Total Factor Productivity Growth in the Sawmill and Wood Preservation Industry in the United States and Canada: A Comparative Study

Daowei Zhang and Rao V. Nagubadi

Abstract: By using the Törnqvist-Theil index approach, we analyze trends in total factor productivity (TFP) growth in the United States and Canadian sawmill and wood preservation industries (NAICS 3211) between 1958 and 2003. The results indicate that the TFP grew at an average annual compound rate of 1.11% due to higher growth in aggregate outputs by 1.42% and a smaller growth in aggregate inputs by 0.31% in the United States. In Canada, TFP grew at a smaller average annual compound rate of 0.61% as a result of growth in aggregate outputs and inputs by 3.57% and 2.94%, respectively. Although productivity growth for production worker input was similar in both countries, large gaps in productivity growth existed for nonproduction workers, material, capital, and energy inputs. The gap in TFP growth between the two countries appears to have widened since 1987, primarily due to the differences in capital stock growth. Volatility in lumber prices after 1991 might have also played a role, as the Canadian industry could not adequately respond to changing market situations in the face of uncertainty and trade barriers on softwood lumber exports to the United States. For. Sci. 52(5): 511–521.

Key Words: Törnqvist-Theil index number, productivity convergence, US–Canada Free Trade Agreement, US–Canada softwood lumber trade dispute, lumber price volatility.

Productivity, defined as the ratio of output to input, is a measure of technical efficiency in production and a major source of competitiveness. Higher productivity means that more outputs can be produced with the same quantity of inputs, or that the same amount of outputs can be obtained from a reduced quantity of inputs. Single-factor productivity measures the ratio between outputs and an input, while total factor productivity (TFP) measures that between multiple outputs and inputs. Productivity growth measures the increase in technical efficiency over time.

Previous studies (e.g., Singh and Nautiyal 1986, Martinello 1987) suggest that there has been little or no technical progress in the sawmill industry in Canada using data before 1982. In addition, productivity growth in the Canadian sawmill industry has been lower than the US sawmill industry (Constantino and Haley 1989, Ghebremichael et al. 1990, Abt et al. 1994). A recent comparative study of productivity growth in the manufacturing sector between Canada and the United States suggests that, between 1961 and 1995, TFP in the lumber and wood products sector increased at an annual rate of 0.62% in Canada, but decreased at an annual rate of 0.21% in the United States. (Gu and Ho 2000) [1].

Before the signing of the Canada–US Free Trade Agreement (CUFTA) in 1988 and North American Free Trade Association (NAFTA) in 1993, some economists and trade experts (e.g., Cox and Harris 1986) predicted a convergence in productivity levels between the United States and Canada. The convergence hypothesis states that with free trade and through international diffusion of knowledge and technology, countries with low productivity have an opportunity to adopt and hence catch up with higher-productivity countries. It is believed that increased trade and export activity boosts productivity growth in the relevant industries and countries (Feenstra 2004). Furthermore, it is generally recognized that the Canadian sawmill and wood preservation industry is more technologically efficient and up-to-date than its counterpart in the United States [2]. Consequently, one might expect a higher productivity growth in the Canadian industry than in the US industry. Over time, the productivity in the industries between different countries should converge. However, Bernstein et al. (2002) suggest that this has not happened, as the productivity gap between the United States and Canada in the manufacturing sector has widened since 1988.

The purpose of this article is to investigate whether there is a convergence in the productivity growth between the United States and Canada in the sawmill and wood preservation industry and to explain why convergence has happened or has not happened. Our results indicate that the productivity gap in the sawmill and wood preservation industry between the United States and Canada has widened. This is due to the lack of capital investment and price

Daowei Zhang, Professor, School of Forestry & Wildlife Sciences, 602 Duncan Dr., Auburn University, Auburn, AL 36849-5418—Phone: (334) 844-1067; Fax: (334) 844-1084; zhangdw@auburn.edu. Rao Nagubadi, Postdoctoral Fellow, School of Forestry & Wildlife Sciences, Auburn University, Auburn, AL 36849-5418—Phone: (334) 844-1052; nagubve@auburn.edu.

Acknowledgments: The comments and suggestions from Wayne Gray, David Laband, Munisamy Gopinath, Josh McDaniel, and two anonymous reviewers and an associate editor of this journal on an earlier draft are gratefully acknowledged. Any remaining errors are the responsibility of the authors.

Manuscript received April 26, 2004, accepted January 31, 2006

volatility and uncertainty associated with trade barriers. These results may have implications for US–Canada trade policy.

This study differs from previous analyses in three aspects. First, we consider all outputs in estimating single and TFP growth in the entire industry using national level data, while previous studies ignored wood preservation products, wood ties, shingles and shakes, and other forest products. Second, we use the service price of capital, a combination of the interest rate for capital and depreciation for machinery, equipment, plants, and structures, as a measure of capital cost. Previous analyses used value-added minus labor cost as returns to and service price of capital [3]. Finally, we use the latest data available in the newly created North American Industry Classification System (NAICS) and illustrate differing trends in productivity growth in the two largest trading partners since the US–Canada Free Trade Agreement was signed in 1988. The next section describes the methodology and data used in this study and the trends in inputs and outputs in the industry in the United States and Canada. Section three presents the results and speculates on factors responsible for the widening of gap in productivity growth. The final section summarizes the results and presents conclusions.

Methodology and Data

Our study period is from 1958 to 2003. For our purposes, we divided it into four roughly decade-long periods, 1958–70, 1970–82, 1982–91, and 1991–2003 [4]. Although the first two periods were devoid of any incidents related to softwood lumber disputes between the United States and Canada, period 3 covers two early stages of the US–Canada softwood lumber trade dispute (Lumber I and II), during which countervailing duty petitions were filed and an MOU (Memorandum of Understanding) was signed in 1986 and terminated in 1991. This period also saw the negotiation and implementation of the CUFTA in 1988 and 1989. Period 4 covers Lumber III, during which a 5-year US–Canada Softwood Lumber Agreement (SLA) was implemented from Apr. 1996 to Mar. 2001. Within this period, in Jan. 1994, Canada, the United States, and Mexico launched the NAFTA. Volatility in softwood lumber prices was the highest in period 4 (Zhang and Sun 2001). Period 4 also witnessed the start of the long-drawn phase of Lumber IV after the expiration of the SLA.

Previous studies on forest products sector productivity have used historical, index number, and econometric approaches (Stier and Bengston 1992). This study uses the index approach, which does not require data on factor prices if expenditure data are available and does not suffer from potential limitation in degrees of freedom in the analysis. We address absolute levels of productivity, not relative levels of productivity between the two countries (the latter involves the use of purchasing power parity and exchange rate) [5].

The index approach assumes constant returns to scale and competitive conditions exist in input and output markets. At the industry level, constant returns to scale are a reasonable assumption in both countries (Stier 1980, Martinello 1987, Bartlesman and Doms 2000) [6]. The industry is close to competitive market conditions in the United States and in Canada (Murray 1995, Bernstein 1994). A large number of mills exist in the United States with the four-firm concentration ratio of 14.5% and the Herfindahl-Hirschman Index of 86.7 for the 50 largest companies in 1997 (US Census Bureau 2001) [7].

Single and total factor productivities are computed using the Törnqvist-Theil index number approach. Diewert (1976) shows that the Törnqvist-Theil index is an "exact" and "superlative" index corresponding to the standard translog utility function. Caves et al. (1982) recommend its use for the purposes of price, output, and productivity comparisons. Diewert (1976) further demonstrates that the Fisher and Törnqvist-Theil index numbers provide good approximations even when the form of utility function is unknown [8]. According to the Törnqvist-Theil index, the TFP growth (TFPG) index is computed as follows:

Aggregate output growth:

$$\ln\left(\frac{Q_t}{Q_{t-1}}\right) = \sum_{i=1}^{m} ½(R_{i,t} + R_{i,t-1})\ln\left(\frac{q_{i,t}}{q_{i,t-1}}\right), \qquad (1)$$

Aggregate input growth:

$$\ln\left(\frac{X_t}{X_{t-1}}\right) = \sum_{j=1}^{n} ½(S_{j,t} + S_{j,t-1})\ln\left(\frac{x_{j,t}}{x_{j,t-1}}\right), \qquad (2)$$

TFP growth:

$$\frac{\mathrm{TFP}_t}{\mathrm{TFP}_{t-1}} = \exp\left\{\ln\left(\frac{Q_t}{Q_{t-1}}\right) - \ln\left(\frac{X_t}{X_{t-1}}\right)\right\}, \qquad (3)$$

where Q = the aggregate of outputs; X = the aggregate of inputs; $R_i = p_iq_i/\sum_{i=1}^{m} p_iq_i$ = output revenue shares, $i = 1, 2, \ldots, 6$; $S_j = w_jx_j/\sum_{j=1}^{n} w_jx_j$ = input cost shares, $j = 1, 2, \ldots, 5$; $q_{i,t}$ = the output of product i at time t; $x_{j,t}$ = the quantity of input factor j at time t; p_i = output prices; w_i = input prices; and TFP = the total factor productivity.

The TFP growth index is computed as a chained index relative to the base year 1958 = 1 [9]. This study uses six outputs: softwood lumber, hardwood lumber, wood chips, wood preservation products, shingles and shakes, and other products; and five inputs: production labor, nonproduction labor, capital, energy, and materials. Single-factor productivities are computed by the same formula in (3) except that the second term on the right-hand side relates to a single input.

Data Construction

The nominal value of shipments for the sawmill and wood preservation industry grew from US$2.67 to US$26.68 billion and value added increased from US$1.08 to US$8.40 billion in the period from 1958 to 2003 in the United States. The rise of industry output was faster in Canada, growing from US$0.55 to US$11.27 billion in value of shipments and from US$0.24 to US$3.55 billion in value added. In 2003, the share of the industry in the total manufacturing value of shipments was 2.06% for Canada and 0.67% for the United States.

The industries included in this study for the United States are Standard Industrial Classification (SIC) code 2421 (sawmills and planing mills), SIC 2429 (special products sawmills), and SIC 2491 (wood preserving) for the period 1958 to 1996; and North American Industry Classification System (NAICS) code 321113 (sawmills) and 321114 (wood preservation) from 1997 to 2003. The principal sources of data for the United States are Annual Survey of Manufactures (ASM) and Census of Manufacturing (CM).

The corresponding industries for Canada are listed as SIC 2512/2513 (sawmills and planing mill products), SIC 2511 (shingle and shake mills) and SIC 2591 (wood preservation) for the period 1961 to 1996; and NAICS 321111 (sawmills—except shingle and shake mills), 321112 (shingle and shake mills), and 321114 (wood preservation) from1997 to 2003[10]. The primary sources of data for Canada are Annual Census of Manufactures (ACM) and Statistics Canada publications Catalog #35-204 and 35-250.

The details of data construction are given in the Data Appendix. The unit for production worker input is hours worked and for nonproduction workers is worker-years employed. The capital stock input is in real 2001 dollars in their respective currencies, while energy and material inputs are imputed quantities in British thermal units (Btu) and thousand board feet (mbf). Material inputs include nonwood materials and contract work, but were represented as wood-equivalent material quantities [11]. Wherever data are unavailable, suitable interpolations and imputations are made to fill in the gaps.

Trends in Inputs, Outputs, and Prices

In the aggregate, growth in inputs was smaller and growth in outputs was higher, leading to an increase in productivity growth during the study period in the United States. (Figure 1, Table 1) [12]. In Canada, growth in outputs was slightly greater than the growth in inputs, leading to a smaller productivity growth between 1958 and 2003.

Input and output prices grew in similar magnitude in both countries (Figure 2, Table 1). However, while output prices grew slightly faster than input prices in Canada, input prices grew slightly faster than output prices in the United States. This trend may add increasing pressure on the US industry to increase its productivity growth.

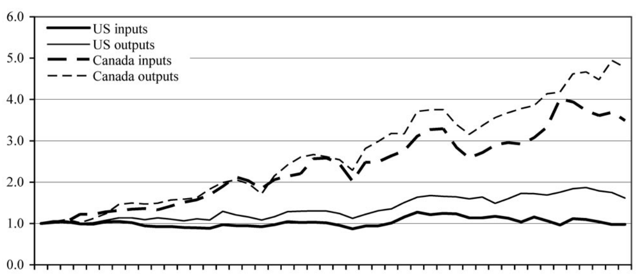

Figure 1. Aggregate growth indexes for input and output quantities (1958 = 1).

Table 1. Growth rates in quantities and prices for inputs and outputs in the sawmill and wood preservation industry in the United States and Canada, 1958–2003 (percent per annum)[a]

Input or output	United States Quantity	United States Price	Canada Quantity	Canada Price
Inputs				
Prod worker	−1.168	5.727	0.737	7.160
Non-prod worker	0.061	5.775	0.085	7.702
Capital	0.422	0.632	3.209	0.440
Energy	−0.571	6.730	5.365	4.430
Materials	0.652	6.304	3.498	5.711
Aggregate input	0.308	2.788	2.936	2.733
Outputs				
Softwood lumber	0.297	4.859	3.495	5.391
Hardwood lumber	3.378	4.646	0.707	5.889
Wood chips	5.791	3.870	5.703	5.307
Wood pres.	3.322	4.714	4.089	5.015
TSS	−3.570	5.634	0.362	7.345
Other	1.798	5.070	5.145	4.976
Aggregate output	1.424	2.666	3.567	2.870

[a] See endnotes 12 and 13.

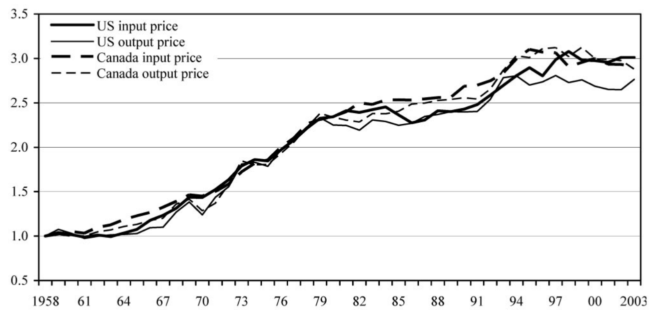

Figure 2. Aggregate growth indexes for input and output prices (1958 = 1).

Among individual inputs, wages for production and nonproduction workers grew the fastest in Canada, whereas prices for energy and materials grew the fastest in the United States. (Table 1). Consequently, one might expect substitution of other inputs for labor in Canada and substitution of other inputs for material input in the United States. Our data show just that: Production and nonproduction worker inputs grew the least and the use of capital, energy, and material inputs increased at faster rates in Canada. Energy and material inputs declined or increased at smaller growth rates in the United States. However, the service price of capital grew the least in both countries; capital input was used to substitute for other inputs.

In both countries, materials had the largest share in input cost, increasing from 46% to 73% in the United States and from 50% to 72% in Canada (Table 2). In early periods, capital cost share was the second highest, while in later periods the share of combined labor cost surpassed that of capital cost in the US industry. Combined labor cost share was the second highest in the Canadian industry in all

Table 2. **Input cost shares in the sawmill and wood preservation industry in the United States and Canada**

Year	P worker	NP worker	Capital	Energy	Materials
United States					
1958	0.196	0.036	0.287	0.019	0.462
1970	0.194	0.039	0.271	0.023	0.474
1982	0.160	0.039	0.231	0.028	0.544
1991	0.154	0.040	0.092	0.026	0.687
2003	0.141	0.038	0.061	0.026	0.734
Canada					
1958	0.207	0.044	0.237	0.016	0.496
1970	0.207	0.041	0.217	0.018	0.516
1982	0.218	0.054	0.175	0.036	0.516
1991	0.201	0.046	0.084	0.030	0.640
2003	0.173	0.030	0.038	0.037	0.723

periods. Capital service cost share declined steadily from 29 to 6% (a 79% decline) in the United States and from 24 to 4% (an 84% decline) in Canada.

In the aggregate, both output quantities and output prices rose faster in Canada than in the United States, consistent with the trend of output prices rising faster in an exporting country (Table 1, Figure 2). Prices for wood chips and wood preservation products rose much faster in Canada than in the United States. The outputs of the most prominent products—softwood and hardwood lumber—increased respectively at annualized rates of 0.3% and 3.4% in the United States, while softwood lumber production increased at an annualized rate of 3.5% and hardwood lumber output slightly increased by 0.7% in Canada. The output of wood chips rose dramatically in both countries, and wood preservation products rose sharply in the United States. However, the importance of wood-ties-shingles-shakes has declined over the study period in both countries.

Among the industry's primary products, revenue shares for softwood lumber declined from 74% to 45% and the share of hardwood lumber increased from 7% to 17% in the United States, while these shares declined from 76% to 72% and 6 to 3%, respectively, in Canada (Table 3). However, revenue shares for wood chips and wood preservation products increased in both countries.

Results and Discussion

Growth in Single-Factor Productivities

Single-factor productivity growth indexes for all inputs are shown in Figures 3–5. To further examine the trends in the growth of factor productivities in the four periods, annualized growth rates were estimated using a semi-log-linear regression equation [13]. During the study period, production worker input experienced the highest growth in productivity while capital input experienced the lowest productivity growth in the United States. In contrast, nonproduction worker input experienced the highest growth while energy input had negative growth in Canada.

Production and Nonproduction Workers.— Over the study period, productivity growth for production workers was similar for the United States and Canada at 2.62% and 2.81% per annum, respectively, but differed in its performance in different periods (Figure 3). The US industry had the highest productivity growth (3.55%) for production worker input in the first period and lowest growth (2.1%) in the second period (Table 4). The Canadian industry had the highest growth (3.28%) in the third period and the lowest growth (2.29%) in the first period in respect to production worker productivity.

Productivity growth for nonproduction worker input in the Canadian industry was higher than for the US industry in all periods (Figure 3). The United States had the highest

Table 3. **Output revenue shares in the sawmill and wood preservation industry in the United States and Canada**

Year	Softwood	Hardwood	Wood chips	Wood pres.	TSS	Other
United States						
1958	0.743	0.066	0.014	0.074	0.033	0.071
1970	0.653	0.088	0.071	0.092	0.028	0.068
1982	0.477	0.090	0.144	0.136	0.016	0.138
1991	0.522	0.121	0.120	0.149	0.011	0.078
2003	0.452	0.167	0.070	0.174	0.011	0.126
Canada						
1958	0.760	0.056	0.037	0.034	0.036	0.077
1970	0.738	0.038	0.094	0.030	0.035	0.064
1982	0.654	0.016	0.181	0.036	0.021	0.093
1991	0.634	0.021	0.142	0.044	0.027	0.133
2003	0.717	0.032	0.099	0.042	0.026	0.083

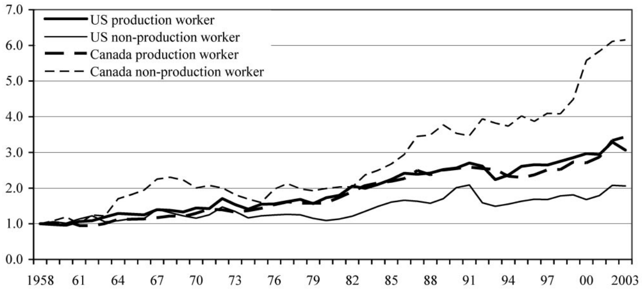

Figure 3. Single-factor productivities for production and nonproduction workers (1958 = 1).

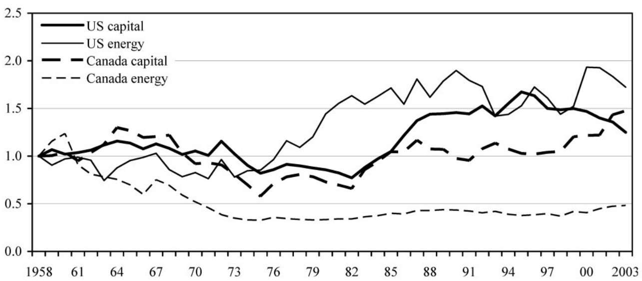

Figure 4. Single-factor productivities for capital and energy (1958 = 1).

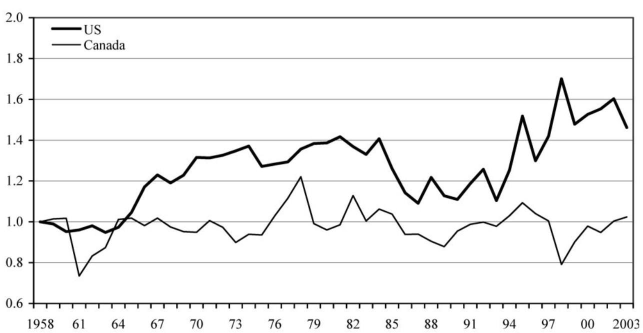

Figure 5. Single-factor productivity for materials (1958 = 1).

productivity growth (5.13%) for nonproduction worker input in the third period, preceded by a negative growth (−0.93%) in the second period. Canadian industry had the highest productivity growth (8.08%) for this input in the first period and the lowest (0.41%) in the second period.

Capital.— Productivity growth in capital input is vital to the industry for several reasons. Capital input embodies new technology and enhancements for better productivity through research and development in the industry. However, as capital input increases its productivity growth may be falling but will increase the productivity of the other factors. The United States experienced the highest productivity growth (7.67%) for capital input in the third period and negative growth (−2.41%) during the second period. Canada experienced similar trends (Figure 4). However, in the final period, the United States had negative growth (−1.08%) in contrast to Canada's positive capital productivity growth (2.82%).

Energy.— Energy was the only input that experienced a negative productivity growth during the entire period in Canada in contrast to a positive productivity growth in the United States (Figure 4). Apparently, the US industry succeeded in its efforts to increase productivity of energy in the aftermath of the energy crisis of the 1970s.

Materials.— Because material inputs accounted for the largest portion (roughly 72–73% in both countries as of 2003) of the cost, its productivity growth is a major determinant of TFP growth of the industry. Increases in productivity of materials could come either from an increased lumber recovery per unit of round wood input through technological advances or from making more marketable products out of wood chips and other residues that have been traditionally underutilized (Ince 2000). Industrial wood productivity increased in the United States by 39% from 1900 to 1998, largely because of increases in wood residues such as chips, slabs, edgings, and planer shavings from sawmills and planing mills (Ince 2000).

While materials productivity grew at an annualized rate of 0.77% in the United States, it was essentially flat at 0.07% in Canada (Figure 5). Only in the second period (1970–82) did materials productivity growth in Canada exceed that of the United States. During the final period, a diverging trend in productivity growth in material inputs was apparent as the US industry had the larger positive growth of 2.6%, while the Canadian industry had negative growth in material productivity during the final two periods. The decline in materials productivity growth in Canada may be related to a reduction in the size of logs, deteriorating log quality due to mountain pine beetle infection, lack of emphasis on lumber recovery per unit of round wood input, and insufficient signals in the movement of relative prices in favor of conserving wood materials.

Growth in TFP

The TFP growth rates and indexes of growth in TFP in the industry for both countries are shown in Table 4 and Figure 6. Overall, the United States experienced a higher productivity growth of 1.11% compared to Canada's 0.61% per annum. Growth in TFP was positive in 28 years and negative in the remaining 17 years in the United States, as compared to 25 years of positive and 20 years of negative growth in Canada.

Except for the first period, we see a gap in the TFP growth between the two countries from the 1970s onward (Figure 6). The gap has increased since 1994, roughly corresponding to the commencement of NAFTA. Periodwise, TFP growth was the highest (2.22%) during the final period (1991–2003) and was basically stagnant in the preceding two periods in the United States. In contrast, Canada experienced the highest TFP growth (1.08%) in the first period (1958–70), but the growth rates declined thereafter in each subsequent period. Interestingly, the growth rates in Canada were higher than the United States in the last 5 years of our study period.

Our results are not strictly comparable with previous studies because our study is national in scope, includes all

Table 4. Period-wise single and TFP growth in the United States and Canada, 1958–2003 (percent per annum)[a]

Period	Single factor productivity growth					Output growth	Input growth	TFP growth
	PW	NPW	Capital	Energy	Materials			
United States								
1958–70	3.554	1.773	0.329	−1.046	2.680	0.885	−1.190	2.100
1970–82	2.109	−0.932	−2.415	6.440	0.481	0.777	0.525	0.251
1982–91	3.296	5.132	7.672	1.666	−2.278	4.401	3.895	0.487
1991–2003	2.163	1.385	−1.082	1.088	2.578	0.962	−1.227	2.216
1958–2003	2.623	1.363	0.998	2.006	0.768	1.424	0.308	1.113
Canada								
1958–70	2.288	8.085	0.770	−5.818	0.362	4.675	3.560	1.077
1970–82	2.664	0.406	−2.088	−2.513	1.429	3.625	3.044	0.564
1982–91	3.283	6.640	3.121	2.619	−1.754	3.719	3.293	0.412
1991–2003	2.453	4.961	2.817	1.173	−0.379	3.647	3.226	0.408
1958–2003	2.810	3.480	0.347	−1.707	0.067	3.567	2.936	0.613

[a] See endnotes 12 and 13.

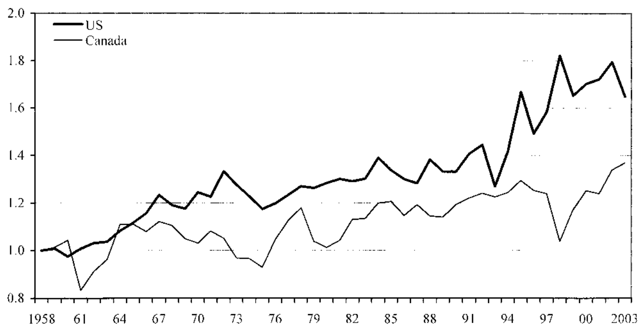

Figure 6. TFP growth in the United States and Canada, 1958–2003 (1958 = 1).

products in the sawmill and wood preservation industry, and involves a longer period. Nonetheless, our results are broadly consistent with the findings of previous studies. Abt et al. (1994) estimate the growth in TFP for the sawmill industry at 1.6 and 1.3% for the Pacific Northwest and Southern regions in the United States and −0.1 and 1.2% for Canada's most important regions of the BC Coast and the BC Interior between 1965 and 1988. Ghebremichael et al. (1990) report a TFP growth of 0.4 and 0.9% for the sawmill industry in the BC Coast and BC Interior regions over the period 1962–85.

Factors Influencing the Productivity Gap

The widening gap in TFP growth in this particular industry between the United States and Canada is largely consistent with the findings of widening gaps in productivity growth for the entire manufacturing sector between the two countries (Eldridge and Sherwood 2001, Bernstein et al. 2002). In an interrelated economic system, productivity growth depends on a multitude of variables. Baumol and McLennan (1985) list some of the variables: production techniques, capital equipment, skill of the workforce, managerial performance, rate of capacity utilization, scale of operation, materials flow, product mix, the state of labor-management relations, quality of the work environment, expenditure on research and development, direct and indirect cost of regulations, and business cycles.

There are major differences in capital stock per production worker hour and capital stock used per unit of material inputs in the industry between the countries. The total capital stock (in 2001 constant dollars) per production worker hour in the United States was higher and increased from US$24 to US$60, whereas in Canada it was lower and increased from US$16 to US$26 over the study period (Figure 7). The gap widened in the last period. Similarly, the capital stock per unit of material input increased from US$209 to US$245 in the United States, whereas it declined from US$158 to US$76 in Canada. During this period, material inputs handled by the industry increased only by 8% in the United States compared to an increase of 366% in Canada. It is clear that the increase in capital stock has not kept pace with heavy increases in material inputs handled by the industry in Canada.

Differences also existed in new capital invested in the industry between the two countries. New capital expenditure in 2001 constant US dollars per production worker increased from US$1.57 to US$4.12 in the United States, while it increased at a slower pace from US$1.33 to US$2.66 in Canada (Figure 8). New capital expenditure per mbf of material inputs declined drastically from US$13 to US$8 in the Canadian industry, while it increased from US$14 to US$17 for the US industry over the same period. Higher intensity of new capital investment might have contributed to higher productivity growth for material input in the United States. Figure 9 illustrates differences in real

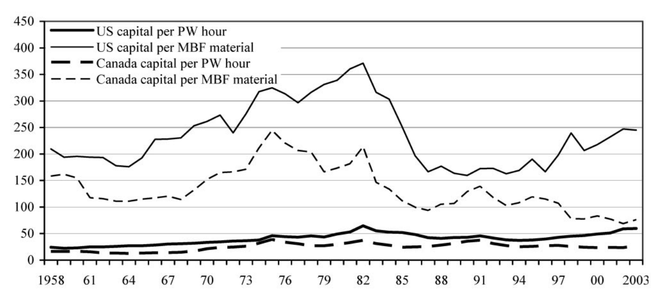

Figure 7. Total capital stock per production worker (PW) hour and per thousand board feet (MBF) of material handled (in 2001 US dollars).

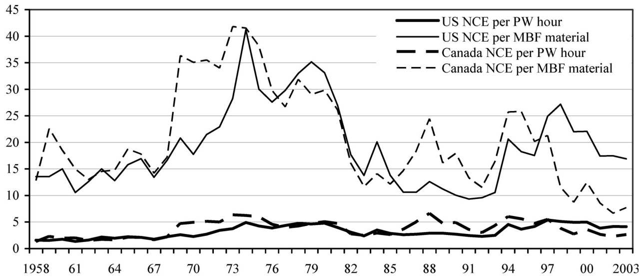

Figure 8. New capital expenditure (NCE) per PW hour and per MBF of material handled (in 2001 US dollars).

capital stock per US dollar real value of output in the industry in both countries. A relatively weak performance in terms of capital accumulation in Canadian industry than in the United States might have hindered productivity growth in Canada (Rao and Tang 2004).

There were differences in the price growth for inputs and outputs. This is another factor in the widening productivity gap between the US and Canadian industries. Higher growth in input prices compared to lower price growth for outputs led to competitive pressures on the part of the US industry to increase output per unit of input, helping in its productivity growth.

Trade restrictions and lumber trade disputes between the two countries and consequent volatility in lumber prices, particularly in the period from 1991 to 2003, might have contributed to negative productivity growth in the Canadian industry. For example, the SLA set up a tariff-rated quota system on Canadian lumber exports to the United States. It reduced exports from and profitability of lumber producers in Canada and in turn may have lowered the industry's ability to reinvest and enhance its productivity. Furthermore, lumber price volatility, as examined by Zhang and Sun (2001), was highest during 1991–96, and second highest during 1996–2000. Uncertainty created by higher volatility in lumber prices would make it difficult for Canadian firms to optimize the inputs and outputs. Although our data do not permit us to draw firm conclusions, it appears that lumber price volatility might have played a role in the widening gap in productivity growth between the two countries.

The business cycles might have influenced the productivity growth in the industry in both countries, as expectations of downsizing might lead to higher productivity growth and expectations of expansion would lead to lower productivity growth (Bartelsman and Doms 2000) [14]. In the case of this industry, we can assume that US firms would expect to downsize (sawmill closures) and the Canadian firms expect to expand due to absolute and comparative advantage in softwood timber resource endowment in Canada. This might be another reason for the widening gap in productivity growth in the industry between the United States and Canada.

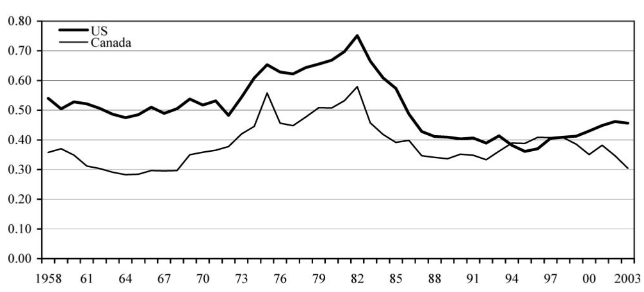

Figure 9. Capital stock per one US dollar of real output (in 2001 US dollars).

Despite its technologically efficient and more up-to-date production facilities, it is worth noting that the Canadian industry experienced the lowest productivity growth between 1991 and 2003. This period is marked by Canadian unilateral termination of MOU, subsequent interim countervailing duties, and the SLA that mandated tariff-rated quotas. In the aftermath of CUFTA, the Canadian manufacturing firms that experienced deep tariff cuts for the goods exported to the United States have boosted their productivity growth (Trefler 2004). However, in the case of the sawmill and wood preservation industry in Canada the reverse has occurred. Thus, the countervailing duties and SLA after 1991 could have contributed to the widening gap in productivity growth in the industry between the two countries.

Summary and Conclusions

This study compares single and total factor productivity growth in the sawmill and wood preservation industry in the United States and Canada between 1958 and 2003 using the Törnqvist-Theil index approach. The TFP grew at an annualized compound growth rate of 1.11% in the United States and at a much slower rate of 0.61% in Canada. The highest growth in TFP occurred during the final period (1991–2003) and the second-highest growth in TFP occurred in the first period in the United States. In contrast, Canada experienced the highest growth in TFP growth in first period and smaller growth in all successive periods. The main conclusion of this study is that the gap in productivity growth, instead of closing, has widened further between the United States and Canada. Contrary to the theoretical expectations, the US–Canada Free Trade Agreement has not worked in closing the productivity gap in this industry between the two countries.

A difference in capital intensity in the sawmill and wood preservation industry between the United States and Canada may be an important factor for the widening gap in productivity growth. The softwood lumber dispute, trade restrictions, and the consequent volatility in lumber prices might also have helped in boosting productivity growth in the US industry while hindering productivity growth in the Canadian industry, thus contributing to the widening gap in productivity growth. Because there is no trade dispute in pulp and paper products, a study on the productivity growth gap in the pulp and paper industry in both countries would provide evidence of the impact of a trade dispute on productivity growth.

Finally, this study is about growth in absolute productivity, not relative productivity or competitiveness. Although the US sawmill and wood preservation industry (which covers the softwood lumber industry) has increased its productivity, the increasing share of Canada softwood lumber in the US market in the last few decades indicates that Canada has a competitive advantage over the US softwood lumber industry. Further studies can be conducted on relative competitiveness of the softwood sawmill industry in the two countries.

Endnotes

[1] The sawmill and wood preservation industry (primarily SIC 242 and 249) is about 29% of value of shipments of lumber and wood products represented by SIC 24 in the United States in 1997.

[2] The authors are grateful to an associate editor of this journal for bringing this and other points to our attention.

[3] Service or rental price of capital is based on the principle of opportunity cost of capital stock. The value-added minus labor-cost method leads to unrealistically high estimates of service price as percentage (sometimes as high as 90%) of total capital stock.

[4] The division of the study period into four subperiods is arbitrary to facilitate comparison of the performance of the industry over time.

[5] We use prices only in the construction of cost shares of inputs and revenue shares of outputs, and we use exchange rate only in the comparison of capital used per production worker, per thousand board feet (mbf) of material handled, or per unit of output. See Nagubadi and Zhang (2006) for an analysis of relative productivity and competitiveness in the industry between the two countries.

[6] However, recent studies in the Norwegian and Swedish sawmill industries point to evidence of economies of scale of 1.17 and 1.10, respectively (Baardsen 2000, Månsson 2003).

[7] Four-firm concentration ratio is the percentage of total market share contributed by the largest four firms ranked in order of market shares. The Herfindahl-Hirschman Index (HHI) is a measure of concentration of the production in an industry calculated as the sum of the squares of market shares for each firm. The HHI attains a maximum value of 10,000 for a monopoly when the market shares are measured in percentage terms (Scherer and Ross 1990).

[8] The Fisher index is the square root of product of Laspeyres and Paasche indexes. The difference between the Fisher index and the Törnqvist-Theil index is that the former satisfies all tests for an ideal index except the circularity test, while the latter does not satisfy both circularity and factor reversal tests (Selvanathan and Rao 1994, Diewert and Nakamura 2003).

[9] Following Bernstein (1999) and Diewert and Nakamura (2003), we distinguish between TFP and TFP growth (TFPG). Note that we are measuring the growth in the TFP as the difference in growth rates between outputs and inputs, and it is an index number, or growth accounting, calculation.

[10] There is a slight difference in the NAICS classification codes for the industry. Canada preferred to have two codes separately for sawmills and planing mills (321111) and shingle and shake mills (321112), while in the United States this industry is represented as one group (321113).

[11] According to the 2002 Manufacturing Census, wood materials, nonwood materials, and products not classified, including contract work, accounted for 67.5, 8.5, and 24%, respectively, of the material costs in the US industry.

[12] The aggregate growth rates were estimated, using a semi-log form of regression equation, from the chained translog indexes of quantities and prices of inputs or outputs using revenue shares and cost shares and revenue shares as weights. See also endnote 13.

[13] The equation is $\ln Y_t = a + * T + u$, where $\ln Y_t$ is the natural logarithm of single or TFP index at time t, T is time in years, a and b are coefficients, and u is random error; from this equation the annualized compound growth rates are calculated using the formula $(e^b - 1) * 100$.

[14] Bartelsman and Doms (2000) state, "Firms that expect to be downsizing would not let workers sit idle during a cyclical downturn but would make use of the opportunity to dismiss them. However, the same firms would certainly attempt to use workers harder during a temporary upswing rather than add extra workers. Similarly, firms that expect to grow over time would hire during an unexpected temporary boom but likely would let workers sit idle during a temporary downturn."

Literature Cited

ABT, R.C., J. BRUNET, B.C. MURRAY, AND D.G. ROBERTS. 1994. Productivity growth and price trends in the North American sawmilling industries: An inter-regional comparison. Can. J. For. Res. 24:139–148.

ADAMS, D.M., K.C. JACKSON, AND R.W. HAYNES. 1988. Production, consumption, and prices of softwood products in North America: Regional time series data, 1950–1985. USDA For. Serv. Res. Bull. PNW-RB-151. 49 p.

BAARDSEN, S. 2000. An econometric analysis of Norwegian sawmilling 1974–1991 based on mill-level data. For. Sci. 46(4):537–547.

BARTELSMAN, E.J., AND M. DOMS. 2000. Understanding productivity: Lessons from longitudinal microdata. J. Econ. Lit. 38(3):569–594.

BAUMOL, W.J., AND K. MCLENNAN. 1985. U.S. productivity performance and its implications. P. 3–28 *in* Productivity growth and U.S. competitiveness, Baumol, W.J., and K. McLennan (eds.). Oxford University Press, New York.

BERNSTEIN, J.I. 1994. Exports, margins and productivity growth: With an explanation to the Canadian softwood lumber industry. Rev. Econ. Stat. 76:291–301.

BERNSTEIN, J.I. 1999. Total factor productivity growth in the Canadian life insurance industry. Can. J. Econ. 32:500–517.

BERNSTEIN, J.I., R.G. HARRIS, AND A. SHARPE. 2002. The widening Canada-US manufacturing gap. Int. Prod. Monitor 5(Fall):3–22.

CAVES, D.W., L.R. CHRISTENSEN, AND W.E. DIEWERT. 1982. The economic theory of index numbers and the measurement of input, output, and productivity. Econometrica 50:1393–1414.

CONSTANTINO, L.F., AND D. HALEY. 1989. A comparative analysis of sawmilling productivity on the British Columbia coast and in the U.S. Douglas-fir region: 1957 to 1982. Forest Prod. J. 39(4):57–61.

COX, D., AND R. HARRIS. 1986. A quantitative assessment of the economic impact on Canada of sectoral free trade with the United States. Can. J. Econ. 19:377–394.

DIEWERT, W.E. 1976. Exact and superlative index numbers. J. Econometrics 4:115–145.

DIEWERT, W.E., AND A.O. NAKAMURA. 2003. Index number concepts, measures and decomposition of productivity growth. J. Productiv. Anal. 19:127–159.

ELDRIDGE, L.P., AND M.K. SHERWOOD. 2001. A perspective on the U.S.-Canada manufacturing productivity gap. Monthly Labor Rev. (Feb.):31–48.

FEENSTRA, R.C. 2004. Advanced international trade: Theory and practice. Princeton University Press, Princeton, NJ. 484 p.

GHEBREMICHAEL, A., D.G. ROBERTS, AND M.W. TRETHEWAY. 1990. Productivity in the Canadian lumber industry: An inter-regional comparison. Information Report O-X-411. Forestry

Canada, Ontario Region, Great Lakes Forestry Centre, Sault Ste. Marie, Ont.

GU, W., AND M.S. HO. 2000. A comparison of industrial productivity growth in Canada and the United States. Amer. Econ. Rev. 90(2):172–175.

HOWARD, J.L. 2003. U.S. timber production, trade, consumption, and price statistics 1965–2002. USDA For. Serv. For. Prod. Lab. Res. Pap. FPL-RP-615. 90 p.

INCE, P. 2000. Industrial wood productivity in the United States, 1990–1998. USDA For. Serv. For. Prod. Lab. Res. Note FPL-RN-0272. 14 p.

MÅNSSON, J. 2003. Economies of scale in the Swedish sawmill industry. J. For. Econ. 9:169–179.

MARTINELLO, F. 1987. Substitution, technical change and returns to scale in British Columbian wood products industries. Applied Econ. 19:483–496.

MURRAY, B.C. 1995. Measuring the oligopsony power with shadow prices: U.S. markets for pulpwood and sawlogs. Rev. Econ. Stat. 77:486–498.

NAGUBADI, R.V., AND D. ZHANG. 2006. Competitiveness in the sawmills and wood preservation industry in the United States and Canada. For. Sci. 52:340–352.

RAO, S., AND J. TANG. 2004. Competitiveness challenges facing Canadian industries. Canadian Public Policy 30(4):365–380.

SCHERER, F.M., AND D. ROSS. 1990. Industrial market structure and economic performance. Houghton Mifflin Company, Boston, MA. 713 p.

SELVANATHAN, E.A., AND D.S.P. RAO. 1994. Index numbers: A stochastic approach. University of Michigan Press, Ann Arbor, MI. 242 p.

SINGH, B.K., AND J.C. NAUTIYAL. 1986. A comparison of observed and long-run productivity and demand for input in the Canadian lumber industry. Can. J. For. Res. 16:443–455.

STIER, J.C. 1980. Estimating the production technology of the U.S. forest products industries. For. Sci. 26(3):471–482.

STIER, J.C., AND D.N. BENGSTON. 1992. Technical change in the North American forestry sector: A review. For. Sci. 38(1):134–159.

TREFLER, D. 2004. The long and short of the Canada-U.S. Free Trade Agreement. Am. Econ. Rev. 94(4):870–895.

US CENSUS BUREAU. 2001. Concentration ratios in manufacturing. 1997 economic census. EC97M31S-CR. United States Department of Commerce, Washington, DC.

ZHANG, D., AND C. SUN. 2001. U.S.-Canada softwood lumber trade disputes and lumber price volatility. Forest Prod. J. 51(4):21–27.

Data Appendix

NAICS and SIC Data Bridge, US

A bridge between SIC and NAICS based on value of shipments (84% of SIC 2421—sawmills and planing mills, 21% of SIC 2429–special product mills, and all of SIC 2491–wood preserving) in 1997 was applied. The data were assembled from CM and ASM of the United States.

Output Quantities and Prices

Softwood Lumber.—The data on the softwood lumber production are derived by dividing the value of shipments by weighted average prices for softwood lumber. Data for value of shipments were from SIC 24212 for 1958–96, and NAICS 3211133 for 1997–2003. A weighted average price ($/mbf) was constructed for the years 1958–96 using production in nine regions as weights, and prices for seven regions obtained from Darius Adams (Department of Forestry, Oregon State University, Corvallis, OR. Personal communication, 2003). For the years 1997–2003, price series were extended using percentage changes in producer price index (PPI) for softwood lumber.

Hardwood Lumber.—Data on hardwood lumber production are derived by dividing the value of shipments with weighted average prices for hardwood lumber. The shipment values were for SIC 24211 for 1958–96 and NAICS 3211131 for 1997–2003. Weighted prices for hardwood lumber ($/mbf) for 1958–2003 were developed using details of species proportion and lumber grade composition within species obtained from W.G. Luppold (USDA Forest Service, Northeastern Research Station, Princeton, WV. Personal communication, 2003).

Wood Chips.—The output of wood chips was derived by dividing the value of shipments of SIC code 24215 for 1958–96 and NAICS code 3211135 for 1997–2003 with price series for wood chips constructed for the purpose. Data on value of shipments for 1959–62 and 1964–66 were interpolated using compound growth rates. Prices ($/bone-dry ton) for wood chips for 1958–80 were from Adams et al. (1988). For 1981–82, percentage changes in average prices of wood chips and residues for the Southcentral and Southeast regions, and for 1983–2003 percentage changes in PPI for wood chips were used.

Wood Ties, Siding, Shingles and Shakes.——This product group is listed under NAICS 3211137 and SIC 2429. Prices of western redcedar for shingles (5X, #2) products ($/square) from Random Lengths (various years, Forest product market prices and statistics. Random Lengths Publications Inc., Eugene, OR) were used for the years 1961–2003, and for 1958–60 prices were imputed using percentage changes in PPI for lumber, and these prices were used for deriving output quantities from value of shipments.

Wood Preservation Products.—The values of shipments were derived from SIC code 2491 for 1958–96 and NAICS code 321114 for 1997–2003. Prices reported for treated Southern Yellow Pine for 2×4–12′ lumber by Random Lengths were used for the years 1989–2003, and for the remaining years prices were derived using percentage changes in PPI for Southern Pine dressed lumber. The output quantities were implicitly derived using this price series.

Other Sawmill Products.—These are nsk (not specified by kind) under SIC 24210 for 1958–96, and NAICS 321113W for 1997–2003. The prices were constructed using 2001 price of lumber framing composite (Random Lengths) and working backward to 1958 by percentage changes in the PPI for lumber. Implicit quantities of output were developed using value of shipments and price series constructed for this purpose. Since shipment values for the years 1958–62 were unavailable, the values were interpolated.

Input Quantities and Prices

Production Workers.—The manufacturing labor input was represented as person-hours worked available from CM and ASM. The total compensation includes payroll and fringe benefits (social security, other legally required payments, and employer payments). For the years 1958–66, these were imputed by estimating the total compensation by percentage changes in the payroll.

Nonproduction Workers.—Since hours worked by nonproduction labor were not available, numbers for nonproduction employees were derived by subtracting the number of production employees from total employees. The procedure explained for fringe benefits under production labor was applied for nonproduction labor.

Capital.—We used real capital stock data in 1987 dollars, available from the NBER-CES Manufacturing Industry Database (Bartelsman, E.J., R.A. Becker, and W. Gray. The NBER-CES manufacturing industry database (http://www.nber.org/nberces/nbprod96.htm, June 2000) developed by the National Bureau of Economic Research and Center for Economic Studies of the US Census Bureau. Data were available separately for machinery and equipment (M&E), and plants and structures (P&S) by SIC codes for the years 1958–96. For 1997–2003, data were obtained by the perpetual inventory method using 8.33% depreciation for M&E, and 5% depreciation for P&S on the previous year's capital stock and adding current year new capital expenditure. These were converted to constant 2001 dollars using the GDP deflator for the United States. The service price of capital was computed by adding Moody's AAA bond interest rate on total capital stock, depreciation on P&S based on 20-year life, and depreciation on M&E based on 12-year life.

Energy.—The energy cost was assembled from ASM, CM, and the US Census Bureau's publication, "Fuels and Electric Energy Consumed." However, for missing years data were interpolated using proportions of energy cost available for upper level 3- or 2-digit SIC codes. Fuel prices were derived by constructing a weighted fuels price index using #2 diesel fuel oil price index (46%), gasoline price index (23%), and natural gas price index (31%).

Materials.—Data reported as cost of materials included the cost of wood, nonwood materials, and purchased fuels and electric power. Cost of materials was derived by subtracting the cost of fuels and electric power. The price for material inputs was calculated as a weighted Louisiana delivered prices for pine and oak using softwood and hardwood lumber production as weights (Howard 2003). Thus implicit quantities of wood-equivalent material inputs were derived.

NAICS and SIC Data Concordance, Canada

Data on inputs and outputs were obtained from Catalog 35-204 for 1958–89 and from CANSIM II for 1990–97 (Statistics Canada). The series was merged using average proportions developed from data reported for the same years (1990–97) under NAICS and SIC classifications. This resulted in downward scaling of all data from 1958 to 1989 by 1.8%.

Output Quantities and Prices

Softwood Lumber.—Output quantities of softwood lumber were derived by dividing the total value of shipments for softwood lumber with softwood lumber price for the years 1958–85, 1988–90, and 1992–95. For the years 1986–87, 1991, and 1996–2003, prices were derived using percentage changes in industry selling price index for softwood lumber and ties and then quantities were imputed by dividing the value of shipments with the derived prices. In the absence of figures for value of shipments for the years1996 to 2003, the softwood lumber production numbers from Howard (2003) were used, and price series were extended using percentage changes in the industry selling price index for softwood lumber and ties.

Hardwood Lumber.—Output quantities for hardwood lumber were imputed using total value of shipments and prices for hardwood lumber for 1958–84, 1988–90, and 1992–95. Hardwood lumber prices were derived from value of shipments and quantities provided by ACM. For the years 1996–2003, data on hardwood lumber production were taken from Howard (2003. For the years 1985–87, 1991, and 1996–2003, prices were derived using percentage changes in the industry selling price index of hardwood lumber and ties.

Wood Chips.—The quantities for chips were taken from the ACM and the prices were derived by dividing the value of shipments with quantities for the period 1958 to 1992. For the period 1993 to 2003, value of shipments for chips was assumed to be 12% (average of previous 5 years) of total value of shipments of entire sawmills and the wood preservation industry.

Shingles and Shakes.—This product is listed in both sawmills (SIC 2513) and shingle and shake mills (SIC 2511) and a weighted price, using value of shipments as weights, is constructed for 1958–81, and for the remaining period prices were extended by percentage changes in the industry selling price index for this group.

Wood Preservation Products.—The price index for this group of products was derived from the industry selling price index for preserved and treated wood from 1981 to 2003 and extended back to 1958 by percentage changes in the lumber price index. Using this price index and an approximate price for major quantity of wood preservation products in 1984, the entire price series was constructed and used in deriving the output quantity for this group of products.

Other Sawmill Products.—Although this product group consists of several outputs including contract work and miscellaneous products, quantity equivalents were derived by dividing the value of shipments by price series developed for this product group. The price series was developed using the 1958 price of wood preservation product group and then extending forward up to 2003 by percentage changes in the overall lumber price index.

Input Quantities and Prices

Production Workers.—In contrast to US data on production workers compensation, which was "hours worked," the Canadian data related to "hours paid," which includes paid vacation time. Because data on supplementary wages paid to the production workers in the industry were unavailable, compensation was added using a national percentage of supplementary wages.

Nonproduction Workers.—The number of nonproduction employees reported in thousands was used. Supplementary income based on national level percentage of wages and salaries was added. Annual compensation was derived implicitly by dividing the total compensation for nonproduction employees with the number of nonproduction employees.

Capital.—Capital stock data in 1997 constant Canadian dollars, computed using the straight-line method of depreciation, were taken from Statistics Canada. Data were converted to 2001 constant dollars using the GDP deflator for Canada. The service price of capital was constructed by adding interest rate based on Scotia Capital, Inc., Long-Term Average Weighted Yield on Bonds and McLeod, Young, Weir's 10 Industrials Bond Average yield rate, a depreciation based on 20-year life for building and engineering construction, and 12-year life for M&E.

Energy.—Cost of purchased fuels and electricity was assembled from Catalogues 35-204, 35-250, and 57-208 for the years 1958–84. For Canada, data do not include own-generated electricity consumed in the industry. Price per kWh of electricity was imputed from available quantities and dollar values for the years 1958 to 1984, and thereafter, price series were extended to 2003 using percentage changes in nonresidential electric power selling price index at the national level. For fuels, available quantities were converted to Btu and dollar values were used to determine prices. Fuel prices were extended from 1985 to 2003 using percentage changes in the weighted price index of natural gas, gasoline, fuel oils, and liquefied petroleum gas.

Materials.—Materials included wood and nonwood materials. Available quantities in mbf and their dollar values were used to determine price. The total quantity of wood material was imputed using this price and total cost of material inputs; thus, nonwood materials were also reflected as wood-equivalent quantities. Price of materials was extended to 2003 using percentage changes in the raw materials price index for logs and bolts for NAICS 3211.