0.91
Manitoba	0.73**	0.85**	1.18**	1.04	1.08	1.04	1.36**	0.80*	1.00	0.67**
New Brunswick	0.92	1.25**	1.08**	1.01	1.05*	1.12**	1.22**	1.14**	0.82**	0.94
Nova Scotia	0.89	0.98	0.92*	0.99	1.05	1.04	1.04	1.00	0.96	1.07
Ontario	1.08	1.01	1.11*	1.04	0.93	1.06	1.27**	1.03	0.95	0.86
Quebec	1.01	0.88	0.99	0.98	1.06	1.05	1.01	1.06	0.95	0.89
Saskatchewan	1.17	1.07	0.81*	1.06	1.05**	1.01	1.18	1.04	0.97	0.80**
Alabama	1.02	0.93**	1.05*	0.98	1.04**	1.09**	1.16**	1.34**	0.79**	0.90**
Arkansas	1.00	0.93	1.10**	1.02	1.04*	1.07**	1.13**	1.30**	0.79**	0.90**
California	0.99	0.94	1.06*	0.96	1.05	1.02	1.21**	1.26**	0.93**	1.03
Florida	1.00	0.96	1.20**	0.96	1.02	1.06	1.20**	1.21**	0.83**	1.02
Georgia	0.95**	0.93**	1.00	1.03	0.99	0.97	1.03	1.29**	0.84**	0.98
Idaho	1.04	0.94	1.02	0.96	1.04	1.01	1.21**	1.23**	0.88*	0.99
Indiana	0.99	1.02	1.47**	0.93	1.04	1.02	1.24**	1.18**	0.90**	1.00
Kentucky	0.92	0.86**	1.01	0.97	1.02	1.08	1.11	1.23**	0.79**	0.94
Louisiana	1.01	0.94**	1.04	0.98	1.02	1.06	1.11**	1.27**	0.83**	0.96*
Maine	0.98	0.87	1.14**	0.99	1.05	1.03	1.17**	1.23**	0.81**	0.89**
Michigan	0.94	1.00	1.04	1.05	1.02	0.85*	1.19**	1.25**	0.77**	0.97
Missouri	1.03	0.72**	0.96	0.94*	1.04**	1.18**	1.41**	1.16	0.85**	0.99
Mississippi	1.01	0.96	1.07**	0.93**	1.03*	1.09*	1.13**	1.33**	0.79**	0.99
Montana	1.04	0.99	1.03	0.99	1.13**	0.98	1.12**	1.34**	0.77**	1.09
North Carolina	1.03**	1.00	1.14**	0.97	1.03*	1.07**	1.20**	1.31**	0.82**	1.05
New York	0.82*	1.05	1.66*	1.04	0.67	1.01	1.23**	1.25**	0.76**	1.48*
Ohio	0.90	1.02	1.10	1.05	0.92	1.05	1.30**	1.21**	0.78**	0.90**
Oregon	1.03	0.93	1.05	1.01	0.99	0.97	1.11**	1.24**	0.91**	1.01
Pennsylvania	0.43*	1.09	1.13	1.00	1.03	0.86	1.59**	1.45**	0.55**	0.98
South Carolina	1.02	1.00	1.15**	0.95	1.03	0.94*	1.16**	1.48**	0.74**	1.09
Tennessee	0.98	0.81**	1.00	1.02	1.03	1.19**	1.15*	1.26**	0.84**	0.97
Texas	1.04**	0.99	1.07**	0.90**	1.05**	1.07**	1.22**	1.44**	0.75**	0.92**
Virginia	0.99	1.02	1.03	1.03	1.01	0.99	1.11**	1.34**	0.76**	0.94
Washington	0.80**	0.87**	1.10	0.96*	1.04	1.05*	1.26**	1.26**	0.84**	1.04
Wisconsin	1.11	1.04	1.53*	1.05	0.68*	1.00	1.16**	1.14**	0.87**	0.99
West Virginia	1.00	1.47**	1.07	1.00	0.79*	1.01	1.17**	1.18**	0.80**	1.05

Note: * denotes significant difference from unity at the 10% level; ** denotes significant difference from unity at the 5% level.

Appendix B: Bootstrap Results of Technical Change by Year (Continued)

State/Province	1973/1974	1974/1975	1975/1976	1976/1977	1977/1978	1978/1979	1979/1980	1980/1981	1981/1982	1982/1983
Alberta	0.81**	0.96	1.04	0.93**	1.02	0.98	0.96	1.12	1.05	1.25**
British Columbia	0.95	0.99	1.09**	0.96	1.00	0.98	0.98	1.07**	0.99	1.10**
Manitoba	1.10	0.84**	1.03	0.91**	0.97	1.07**	0.93**	0.92**	1.14**	0.96
New Brunswick	0.95	0.75	0.86**	0.95**	1.35**	1.13	0.87	0.83**	0.98	0.99
Nova Scotia	0.77**	0.99	0.88*	0.94**	1.23**	1.04	0.83**	0.90**	1.23**	1.02
Ontario	1.02	1.11	0.91	0.98	1.12**	1.03	0.98	1.00	1.02	1.03
Quebec	0.93	1.06	0.88**	0.92	1.16**	1.05	0.90*	0.97	1.03	0.92
Saskatchewan	0.93	1.02	1.15	1.03	0.97	0.88*	1.03	1.23*	0.87	1.08**
Alabama	1.14*	1.04	1.03	0.80**	1.13**	1.08*	0.71**	0.92**	1.34**	1.08**
Arkansas	1.13**	1.01	1.01	0.82**	1.14**	1.12**	0.71**	0.90*	1.28**	1.11**
California	1.08	1.14**	1.07**	0.73**	1.12**	1.04**	0.62**	0.89**	1.43**	1.16**
Florida	1.03	1.14**	0.97	0.83**	1.12**	1.06**	0.68**	0.91	1.43**	1.27**
Georgia	1.11**	1.09**	1.01	0.81**	1.14**	1.06*	0.62**	0.93**	1.33**	1.13**
Idaho	1.04	1.12	1.13**	0.69**	1.20**	0.94**	0.68**	0.93*	1.38**	1.26**
Indiana	1.11	1.20**	1.09	0.62**	1.08	0.97	0.56**	0.98	1.50**	1.01
Kentucky	0.97	1.02	1.01	0.97	0.91*	1.17**	1.02	0.88	1.45**	1.09*
Louisiana	1.07	1.11**	0.99	0.80**	1.13**	1.13**	0.73**	0.89**	1.14**	1.06
Maine	1.11**	1.01	1.01	0.84**	1.14**	1.12**	0.73**	0.93	1.27**	1.12**
Michigan	0.98	1.11**	0.98	0.95	0.94	1.06	0.72**	0.99	1.02	1.00
Missouri	1.04	1.19**	0.96	0.71**	1.26**	1.01	0.53**	0.95	1.57**	1.05
Mississippi	1.12**	1.10**	1.02	0.81**	1.15**	1.07**	0.57**	0.94	1.26**	1.11**
Montana	0.90*	1.03	1.17*	0.93	1.00	0.97	0.72**	0.88	1.34**	1.23**
North Carolina	1.08	1.13**	1.00	0.81**	1.17**	1.11**	0.65**	0.93**	1.32**	1.09**
New York	0.87	1.41	1.02	0.63	0.98	1.11	0.76**	0.97	1.02	0.98
Ohio	1.09	1.10	0.98	0.83**	1.01	1.14**	0.77**	1.03	0.98	1.12**
Oregon	1.17*	0.99	1.06**	0.73**	1.22**	1.02	0.67**	0.92**	1.41**	1.23**
Pennsylvania	1.01	1.09*	0.97	0.91	0.97	1.16*	0.73**	0.94	1.07	1.00
South Carolina	0.94	1.24**	0.88	0.89**	1.07	1.04	0.75**	0.92*	1.36**	1.09**
Tennessee	1.07	1.08	0.99	0.82*	0.97	1.12**	0.61**	0.97	1.53**	1.09**
Texas	1.13**	0.94	1.03	0.92**	1.05	0.99	0.79**	0.91	1.32**	1.07
Virginia	1.03	1.05	1.01	0.83**	1.10*	1.15**	0.68**	0.90*	1.24**	1.11**
Washington	0.91	1.08	0.85	0.90*	1.29**	1.00	0.58**	0.84**	1.43**	1.19**
Wisconsin	1.00	0.91	1.14**	1.01	0.87	1.19**	0.80**	0.94	0.89	1.02
West Virginia	1.08	1.25**	0.97	0.83	0.81**	1.32**	0.77**	0.98	1.06	1.14**

Note: * denotes significant difference from unity at the 10% level; ** denotes significant difference from unity at the 5% level.

Appendix B: Bootstrap Results of Technical Change by Year (continued)

State/Province	1983/1984	1984/1985	1985/1986	1986/1987	1987/1988	1988/1989	1989/1990	1990/1991	1991/1992	1992/1993
Alberta	1.05	1.00	1.20**	1.14	1.23	0.88	0.90	1.01	0.94	0.98
British Columbia	0.97	0.92	1.13**	0.99	1.13	1.03	0.93*	0.98	0.92**	1.08
Manitoba	1.13*	0.77**	0.98	1.07	1.01	1.21	0.85**	0.89**	1.08*	1.49**
New Brunswick	1.33**	0.63**	1.06	0.96	1.14	1.11	0.84**	1.00	0.89	1.10
Nova Scotia	1.27**	0.58**	1.02	0.98	1.12*	1.14	0.95	0.98	0.97	1.22**
Ontario	1.09**	0.71**	1.12**	0.99	1.17**	1.02	0.88	0.93	1.04	1.16**
Quebec	1.17**	0.70**	1.08**	0.97*	1.35**	1.08	0.83**	0.97	0.97	1.26**
Saskatchewan	1.06	0.91	1.09**	0.97	1.00	1.10	0.88*	1.01	1.00	1.10
Alabama	1.00	0.92**	0.88**	1.01	1.02	1.08*	1.01	0.94*	1.22*	0.96
Arkansas	0.97	0.98	0.89**	1.06**	1.08	1.10**	0.92*	0.97	1.02	1.20**
California	0.94**	0.98	0.91**	1.03	1.01	1.12**	1.09	0.92	1.01	1.07*
Florida	0.97	0.93*	0.89**	1.02	0.98	1.14**	0.99	1.01	1.04	1.19**
Georgia	0.95**	0.92**	0.88**	0.98	1.02	0.93	1.10**	1.00	1.01	1.09
Idaho	0.92**	0.99	1.01	1.10	0.96	0.96	0.98	1.04	1.01	0.96
Indiana	1.35**	1.06	0.88	0.76**	0.94	0.92	0.91*	1.14	0.95	1.08
Kentucky	1.01	0.94**	0.93	1.04	1.01	1.58	1.04	N.A	N.A	1.27
Louisiana	1.06	0.86**	0.94**	1.04*	1.04	0.94	1.48	0.67**	0.88	1.11**
Maine	0.95	0.95**	0.87**	1.05**	1.00	1.12**	0.92	0.98	1.06**	1.09**
Michigan	1.01	0.97**	0.92	1.05*	1.02	1.05	1.01	0.82	0.93*	1.07
Missouri	1.05	1.05	1.04	0.98	0.95	0.94	1.00	0.87**	1.04	1.09*
Mississippi	0.97	0.95**	0.91**	1.11**	0.98	1.10**	1.00	1.00	1.01	1.20**
Montana	1.18*	1.07*	0.96	0.90**	0.94**	1.01	0.95*	0.97	0.96	1.00
North Carolina	0.99	0.93**	0.88**	1.02	1.06	1.05	1.00	0.89**	1.02	1.14**
New York	1.01	0.97**	0.93**	1.15**	1.05	1.06	1.09	1.07	0.86**	1.15**
Ohio	1.19**	0.98	0.97	0.86*	1.10	0.95	0.98	1.04	0.96	3.37**
Oregon	0.93**	0.97*	0.95	1.04	1.00	1.07**	0.94	1.00	1.02	0.95
Pennsylvania	0.99	0.96**	0.93**	1.12**	1.06	0.90	1.06	0.95	0.97	1.06*
South Carolina	1.00	0.90**	0.92**	0.99	1.00	1.01	1.06	0.96	1.04	1.01
Tennessee	1.02	0.98**	0.91**	1.16**	1.02	1.15**	0.97	0.88**	1.06	1.51**
Texas	1.12*	0.87**	0.92	0.95	0.92**	0.91	1.00	0.90**	1.07**	1.09**
Virginia	1.04	0.96**	0.95*	1.13**	1.00	1.18	1.16	1.31**	0.41**	1.02
Washington	0.91**	0.96*	0.92*	1.02	1.00	1.13**	1.02	0.99	0.98	1.07
Wisconsin	1.08**	0.87**	0.93	1.08**	1.07	1.03	1.06	1.06	0.91**	1.11
West Virginia	1.47**	0.88**	0.95	0.88*	1.25**	0.97	0.92	1.02	0.97	1.08

Note: * denotes significant difference from unity at the 10% level; ** denotes significant difference from unity at the 5% level.

Appendix B: Bootstrap Results of Technical Change by Year (continued)

State/Province	1993/1994	1994/1995	1995/1996	1996/1997	1997/1998	1998/1999	1999/2000	2000/2001
Alberta	0.90**	1.20	0.83**	0.94	0.96	1.15**	0.96	1.09
British Columbia	0.87**	1.16**	0.94	0.92	1.19	0.93	1.11	0.89
Manitoba	0.83**	1.35	0.86	0.96	1.01	1.49*	0.72**	1.00
New Brunswick	0.87**	1.37**	0.85**	1.07	0.90*	1.12	0.94	0.97
Nova Scotia	0.93**	1.18**	0.90**	1.26**	1.02	1.05	0.91**	0.93
Ontario	0.86**	1.47**	0.72**	0.91**	0.89	1.12**	1.09	0.90
Quebec	0.76**	1.17*	0.90	1.05	1.06	1.00	0.96	0.95
Saskatchewan	0.95*	1.15*	0.89*	1.05	0.99	1.17	0.88	1.19**
Alabama	1.02	0.96*	0.98	1.19**	1.05**	1.13**	0.91**	0.91**
Arkansas	1.02	1.00	1.12**	1.17**	1.06**	1.17**	0.90**	0.93**
California	1.05	1.00	0.95**	1.25**	1.06*	1.14**	0.91**	0.91**
Florida	0.91**	1.07	0.98	1.10**	1.00	1.09**	0.96	0.94**
Georgia	0.97	1.02	1.03	1.24**	1.07**	1.13**	0.91**	0.90**
Idaho	1.20**	1.01	1.05	1.00	1.03	1.22**	0.91**	0.81**
Indiana	0.89	0.93**	0.95**	1.13	1.06**	0.99	0.90**	0.94**
Kentucky	0.91	1.03	1.28**	1.00	1.03	1.17**	0.90**	0.97
Louisiana	0.99	1.16*	0.98	1.19**	1.07**	1.06	1.01	1.02
Maine	0.92**	1.06	1.16**	1.15*	1.07**	1.15*	0.98	1.07
Michigan	1.06	1.10**	1.19**	1.00	0.94*	1.14**	0.90	0.89**
Missouri	1.02	0.99	1.09*	1.18**	0.92**	1.17**	0.94	0.92
Mississippi	0.98	0.97	1.00	1.16**	1.04	1.11**	0.92**	0.93**
Montana	1.02	1.01	0.94	1.45**	0.98	1.08**	0.95	0.91*
North Carolina	0.92*	1.06	1.03	1.11	1.05**	1.19**	0.93	0.88**
New York	0.97	1.04*	1.06*	1.23**	1.08**	1.22**	0.90	0.95
Ohio	0.33*	1.02	1.12**	1.12*	1.11**	1.15**	0.86**	0.91**
Oregon	1.33**	1.56*	1.06	0.51	1.06**	1.15**	0.96	1.00
Pennsylvania	1.01	1.05*	1.11**	1.19**	0.95**	1.32**	0.86*	1.06
South Carolina	1.11**	0.99	0.99	1.24**	1.02	1.16**	0.91**	0.91**
Tennessee	0.70**	1.06	1.15*	1.17	0.94*	1.27**	0.90**	0.97
Texas	1.00	0.96	1.01	1.01	1.00	1.07**	0.93**	0.90**
Virginia	1.02	1.03	1.09**	1.02	1.10**	1.16**	0.95	0.92**
Washington	1.06	0.94	1.03	1.18**	1.08**	1.20**	0.92**	0.96
Wisconsin	1.02	1.02	1.07**	1.17*	1.02	1.14**	0.88**	0.96
West Virginia	0.94	1.05	1.07	1.17	1.02	1.33**	0.72**	1.08

Note: * denotes significant difference from unity at the 10% level; ** denotes significant difference from unity at the 5% level.

Appendix C: Bootstrap Results of Efficiency Change by Year

State/Province	1963/1964	1964/1965	1965/1966	1966/1967	1967/1968	1968/1969	1969/1970	1970/1971	1971/1972	1972/1973
Alberta	1.00	0.90	1.04	0.94*	1.02	1.01	1.12*	1.00	1.00	1.00
British Columbia	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.94	1.07
Manitoba	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
New Brunswick	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Nova Scotia	0.93	0.98	1.02	1.04	0.81**	1.09**	1.07	0.93**	1.17**	0.33**
Ontario	0.99	1.03	0.94	0.98	1.03	0.93*	1.00	0.96	1.10*	1.08
Quebec	1.00	1.00	0.93	1.07	1.00	0.94	0.96	1.00	0.98	1.11
Saskatchewan	0.78*	1.28	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Alabama	1.07**	1.08**	1.01	0.88**	0.97	0.98	0.98	0.94	1.04	1.05
Arkansas	1.06**	1.08*	0.91**	0.88**	1.01	1.02	1.11**	1.04	0.95	1.01
California	1.01	0.92*	1.00	1.00	1.06*	1.02	0.97	1.03	1.00	1.00
Florida	1.05	1.01	1.01	0.95	1.04**	0.98	1.02	1.00	1.00	0.89**
Georgia	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.01	0.89*
Idaho	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Indiana	1.11	0.87	1.19	0.77	1.02	1.05*	1.17**	1.03	0.97	0.93
Kentucky	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Louisiana	1.00	0.97	1.01	0.85**	1.01	1.02	1.01	1.14	0.89	0.91**
Maine	1.24	0.95	1.05	0.65**	1.01	1.03	1.09	1.00	0.99	1.01
Michigan	1.12	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Missouri	1.00	1.00	0.95	1.03	1.03	1.00	1.00	0.99	0.90**	1.04
Mississippi	0.98	0.97	0.97	1.02	1.02*	1.06	0.98	0.90**	1.11**	1.00
Montana	0.96	0.91*	1.14*	1.00	1.00	1.00	1.00	1.00	1.00	1.00
North Carolina	0.98*	0.84**	0.97	1.03	1.04**	1.04	1.00	0.99	1.15**	0.92**
New York	1.28**	0.75**	1.34	1.00	0.86	1.06	0.86*	1.13**	0.95	1.18
Ohio	1.00	0.88	1.09	0.79**	1.12	1.07	1.11	1.00	1.00	1.00
Oregon	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Pennsylvania	1.00	0.92*	0.92	1.17**	1.01	1.00	1.00	1.00	0.93	1.07
South Carolina	0.97**	1.00	0.96	1.18**	1.00	1.00	1.00	1.00	1.00	1.00
Tennessee	1.14*	1.01	1.00	0.90*	1.03	0.90*	1.00	1.00	1.20	0.95
Texas	1.00	0.89**	0.95**	1.11**	1.04	1.03	0.90**	0.97	1.03	0.91**
Virginia	1.00	1.00	1.00	0.90**	1.04	1.06	0.96	0.90**	1.05	0.96
Washington	1.00	0.99	0.92	0.97	1.05*	1.00	0.97	1.08**	0.94	1.09
Wisconsin	1.09	1.00	0.70*	0.96	1.50*	1.00	1.00	1.00	1.00	1.00
West Virginia	1.11	1.00	1.00	0.82	1.22	1.01	1.00	1.00	1.00	1.00

Note: * denotes significant difference from unity at the 10% level; ** denotes significant difference from unity at the 5% level.

Appendix C: Bootstrap Results of Technical Change by Year (Continued)

State/Province	1973/1974	1974/1975	1975/1976	1976/1977	1977/1978	1978/1979	1979/1980	1980/1981	1981/1982	1982/1983
Alberta	1.00	0.93	0.87**	1.09**	1.02	0.96	1.15**	1.00	1.00	1.00
British Columbia	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Manitoba	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.01	1.00
New Brunswick	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Nova Scotia	2.48**	0.92	1.33**	0.98	0.84**	0.98	1.16**	1.07	0.89**	1.12
Ontario	0.92	0.87*	1.25**	1.00	1.00	0.98	1.02	1.00	1.00	1.00
Quebec	0.85*	0.92	1.08**	1.18**	0.93	1.00	1.11*	1.00	1.00	1.00
Saskatchewan	1.00	0.89**	1.12	1.00	1.00	0.98	1.02	1.00	1.00	0.99
Alabama	0.96	1.05	1.03	0.98	0.98	0.95*	0.93**	1.04	1.26**	1.06**
Arkansas	0.85**	1.09	1.04	1.01	1.07	0.92**	0.93	0.92	1.23**	1.06**
California	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Florida	1.13**	1.00	0.97	0.97	0.99	0.91**	0.95	1.22**	1.02	1.00
Georgia	0.92	1.06	0.97	1.04	0.99	0.95	0.94**	1.20**	1.05	1.03
Idaho	1.00	1.00	1.00	0.99	1.01	1.00	1.00	1.00	1.00	1.00
Indiana	1.10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Kentucky	1.00	1.00	0.97	0.99	1.04	1.00	1.00	0.77	1.29**	1.00
Louisiana	1.03	1.11**	0.94**	1.14**	0.87**	0.97	0.83**	1.04	1.31**	1.06
Maine	1.05	1.17**	0.93**	0.95**	0.99	0.95**	1.04	1.28**	0.99	1.01
Michigan	1.00	0.99	0.91**	1.02	1.09	0.83	0.99	1.02	1.14	1.05
Missouri	0.98	0.96	1.03	1.07	0.81**	1.04	0.97	1.05	1.17**	0.97
Mississippi	0.85**	1.02	1.04	1.11**	1.02	1.00	0.91**	1.10	1.00	1.00
Montana	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
North Carolina	1.08**	0.92**	0.97	0.96	0.85**	1.00	0.83**	1.02	1.50**	0.94**
New York	1.00	1.00	1.00	0.92	0.87**	0.88	0.90*	1.18**	1.30**	1.03
Ohio	1.00	1.00	0.90	0.98	0.79**	0.94	1.04	1.03	1.43**	0.98
Oregon	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Pennsylvania	0.95	1.05	1.00	0.91*	0.96	0.85*	0.94*	1.11**	1.17*	1.10
South Carolina	0.96	1.05	0.90	0.94	1.06	0.89	1.06	0.95	1.12**	1.00
Tennessee	1.06	1.00	0.85*	1.10**	1.00	0.97	0.95	0.92	1.24**	1.02
Texas	0.78**	1.20	1.16*	0.93	1.14*	0.93	1.11*	0.96	1.09	0.96
Virginia	1.02	0.99	0.97	1.04	0.98	0.94	0.89**	1.10	1.14**	1.01
Washington	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.96	1.05	1.00
Wisconsin	1.00	1.00	1.00	1.00	0.88	0.88*	0.91*	1.04	1.31**	1.04
West Virginia	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Note: * denotes significant difference from unity at the 10% level; ** denotes significant difference from unity at the 5% level.

Appendix C: Bootstrap Results of Efficiency Change by Year (continued)

State/Province	1983/1984	1984/1985	1985/1986	1986/1987	1987/1988	1988/1989	1989/1990	1990/1991	1991/1992	1992/1993
Alberta	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
British Columbia	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Manitoba	0.98	1.02	0.99	1.01	0.93	1.07	1.00	1.00	1.00	1.00
New Brunswick	1.00	1.00	1.00	1.00	0.71**	1.40**	0.92	0.80**	1.12	1.17*
Nova Scotia	1.00	0.90	0.99	0.93**	0.89	1.31	0.86	1.04	1.07	0.88**
Ontario	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.98	1.03	1.00
Quebec	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Saskatchewan	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Alabama	0.99	1.03	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.91
Arkansas	1.04	1.00	0.96	0.98	0.84**	1.05	1.06*	1.06	1.06**	0.94
California	1.00	1.00	1.00	1.00	1.00	0.99	0.87*	1.15	1.00	0.99
Florida	1.00	1.00	1.00	1.00	0.96**	0.96	1.09	1.00	1.00	1.00
Georgia	0.92**	0.99	1.02**	1.03	0.94	1.11*	1.00	1.00	1.00	1.00
Idaho	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Indiana	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Kentucky	1.00	1.00	1.00	0.94	0.96	1.11	1.00	1.00	1.00	1.00
Louisiana	0.88**	1.02	1.06**	0.90**	1.00	1.17**	1.00	1.00	0.97	1.03
Maine	1.00	0.97**	1.02	0.91**	0.88**	1.06*	1.14**	1.04	1.00	1.00
Michigan	0.92**	1.03**	1.00	0.99	0.87*	1.23	1.00	1.00	1.00	0.88**
Missouri	1.06	1.00	1.00	1.00	1.00	0.95	1.05	0.90	1.08	0.95
Mississippi	0.96	1.00	1.00	1.01	0.93**	0.99	1.06	1.03	1.01	0.92*
Montana	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
North Carolina	1.06**	1.02**	1.01	0.99	0.85**	1.12*	0.96	1.22**	0.89**	0.83**
New York	0.96	1.00	1.02	0.89**	0.91**	1.21**	0.87**	1.18	1.00	1.00
Ohio	0.85*	0.96	0.96	1.22	0.85**	1.21	1.02	1.02	0.99	1.01
Oregon	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Pennsylvania	0.87*	1.10**	0.99	0.91**	0.83**	1.39**	0.91	1.03	0.96	0.99
South Carolina	1.02	1.03	0.99	1.02	1.05*	1.00	0.92*	0.96	1.13	1.00
Tennessee	1.00	1.00	1.00	0.95	0.91**	0.92**	0.96	1.16**	0.93	1.22
Texas	0.91	1.06	0.90**	1.15**	0.93	1.12*	1.00	1.00	0.95	1.00
Virginia	1.06	1.00	1.00	0.91	1.04	1.05	1.00	1.00	1.00	1.00
Washington	1.00	1.00	0.97	1.03	0.96	1.04*	0.96	1.05	1.00	0.94
Wisconsin	1.00	0.97	1.01	0.85**	1.01	1.10*	1.07	1.00	1.00	1.00
West Virginia	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Note: * denotes significant difference from unity at the 10% level; ** denotes significant difference from unity at the 5% level.

Appendix C: Bootstrap Results of Efficiency Change by Year (continued)

State/Province	1993/1994	1994/1995	1995/1996	1996/1997	1997/1998	1998/1999	1999/2000	2000/2001
Alberta	0.96	1.05	1.00	1.00	1.00	1.00	1.00	1.00
British Columbia	0.99	0.87**	1.17	0.87	1.15	0.84	1.19	0.96
Manitoba	1.00	1.00	0.89	0.98	1.00	1.15	0.68**	0.93
New Brunswick	0.94	1.10	1.00	1.00	1.00	0.80*	0.99	1.02
Nova Scotia	0.98	1.07	0.99	0.86	1.05	0.82**	0.93	1.08
Ontario	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Quebec	1.00	0.76**	1.31**	0.69**	1.24*	0.78**	1.23*	0.98
Saskatchewan	1.00	1.00	1.00	1.00	0.97	1.03	0.89	1.12
Alabama	1.10	1.00	1.00	0.98	1.00	1.02	0.97	0.94**
Arkansas	1.07	0.95	0.98	1.07	1.00	1.00	0.99	0.92**
California	1.01	0.94*	1.03	0.87**	0.99	0.90**	1.02	1.00
Florida	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Georgia	1.00	1.00	1.00	0.88**	1.00	1.02*	0.97	1.05**
Idaho	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Indiana	1.00	1.00	0.98	0.61**	0.92**	1.06	0.97	0.78**
Kentucky	1.00	1.00	1.00	1.00	1.00	0.91	1.10	0.98
Louisiana	0.99	1.01	1.00	1.00	1.00	1.00	1.00	0.98
Maine	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Michigan	1.14	1.00	1.00	1.00	0.90**	0.77**	1.19**	0.94
Missouri	1.08	0.99	0.84**	1.21**	1.00	0.87*	1.15	0.97
Mississippi	1.09	1.00	0.94	1.06	1.00	1.00	1.00	1.00
Montana	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
North Carolina	1.24**	0.89*	0.99	1.05	0.96**	0.93*	1.01	1.10**
New York	0.96	1.04	0.94*	0.98	0.92**	0.88**	1.00	0.98
Ohio	1.00	1.00	0.97	0.66**	0.96*	1.04	0.98	0.91**
Oregon	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Pennsylvania	1.02	1.05*	0.97	0.92	1.02	0.88*	1.07	0.91
South Carolina	1.00	0.96	1.04	1.00	1.00	0.95**	1.03*	0.98
Tennessee	0.91	1.02	0.91	0.92	0.92	0.95	1.16*	1.06
Texas	1.06	0.96	1.04	0.87*	0.83**	1.07	0.99	1.07**
Virginia	1.00	0.93**	0.91**	1.09	0.95**	0.98	1.16	1.00
Washington	1.05	1.01	1.00	1.00	1.00	1.00	1.00	1.00
Wisconsin	0.99	0.92**	0.94**	0.63**	1.01	0.99	0.97	1.01
West Virginia	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Note: * denotes significant difference from unity at the 10% level; ** denotes significant difference from unity at the 5% level.

Appendix D. List of companies in the study

No.	Company Name	Symbol	SIC[1]	Year
1	BADGER PAPER MILLS INC	BPMI	2671	1988-2003
2	BEMIS CO INC	BMS	2671	1988-2003
3	BOISE CASCADE	BCC	2621	1989-2003
4	BONTEX INC[2]	BOTX	2621	1988-2002
5	BOWATER INC	BOW	2621	1988-2003
6	CHAMPION INTERNATIONAL	CHA	2631	1988-1999
7	CHESAPEAKE CORP /VA/	CSK	2650	1988-2003
8	CONSOLIDATED PAPER[3]	CDP	2621	1988-1999
9	DELTIC TIMBER CORP	DEL	2421	1992-2003
10	FEDERAL PAPER BOARD[4]	FPBO	2631	1989-1994
11	GEORGIA PACIFIC	GP	2611	1988-2003
12	GLATFELTER P H CO	GLT	2621	1988-2003
13	GREIF BROTHERS[5]	GEF	2650	1990-2003
14	INTERNATIONAL PAPER CO	IP	2621	1988-2003
15	JAMES RIVER	JR	2621	1988-1998
16	KIMBERLY CLARK CORP	KMB	2621	1988-2003
17	LONGVIEW FIBRE CO	LFB	2621	1988-2003
18	LOUISIANA PACIFIC CORP	LPX	2421	1988-2003
19	MEAD	MEA	2631	1988-2000
20	MEAD WESTVACO CORP	MWV	2621	2002-2003
21	MERCER INTERNATIONAL INC	MERCS	2621	1988-2003
22	MOSINEE PAPER CORP.	MOSI	2621	1988-1996
23	PACKAGING CORP. OF AMERICA	PKG	2653	1996-2003
24	POPE & TALBOT INC	POP	2621	1988-2003
25	POTLATCH CORP	PCH	2621	1988-2003
26	RAYONIER INC	RYN	2411	1988-2003
27	SMURFIT STONE CONTAINER CORP	SSCC	2631	1998-2003
28	SONOCO PRODUCTS CO	SON	2631	1988-2003
29	STONE CONTAINER[6]	STO	2631	1988-1997
30	TEMPLE INLAND INC	TIN	2653	1988-2003
31	UNION CAMP	UCC	2621	1988-1998
32	UNIVERSAL FOREST PRODUCTS INC	UFPI	2421	1991-2003
33	WAUSAU MOSINEE PAPER MILLS CORP	WPP	2621	1988-2003
34	WESTVACO	W	2621	1988-2000
35	WEYERHAEUSER CO	WY	2400	1988-2003
36	WILLAMETTE INDUSTRIES	WLL	2621	1988-2001

Notes:

1. Standard Industry Classification Code.
2. Financial information of Year 2003 is not available.
3. Consolidated Paper was acquired by Stora Enso Oyj (Finland) on August 31, 2000.
4. Financial information is not available for 1995.
5. Financial information is not available for 1988 and 1989.
6. Smurfit-Stone Container Corporation acquired Stone Container on Nov. 18, 1998.