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This study utilizes the Timber Assessment Market Model (TAMM) to examine the differences in Canadian softwood lumber market forecasts arising from econometric versus activity analysis supply curves. A restricted profit function approach is applied to three lumber producing regions using the most recent data available on costs, prices, and output to estimate the econometric supply curve along with factor demands. The corresponding own- and cross-price elasticities along with the elasticities of substitution are estimated and compared to past studies. An activity analysis supply curve is presented utilizing two production technologies. Market forecasts for the period 1996-2005 are estimated via the TAMM model. A comparison of TAMM solutions for a base case and three exogenous shock scenarios is presented. Similar price and quantity values are obtained in the historic period, while the activity analysis provide a much more volatile reaction to exogenous stimuli.

Effects of Econometric and Activity Analysis Derived Supply Curves on Canadian Sawmilling Industry Market Forecasts

by

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Effects of Econometric and Activity Analysis Derived Supply Curves on Canadian Sawmilling Industry Market Forecasts

INTRODUCTION

The Forest and Rangeland Renewable Resources Planning Act (RPA) of 1974, as amended by the National Forest Management Act of 1976, directs the Secretary of Agriculture to prepare a Renewable Resource Assessment each decade and a Renewable Resource Program every 5 years (Haynes et al., 1995). The basis for this assessment is that good policy requires good information. This information includes both explanations of past economic activity as well as forecasting future trends in supply and demand for forest products. For the past twenty years the primary vehicle for generating this information has been the Timber Assessment Market Model (TAMM). TAMM is a spatial non-linear optimization model of the North American forest products market with nine U.S. supply regions and six U.S. demand regions. In recognition of the interwoven nature of U.S and Canadian forest products markets, TAMM also includes three Canadian supply regions and one Canadian demand region(Adams and Haynes, 1996).

In the past, all supply and demand curves for solidwood products have been econometrically estimated in TAMM. In the most recent version of TAMM, the North American pulp and paper industry was modeled using the North American Pulp and Paper Model (NAPAP). NAPAP is a joint product of the United States Forest Products Laboratory and the Canadian Forest Service using process-specific activity analysis representations of supply. An activity analysis supply function is a step function with each step being horizontal, representing constant cost of production for a specific technology of output. These constant costs of production are in the form of input/output coefficients. TAMM and NAPAP have been linked so that each year's solution, or iteration, first solves the solid wood sector in TAMM, then takes residues and uses them in the NAPAP solution. The forest growth model in TAMM is then adjusted by the pulpwood harvest predicted by NAPAP, and another iteration begins.

In another partnership between the U.S.F.S. Forest Products Laboratory and the Canadian Forest Service, a solid wood companion to NAPAP called NASAW is currently being developed. NASAW will also use process-specific activity analysis to derive its supply curves. NASAW and NAPAP will then be able to be solved simultaneously thereby eliminating the need for the iteration involved in the current TAMM/NAPAP solution.

The primary purpose for the proposed NAPAP/NASAW model is for policy analysis and future RPA assessments. As can be expected there is much speculation on how this new NAPAP/NASAW model's forecast will compare to the traditional TAMM forecasts. This study examines the differences arising from the two supply forms in the context of the TAMM model. In addition to a base case comparison, three forms of exogenous shocks will be modeled to determine the reaction of each form of supply curve; tariffs on Canadian exports of lumber to the U.S., harvest limits in Canada, and exchange rate forecasts. While this study will by no means answer all questions about the comparative performance of the two model forms, it will provide some insight into potential concerns in a practical context.

The next section describes the derivation of the two supply forms. The third section presents the results of the comparative simulations. The final section contains a discussion of the results and concluding remarks.

CHAPTER 1

AN ECONOMETRIC ANALYSIS OF OUTPUT SUPPLY AND INPUT DEMAND IN THE CANADIAN SOFTWOOD LUMBER INDUSTRY

Introduction

In the ongoing debate over tariffs and other restrictions in the Canadian-US softwood lumber trade, economic analysis of potential output, price and trade responses has played an important role in the negotiation process (Kalt, 1988). A critical element in this analysis is knowledge of the price responsiveness of Canadian softwood lumber output, the own- and cross-price elasticities of supply and input factor demand (Adams et al. 1986, Chen et al. 1988, Myneni et al. 1994). Over the past two decades production characteristics of the Canadian lumber industry have received considerable attention from economists. All but a few of these studies have employed cost function approaches, assuming (in some cases arguing) that output is exogenous and fixed. As a result, while these studies have given much insight into factor substitution in the sector, they have not extended our understanding of output price responsiveness. At the same time, the utility of those few studies directly addressing lumber supply behavior is limited. In some cases they fail to examine all of the lumber producing regions in Canada, most employ estimation samples that do not include data from the 1990's, some fail to meet behavioral conditions necessary for the approaches employed and some report widely divergent results.

The present study offers an analysis of Canadian softwood lumber supply designed to fill a portion of this information gap. It employs a restricted profit function approach applied to three lumber producing regions using the most recent data available on costs, prices, and output. Empirical findings are converted into forms that allow direct comparison with past studies. The discussion proceeds in the next section with a summary and characterization of past studies. The empirical model and data are then presented followed by a discussion and analysis of results with contrasts to previous work.

Past Studies

Duality studies of the Canadian lumber industry have employed both cost and profit function forms. In most cases, data for the industry are from Statistics Canada for

Table 1.1 Past duality studies of the Canadian lumber industry

Study	Functional Form[1]	Outputs[2]	Inputs[3]	Data	Regions[4]
Profit Function					
Adams & Haynes (1996)	NQ	L	WO (K)	56-89	BIE
Baker (1989)	TLD3	L*XC	WLK	63-82	C
Baker (1990)	TLD3	LC	WLEM	62-86	BIQO
Bernard etal. (1997)	SNQ	L	V	65-90	QO
Constantino & Haley (1988)	TL	LC	WL (KQT)	57-81	B
Cost Function					
Banksota (1985)	TL	L	WLEK	1978	A
Constantino & Townsend (1986)	TL	L	(WLEKT)	62-83	C
Martinello (1985)	TL	L*	WLEK(T)	63-82	C
Martinello (1987)	TL	L	WLK(T)	63-79	BI
Meil & Nautiyal (1988)	TL	O	WLE(KT)	68-84	BIQO
Meil etal. (1988)	TLD2	O	WLE(KT)	48-83	I
Nautiyal & Singh (1985)	TL	L*	WLEK	65-81	C
Singh & Nautiyal (1986)	TLD2	L*	WLEK	55-82	C

1 NQ is normalized quadratic, SNQ is symmetric normalized quadratic, TL is translog, TLD2 is translog with partial adjustments, TLD3 is translog with endogenous adjustments

2 L is softwood lumber (* indicates hardwood content included), X is lumber produced for export, C is chips, O is all ouputs.

3 W = roundwood, L is labor, E is energy, K is capital stock, Q is wood quality, V is variable inputs,T is technology level (not an input), () indicates quasi-fixity of an input.

4 A is Alberta, B is BC Coast, C is Canada, E is East, I is BC Interior, O is Ontario, Q is Quebec.

standard industrial classification code (SIC) 2512, sawmills and planing mills. Table 1.1 lists studies of the Canadian lumber industry published since 1980 indicating functional form, outputs and inputs with quasi-fixed factors in brackets, the data sample used and regions considered. Output is primarily treated as softwood lumber (ignoring chips) or a chip and lumber composite. Inputs include roundwood, labor, energy, and capital stock. Most studies include a time trend to represent technology as well.

Five prior studies have employed profit function approaches. Adams and Haynes (1996) used a normalized quadratic profit function in their estimation of supply for three Canadian regions, but estimated only the supply equation. Symmetry was therefore not imposed and curvature could not be checked. Baker (1989) reestimated the Bernstein (1988) model with a corrected data set for all of Canada. This model utilized a translog profit function with endogenous capital stock adjustment and reported elasticities for three lengths-of-run to illustrate the effects of adjustment over time. Reported factor demand elasticities are much higher than other studies and curvature properties of the model were not reported. Baker (1990) applies the Bernstein (1988) model to the British Columbia Coast, British Columbia Interior, Quebec, and Ontario. Curvature properties of the model were not reported and elasticities were widely divergent and far above any others existing in the literature. Bernard et al. (1997) used a symmetric normalized quadratic profit function to model lumber in Quebec and Ontario. They considered air-dried and kiln-dried lumber independently, however all inputs were included in a single "variable input" category and capital stock was fixed. Constantino & Haley (1988) estimated a translog profit function for the British Columbia Coast. Wood quality was included as a quasi-fixed input to test whether declining wood quality explained the lack of growth in productivity. While the estimated supply and factor demand curves had the expected slopes, the full set of second order curvature properties were violated at 60 percent of observations.

The majority of previous studies have estimated cost functions. While these studies provide insights into some aspects of factor substitution, output is treated as exogenous and thus we learn nothing about supply behavior or unconditional factor response to price changes. Banksota et al. (1985) applied a translog cost function to cross sectional data from a 1978 sample of 83 Alberta sawmills. Curvature properties were not discussed and results could be biased by economic events unique to the sample year. Constantino & Townsend (1986) compared the usual system of factor demands for a given level of output, labeled an instantaneous adjustment (IA) model, to a quasi-fixed (QF) model which jointly estimated factor demands and an operating rate function. Constant returns to scale for the industry was assumed and curvature was not checked. The QF model outperformed the IA model in goodness-of-fit statistics, however, the sawmilling IA model showed signs of severe autocorrelation. Martinello (1985) employed a translog cost function to estimate factor demand equations for the industry at the three digit SIC level (SIC 251) for all Canada. This classification includes shingles and shakes, and curvature properties of the model were satisfied at the means of the data. Martinello (1987) employed the same basic technique as Martinello (1985), but for the industry at the four digit SIC level (SIC 2512) for the BC Coast and BC Interior. Curvature properties of the model were satisfied at the means of the data. Meil and Nautiyal (1988) developed a translog cost function model which separated Canada into four regions; BC Coast, BC Interior, Ontario, and Quebec, and also classified firms into four separate size classes depending on the number of employees. Meil et al. (1988) applied a translog cost function to the BC Interior, incorporating a partial adjustment mechanism for capital stock in the factor demand relations. Nautiyal & Singh (1985) estimated a translog cost function for Canada as a whole using as output a composite of softwood and hardwood lumber. Singh & Nautiyal (1986) estimated a translog cost function applying a cross-stock adjustment process to factor demands as a test for instantaneous adjustment in the long-run. As a group these studies are all at least ten years old with databases extending at best into the early 1980's.

Findings of past studies will be presented and compared to the current study in the results section of this paper.

The Empirical Model and Data

In the present study, the Canadian softwood lumber industry is divided into three producing regions; the British Columbia Coast (BCC), British Columbia Interior and Alberta (INT), and the rest of Canada (EAST). One output, a composite of softwood lumber and chips (treated as a byproduct produced in fixed proportions to lumber) is considered. Variable inputs include softwood roundwood, labor, and other materials. Capital stock is treated as quasi-fixed and technology is represented by a time trend. The industry is assumed to be competitive with producers attempting to maximize profits given endogenous prices of lumber and wood and exogenous prices of labor and other materials.

We approximate the industry's indirect profit function by means of a normalized restricted quadratic form, as given in Equation 1.1.[1]

$$\tilde{\pi} = \alpha_0 + \sum_i \beta_i \frac{p_i}{p_n} + \frac{1}{2}\sum_i \sum_j \beta_{ij} \frac{p_i}{p_n}\frac{p_j}{p_n} + \sum_i \beta_{ik} \frac{p_i}{p_n} k \qquad [1.1]$$
$$+ \sum_i \beta_{it} \frac{p_i}{p_n} t + \beta_k k + \beta_t t + \beta_{kt} kt + \beta_{kk} k^2 + \beta_{tt} t^2$$

Applying Hotelling's Lemma, the supply curve and negatives of the factor demand curves are:

$$\frac{\partial \tilde{\pi}}{\partial \frac{p_i}{p_n}} = x_i = \beta_i + \sum_j \beta_{ij} \frac{p_i}{p_n} + \beta_{ik} k + \beta_{it} t \qquad \text{for i,j=o,w,l} \qquad [1.2]$$

Where o is output composite of lumber and chips (the latter assumed to be produced in fixed proportion to lumber), w is softwood roundwood, l is labor, n is other materials, k is capital stock, and t is level of technology. P_i's are prices and x_i's are quantities with sets i and j consisting of o,w,and l.

To satisfy all the properties of a well-behaved profit function $\tilde{\pi}$ must be:

non-decreasing in output price	$\beta_{ii} \geq 0$	for i=o	[1.3]
non-increasing in input prices	$\beta_{ii} \leq 0$	for i=w,l	[1.4]
linear homogeneous in all prices	$\tilde{\pi}(tp_i) = t\tilde{\pi}(p_i)$	for i=o,w,l	[1.5]
quasi-convex in all prices	β positive semidefinite		[1.6]
symmetric in all prices	$\beta_{ij} = \beta_{ji}$	for i ,j=o,w,l	[1.7]

[1] See Lau (1978) and Chambers (1988) for treatments of the properties of the normalized profit function.

The empirical model consists of Equations 1.1 and 1.2 with symmetry imposed and normally distributed stochastic disturbances of mean zero and constant variance appended. Dummies were also included in supply and wood demand equations in BCC and INT to represent the effects of labor strikes in British Columbia in 1975 and 1986.

Time series data including annual observations from 1962 to 1995 for each of the three Canadian regions were used in the estimation of the model. Data for prices and quantities of output, roundwood and labor were obtained from Statistics Canada. Capacity as described in Adams and Haynes (1996) was used as a proxy for capital stock. The price index for other materials was a national producers' selling price index. Further discussion of the data can be found in Appendix 1.

Relations for the three regions were estimated separately using nonlinear three stage least squares with a set of instruments including exogenous variables together with the lagged values of all endogenous variables for all regions.[2] Durbin Watson statistics from initial estimates showed signs of autocorrelation in all regions. As a result first order autocorrelation terms (ρ) were added to each equation.

Results

Parameter estimates and asymptotic t-ratios along with statistics for the equations within each system can be found in Table 1.2. For the quadratic functional form, the

[2] Coefficient estimates were developed using the SHAZAM econometrics computer program. It should be noted that for the estimation of the EAST region the inclusion of only regional instruments resulted in an elasticity over 3 times greater than that estimated using all regions instruments. This is due to poor correlation between the regional instruments and the endogenous prices.

Table 1.2. Estimated coefficients

Coefficient	BCCoast	Interior	East	Coefficient	BCCoast	Interior	East
α_0	-100.56 (-3.00)	23.49 (2.11)	10.33 (2.37)	β_{KT}	-0.04 (-0.57)	-2.62 (-2.24)	-0.47 (-1.45)
β_O	-2.32 (-1.52)	-2.93 (-4.48)	-0.32 (-0.46)	β_{TT}	0.00 (-0.27)	0.59 (2.53)	0.05 (1.15)
β_W	8.77 (2.12)	13.63 (2.74)	0.10 (0.05)	β_{KK}	-3.42 (-2.76)	3.27 (2.26)	1.03 (1.72)
β_L	0.51 (0.72)	-5.17 (-1.32)	-8.33 (-3.43)	β_{D1}	-0.93 (-6.54)	-1.33 (-4.14)	
β_{OO}	0.66 (4.96)	0.89 (4.39)	0.80 (3.13)	β_{D2}	-0.53 (-3.71)	-1.27 (-3.93)	
β_{WW}	1.88 (2.82)	1.59 (3.09)	3.08 (3.14)	β_{D3}	1.77 (7.93)	2.04 (4.35)	
β_{LL}	0.30 (4.63)	0.35 (1.63)	0.06 (0.16)	β_{D4}	0.86 (3.72)	2.19 (4.67)	
β_{OW}	-0.98 (-4.11)	-1.05 (-3.67)	-1.00 (-2.31)	β_{D5}	0.33 (6.99)	0.31 (3.71)	
β_{OL}	-0.11 (-2.60)	-0.14 (-2.57)	-0.20 (-1.67)	β_{D6}	0.16 (3.51)	0.26 (3.14)	
β_{WL}	0.13 (1.15)	-0.08 (-0.64)	0.29 (1.04)	ρ_π	0.80 (13.97)	1.25 (18.51)	0.44 (4.00)
β_{OK}	0.90 (2.86)	1.09 (5.79)	0.16 (0.53)	ρ_O	0.76 (11.23)	0.76 (12.19)	1.02 (28.18)
β_{WK}	-2.08 (-3.12)	-2.02 (-5.74)	-0.21 (-0.35)	ρ_W	0.89 (23.73)	0.99 (44.87)	1.03 (82.04)
β_{LK}	-0.37 (-2.80)	-0.23 (-2.92)	-0.01 (-0.09)	ρ_L	1.02 (71.39)	0.96 (36.28)	0.98 (165.21)
β_{OT}	0.02 (0.93)	-0.09 (-1.37)	0.15 (0.19)	R^2_π	.58	.87	.86
β_{WT}	-0.10 (-1.92)	0.22 (1.05)	0.03 (1.51)	R^2_O	.56	.98	.95
β_{LT}	0.05 (2.11)	0.13 (2.04)	0.10 (1.51)	R^2_W	.65	.98	.95
β_T	0.26 (0.36)	3.36 (1.40)	0.11 (0.26)	R^2_L	.86	.82	.76
β_K	35.67 (2.81)	-13.10 (-2.31)	-2.73 (-1.47)				

Note: Asymptotic t-statistics in parentheses. β_{ij} is a coefficient. ρ_i is a first order autocorrelation correction coefficient. The R^2 is the pseudo R^2 calculated as the square of the correlation coefficient between the actual and predicted values. O is output, W is roundwood input, L is labor, K is capital stock, T is technological level, D is a dummy. The dummies are for British Columbia labor strike years of 1975 and 1986 in the output supply and two factor demand equations.

Hessian matrix of second order partial derivatives contains only constants (the estimated coefficients) and hence its curvature properties are global. Eigenvalues of the Hessian for each system were checked and found to be non-negative in all cases. Thus the Hessians are positive semi-definite and the functions convex at all points. Marshallian (output adjusted) own-price and cross-price elasticities are given by Equation 1.8. Values were calculated at the sample means and appear in Table 1.3 together with ratios of the elasticities to their estimated standard errors.[3]

$$e_{ij} = \beta_{ij} \frac{(p_j/p_n)}{x_i} \qquad \text{for i,j=o,w,l} \qquad [1.8]$$

All elasticities were found to be in the inelastic range. Output supply was most responsive to input and output prices in BCC and least responsive in INT. Wood price changes had a greater effect on output level than labor price in all three regions. Cross-price elasticities were small in all regions suggesting low substitutability between factors. Factor demands in BCC were most responsive to changes in their own prices. The INT region showed a limited response of wood demand to wood price, yet labor demand was fairly responsive to labor price. The situation in the EAST is the opposite with a low own-price elasticity of labor demand but a moderate wood demand response to own-price changes.

Table 1.3. Marshallian elasticities

	BCC	INT	EAST
e_{OO}	0.84	0.38	0.65
	(3.28)	(1.99)	(1.76)
e_{OW}	-0.46	-0.13	-0.24
	(-2.84)	(-1.90)	(-1.57)
e_{OL}	-0.11	-0.06	-0.09
	(-2.48)	(-1.79)	(-1.33)
e_{WO}	0.78	0.26	0.47
	(3.01)	(1.90)	(1.57)
e_{WW}	-0.55	-0.12	-0.42
	(-2.30)	(-1.81)	(-1.78)
e_{WL}	-0.08	0.02	-0.08
	(-1.14)	(0.62)	(-0.94)
e_{LO}	0.42	0.24	0.34
	(2.22)	(2.17)	(1.57)
e_{LW}	-0.18	0.04	-0.15
	(-1.10)	(0.63)	(-1.01)
e_{LL}	-0.80	-0.58	-0.05
	(-3.90)	(-1.59)	(-0.16)

Note: ratios of the elasticities to their estimated standard errors appear in parentheses. O is output, W is roundwood input, L is labor

[3] Variances for Marshallian elasticities are calculated as per Miller et al. (1984) because the elasticity consists of a ratio of stochastic variables

A comparison of the elasticities with those from prior studies is given in Table 1.4. Estimates of unconditional elasticities are limited, the largest number coming from

Table 1.4. Comparison of current and past study Marshallian elasticities

Study	e_{OO}	e_{OW}	e_{OL}	e_{WO}	e_{WW}	e_{WL}	e_{LO}	e_{LW}	e_{LL}
Canada									
Baker (1989)	0.63	-0.17	-0.57	0.01	-2.01	-0.90	0.44	-3.18	-2.30
BCC									
Adams & Haynes (1996)	0.94		-0.99						
Baker (1990)	14.30	-8.80	-4.40	14.00	-8.50	4.50	18.40	11.80	-6.80
Constantino & Haley (1988)	1.11	-0.93	-0.39	1.50	-1.43	-0.48	1.42	-1.10	-0.74
Current Study	**0.84**	**-0.46**	**-0.11**	**0.78**	**-0.55**	**-0.08**	**0.42**	**-0.18**	**-0.80**
INT									
Adams & Haynes (1996)	0.45		-0.26						
Baker (1990)	3.70	-2.40	-1.20	4.40	-3.00	2.10	4.60	4.40	-2.00
Current Study	**0.38**	**-0.13**	**-0.06**	**0.26**	**-0.12**	**0.02**	**0.24**	**0.04**	**-0.58**
EAST									
Adams & Haynes (1996)	0.49		-0.41						
Baker (1990), Quebec	1.90	-2.30	-1.10	3.00	-3.70	1.30	3.90	3.70	-2.30
Baker (1990), Ontario	11.90	-10.20	-3.70	13.50	-11.60	4.40	12.40	11.10	-4.40
Bernard et al. (1997)	1.03				-0.19				-0.19
Bernard et al. (1997)	2.27				-0.39				-0.39
Current Study	**0.65**	**-0.24**	**-0.09**	**0.47**	**-0.42**	**-0.08**	**0.34**	**-0.15**	**-0.05**

Note: O is output, W is roundwood input, L is labor

the two studies by Baker (1989 and 1990). The Baker (1990) study, however, yielded elasticities far higher than any reported elsewhere in the literature for either the U.S. or Canada. Apart from the Baker (1990) study, there is some concurrence among studies on own-price elasticities but wide divergence on cross-price elasticities. In all regions, Adams and Haynes (1996) report own-price supply elasticities that are similar to those of the present study, yet find output to be far more responsive to labor price changes. In the BCC, Constantino and Haley (1988) also found a supply elasticity similar to the present study, yet with the exception of own-price labor elasticity factor demands are much more responsive to all price stimuli. Bernard et al. (1996) found supply to be elastic with respect to its price, yet the variable factor demand elasticity is closer to the results of the present study.

The largest number of past studies of the Canadian industry have employed cost functions. In all cases output was treated as exogenous.[4] Because output is predetermined, when a factor price changes the only way for the demand for the factor to change is if firms change use of a substitute.

Hicksian (constant output) elasticities (e^c_{ij}) for the response of the ith factor demand to a change in the price of factor j can be determined from Marshallian elasticities as:

$$e^c_{ij} = e_{ij} - \frac{e_{oj} * e_{io}}{e_{oo}} \qquad \text{for i,j=w,l} \qquad [1.9]$$

where o represents output.

Hicksian demand elasticities along with ratios to their approximate standard errors[5] can be found in Table 1.5.

A comparison of the Hicksian demand elasticities from the current and

Table 1.5. Hicksian elasticities

	BCC	INT	EAST
e_{WW}	-0.12	-0.03	-0.25
	(-1.78)	(-1.41)	(-2.39)
e_{WL}	0.02	0.06	-0.01
	(0.76)	(2.44)	(-0.17)
e_{LL}	-0.75	-0.55	-0.01
	(-4.51)	(-1.55)	(-0.02)
e_{LW}	0.05	0.13	-0.02
	(0.76)	(2.44)	(-0.17)

Note: ratios of the elasticities to their estimated standard errors appear in parentheses. W is roundwood input, L is labor

[4] This is not necessary. Chambers (1982) presents a method for treating output as jointly dependent in estimating the cost function.

[5] Variances for Hicksian elasticities are calculated based on the assumption that all elements of the elasticity other than the estimated parameters are nonstochastic.

Table 1.6. Comparison of current and past study Hicksian elasticities

Study	Hicksian Elasticities			
	e^c_{WW}	e^c_{WL}	e^c_{LL}	e^c_{LW}
Canada				
Baker (1989)	*-2.01*	*-0.89*	*-1.91*	*-3.06*
Constantino & Townsend (1986)	-0.30		-1.14	
Martinello (1985)	-0.37	0.00	-0.24	0.00
Nautiyal & Singh (1985)	-0.44	0.14	-0.48	0.30
Singh & Nautiyal (1986)	-0.69	0.77	-0.86	0.13
BCC				
Baker (1990)	*0.12*	*8.81*	*-1.14*	*23.12*
Constantino & Haley (1988)	*-0.17*	*0.05*	*-0.24*	*0.09*
Current Study	**-0.12**	**0.02**	**-0.75**	**0.05**
Martinello (1987)	-0.07	0.04	-0.31	0.14
Meil & Nautiyal (1988)	-0.08	0.08	-0.27	0.19
INT				
Baker (1990)	*-0.15*	*3.53*	*-0.51*	*7.38*
Current Study	**-0.03**	**0.06**	**-0.55**	**0.13**
Banksota (1985)	-0.07	0.03	-0.36	0.02
Martinello (1987)	-0.15	0.01	-0.32	0.03
Meil & Nautiyal (1988)	-0.18	0.14	-0.33	0.26
Meil etal. (1988)	-0.11	0.23	-0.31	0.12
EAST				
Baker (1990), Quebec	*-0.03*	*8.60*	*-0.54*	*21.73*
Baker (1990), Ontario	-0.07	3.04	-0.04	8.42
Current Study	**-0.25**	**-0.01**	**-0.01**	**-0.02**
Meil & Nautiyal (1988), Quebec	-0.17	0.18	-0.44	0.25
Meil & Nautiyal (1988), Ontario	-0.09	0.13	-0.42	0.20

Note: W is roundwood input, L is labor. Numbers in Italics are not calculated in the original study.

prior studies is given in Table 1.6. Numbers in italics are calculated for this comparison and did not appear in the original papers. With some exceptions, (and apart from the Baker studies) estimates from the present study fall in the range of results from past work. In the BCC, the present study finds labor to be more sensitive to changes in labor price and less sensitive to changes in wood price. Estimates for the INT are in line with prior studies with a slightly more elastic labor demand and inelastic wood demand. In the EAST, the labor own-price and cross price elasticities are lower than prior estimates.

Because wood is such a large portion of the total cost of lumber output, and (as found in Table 1.4) there is limited substitutability with labor, there is a large output effect in lumber.[6] Table 1.7 presents output adjustment effects for the three Canadian regions. In the BCC, for example, if the price of softwood roundwood were to rise 1% there would be only a .12% reduction in quantity demanded due to the substitution effect (e^c_{ww}), and a .44% reduction due to the output effect. Prior studies that have used cost functions in their analysis would have reported the .12% change only. The use of conditional factor demand elasticities would thus lead to an underestimate of roundwood demand response to a change in roundwood price or stumpage royalties.

Table 1.7. Output adjustment effect

	BCC	INT	EAST
e_{WW}	-0.43	-0.09	-0.17
e_{WL}	-0.10	-0.04	-0.06
e_{LL}	-0.23	-0.08	-0.13
e_{LW}	-0.05	-0.04	-0.05

Note: W is roundwood input, L is labor

As an indicator of factor substitution, this study computes the Morishima elasticity of substitution (MES) rather than the Allen-Uzawa partial elasticity of substitution (AES) as has been customary in earlier cost function approaches. The MES "turns out to be a much more economically relevant concept than the Allen elasticity since it is an exact measure of how the i,j input ratio responds to a change in w_j " [Chambers, 1988]. Blackorby and Russell (1989) point out that MES has a natural

[6] Combining Tables 1.3 and 1.5 it is possible to estimate the output adjustment effect on own- and cross-price factor demand responses. Output adjustment effect here is measured as e_{ij}-e^c_{ij}, the difference between the Marshallian elasticity (Table 1.3) and Hicksian elasticity (Table 1.5).

asymmetry, unlike the AES, since its value depends on whether it is the price of factor i or factor j that is changing.

Morishima elasticities of substitution were calculated as:

$$\sigma_{ij}^{m} = e_{ij}^{c} - e_{jj}^{c} \qquad \text{for i,j=w,l} \qquad [1.10]$$

Results are presented in Table 1.8 along with ratios of the elasticities to their approximate standard errors. The elasticities indicate wood and labor are substitutes (MES>0) in the BCC and INT, yet in the EAST complementary (MES<0) behavior is found if the price of labor changes. The elasticity of substitution estimates in the EAST highlight the asymmetry of the MES. The AES elasticity would indicate wood and labor are complements based on the negative Hicksian cross-price elasticities[7] however the MES finds them to be substitutes if the wood price changes and complements for labor price changes.

Table 1.8. Morishima elasticity of substitution

	BCC	INT	EAST
σ_{WL}^{M}	0.77	0.61	-0.01
	(4.71)	(1.74)	(-0.02)
σ_{LW}^{M}	0.18	0.15	0.23
	(2.61)	(3.18)	(1.23)

Note: ratios of the elasticities to their estimated standard errors appear in parentheses. W is roundwood input, L is labor

A comparison of elasticities of substitution in the current and prior studies can be found in Table 1.9. AES estimates from prior studies have also been included. Regional results from the present study fall in a relatively narrow range (.18, .15, .23) when the price of wood changes. The EAST, however, is unresponsive to changes in labor price while the BCC and INT are more responsive to changes in labor price.

[7] This is because $AES = e_{ij}^{c}/S_j$ where S_j is factor j's share of total cost and e_{ij}^{c} is sign symmetric.

Table 1.9. Comparison of current and past study elasticities of substitution

Study	MES		AES
	σ^{m}_{WL}	σ^{m}_{LW}	σ^{a}_{LW}
Canada			
Baker (1989)	*1.02*	*-1.05*	
Martinello (1985)	*0.24*	*0.37*	0.00
Nautiyal & Singh (1985)	*0.62*	*0.74*	0.60
Singh & Nautiyal (1986)	*1.63*	*0.82*	0.24
BCC			
Baker (1990)	*9.95*	*23.01*	
Constantino & Haley (1988)	*0.29*	*0.26*	
Current Study	**0.77**	**0.18**	
Martinello (1987)	*0.35*	*0.21*	0.20
Meil & Nautiyal (1988)	*0.36*	*0.27*	0.28
INT			
Baker (1990)	*4.04*	*7.53*	
Current Study	**0.61**	**0.15**	
Banksota (1985)	*0.39*	*0.09*	0.06
Martinello (1987)	*0.34*	*0.17*	0.05
Meil & Nautiyal (1988)	*0.47*	*0.44*	0.42
Meil etal. (1988)	*0.54*	*0.23*	0.36
EAST			
Baker (1990), Quebec	*9.14*	*21.76*	
Baker (1990), Ontario	*3.08*	*8.49*	
Current Study	**-0.01**	**0.23**	
Meil & Nautiyal (1988), Quebec	*0.62*	*0.42*	0.46
Meil & Nautiyal (1988), Ontario	*0.56*	*0.29*	0.35

Note: MES is Morishima elasticity of substitution, AES is Allen-Uzawa partial elasticity of substitution. W is roundwood input, L is labor. Numbers in italics are not calculated in the original study

Econometric studies have typically presented elasticities calculated at the sample mean only. In a data set containing several variables moving in definite trends over time it is possible that the elasticities obtained from the data may be characterized by trends as well. Figures 1.1 through 1.3 show the own price supply and demand elasticities for the three regions for the period 1963-1995. It is evident from the graph that the BCC supply and wood demand relations have become more elastic, while the INT and EAST have become less elastic. Labor own-price elasticities all are moving slightly upward. The

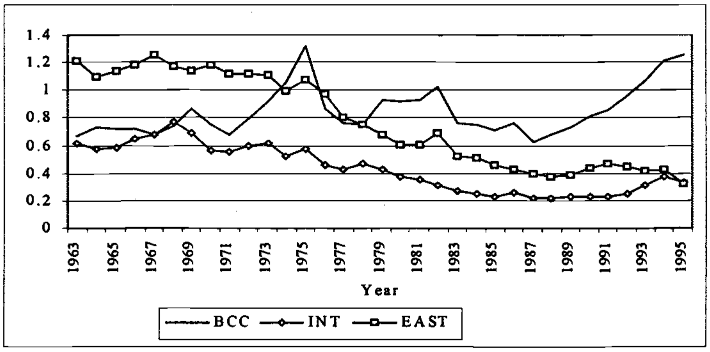

Figure 1.1. Lumber own-price supply elasticities, 1963-1995

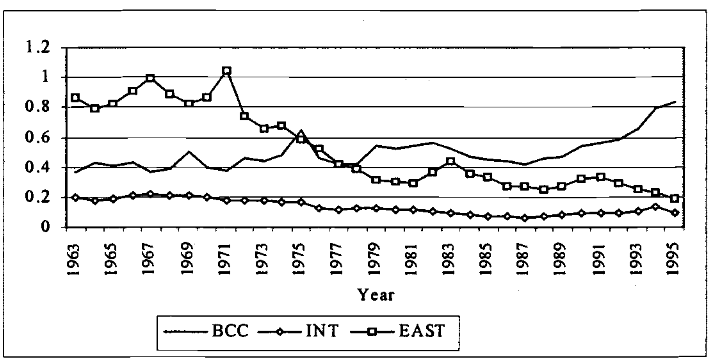

Figure 1.2. Roundwood own-price demand elasticities, 1963-1995

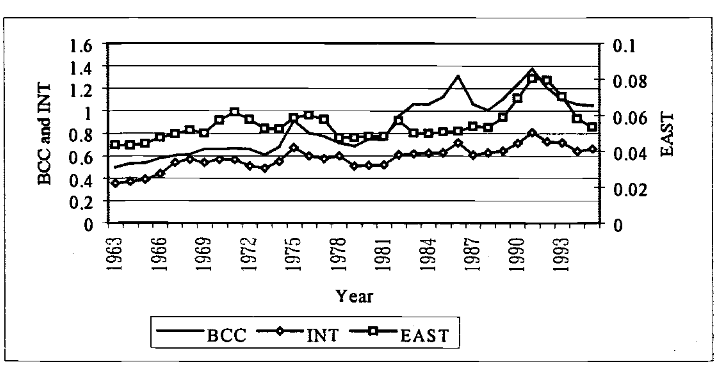

Figure 1.3. Labor own-price demand elasticities, 1963-1995

statistical significance of these trends was examined by fitting a simple time trend regression line through the elasticity data via ordinary least squares (OLS). Results of the OLS trend regressions are listed in Appendix 2. All slope coefficients were found to be significant at the 99% level with the exception of the BCC own price supply elasticity, which was significant at the 95% level.

One possible explanation for the disparity in elasticity trends of output supply and wood demand in the three regions is the declining softwood roundwood supply in the BCC.[8] This would result from a shift in supply in the BCC log market to the left in price-quantity space thereby raising the price of roundwood and lowering the quantity demanded. Together these actions (P_w up, Q_w down) would cause the own-price wood demand elasticity to rise in the present model.[9] This reduction in log demand would correspond to a reduction in supply at the softwood lumber market level. Demand at this market level can be considered to be national in scope and include U.S. demand for imports. The reduction in BCC supply would reduce the national output available for export, thus raising prices nationally. The effect of this, in turn, would be to increase production in the INT and EAST. Higher lumber production in these regions in turn would raise demand for softwood roundwood and labor in these regions as well. It is through this series of actions that elasticity trends such as those reported could exist.

The existence of trends in elasticities may have important implications for policy analysis. Consider the possible imposition of a tariff on softwood lumber exports to the United States. If the tariff is based on reported own price supply elasticities of .84, .38,

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[8] Miller (1994) reports declining allowable annual cut's (AAC) since 1990 and sharply declining harvest since 1987.

[9] Recall equation [9] where B_{ww} is a constant therefore the ratio of P_w/Q_w determines elasticity trends.

and .65 in the BCC, INT, and EAST respectively the effect would be much larger than expected in BCC, slightly less than expected in the INT and much less than expected in the EAST. This is due to the fact that the own price elasticities of supply in 1995 for each of these regions are 1.26, .33, and .32.

Discussion

Limitations in past work were the primary motivation for this study. The Canadian softwood lumber subsidy dispute between the U.S. and Canada has been the single biggest issue affecting the industry over the past 18 years, yet the majority of production studies of the industry either do not provide lumber supply information, or fail to recognize regional differences. Our approach departs from those studies by providing a regional representation utilizing a normalized restricted profit function. Choice of a quadratic functional form ensured that curvature properties would be global. This is also the first study to recognize and model output and roundwood input prices and quantities as endogenous[10]. The modeling framework allowed estimation of output supply elasticities central to the Canadian softwood lumber tariff issue.

An important step in assessing the results of the present study is a comparison of findings with past studies. Tables 1.4, 1.6, and 1.9 presented elasticities from this study along with values obtained in the thirteen studies examined in the literature review. The present study generally suggests that the results of the various and disparate past studies are broadly consistent. For the few profit function studies, Marshallian elasticities fell

[10] Constantino and Haley (1988) noted that these prices should be treated as endogenous but abandoned the approach in the face of deteriorating estimation results.

within the range of past findings (except Baker). This was also true for the far larger set of Hicksian elasticities estimated in the past. Cross-price and own-price labor elasticities in the EAST were the major exception, but these were not significantly different from zero. A substantial output adjustment effect was found, yielding large differences between Marshallian and Hicksian elasticities. Results of the present study may also vary from past work due to:

i. differences in the sample period. See Table 1.1.

ii. input and output classification. See Table 1.1.

iii. violation of curvature properties. Adams and Haynes (1996) estimated supply and factor demand independently therefore symmetry was not imposed, and curvature was not checked; Constantino and Haley (1988) report violation of curvature at 60% of the data points; Constantino and Townsend (1986), Martinello (1985), and Martinello (1988) meet curvature at means only; Baker (1989), Baker (1990), and Banksota (1985) make no mention of curvature.

iv. industry definition. Martinello (1985) uses SIC 251.

v. inclusion or exclusion of equations in the system. Adams and Haynes (1996) estimate supply and demand separately while Bernard et al (1997) estimate lumber supply and input demand along with a demand curve for lumber.

Employing the Morishima elasticity of substitution, results from the present study were generally higher than the past studies for σ^M_{WL} but lower or in the lower end of the range for σ^M_{LW}, with the exception in the case of the highly imprecise results for the

EAST region. Analysis of current and past results also revealed an asymmetry in factor substitution responses with σ_{WL}^{M} greater than or equal to σ_{LW}^{M} in all but two cases: wood use changes more when labor price changes than does labor use when wood price shifts.

Finally, our findings suggest that there have been fairly consistent trends in lumber output and log demand elasticities in the sector over the past two decades, rising in the BCC and declining elsewhere. These trends would be consistent with declining log supply in BCC and a shift of output share to the INT and EAST.

Findings and limitations in the present and past studies suggest a number of important and potentially fruitful avenues for future research. The treatment of chips as a fixed by-product of lumber production in this and many past studies is less than satisfactory, particularly in light of the revenue generated by chip sales. Tests for jointness of production seem warranted, yet data on chip output will require some improvement before this can be undertaken with confidence. The concentration of work using only two flexible functional forms (quadratic and translog, see Table 1.1) is also of concern. Numerous studies have shown that findings can vary markedly with alternative forms. Alternative estimates with other forms (the generalized McFadden and generalized Leontief) would be particularly useful for assessing the finding of elasticity trends in the present study.

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CHAPTER 2

EFFECTS OF ECONOMETRIC AND ACTIVITY ANALYSIS DERIVED SUPPLY CURVES ON CANADIAN SAWMILLING INDUSTRY MARKET FORECASTS

Introduction

Over the last few years there has been an abundance of research directed at accurately modeling North American forest products markets. The primary goal of these studies has been to use historical data to analyze possible future supply and demand issues and policy effectiveness. The scope of these studies has varied from one-region one-product models, to complex multi-market interregional models. There are, however, two basic production-modeling techniques employed as described by Cardellichio and Kijasniemi (1987) – the "engineering approach" and the "economic approach".

The engineering approach, or activity analysis, involves specifying input-output coefficients utilizing production data for each mill or homogenous group of mills in a given region. NAPAP (Zhang et al., 1996) model and its predecessor PAPYRUS (Gilles andd Buongiorno, 1987) are examples of this technique. The resulting supply curve is a discontinuous series of horizontal segments in each of which marginal cost is constant. The length of each segment is determined by a known capacity for the associated mill or mill group. Some advantages of activity analysis are ease of estimation and model solution as well as ability to incorporate new or hypothetical technologies. Disadvantages include large data requirements and special data on unit costs and use of inputs (detailed and often proprietary).

The economic approach utilizes economic theory to specify the supply curve. The Timber Assessment Market Model (TAMM) (Adams and Haynes, 1996) and FORSIM (Cardellichio and Veltkamp, 1981) are examples of models that employ this method in their modeling framework. A system of supply and demand functions for the industry is derived assuming profit-maximization and applying duality theory. The result is a smooth, continuous supply function. The advantages of this approach are consistency with economic theory, functional forms, and lack of a need for information on individual plant production processes. Disadvantages include sensitivity to data quality, data limitations, and complexity of production technology representation.

There have been attempts in the past to evaluate these modeling techniques (Cardellichio and Kijasniemi, 1987). There has not been, however, a direct comparison of the two methods in a controlled simulation experiment. In an attempt to fill that knowledge gap, this study examines the differences arising from the two supply forms in the context of the TAMM model. Two supply curves for the Canadian softwood lumber industry are independently derived utilizing activity analysis and econometric methods. In addition to a base case comparison, three forms of exogenous shocks are modeled to determine the reaction of each form of supply curve: tariffs on Canadian exports of lumber to the U.S., harvest limits in Canada, and exchange rate trends. While this study will by no means answer all questions about the comparative performance of the two model forms, it will provide some insight into potential concerns in a practical context.

The next section presents theoretical developments and empirical results. The following section compares the TAMM solutions for the base case and the three exogenous shock scenarios. A final section discusses results and offers some tentative generalizations.

Supply Representations

Econometric and activity analysis representations of supply were developed for the three Canadian supply regions employed in the TAMM model: British Columbia Coast (BCC), British Columbia Interior and Alberta (INT), and the rest of eastern Canada (EAST). Data used for the econometric estimation as well as the base year calibration of the activity analysis supply are presented in Appendix 1. Supply elasticities for the econometric supply are given and it should be noted that as activity analysis supply is independent of quantity produced, the supply elasticities are perfectly elastic.

Econometric Supply

The Canadian softwood lumber industry is assumed to be driven by profit maximization. A restricted normalized quadratic profit function is chosen to represent the production technology. Outputs are a composite of softwood lumber and chips; variable inputs are softwood roundwood, labor, and other materials. Capital is modeled as quasi-fixed, and a time trend is added as a proxy for technological change. Dummy variables were added in BCC and INT in the years 1975 and 1986 to account for labor strikes in British Columbia. Output supply and input demands are found by Hotelling's Lemma and estimated together with the profit function using time series data from 1963-1995. A stochastic disturbance of mean zero was added. Initial estimates of the equations had high levels of autocorrelation resulting in the addition of a first-order autocorrelation correction coefficient to each.

The final form of the econometric supply equation is given in Equation 2.1.

$$x_o = \beta_o + \sum_{i=1}^{n-1} \beta_{oi} \frac{p_i}{p_n} + \beta_{ok} k + \beta_{ot} t + \beta_{D1} D75 + \beta_{D2} D86 + \rho_O e_{t-1} + e_t \qquad [2.1]$$

Elasticities of supply were calculated at the sample means of the data using Equation 2.2.

$$e_{ij} = \beta_{ij} \frac{(p_j / p_n)}{x_i} \qquad [2.2]$$

Table 2.1 Parameter estimates and elasticities for econometric supply

Coefficient	BCCoast	Interior	East	Coefficient	BCCoast	Interior	East
β_O	-2.32 (-1.52)	-2.93 (-4.48)	-0.32 (-0.46)	β_{D2}	-0.53 (-3.71)	-1.27 (-3.93)	
β_{OO}	0.66 (4.96)	0.89 (4.39)	0.80 (3.13)	ρ_O	0.76 (11.23)	0.76 (12.19)	1.02 (28.18)
β_{OW}	-0.98 (-4.11)	-1.05 (-3.67)	-1.00 (-2.31)	R^2	.56	.98	.95
β_{OL}	-0.11 (-2.60)	-0.14 (-2.57)	-0.20 (-1.67)				
β_{OK}	0.90 (2.86)	1.09 (5.79)	0.16 (0.53)	e_{OO}	0.84 (3.28)	0.38 (1.99)	0.65 (1.76)
β_{OT}	0.02 (0.93)	-0.09 (-1.37)	0.15 (0.19)	e_{OW}	-0.46 (-2.84)	-0.13 (-1.90)	-0.24 (-1.57)
β_{D1}	-0.93 (-6.54)	-1.33 (-4.14)		e_{OL}	-0.11 (-2.48)	-0.06 (-1.79)	-0.09 (-1.33)

Note: O is output, W is roundwood, L is labor, K is capital, and T is technology. Asymptotic t-statistics in parentheses. The R^2 is the pseudo R^2 calculated as the square of the correlation coefficient between the actual and predicted values. e_{OO} is the elasticity of supply with respect to output price. Numbers in parentheses under elasticities are the ratios of the elasticities to their standard errors.

Table 2.1 presents coefficient estimates, equation statistics, and elasticities of supply. Asymptotic t-statistics are included in parentheses. Equations employed in TAMM must be in price dependent form. Appendix 3 shows the derivation of the supply curve in price dependent form with the first order autocorrelation correction.

Activity Analysis Supply

The activity analysis supply representation is based on technical information relating to the production process. Cardellichio and Kirjasneimi (1987) identify three key steps in constructing an activity analysis representation of supply.

1. *Identify all significant production sites and the capacity at these mills.*
2. *Appraise the technical status of each mill and how this impacts the usage of major inputs in the production of a unit of output.*
3. *Compile input cost data for each location or region.*

Another necessity for modeling supply via activity analysis is that within each region production must be technologically uniform for each production process specified (Takayama, 1964). In 1995 there were 883 mills categorized by standardized industrial code 2512 (sawmills and planing mills) in Canada but data on their technology, cost, output, and capacity characteristics are not available. As a consequence grouping below the provincial level cannot be identified and an aggregate approach must employed.

Based on data from Spelter (pers. comm.), input/output coefficients are calculated for softwood roundwood and all other inputs (labor, fuel and electricity). Capacities are the capacities used in the econometric model as defined in Adams and Haynes (1996). Production consists of two processes: regular and overtime production. Overtime production employs the same roundwood inputs per unit of output but requires a ten percent increase in other inputs and associated costs. Capacity for regular production is taken as ninety percent of total production with the remainder being overtime capacity. Equation 2.3 is the price equation for the regular process where P_o is the price of the lumber output, α is the lumber recovery factor for logs, P_w is the roundwood price, and NWC is the non-wood cost.

$$P_O = \alpha P_W + NWC \quad \text{for} \quad Q \le .9Q_{TOTAL}$$

$$P_O = \alpha P_W + 1.1NWC \quad \text{for} \quad .9Q_{TOTAL} \le Q \le Q_{TOTAL} \qquad [2.3]$$

The base year (1976) data for the activity analysis approach is given in Table 2.2.

Table 2.2 Base year (1976) data for activity analysis supply in Canadian dollars per MBF

	BCC	INT	EAST
P_w	218.06	123.48	184.08
NWC	90.47	75.98	100.57

Figure 2.1 presents a graphical representation of the econometric (denoted EC) and activity analysis (AA) supplies.

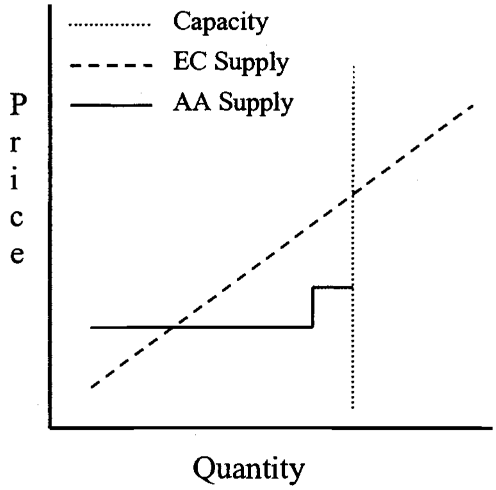

Figure 2.1 Graphical representation of linear econometric and activity analysis supply curves

Comparison of Simulations

TAMM is a spatial model of solid wood products markets and timber inventory. The Canadian lumber component of the model consists of three regional supplies along with one Canadian and six U.S. regional demands. The econometric (EC) and activity analysis (AA) models consist of the TAMM model with the three regional Canadian lumber supplies replaced by their respective supply curves presented in the previous section. Each model solution produces estimates of the lumber price, lumber production and U.S. imports of Canadian lumber. While Canadian lumber results are emphasized here, each model run was completed for all U.S. and Canadian regions and all products.

This section presents results of the comparison of a base case scenario along with three other scenarios in which exogenous shocks to the model are simulated. All model runs were executed from 1977 through 2005. The base case scenario allows analysis of how each supply curve estimates actual historic data (1977-1995) and comparison of forecasts under the market assumptions given in Adams (1996). The exogenous shock scenarios use actual conditions through the historic data period (1977-1995) with shocks applied beginning in 1996. The shocks to be modeled are various levels of a tariff on US imports, harvest constraints or limits in Canada, and different exchange rate forecasts.

The base case scenario is the only opportunity to directly compare the levels of projections from the econometric and activity analysis supply models. Comparisons of the three scenarios must be made indirectly by using measures of the solutions in relation to their respective base case forecasts. This will allow determination of the sensitivity of each supply representation to the degree of shock. Lumber price and lumber quantity produced for the three Canadian supply regions and US imports of Canadian lumber are employed in the comparisons. Three quantitative measures were calculated in an effort to describe the range of response, volatility, and direction of change for the exogenous shock scenarios. The absolute annual percentage difference (AAPD) is used as a measure of the range of response. It is calculated as the absolute value of the average percentage difference between the maximum predicted value and the minimum predicted value divided by the average of all predicted values. The mean annual period-to-period variation (MAPV) is used to measure the volatility of the forecast. It is calculated as the average change in a predicted value from one year to the next. The direction of change (DOC) shows the percentage of annual forecasts that move in the same direction in response to the exogenous shock.

Base Case Scenario

Analysis and comparison of equilibrium for the base case will be separated into the historic period (1977-1995) which is compared to actual equilibrium quantities and prices, and the forecast period (1996-2005). Graphical results of the forecasts are presented in Figure 2.2. Table 2.3 presents the statistics for the base case. For the base case AAPE is the average absolute percentage difference between the predicted and actual values. MAPV is calculated as described above for the scenarios. DOC shows the

Table 2.3 Statistics for base case

	AAPE*		MAPV**		DOC*		R^2*	
	EC	AA	EC	AA	EC	AA	EC	AA
BCC								
Price of Lumber	22%	16%	45	47	67%	67%	0.65	0.69
Quantity of Lumber	6%	13%	258	460	78%	72%	0.73	0.61
INT								
Price of Lumber	36%	27%	44	50	67%	61%	0.71	0.72
Quantity of Lumber	4%	9%	448	897	72%	83%	0.98	0.85
EAST								
Price of Lumber	40%	34%	44	47	78%	67%	0.37	0.37
Quantity of Lumber	11%	35%	375	735	78%	72%	0.75	0.57
CANADA								
Exports to US	14%	19%	878	1413	72%	72%	0.91	0.79

Note: AAPE is the average absolute percentage error between the predicted and actual values, MAPV is the average change in a predicted value from one year to the next, DOC shows the percentage of observations in which the predicted value moves in the same direction as the actual value. R^2 is the correlation betweeen actual and predicted values squared.

* For 1977-1995 period only

** For 1977-1995 period

percentage of observations in which the predicted value moves in the same direction as the actual value. R^2 is the correlation between the actual and predicted values squared. AAPE, DOC and R^2 are calculated for the historic period only, while MAPV is calculated for the entire run.

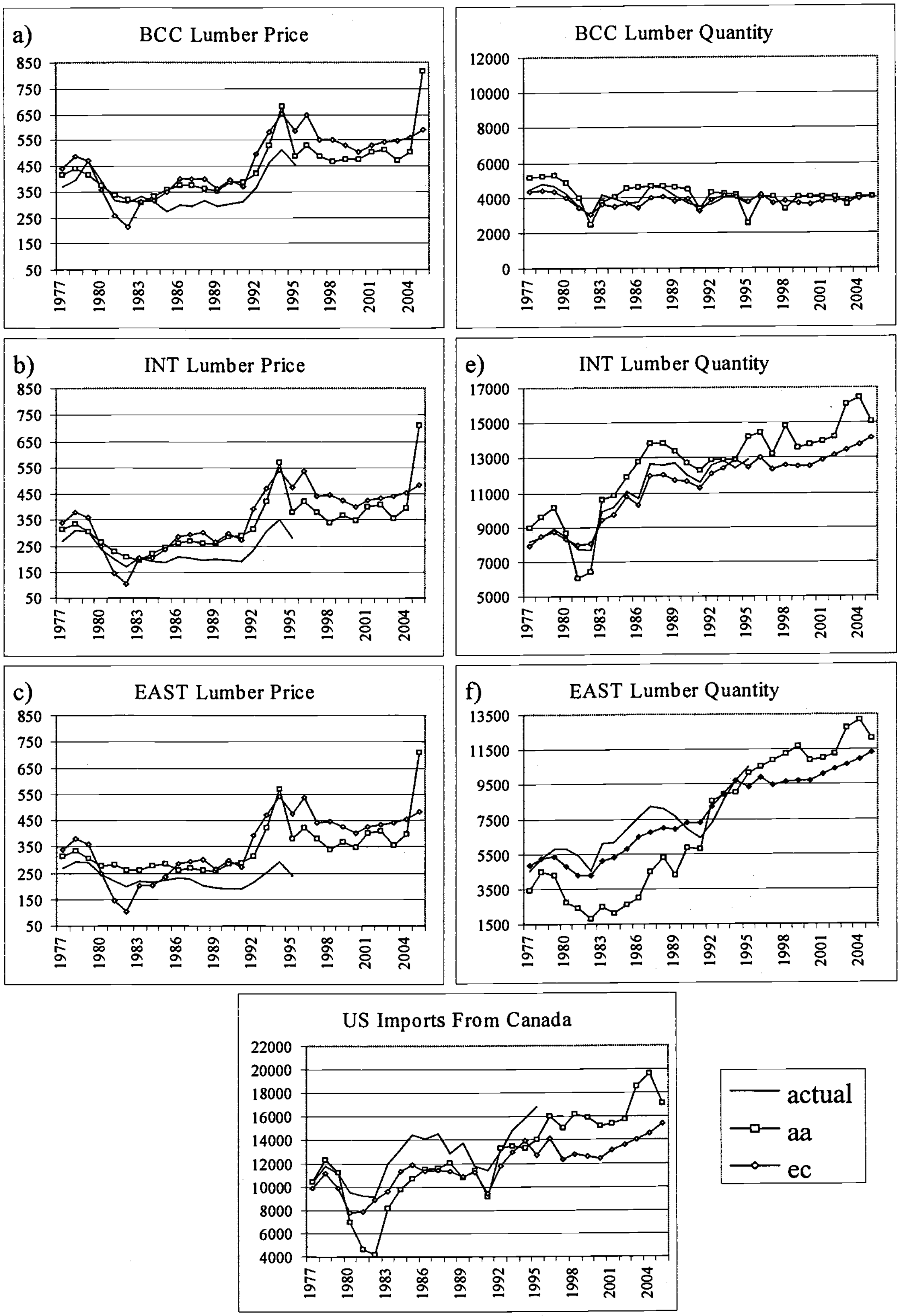

Figure 2.2 Base case scenario for econometric and activity analysis models

From Figure 2.2 it is evident that lumber prices in both the AA and EC runs are high throughout the period prior to 1995, although the EC prices take a deep swing down in the 1981-1983 period. In the post 1995 period (with the exception of 2005) the AA forecast is lower than the EC forecast. With the exception of AA in the EAST, lumber quantity is modeled much closer to the actual numbers over the historic period. The AA consistently under predicts quantity in the EAST. AAPE values indicate that neither model does well in projecting lumber price with correlation between the actual and predicted values of lumber price being particularly poor in the EAST. The AA model does a somewhat better job tracking prices while the EC model has smaller errors estimating quantity. AA quantity forecasts vary between vertical step segments on the supply curve either at capacity or ninety percent of capacity, with the exception of the two years 1998 and 2003 in the BCC. Forecasts follow the basic trends in capacity with a few sharp departures in years of industry downturn. The EC model quantity forecast is much more stable, with a smoother trajectory occurring entirely within capacity bounds. Forecast volatility as indicated by MAPV is less in the EC model for both prices and quantities. The DOC values indicate both supply curves project similar directions of change in historical prices and quantities. In the historic period it is interesting to note that because of the dip in prices in the EC model between 1981 and 1983, imports do not fall as they do in the AA model. Differences in the imports projections beyond 1995 can be explained by the higher prices in the EC model leading to less trade between the US and Canada than the AA model predicts.

Tariff Scenario

The tariff scenario consists of five separate runs with different tariff rates applied to the price of U.S. softwood lumber exports for the years 1996 through 2005. The fivetariff rates considered are 10, 15, 20, 25, and 30 percent. Graphs depicting lumber price, quantity and U.S. export forecasts are presented in Figures 2.3, 2.4, and 2.5. The EC model produces forecasts that are more stratified, or distinct, and less volatile than the AA model. Price forecasts for both models follow the same trends across regions[11]. It is interesting to note that with the tariffs the AA model forecasted prices are more stable over the period and the price spike in 2005 does not occur. The lumber quantity forecast for the AA model show the effects of the step in the supply curve. Production in the BCC falls well below the regular capacity level for the majority of the forecast, while output jumps back and forth between overtime capacity and regular capacity in the INT and EAST making for an erratic forecast. Studying the trade forecast for the AA model, however, doesn't reveal the turbidity of the production numbers. The forecasts for each level of tariff are nearly perfectly stratified.

Table 2.4 presents statistics for the tariff scenario. AAPD values indicate that the range of response for price forecasts is similar in both modeling techniques while forecasted quantities have a wider range in the AA model. Forecast price volatility as measured by MAPV is similar while the AA model produces more variable quantity forecasts. The DOC numbers suggest that the EC model produces more distinct projections with each scenario moving in the same direction as the others. The AA model has lower DOC

[11] Prices shown are prices paid by Canadian lumber consumers and thus drop as tariff rates rise.

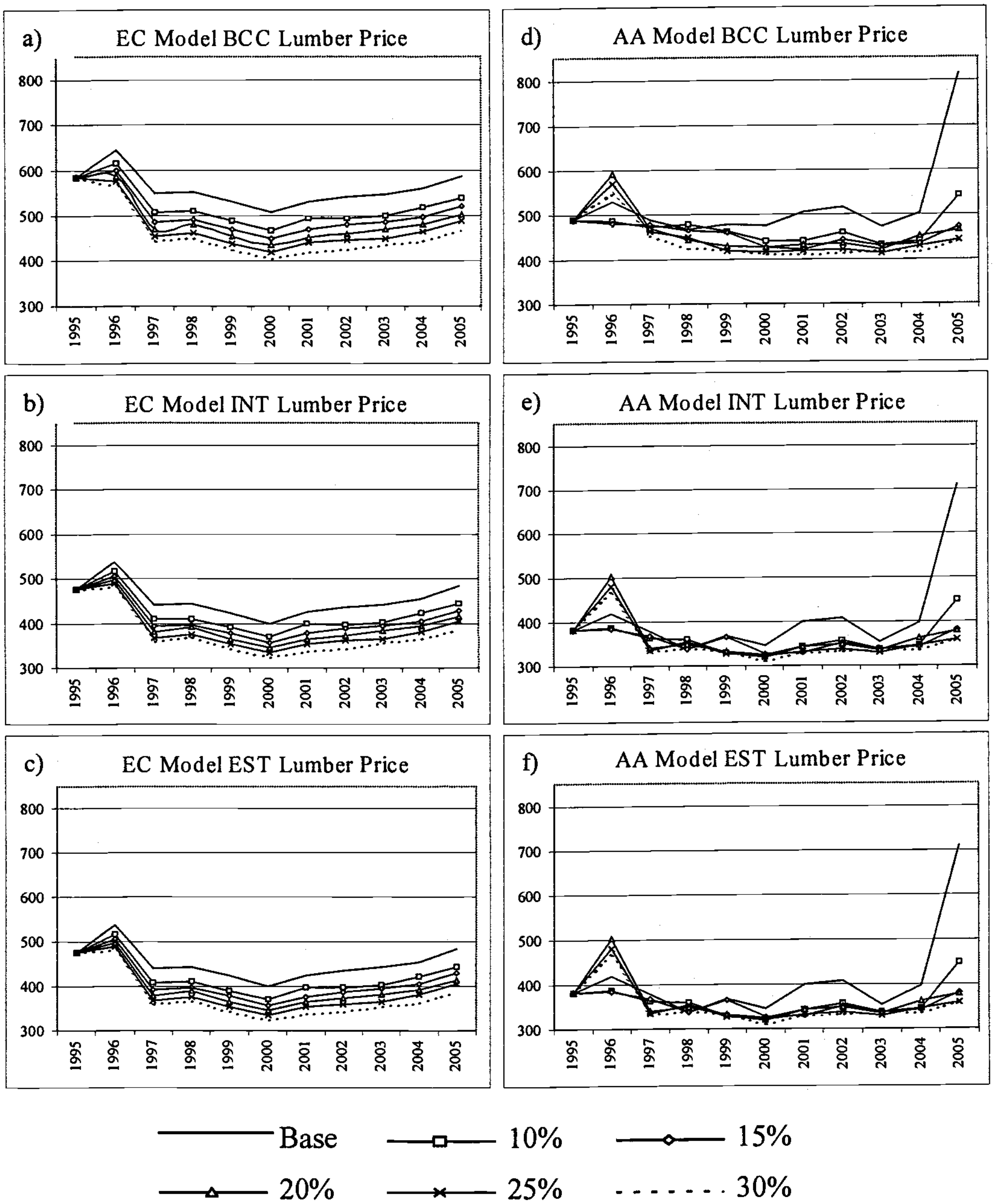

Figure 2.3 Lumber price ($1982/MBF) forecasts for tariff scenario

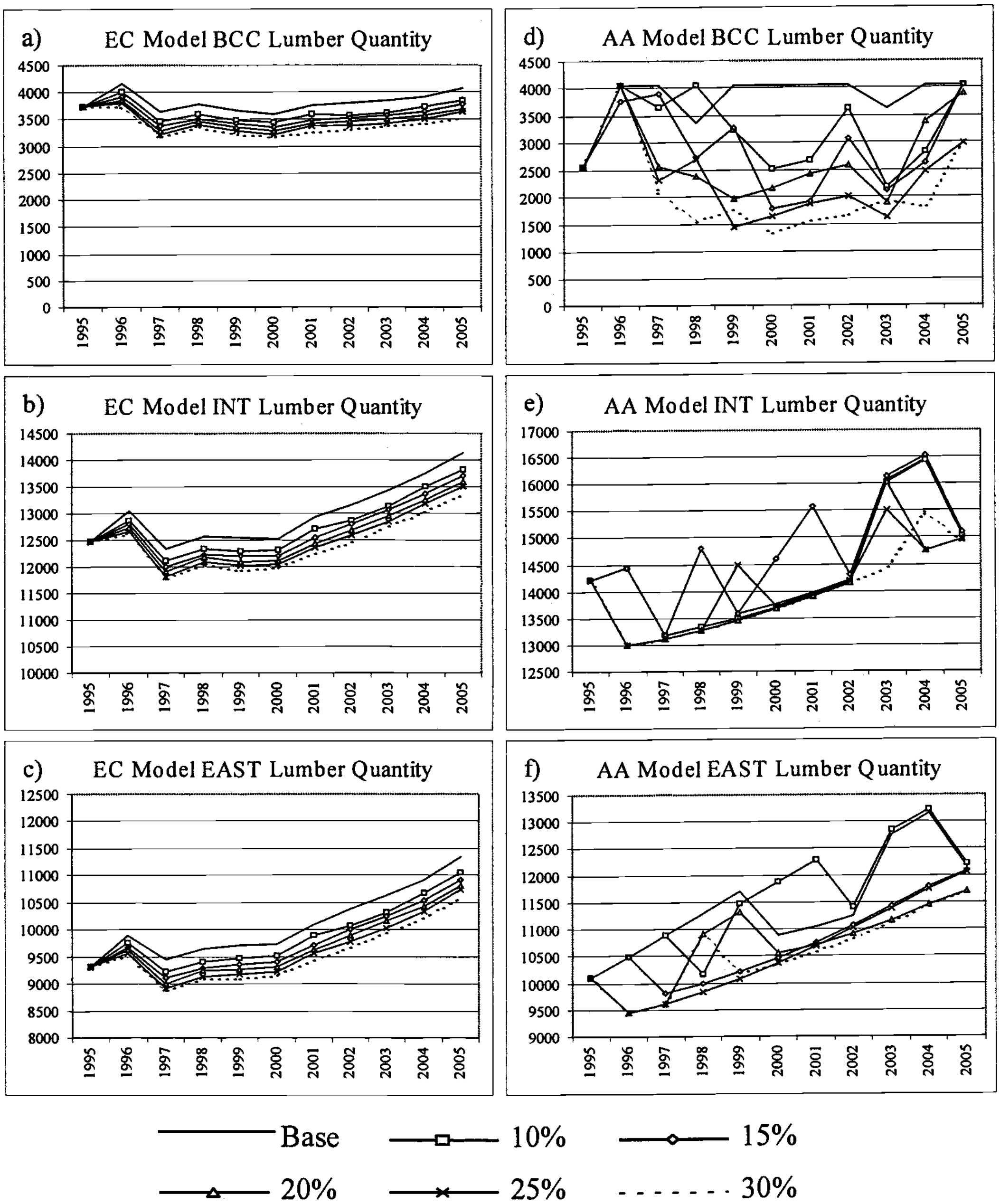

Figure 2.4 Lumber quantity (MMBF) forecasts for tariff scenario

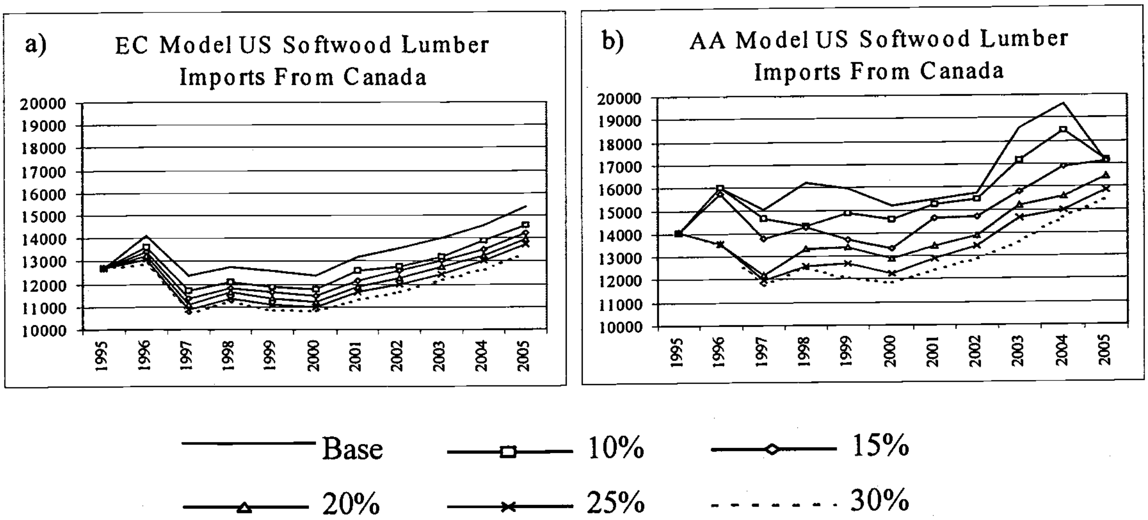

Figure 2.5 US softwood lumber import (MMBF) forecasts for tariff scenario

Table 2.4 Statistics for tariff scenario

	AAPD		MAPV		DOC	
	EC	AA	EC	AA	EC	AA
BCC						
Price of Lumber	22%	22%	25	24	98%	89%
Quantity of Lumber	13%	70%	144	753	98%	72%
INT						
Price of Lumber	21%	23%	26	30	98%	87%
Quantity of Lumber	5%	7%	286	667	98%	80%
EAST						
Price of Lumber	21%	23%	26	30	98%	87%
Quantity of Lumber	6%	12%	272	457	100%	85%
CANADA						
Exports to US	14%	23%	625	793	100%	89%

values indicating that the scenarios follow different trajectories over the projection period crossing over each other at various points.

Harvest Limit Scenario

Four separate runs were made simulating the implementation of harvest limits in Canada. Limits were set at 90, 100, 110 and 120 percent of 1995 harvest. The limits were modeled as an additional constraint for the nonlinear programming problem solved at each annual iteration of TAMM. Figures 2.6, 2.7, and 2.8 show prices, quantity and trade for the EC model. There is limited volatility following the surge in prices in 1997. The EC model predicts little price, quantity, or export change due to harvest limits of 120 and 110 percent. The AA model shows similar trends, however with the additional production in the INT and EAST the 110 percent limit becomes binding. This has little effect on prices except for the price spike in 1996, but it does cause a reduction in exports for that scenario. The lumber quantity forecasts reveal that if there are any harvest constraints the long term costs to the lumber industry will be borne by the INT and EAST regions. This is due mainly to the lack of capacity growth predicted for BCC. Limiting harvest to current levels allows production to continue at capacity. For the INT and EAST where capacity growth is predicted, however, the harvest constraints will be far more limiting. Since the two regions most affected by harvest reductions are the major producing and exporting regions, exports to the US fall with any kind of harvest restriction.

Table 2.5 presents the statistics for the harvest limit scenario. AAPD values were smaller for the EC in the BCC and INT for prices and quantities as well as exports for Canada as a whole. The AA model had a smaller range of response in the EAST. Price volatility as measured by MAPV was quite high with an average change of $54/MBF for the EC model and $88/MBF for the AA model. Production volatility was markedly

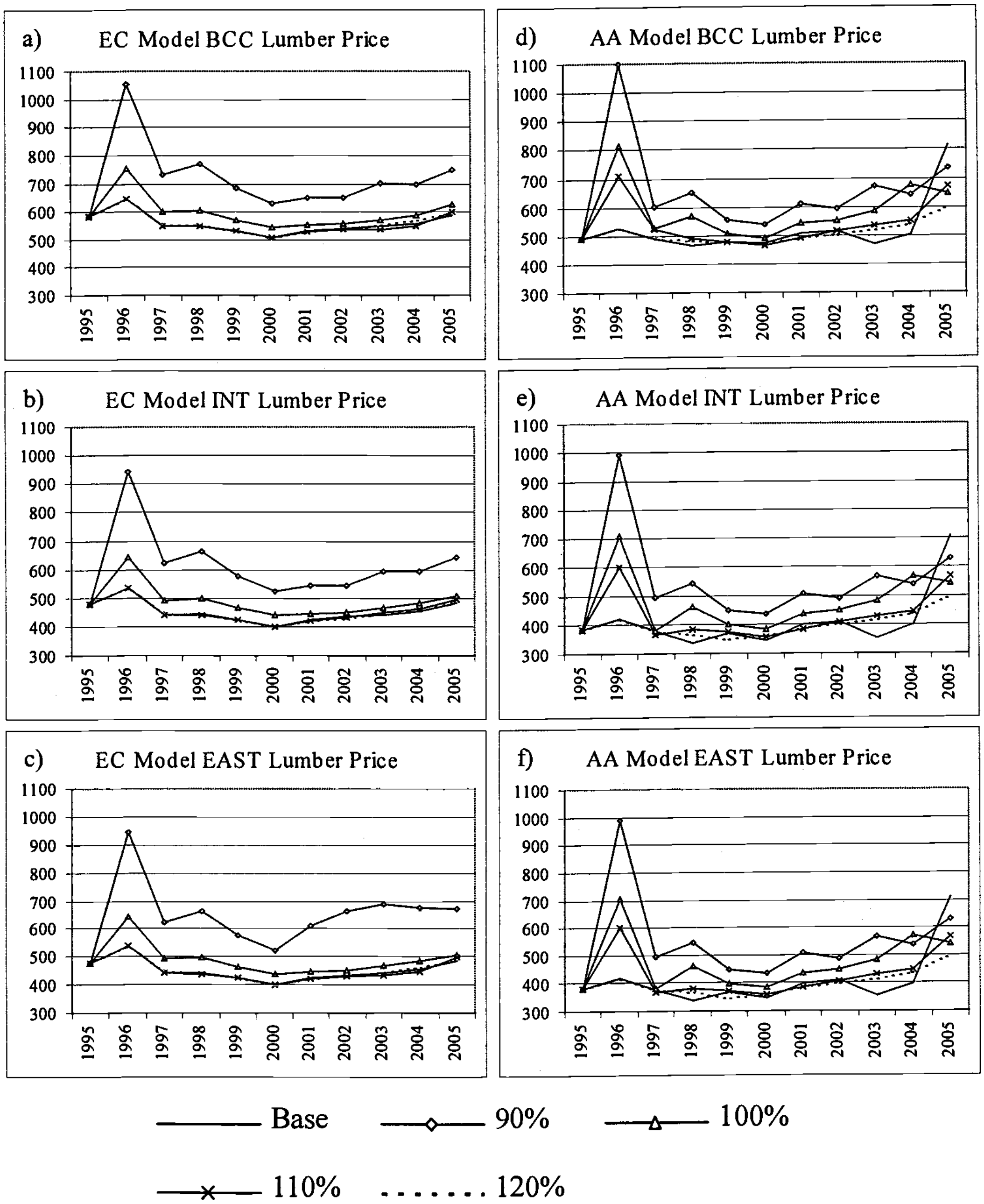

Figure 2.6 Lumber price ($1982/MBF) forecasts for harvest limit scenario

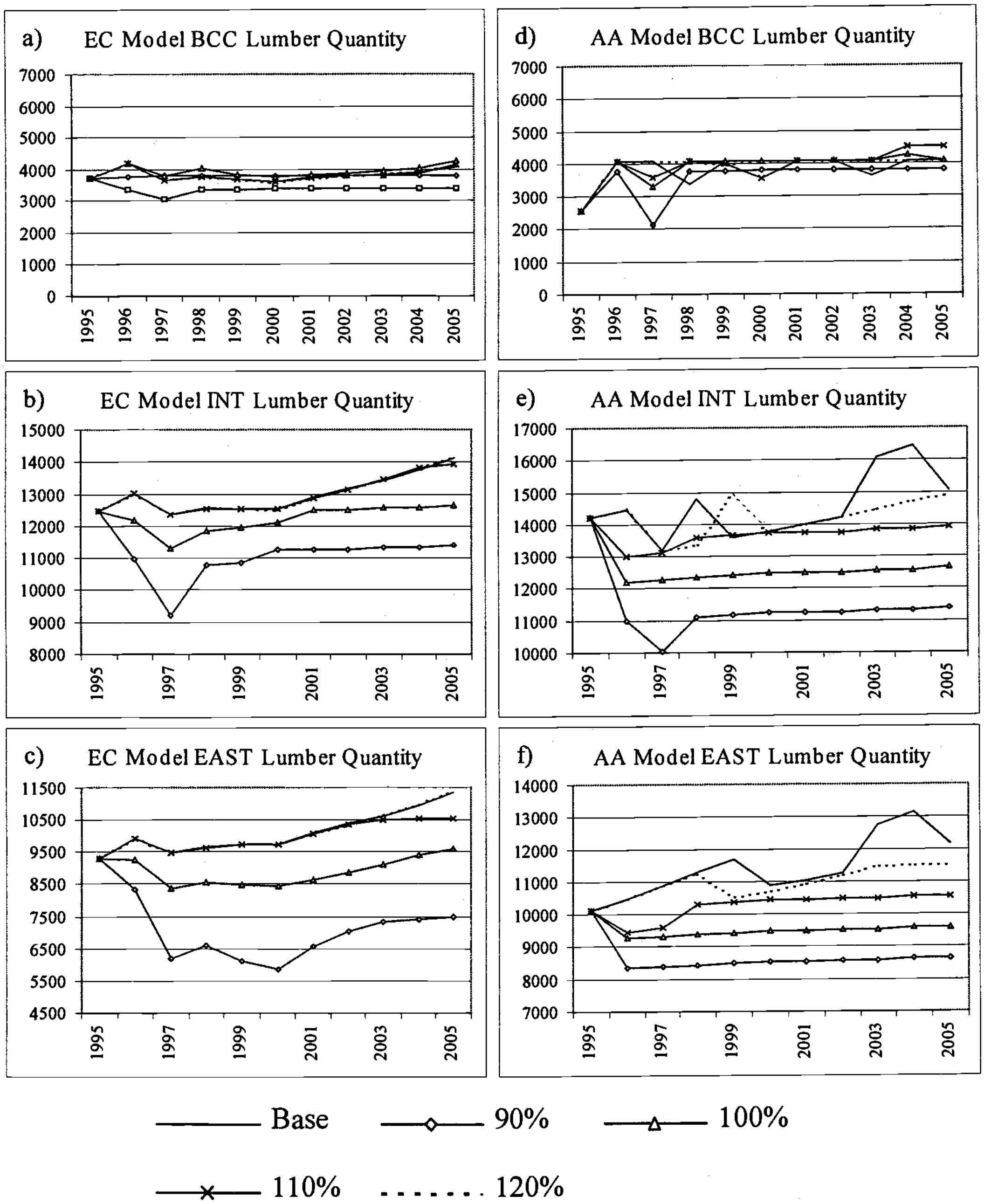

Figure 2.7 Lumber quantity (MMBF) forecasts for harvest limit scenario

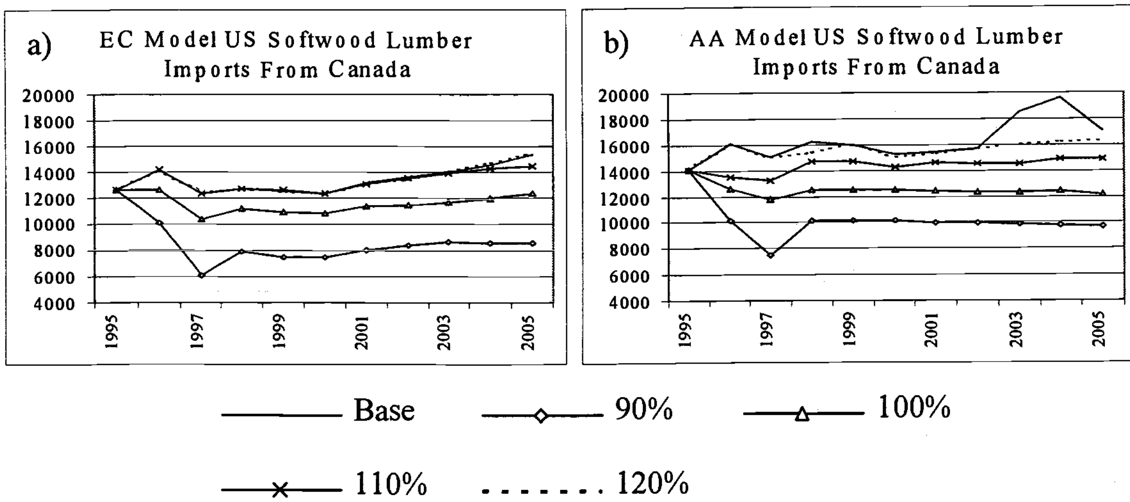

Figure 2.8 US softwood lumber import (MMBF) forecasts for harvest limit scenario

Table 2.5 Statistics for harvest limit scenario

	AAPD		MAPV		DOC	
	EC	AA	EC	AA	EC	AA
BCC						
Price of Lumber	30%	32%	54	85	91%	84%
Quantity of Lumber	6%	15%	132	335	80%	69%
INT						
Price of Lumber	36%	42%	54	89	91%	82%
Quantity of Lumber	17%	27%	349	391	80%	76%
EAST						
Price of Lumber	44%	42%	55	89	91%	82%
Quantity of Lumber	36%	30%	334	197	89%	84%
CANADA						
Exports to US	45%	49%	705	583	98%	73%

lower for the AA model than in the tariff scenario. This is primarily due to the fact that three of the harvest limit constraints (90, 100, and 110 percent) were binding and thus the only changes year to year were as a result of improvements in the log to lumber conversion factor. Like the tariff scenario, the EC model's DOC values indicate its forecasts follow trends over time more consistently than the AA model.

Exchange Rate Scenario

There has been much speculation about the future of the real US/Canadian exchange rate[12]. This scenario models three assumptions of the future of the exchange rate:

1. the real rate will remain fixed at its 1996 level through the modeling horizon;
2. the real rate will rise to .875 $US/$Can by 2000 and then remain at that level through 2005;
3. and the real rate will rise linearly to end at 1.0 $US/$Can in 2005 (a revaluation of the Canadian dollar).

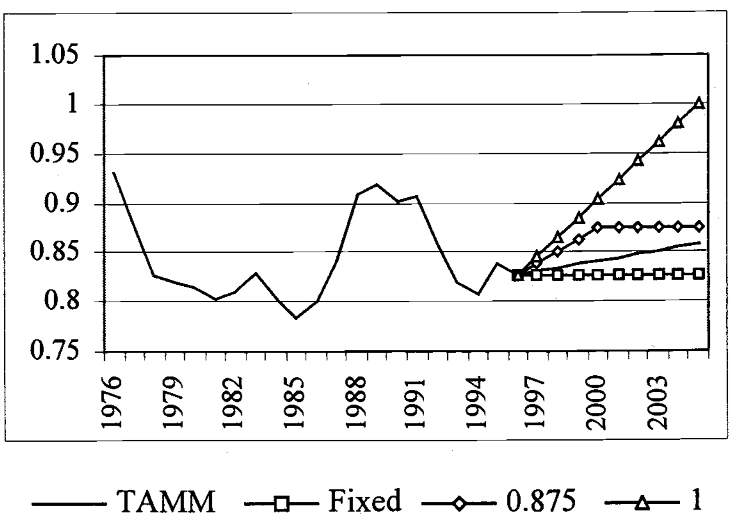

Figure 2.9 Exchange rate scenarios

[12] Real exchange rate is calculated as $\left(\$US/\$CAN\right) * \left(CANPPI82/USPPI82\right)$, where $US/$CAN is the nominal exchange rate and CANPPI82 and USPPI82 are Canadian and U.S. producers price indices.

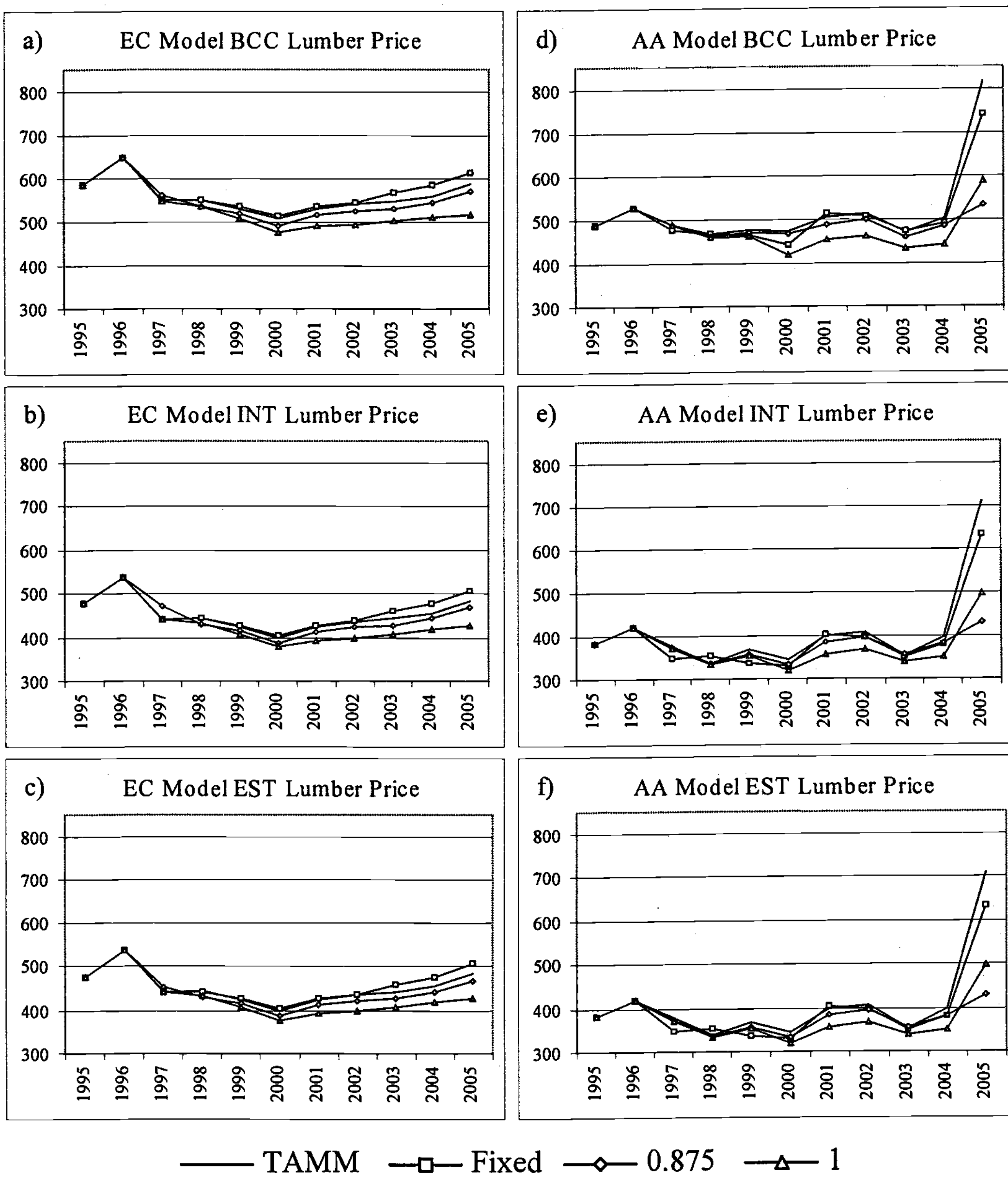

Figure 2.10 Lumber price ($1982/MBF) forecasts for exchange rate scenario

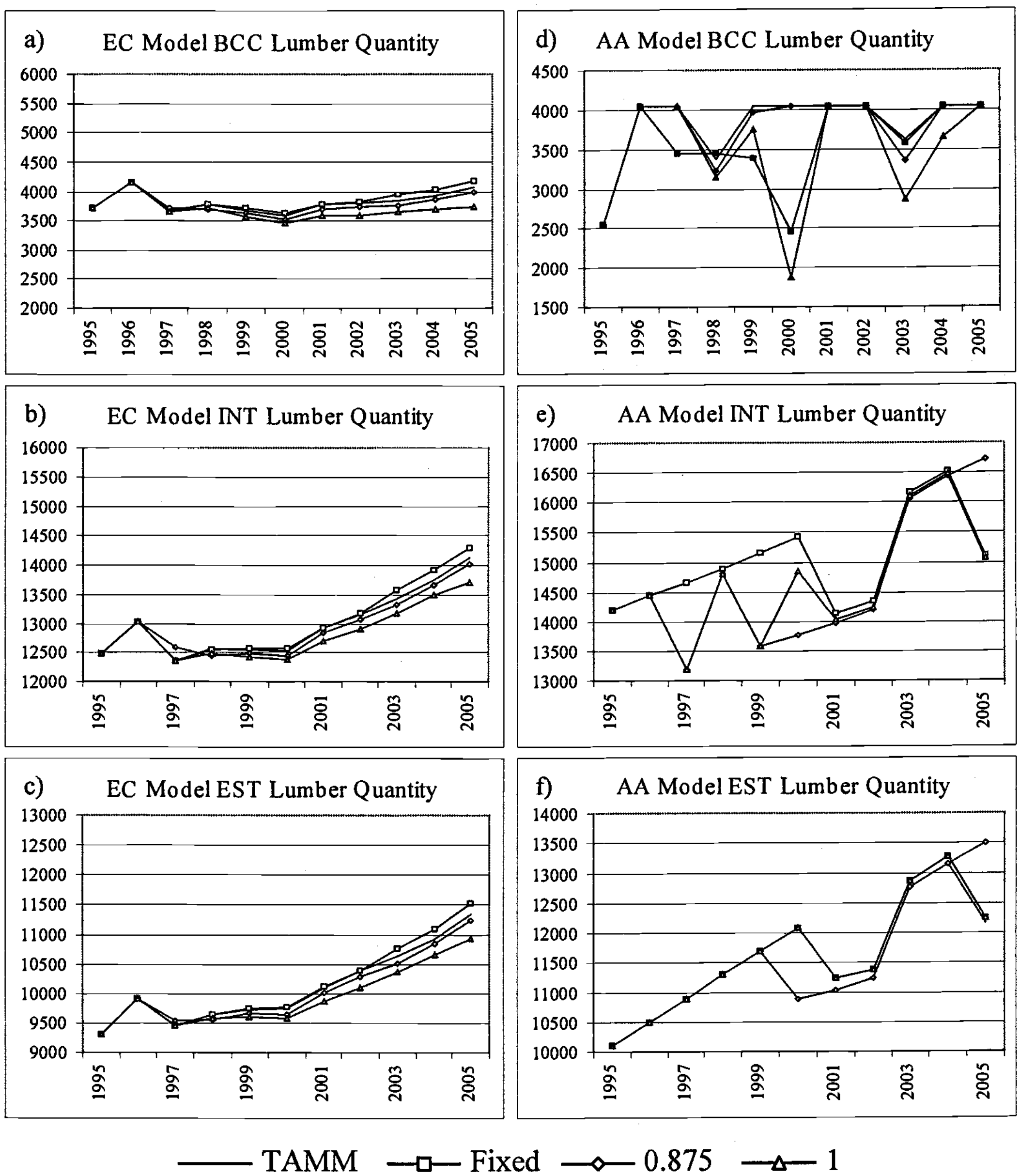

Figure 2.11 Lumber quantity (MMBF) forecasts for exchange rate scenario

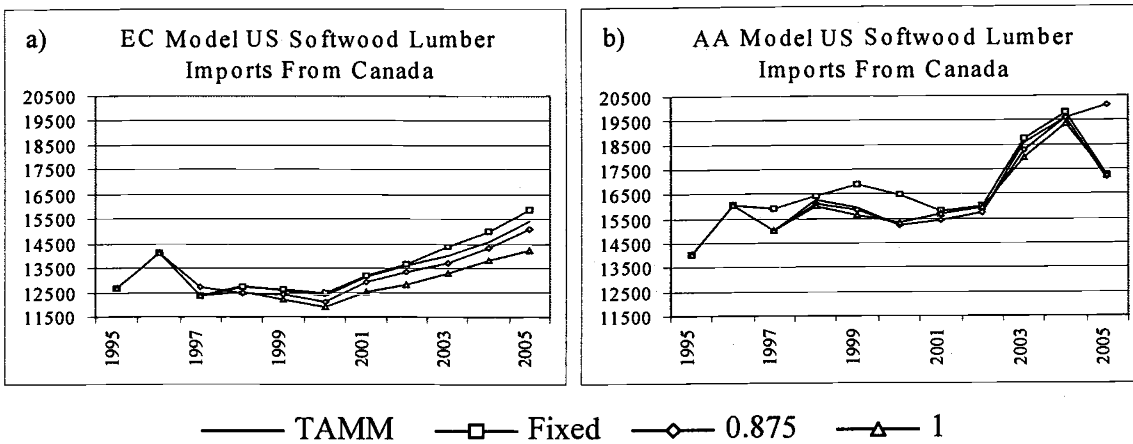

Figure 2.12 U.S. softwood lumber import (MMBF) forecasts for exchange rate scenario

Figure 2.9 graphs the exchange rate values for the three scenarios along with the present TAMM values. Figures 2.10, 2.11, and 2.12 show prices, quantity and trade for the exchange rate scenarios. Following 1997 the EC price forecasts settle into a stratified forecast with the fixed scenario giving the highest prices and the return to a \$1.00 exchange rate giving the lowest prices. The clear stratification found in the EC model is not found in the AA model. In addition to the increased volatility all but the 0.875 scenario follow the base case with its surge in prices in the year 2005. Lumber production and exports in the EC model follows the price trends in the post 1997 period with highest quantities in the fixed case and lowest in the return to even exchange rate. Lumber quantities in the INT and EAST regions as forecasted by the AA model stay close to the capacity limits of one of the two processes throughout the modeling horizon. The BCC production is more erratic with drastic dips in three years for the return to even scenario. Exports in the AA model follow basically two paths. Higher exports are predicted for the fixed scenario from 1996 to 2001 with all other scenarios grouped together below. The 0.875 scenario predicts a rise in exports in 2005, while all other scenarios show a reduction in exports of approximately twelve percent.

Table 2.6 Statistics for exchange rate scenario

	AAPD		MAPV		DOC	
	EC	AA	EC	AA	EC	AA
BCC						
Price of Lumber	8%	12%	29	38	94%	94%
Quantity of Lumber	5%	13%	162	652	97%	81%
INT						
Price of Lumber	8%	14%	29	43	94%	92%
Quantity of Lumber	2%	5%	293	803	92%	86%
EAST						
Price of Lumber	7%	14%	29	43	94%	92%
Quantity of Lumber	2%	3%	278	559	94%	86%
CANADA						
Exports to US	5%	5%	667	1049	97%	92%

Statistics for the scenarios are presented in Table 2.6. The AA model has higher AAPD values for all forecasts except exports. The price forecasts are actually much more similar when the year 2005 is excluded in the AA model. The AA model is much more volatile as evidenced by the MAPV values. The quantity forecasts are especially volatile as production jumps between capacity and ninety percent capacity. DOC values indicated the EC model forecasts moving together through the time horizon.

Comparison to Past Studies

Simulation results with the two supply forms can also be summarized in terms of elasticities of response of key endogenous variables to changes in the exogenous shocks. Effects of a one percent change in the tariff rate on regional price and quantity of lumber and national exports of lumber to the U.S. are presented in Table 2.7. These elasticities

Table 2.7 Elasticities of lumber price and supply quantity with respect to tariff for EC and AA models

	EC	AA
BCC		
Price of Lumber	-0.50	-0.09
Quantity of Lumber	-0.42	-0.15
INT		
Price of Lumber	-0.43	0.13
Quantity of Lumber	-0.12	-0.25
EAST		
Price of Lumber	-0.43	0.13
Quantity of Lumber	-0.15	-0.26
CANADA		
Exports to US	-0.36	-0.47

are calculated as the percentage change in price or quantity with the tariff less the percentage change in price or quantity without the tariff divided by the percent change of tariff for all runs in the year in which the tariff is applied. Price elasticities under the EC model were similar across regions, while the AA model elasticities had different signs in the three regions. The AA model showed prices rising in the INT and EAST as a result of a tariff because production remains at full capacity rather than falling to the 90 percent level. Quantity elasticities were lower in all three regions for the AA model while results were fairly similar for exports to the U.S.

There are a limited number of past studies that present elasticities with respect to tariff rate with which to compare the results. Bernard et al. (1997) reported lumber price elasticity with respect to tariff rate in Quebec as -0.03 compared to the EC model value of –0.43. Their elasticity of Quebec exports to the U.S. northeast with respect to tariff rate at –1.32 is an order of magnitude larger than the EC or AA results. Chen et al. (1988) reports the elasticity of all Canadian softwood lumber with respect to tariff rate as –0.84 which is also higher than those estimated in this study.

Effects of a one-percent change in the exchange rate on regional price and quantity of lumber and national exports of lumber to the U.S. are presented in Table 2.8. These elasticities are calculated as the average of the percentage change in price or quantity

Table 2.8 Elasticities of lumber price and supply quantity with respect to real exchange rate for EC and AA models

	EC	AA
BCC		
Price of Lumber	-1.03	0.94
Quantity of Lumber	-0.67	0.63
INT		
Price of Lumber	-1.05	1.06
Quantity of Lumber	-0.26	-0.19
EAST		
Price of Lumber	-1.04	1.06
Quantity of Lumber	-0.34	-0.43
CANADA		
Exports to US	-0.68	-0.28

with the change in exchange rate less the percentage change in price or quantity in the fixed scenario divided by the percentage change in exchange rate tariff for all runs in the years in which the exchange rate changes. EC model price elasticities for the three regions fall within the single and multi-year national elasticities reported by Adams et al. (1986) of –0.75 and –1.15. Bernard et al. (1997) reports a much more inelastic price elasticity for Quebec of -0.07. AA model price elasticities have the wrong sign and quantity elasticities vary in sign between regions. Quantity elasticities for the EC model are higher in BCC and slightly higher in the EAST than the single and multi-year national elasticities of -0.26 and –0.29 reported by Adams et al. (1986). Export elasticities for both models have the same sign and are inelastic. Export elasticities of -0.46 and -0.4 for single and multi-year cases reported by Adams et al. (1986) and -0.46 reported by Buongiorno et al. (1988) fall between elasticities for the two models.

Discussion and Conclusions

The previous section provided a direct comparison of the two methods of supply representation in response to differing tariffs, harvest limits, and exchange rate projections. While both the EC and AA models tracked historical data similarly there was a difference in how they reacted to the exogenous shocks. The AA model was more volatile, the direction of response was not uniform, and the extent of the response did not always change directly with the degree of exogenous shock. The EC model was less volatile, the forecasts moved in unison, and the degree of response was more closely correlated with the size of the shock. AA model behavior related directly to the shifts between capacity bounds. An important result of this analysis is that because production occurs on the capacity bounds for the AA model, effects of marginal changes are extreme. It either stays on its current capacity bound in which no marginal change is observed or jumps to another capacity bound in which case the effect is large.

In the base case, in the EC and AA models the prices are very similar for the years 1977-1980 and 1982-1995, in spite of the fact that the quantity solutions are quite different. The activity analysis is overestimating quantity in BCC and INT and underestimating quantity in EAST. The econometric model is closer to the actual quantities supplied but tends to estimate below the actual quantity. The recession years of the early eighties 1981-1982 affect the model solutions quite differently. The effect on the econometric model is a dip in prices with quantities and US exports staying close to the actual levels. The activity analysis model hold prices at the actual level and takes a dip in quantity produced and US exports. The forecasts follow similar trends, yet higher prices and lower quantities are forecasted in the econometric model. Another major difference is the volatility of the activity analysis forecasts as production jumps back and forth from capacity to ninety percent of capacity.

There are several possible explanations for the performance of the econometric model. One explanation is that the supply equation was estimated in quantity dependent form. The quantity dependent solution is evidenced by the fact that the quantities TAMM gets at equilibrium are a lot closer to the actual quantities through the historic period than the prices. Another reason is the presence of a first-order autocorrelation correction coefficient in the supply equation. Modeling the supply equation in TAMM with the autocorrelation correction coefficient involves using lagged values of all variables in the supply equation. The problem occurs when using lagged values of endogenous variables. In estimating the coefficients the actual values of the lagged endogenous variables are used to compute the present years estimated value, however in modeling the estimated value of the lagged endogenous variable is used. For years in which the error term was large this can make quite a difference.

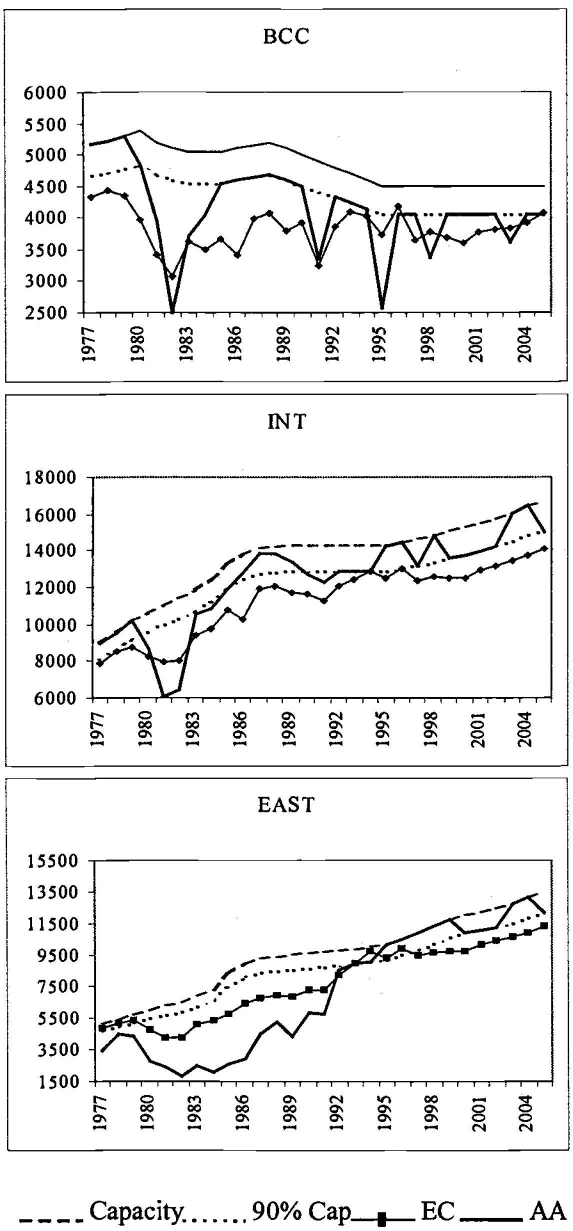

Figure 2.13 Lumber output and capacity for base case

Figure 2.13 shows the production levels plotted together with capacity and 90 percent capacity. Once the activity analysis solution picks up production in the INT and EAST in the early 90's the regions continue to produce at one of the two capacity levels for the remainder of the projection. Econometric supply is below even the ninety percent capacity level in all three regions throughout the majority of the time horizon. These graphs illustrate the importance of process capacity data. With the exception of only two years in the BCC, the capacity estimates were the production quantity solutions in the forecast period (1996-2005). This is particularly troublesome given the lack of good capacity/capital stock data for the Canadian Sawmill sector, a concern often echoed in the literature (Martinello (1987), Meil, et al. (1988)).

By evaluating the degree and form of change a policy or exogenous shock produces in each model some general observations are apparent. The econometric model produces a stratified response to exogenous stimuli. Shocks tend to shift the forecast with the basic trend in the variable remaining the same. The degree of shift is positively correlated with the degree of shock. The activity analysis model is more sensitive to the degree of shock. That is, larger differences in forecasts were found than the econometric model. Also the forecasts were not stratified like the econometric model. This was due primarily to the jumps in output between the 90 percent capacity and full capacity levels. These jumps occur along with changes in price resulting in the forecasts crossing quite often.

It should be noted that this is a fairly coarse activity analysis supply function. Further divisions of the industry might reduce erratic behavior. Another possible problem is due to the complexity of TAMM. With so many regions, market levels, and linkages between them, two solutions that appear similar may not be. It could be that differences between them produced reactions in other parts of the model making the results appear similar. It is because of this that caution must be exercised when interpreting results such as these.

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CONCLUSIONS

The purpose for the study was to provide a direct comparison of the effects of an econometric (EC) versus activity analysis (AA) supply representation in the context of the TAMM model. To accomplish this both EC and AA supply curves were estimated for three Canadian regions. Estimation of the EC supply curves yielded a wealth of information of elasticities and trends in elasticities in the Canadian softwood lumber market. Comparison of the reaction of the two models to exogenous shocks in the form of tariffs, harvest limits, and the real exchange rate provided insight into the behavior of the models. While similar TAMM solutions were obtained in the historic period (1977-1995), the AA model proved more volatile in the forecast period (1996-2005). The cause of the volatility was the tendency for the solution to occur on one of the two capacity constraints thereby either not moving in response to stimuli, or moving abruptly. The major finding with regards to the proposed NASAW/NAPAP linkage is that estimated capacities most likely will be production solutions and thus must be formulated with the utmost diligence.

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APPENDICES

Appendix 1: The Data

The model utilized a time series data set consisting of annual observations from 1962 to 1995 for each of the three Canadian regions; the British Columbia Coast (BCC), British Columbia Interior and Alberta (INT), and the rest of Canada (EAST). The data collected was for Sawmills and Planing Mills as defined by Standard Industrial Classification (SIC) 2512.

Lumber Output

Total lumber output for SIC 2512 1962 through 1978 is reported by Statistics Canada in *Sawmills, Planing Mills, and Shingle Mills*. Species breakdown of hardwood (HW) and softwood (SW) lumber for all industries can be found in *Wood Industries*. To get a breakdown by species, the HW and SW ratios for all industry production was applied to the SIC 2512 numbers. For the period 1979 through 1984 only the all industry production is reported. To get estimates of SIC 2512 output for that period, SIC 2512 production was regressed on all industry using data from 1962 through 1978. The resulting coefficients of determination (R^2) were .984, .993, and .992 for BCC, INT and EAST, respectively. Data for 1985 through 1994 was taken from *Wood Industries,* the only exceptions being 1987 and 1991 in which no survey was issued. Numbers for those two years came from *Selected Forestry Statistics Canada*, with the British Columbia Coast and Interior breakdown based on percentages of production as reported by STATSCAN Pub. #35-002.

Lumber Price

Lumber price in this model is composed of two parts; softwood lumber price and chip value per unit of lumber produced. Softwood lumber price for the years 1962 through 1964 was taken from the TAMM data set [Adams and Haynes, 1996]. For the years 1965 through 1994 prices were estimated as value of shipments divided by the volume of shipments of softwood lumber as reported in *Wood Industries*. Value data for 1985 and volume data for 1987 were not available and therefore prices were computed using the selling price index reported in *Selected Forestry Statistics Canada*.

For the years 1962 through 1984 chip value per unit of lumber produced was found by taking the total chip value as reported in *Sawmills, Planing Mills, and Shingle Mills* and dividing it by the total (HW+SW) lumber production in that region. In the EAST, chip value per unit of lumber is based solely on Quebec and Ontario provincial data. The data from 1985 through 1994 are taken from the TAMM data set [Adams and Haynes, 1996].

Sawlog Input

Data for softwood sawlog input was found for 1965 through 1984 in *Wood Industries*. Softwood lumber recovery rates for those years were computed dividing the softwood lumber output by the softwood log input. Softwood sawlog input for the other years was then computed dividing the softwood lumber output in each year by the average recovery rate of 1965 through 1985.

Sawlog Price

Softwood sawlog price for the years 1962 through 1964 was taken from the TAMM data set. Softwood sawlog price for the years 1965 through 1994 are found by dividing the money spent on total softwood roundwood by the total roundwood purchased as reported by *Wood Industries.* Volume data for 1987 and 1991 was not available and there for the volume was adjusted proportional to value change and then the price computed as with the other years.

Labor Input

Labor input data was taken as the number of total employees in all activities as reported by *Sawmills, Planing Mills, and Shingle Mills* and *Wood Industries*.

Labor Price

Labor price was calculated dividing the total salaries and wages reported in *Sawmills, Planing Mills, and Shingle Mills* and *Wood Industries* by the total employees.

Other Materials Input

Other materials input is the total of fuel, electricity, materials, and supplies not including softwood roundwood as reported in *Sawmills, Planing Mills, and Shingle Mills* and *Wood Industries*.

Other Materials Price

The price of other materials was taken as the Industrial Selling Price Index as reported by the United Nations Department of International Economic and Social Affairs, Statistical Office's in *International Trade Statistics*.

Technology

A time series was used to represent improvements in technology over time.

Capital Stock

Almost all past studies have employed different measures of capital stock. The reason for this is the inadequacy of the capital stock numbers presented by Statistics Canada. Those numbers are the result of a capital acceleration model that adds capital expenditures and subtracts depreciation. What is missing is capital reductions due to mill closures. In this study capital stock is represented by mill "capacity", the maximum feasible volume of lumber output, derived from Adams and Haynes (1996). This measure might be viewed as an estimate of the service provided by the underlying stock of physical plant and machinery in the industry.

Appendix 2: Elasticity Trend Regression Results

Trend Analysis Regression Results

	BCC		INT		EAST	
	slope	R2	slope	R2	slope	R2
e_{OO}	0.007	0.15	-0.015	0.78	-0.032	0.91
	(2.32)		(-10.39)		(-17.29)	
e_{WW}	0.008	0.46	-0.004	0.75	-0.025	0.82
	(5.11)		(-9.62)		(-11.91)	
e_{LL}	0.023	0.81	0.009	0.67	0.001	0.32
	(11.44)		(8.01)		(3.81)	

Note: O is output, W is roundwood, L is labor.

Appendix 3: Preparing the Supply Curve for Estimation in TAMM[13]

There are two steps in preparing the supply curve estimated in SHAZAM for injection into the GAMS framework of TAMM. The first step is to show the structure of the equation as it was solved with an AR(1) correction. The equation was originally represented in the simple form as Equation 1.

$$Y_t = \beta X_t + U_t \qquad [1]$$

Where Y, X, and U are vectors of the t observations of the dependent variable, independent variables including constant, and the error terms. An first order autocorrelation of the error term would mean U is not a stochastic error term, but can be represented as a function of the prior periods error term, U_{t-1} and a stochastic error term E_t. This autocorrelated error term can be represented as Equation 2.

$$U_t = RU_{t-1} + E_t \qquad [2]$$

By lagging Equation 1 one period gives Equation 3.

$$Y_{t-1} = \beta X_{t-1} + U_{t-1} \qquad [3]$$

And solving Equation 3 for U_{t-1} gives Equation 4.

$$U_{t-1} = Y_{t-1} - \beta X_{t-1} \qquad [4]$$

[13] This formulation is presented in Berndt.

Combining Equation 4 into Equation 2 gives Equation 5.

$$U_t = Y_{t-1} - \beta X_{t-1} + E_t \tag{5}$$

Combining equation 5 into equation 1 gives equation 6 which is the final representation of the supply function in terms of exogenous and predetermined variables as well as the stochastic error term.

$$Y_t = RY_{t-1} + \beta(X_t - RX_{t-1}) + E_t \tag{6}$$

Therefore the supply curve solved in SHAZAM without the stochastic error term would have the form of Equation 7.

$$\begin{aligned} O_t = {} & RO_{t-1} + \beta_o(1-R) + \beta_{oo}(P_{o_t} - RP_{o_{t-1}}) + \beta_{ow}(P_{w_t} - RP_{w_{t-1}}) + \beta_{ol}(P_{l_t} - RP_{l_{t-1}}) \\ & + \beta_{oc}(C_t - RC_{t-1}) + \beta_{ot}(T_t - RT_{t-1}) + \beta_{od}(D86_t - RD86_{t-1}) \end{aligned} \tag{7}$$

The second step involves putting equation 7 in a price dependent form, therefore Equation 8 is Equation 7 solved for the price of output.

$$\begin{aligned} P_o = {} & \frac{1}{\beta_{oo}}(O_t - RO_{t-1}) - \frac{\beta_o}{\beta_{oo}}(1-R) + RP_{o_{t-1}} - \frac{\beta_{ow}}{\beta_{oo}}(P_{w_t} - RP_{w_{t-1}}) \\ & - \frac{\beta_{ol}}{\beta_{oo}}(P_{l_t} - RP_{l_{t-1}}) - \frac{\beta_{oc}}{\beta_{oo}}(C_t - RC_{t-1}) - \frac{\beta_{ot}}{\beta_{oo}}(T_t - RT_{t-1}) \\ & - \frac{\beta_{od}}{\beta_{oo}}(D86_t - RD86_{t-1}) \end{aligned} \tag{8}$$

Due to the fact that in the SHAZAM model the price of output included both the price of lumber and the price of residues, or $P_o = P_{lum} + P_{res}$, Equation 8 must be further solved for

Plum alone. That gives the final form of the price dependent lumber supply equation with first order autocorrelation adjustment as Equation 9.

$$
\begin{aligned}
P_{lum} = {} & \frac{1}{\beta_{oo}}(O_t - RO_{t-1}) - \frac{\beta_o}{\beta_{oo}}(1-R) + RP_{lum_{t-1}} + RP_{res_{t-1}} - \frac{\beta_{ow}}{\beta_{oo}}(P_{w_t} - RP_{w_{t-1}}) \\
& - \frac{\beta_{ol}}{\beta_{oo}}(P_{l_t} - RP_{l_{t-1}}) - \frac{\beta_{oc}}{\beta_{oo}}(C_t - RC_{t-1}) - \frac{\beta_{ot}}{\beta_{oo}}(T_t - RT_{t-1}) \\
& - \frac{\beta_{od}}{\beta_{oo}}(D86_t - RD86_{t-1}) - P_{res}
\end{aligned} \qquad [9]
$$