Total Factor Productivity and Canadian Softwood Lumber Imports

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Abstract. The gap in total factor productivity (TFP) growth in sawmill and wood preservation industry widened between the US and Canada over the period 1958 to 2003. Stages of the softwood lumber dispute had different effects on TFP growth. The strong housing market in the US increases imports of Canadian softwood, while the exchange rate and other variables have no effect. Trade restrictions since 1992 have been unable to stem imports due to strong US demand.

Keywords: US-Canada softwood lumber dispute, TFP growth, lumber imports, exchange rates, housing demand

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The US is a major importer of softwood lumber products from Canada. Due to strong US housing demand, softwood lumber consumption increased 26 billion board feet (bbf) between 1958 and 2003 while US production increased only 9 bbf and imports from Canada made up the difference. The share of Canadian imports in US consumption increased from 10% in 1958 to 34% in 2003. The present paper focuses on sawmill & wood preservation industry (North American Industry Classification System 3211) accounting for 46% (US) and 70% (Canada) of the total value of shipments of softwood lumber products in 2003.

Facing increased Canadian imports, US lumber producers have sought protection by petitioning the US Department of Commerce for a countervailing duty (CVD) and anti-dumping duty (ADD) since 1982. The softwood lumber trade war began and has passed through distinct stages. The first stage, Lumber I, began in 1982 and ended with a denial of duties.

The second stage, Lumber II, began in 1986 when an interim CVD was imposed. Negotiations resulted in a Memorandum of Understanding (MOU) in which the ADD and CVD collected by the US government were transformed to a Canadian export tax. In 1989, the Canada-US Free Trade Agreement (CUFTA) began, and Lumber II came to an end when Canada withdrew from the MOU in September 1991.

Lumber III started in 1992 when 66 US Senators asked the President to impose ADD and CVD in the wake of Canada's withdrawal from the MOU. After going through the North American Free Trade Agreement (NAFTA) dispute settlement mechanism, the Softwood Lumber Trade Agreement (SLA) was reached between the US and Canada in 1996 imposing tariff rate quotas. The SLA was in force from April 1996 to March 2001, ending Lumber III and beginning Lumber IV.

Prior to CUFTA and NAFTA, some analysts predicted productivity convergence between the two countries (Cox and Harris, 1986). Trade theory suggests that trade may influence the rate of technology transfer or the speed of productivity convergence. Bernard and Jones (1996) observe at best weak labor productivity (LP) and total factor productivity (TFP) convergence in OECD countries between 1970 and 1987. Bernard and Jensen (1999) uncover causality from productivity to exports but not vice versa, and find that exports reallocate resources from less to more efficient plants. Carree, Klomp, and Thurik (2000) report mixed LP results for 28 manufacturing industries across 18 OECD countries between 1972 and 1992 finding knowledge and capital barriers prevent convergence.

Adams, McCarl, and Homayounfarrokh (1986) and Roberts (1988) find Canadian imports increased with a strong US dollar. Buongiorno, Chavas, and Uusivuori (1988) and Jennings, Adamowicz, and Constantino (1991) find no significant causal link between exchange rates and Canadian imports, while US lumber prices and the US housing market exerted a major influence. Sarker (1993, 1996) finds one long run equilibrium relationship among five excess demand factors (US lumber prices, US disposable income, US housing starts, US construction wages, and the exchange rate). These five factors accounted for about ¾ of the variation in Canadian imports with most of the deviation from the long run equilibrium corrected in one quarter.

The objective of the present study is to examine factors influencing softwood lumber imports from Canada, including productivity growth and the various stages of the softwood lumber dispute.

Theoretical specification

Assume output is a function of inputs

(1) $Y = f(K, L_P, L_N, E, M)$

where Y is output, K is capital, L_P is production labor, L_N is non-production labor, E is energy, and M is material input. A flexible translog production function is assumed to determine predicted values of Y. Total factor productivity (*TFP*) is the difference (residual) between the actual output Y and the predicted output,

(2) $$TFP = Y - \hat{Y}.$$

TFP growth is estimated as the difference between the weighted growth rates of outputs and inputs,

(3) $$\dot{TFP} = \sum a_i \dot{Y}_i - \sum b_j \dot{X}_j$$

where $\dot{TFP}$ is the growth rate of *TFP*, $\dot{Y}_i$ is the growth rate of output *i*, $\dot{X}_j$ is the growth rate of input *j*, and the a_i and b_j are weights or value shares of outputs and inputs.

The total factor productivity is computed using the Törnqvist-Theil index. Diewert (1976) shows that the index is an 'exact' and 'superlative' index corresponding to the translog production function. According to the index, TFP growth (TFPG) is computed as

(4) $$TFPG = TFP_t / TFP_{t-1} =$$

$$exp\{\Sigma^m_i ½(R_{i,t}+R_{i,t-1})ln(Q_{i,t} / Q_{i,t-1}) - \Sigma^n_j ½(S_{j,t}+S_{j,t-1})ln(X_{j,t}/X_{j,t-1})\}$$

where m denotes the number of outputs (m = 1, 6), n denotes the number of inputs (n = 1, 5), $R_{i,t}$ are revenue shares of output i at time t, $Q_{i,t}$ are the outputs of product i at time t, $S_{j,t}$ are the cost shares of input j at time t, and the $X_{j,t}$ are the inputs of factor j at time t.

The TFP growth index is computed as a chained index relative to the base year, 1958 = 1. There are six outputs (softwood lumber, hardwood lumber, wood chips, wood preservation products, shingles & shakes, other products) and five inputs (production labor, non-production labor, capital, energy, materials). Outputs and inputs are aggregated into indices using revenue shares as weights for outputs and cost shares as weights for inputs.

Empirical Specification

Empirically, we estimate the TFPG index as a function of capital/labor ratio, skilled labor/labor ratio, the exchange rate, US housing starts, and dummy variables,

$$(5) \qquad TFPG = f(\frac{K}{L}, \frac{L_N}{L}, E, H, D_i)$$

where K is capital stock, L is the labor force, L_N is skilled or non-production workers, E is exchange rate between Canadian dollar and US dollar (C$/$), H is US housing starts, and D_i are dummy variables indicating stages of the softwood lumber dispute.

The first dummy variable D8791 covers Lumber II between 1987 and 1991, the second D9295 free trade in Lumber III from 1992 to 1995, the third D9600 the period 1996 to 2000, and D0103 represents Lumber IV from 2001 to 2003. Two equations are estimated for each of the US and Canada TFPG indices.

Factors affecting the gap or the difference in productivity growth are examined by estimating

$$(6) \qquad (TFPG_{US} - TFPG_{CN}) = f(diff\frac{K}{L}, diff\frac{L_N}{L}, E, H, D_i)$$

where "diff" is the difference between the US and Canada.

To understand factors influencing imports from Canada the following equation is estimated,

$$(7) \qquad CDNI = f(E, H, P_m, P_d, D_i)$$

where $CDNI$ is the quantity of imports, P_m is the Canadian softwood lumber price index, and P_d is the US softwood lumber price index.

The data are time series and tests for unit roots are conducted to determine stationarity using Augmented Dickey-Fuller (ADF) tests (Enders, 1995). Johansen's multivariate cointegration test explores whether series have common stochastic trends (Johansen 1988, 1995). To find the cointegration rank, trace and maximum-eigenvalue test statistics are used. If the variables are cointegrated, they may contain some linear combination that is stationary or a stochastic trend. If variables are cointegrated, equations (5) to (7) are estimated with error correction models (ECM) to allow adjustment of long and short run movements. If variables are not cointegrated, the vector autoregression (VAR) method is used.

Data

Annual data covers the period 1958 to 2003. The US industries included are Standard Industrial Classification (SIC) code 2421 (sawmills & planning 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 main sources of data for the US are Annual Survey of Manufactures and the Census of Manufacturing.

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

The quantities of six outputs, softwood lumber, hardwood lumber, woodchips, wood preservation products, wood-ties-shingles-shakes, and other products are imputed from the value of shipments using appropriate prices constructed from available quantities and values. The capital stock is in millions of dollars converted to constant 2001 dollars in their respective currencies using GDP deflators. The unit for labor input is hours worked. The units for energy are British thermal units (Btu) and material inputs are in thousand board feet (MBF). Material inputs include non-wood materials such as chemicals and contract work and are represented as wood material equivalent quantities by dividing the expenditure on non-wood materials by wood material prices. In the few cases when data are unavailable, interpolations fill in the gaps.

The data on annual housing starts and C$/$ exchange rates are from website of the St. Louis Federal Reserve Bank. The data on US softwood lumber price index are from the Bureau of Labor Statistics, and the data on Canadian softwood lumber prices are from Statistics Canada.

Estimation results

The TFP growth indices in Figure 1 have diverged since 1986, nearly converging in 1993 but then diverging farther. The overall growth rates of TFP are 1.1% in the US and 0.6% in Canada. It is evident from Figure 1(b) that the difference between TFP growth indexes has increased, contrary to predictions of convergence with CUFTA and NAFTA. Divergence is consistent with observations for most manufacturing industries between the two countries (Eldridge and Sherwood 2001; Bernstein, Harris, and Sharpe 2002).

* Figure 1 *

Figure 2 shows the time trends of the K/L ratios and increasing K/L or capital deepening should raise productivity. The K/L ratio is always lower in Canada than in the US, and increases during the recessions of 1974-75 (oil crisis), 1981-82 (the housing market collapse), and 1991-92 (the recession after Gulf War I) due to decreased employment. The difference in K/L ratios appears to move in waves, almost closing the gap during from 1990 to 1995 but increasing dramatically to all time high by 2003.

* Figure 2 *

The ratio of skilled or non-production labor L_N/L to total labor was higher in Canada until 1991 but then declined to a less than that of the US as seen in Figure 3.

* Figure 3 *

Figure 4 presents the time paths of the exogenous C$/$ exchange rate and the US housing starts, important demand drivers for softwood lumber. The US dollar generally appreciates during the period, lowering the price of imports. US housing starts appear to by cyclical, and increased starts should increase imports as well.

* Figure 4 *

Table 1 presents the results of the ADF unit root tests. Equations with a significant constant or trend are retained. Lag length is selected with the Schwartz Information Criterion (SIC). The DW statistics for most tests are around 2.00 indicating no autocorrelation. Except for US housing starts, all variables in levels exhibit unit roots. The same variables are stationary in first differences. All variables are integrated of order one, I(1). Ordinary least squares (OLS) estimates would be inefficient although unbiased and consistent.

* Table 1 *

Johansen's multivariate cointegration tests for the TFPG Index, capital labor ratio, and skilled to total labor ratio check for cointegration. According to both trace and maximum-eigenvalue statistics, the null hypothesis of no cointegration is accepted in Tables 2 and 3. There is no long run equilibrium between these variables, and each variable has its own stochastic trend. When the variables are non-stationary and not cointegrated, vector auto-regression (VAR) captures the short-run relationships.

* Tables 2 & 3 *

Table 4 presents the results of VAR models with one lag for the TFPG indices. These equations explain about 86% and 71% of the variation in the TFPG indices for the US and Canada. The exchange rate and US housing starts are not significant and are removed from the model. The previous TFPG and the last two dummy variables are significant for the US. Coefficients for the previous TFPG and previous *K/L* are significant and positive for Canada, but none of the dummy variables are significant. While K/L played a positive and significant role in increasing TFP growth in Canada, it exerted no significant influence on the TFP growth in the US. Trade restrictions during the last two periods increased TFP growth in the US while none of the periods influenced TFP growth in Canada.

* Table 4 *

Regarding the difference between the TFPG indices, Johansen's cointegration test reveals that the null hypothesis of no cointegration is rejected according to both the test statistics in Table 5. This result implies there is at least one cointegration relationship, a linear combination or long run equilibrium among the five variables in the estimated equation. There are four stochastic trends in the system moving in four different ways from the long run equilibrium relationship.

* Table 5 *

The appropriate estimation procedure in this situation is the error correction model (ECM) involving a cointegration equation or error correction term. Table 6 indicates that the coefficient for the error correction term is significant at the 1% level. Among the endogenous variables, the negative one year lagged differences in L_N/L helps to close the gap in the TFPG indices. The negative and significant coefficients for the period dummy variables indicate the various trade restrictions have helped to reduce the TFPG gap.

* Table 6 *

Coefficients for the exchange rate and US housing starts are positive, increasing the gap between the two TFPG indices. US dollar appreciation exerts competitive pressure on the US producers to lower cost. Dollar appreciation also makes machinery and equipment imported into Canada more expensive, lowering investment in Canada and productivity. With dollar appreciation, TFP in the US grows at a higher rate, increasing the gap.

Considering imports from Canada, the natural logs of five variables are tested: Canadian imports, exchange rate, US housing starts, the softwood lumber price in Canada, and the US price. Johansen's cointegration test in Table 7 indicates three cointegration relationships according to the trace statistic but two by the maximum eigenvalue test.

* Table 7 *

The two error correction terms are included in the error correction representation. In addition to these five endogenous variables, we include a constant and four period dummy variables as exogenous variables in the ECM. Both error correction terms are significant. Among the endogenous variables, only the previous year's US housing starts have a positive effect on imports.

Canadian softwood lumber imports are balanced between the opposite effects of protection and the demand created by the strong US housing market. The exchange rate and US and Canadian softwood lumber prices have no bearing on imports.

Coefficients for the period dummies indicate that only the early Lumber II period had any effect, decreasing imports. US lumber producers succeeded in stemming imports during Lumber II but not other periods. Trade restrictions since 1992 have been unable to stem imports due to strong US housing demand in the US.

Conclusion

The gap in productivity growth in the sawmill and wood preservation industry in the US and Canada widened contrary to some predictions prior to CUFTA and NAFTA. The various stages of softwood lumber dispute acted differently on the TFP growth. Trade restrictions during the SLA (1996-2000) and Lumber IV (2001-2003) have contributed to increased TFP growth in the US, while trade restrictions have not influenced TFP growth in Canada. Competitive pressures due to imports might have spurred TFP growth in the US. While US housing demand and the exchange rate raised the productivity gap, trade restrictions lowered the gap.

The strong US housing market is the major force increasing softwood lumber imports, while the exchange rate and the other variables are insignificant. Trade restrictions since 1992 have been unable to stem imports due to strong US housing demand.

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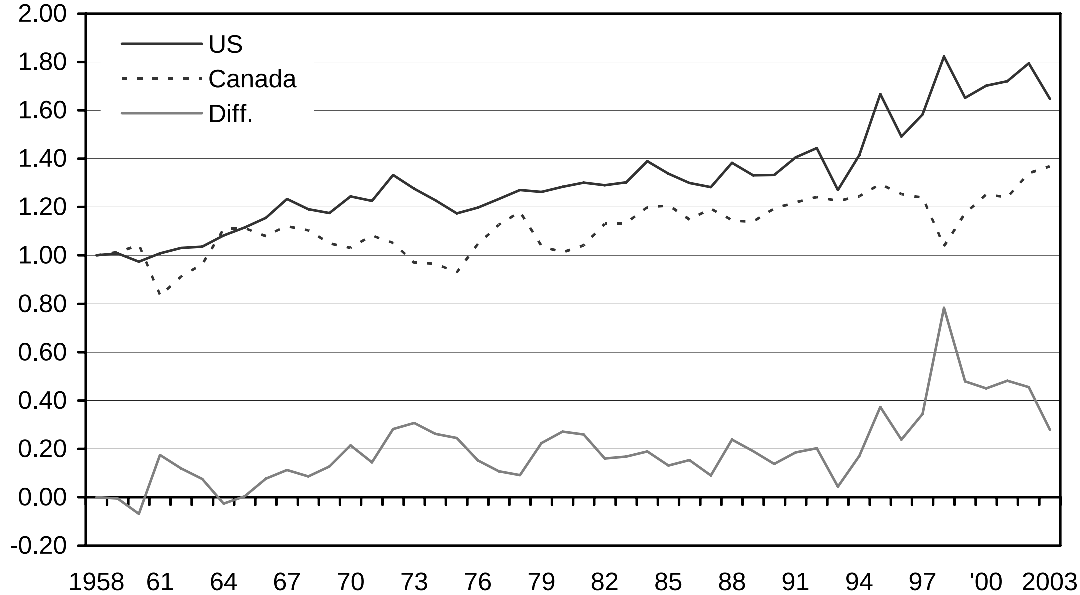

Figure 1. TFP indices

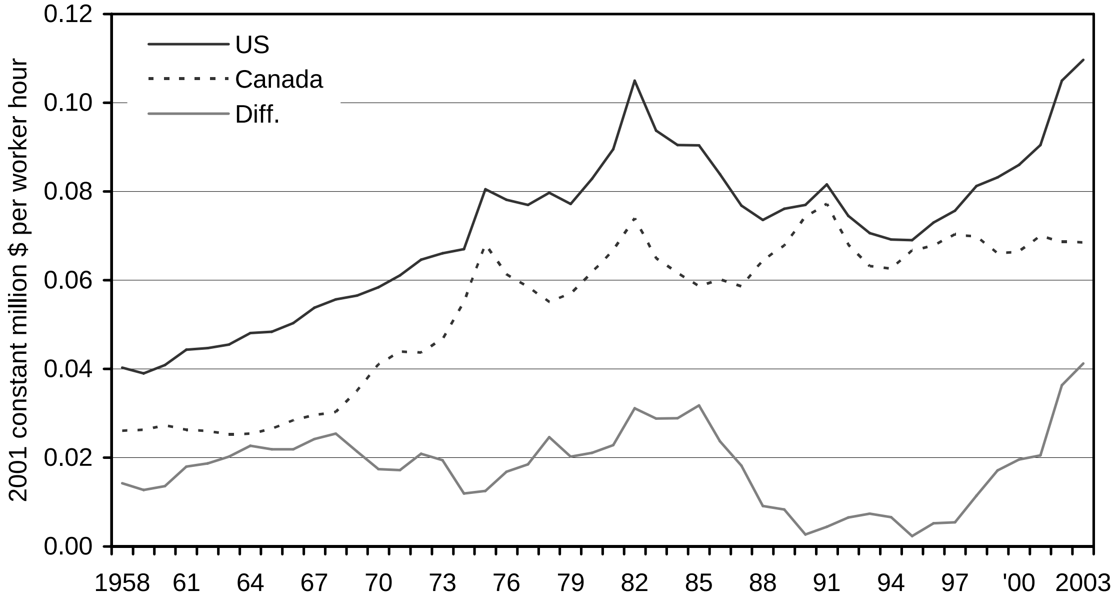

Figure 2. *K/L* ratios

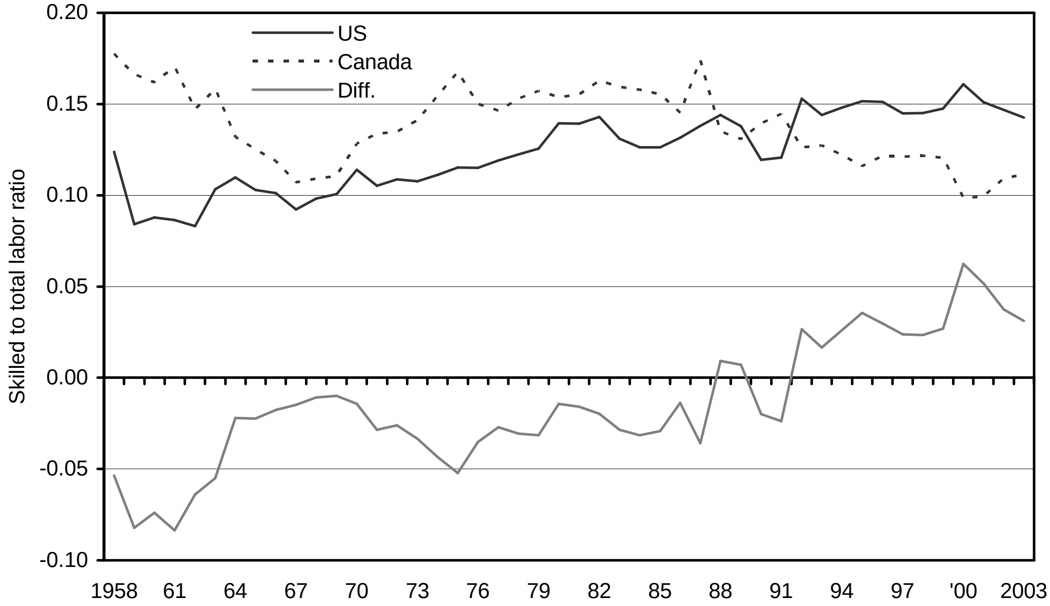

Figure 3. L_N/L **ratios**

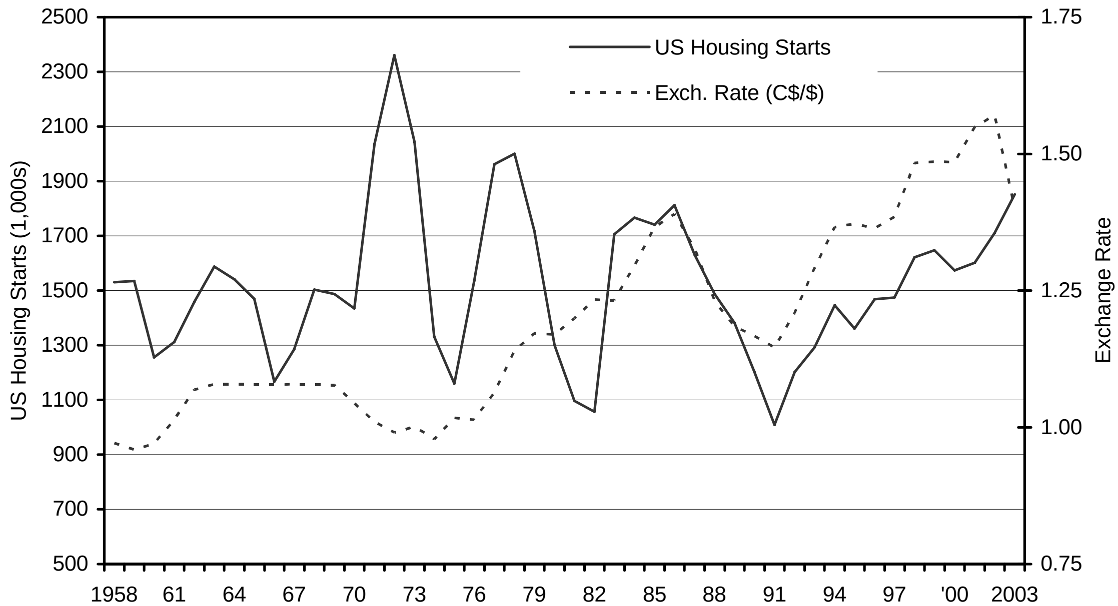

Figure 4. US housing starts and the C$/$ exchange rate

Table 1. Augmented Dickey-Fuller (ADF) tests

Variable	Levels			First-differenced		
	Lags[a]	ADF	DW[b]	Lags	ADF	DW
TFPG, US	0(c)	-1.19	2.24	1(c)	-6.61**	2.09
TFPG, Canada	0(c)	-2.06	1.94	0(c)	-7.01**	2.01
Diff. US – Canada	0(c)	-2.34	2.03	0(c)	-7.43**	2.04
K/L ratio, US	0(c)	-0.54	1.68	0(c)	-5.62**	2.00
K/L ratio, Canada	0(c)	-1.38	1.52	0(c)	-5.12**	1.91
Diff. US – Canada	1(c)	-1.49	2.09	0(c)	-5.06**	2.03
L_N/L ratio, US	0(c)	-1.54	1.68	0(c)	-8.60**	2.04
L_N/L ratio, Canada	0(c)	-2.27	2.29	0(c)	-8.44**	2.04
Diff. US – Canada	1(c,t)	-3.11	1.89	1(c)	-5.83**	2.00
ln(Canada imports)	1(c)	-1.54	2.11	2(c)	-6.40**	2.10
ln(Housing starts, US)	1(c)	-5.25**	1.88	1(c)	-6.23**	2.23
ln(Exch. rate, C$/$)	1(c)	-2.01	1.61	0(c)	-3.33**	1.92
ln(Canada SLPI)	2(c,t)	-2.24	1.89	1(c)	-8.00**	1.99
ln(US SLPI)	0(c)	-1.10	1.78	0(c)	-5.81**	1.49

[a] On the basis of Schwartz Information Criterion (SIC). The letters in parenthesis indicate the exogenous variables included in the equation estimating the ADF statistic, c = constant, and t = trend.
[b] Durbin-Watson statistic.
** and * denote rejection of null hypothesis of a unit root at 1% and 5% significance levels

Table 2. Johansen's multivariate cointegration test for the US TFPG index

Null Hypothesis	Eigen-value	Trace Statistic	5 Percent Critical Value	Max-Eigen Statistic	5 Percent Critical Value	Hypothesized No. of CE(s)
H_o: r = 0	0.26	20.49	29.80	13.41	21.13	None
H_o: r ≤ 1	0.14	7.08	15.49	6.71	14.26	At most 1
H_o: r ≤ 2	0.008	0.37	3.84	0.37	3.84	At most 2

Both Trace test and Max-Eigenvalue test indicate no cointegration at 5%.
Variables included are TFPG index, K/L ratio, and L_N/L for the US.

Table 3. Johansen's multivariate cointegration test for Canada TFPG index

Null Hypothesis	Eigen-value	Trace Statistic	5 Percent Critical Value	Max-Eigen Statistic	5 Percent Critical Value	Hypothesized No. of CE(s)
H_o: r = 0	0.31	22.73	29.80	16.41	21.13	None
H_o: r ≤ 1	0.08	6.33	15.49	3.86	14.26	At most 1
H_o: r ≤ 2	0.05	2.47	3.84	2.47	3.84	At most 2

Both Trace test and Max-Eigenvalue test indicate no cointegration at 5%.
Variables included are TFPG index, K/L ratio, and L_N/L for Canada.

Table 4. VAR model estimates for the TFP growth index

	US TFPG Index		Canada TFPG Index	
Variables	Coefficient	t-value	Coefficient	t-value
TFPG Index $_{t-1}$	0.53***	3.68	0.43**	3.04
K/L ratio $_{t-1}$	2.40	1.48	1.74*	2.13
L_N/L ratio $_{t-1}$	0.30	0.22	-0.33	-0.51
Constant	0.42**	2.44	0.60**	3.15
Dummy (1987-91 = 1)	0.03	0.65	0.04	1.14
Dummy (1992-95 = 1)	0.07	1.19	0.07	1.50
Dummy (1996-00 = 1)	0.16*	2.02	-0.001	-0.03
Dummy (2001-03 = 1)	0.19*	2.25	0.08	1.44
R-squared	0.86		0.71	
ADj. R-squared	0.84		0.66	

***, **, and * indicate significance at 1, 5, and 10% levels.

Table 5. Johansen's multivariate cointegration test for the difference in TFPG

Null Hypothesis	Eigen-value	Trace Statistic	5 Percent Critical Value	Max-Eigen Statistic	5 Percent Critical Value	Hypothesized No. of CE(s)
H_o: r = 0	0.65	90.02*	69.82	46.71*	33.88	None
H_o: r ≤ 1	0.34	43.30	47.86	18.38	27.58	At most 1
H_o: r ≤ 2	0.26	24.92	29.80	13.41	21.13	At most 2
H_o: r ≤ 3	0.19	11.51	15.49	9.16	14.26	At most 3
H_o: r ≤ 4	0.05	2.34	3.84	2.34	3.84	At most 4

*Trace and max-eigenvalue test indicate at least one cointegration equation at 5%
Variables included are diff TFPG, diff K/L, and diff L_N/L, exchange rate, US housing starts

Table 6. ECM for the gap in TFP growth

Variables	Coefficient	t-values
Coint. Eq1. (Error Correction Term) [a]	-0.56***	-4.47
D(Diff. TFPG Index) $_{t-1}$	0.04	0.25
D(Diff. K/L) $_{t-1}$	-0.72	-0.16
D(Diff. L_N/L) $_{t-1}$	-2.70**	-2.69
Constant	-0.42*	-2.16
Exch. Rate	0.29*	1.80
US Housing Starts	0.0001*	1.71
Dummy (1987-91 = 1)	-0.12*	-2.07
Dummy (1992-95 = 1)	-0.22**	-2.61
Dummy (1996-00 = 1)	-0.18*	-2.16
Dummy (2001-03 = 1)	-0.16*	-1.70
R-squared	0.45	
ADj. R-squared	0.28	

[a] Coint. Eq. $= -0.48 + 1.0 * \text{Diff. TFPG}_{(t-1)} +1\ 0.5 * K/L_{(t-1)}^{*} - 5.2 * L_N/L_{(t-1)}^{***}$
*** ** and * indicate significance at 1%, 5%, and 10%

Table 7. Johansen's multivariate cointegration test for Canadian imports

Null Hypothesis	Eigen-value	Trace Statistic	5 Percent Critical Value	Max-Eigen Statistic	5 Percent Critical Value	Hypothesized No. of CE(s)
H_o: r = 0	0.67	112.97*	69.82	48.34*	33.88	None
H_o: r ≤ 1	0.50	64.62*	47.86	30.43*	27.58	At most 1
H_o: r ≤ 2	0.35	34.19*	29.80	19.15	21.13	At most 2
H_o: r ≤ 3	0.24	15.05	15.49	12.14	14.26	At most 3
H_o: r ≤ 4	0.06	2.91	3.84	2.91	3.84	At most 4

*Trace test indicates at least three cointegration equations, while max-eigenvalue tests indicate at least two cointegration equations at 5%
Variables in log form are: Canadian softwood lumber imports, exchange rate, US housing starts, Canadian softwood lumber price index, and US softwood lumber price index

Table 8. ECM for Canadian imports

Variables	Coefficients	t-values
Coint. Eq1. (Error Correction Term 1) [a]	0.31*	1.68
Coint. Eq2. (Error Correction Term 2) [b]	-0.73*	-1.84
D(ln(Canada imports)) $_{t-1}$	-0.33	-1.27
D(ln(Exch. Rate)) $_{t-1}$	0.29	0.48
D(ln(US House Starts)) $_{t-1}$	0.72***	4.05
D(ln(Canada SLPI)) $_{t-1}$	-0.35	-1.54
D(ln(US SLPI)) $_{t-1}$	-0.37	-1.60
Constant	0.09***	4.02
Dummy (1987-91 = 1)	-0.10*	-1.86
Dummy (1992-95 = 1)	0.02	0.35
Dummy (1996-00 = 1)	-0.07	-1.36
Dummy (2001-03 = 1)	-0.09	-1.32
R-squared	0.57	
ADj. R-squared	0.42	

[a] Coint. Eq1. = 8.47+ 1.0*ln(CDN Imports) $_{(t-1)}$ –0.81*ln(US Housing Starts) $_{(t-1)}$ *** - 0.99*ln(Canada SLPI) $_{(t-1)}$ *** -0.08*ln(US SLPI) $_{(t-1)}$
[b] Coint. Eq2. = 1.87+ 1.0*ln(Ex. Rate) $_{(t-1)}$ +0.006*ln(US Housing Starts) $_{(t-1)}$ -0.79*ln(Canada SLPI) $_{(t-1)}$ *** +0.33*ln(US SLPI) $_{(t-1)}$ ***

***, **, and * indicate significance at 1, 5, and 10% levels.