University of Alberta

Analysis of Institutional and Macroeconomic Impacts on the Canadian Forest Sector

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled **Analysis of Institutional and Macroeconomic Impacts on the Canadian Forest Sector** submitted by Janaki Rami Reddy Alavalapati in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Forest Economics.

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Dedicated to my brothers and parents

Abstract

In this thesis, three studies are conducted investigating a range of institutional, micro, and macroecono[illegible]ions which affect the behaviour of Canadian forest product firms. First, the effe[illegible] institutional constraints on the short-run timber supply behaviour is analyzed for quota holders in Alberta. A dynamic optimization technique is used to predict production and estimate shadow prices of institutional constraints. The cost structure of large, medium, and small tenure holders are calibrated and used to determine the shadow prices of processing capacity constraints and annual allowable cut restrictions. Results indicate that all categories of quota holders incur substantial costs due to institutional constraints.

Second, the impact of a British Columbia policy which increased stumpage fees is analyzed. The effect of this policy on the income distribution of two income classes and regions in British Columbia is investigated using a computable general equilibrium approach. Results indicate that the policy causes a significant decline in employment and income of the province. The results suggest that the decline in real gross domestic product is more than the fall in real income. Income for average households falls by more than that of poor households in response to the policy shock. Results also show that negative economic effects of the policy are higher in the Interior of British Columbia than those on the Coast.

Finally, the short-run dynamic impacts of macroeconomic variables on the Canadian pulp industry are investigated using a vector error correction approach. Results from forecast error variance and impulse response analyses show that macroeconomic variables relating to the United States economy are more important, when compared to

domestic variables, in determining the Canadian pulp price. Results p[illegible]de weak evidence of the existence of market power for Canadian pulp producers. The [illegible]ts also indicate that the indirect effects of the shocks in [illegible]acroeco[illegible]mic variables are im[illegible]tant in policy analysis.

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CHAPTER 1 Introduction

This study examines the economic effects of a wide variety of forest policies relating to the Canadian Forest Sector. The forest sector is a major contributor to the Canadian economy. In 1989, it accounted for 2.5 percent of total Canadian employment and 3.3 percent of national gross domestic product. Furthermore, exports of forest products represent approximately 17 percent of total Canadian exports (Forestry Canada 1992a). Because of its importance to the nation's economy, the forest sector is often the subject of economic enquiry. Economic analysis may provide insights into the behaviour of forest product firms, and the industry at large, and may thereby play a role in directing forest policies to further economic efficiency and/or equity.

Policy changes may range from microeconomic to macroeconomic, including such practices as: restrictions on annual allowable cut (AAC) and log sales; policies on stumpage prices and taxes; and exogenous shocks in macroeconomic variables such as exchange rates and world forest product prices.[1] The impacts of those changes may be widespread as policies in one locality spread into other localities. For example, through international trade, subsidizing forest companies in one region may affect the profits of those in other region, and reduction of timber harvests in one region may enhance harvests in another region. Economic enquiry may assist in explaining how these changes within, and/or forces originating outside the sector or region, affect production, prices, and trade of forest products and resulting income and employment.

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[1]Kallio et al. (1987), Boyd and Hyde (1989), and Nemetz (1992) provide an extensive discussion on types of policies and changes which affect the Canadian and/or the global forest sector.

Economic analysis of Canadian forest sector is complicated by at least three types of issues. The first type is related to the institutional features of the Canadian forest sector. In Canada, a large portion of forest lands is under public control with restrictions on AACs; limitations on the length of harvest contracts; and restrictions on log markets set by regional and national forest policies. A second feature is the absence of perfect competition. For example, the supply of a forest product from a region may influence the price of that product in the international market, or a strong union of workers may cause wages to be rigid at least in the short-run. The third issue complicating analyses involves several kinds of interactions between relevant variables. Institutional and market variables may act in concert to affect behaviour of forest firms. Likewise micro and/or macroeconomic variables may interact affecting the forest product sector in opposite directions. Finally, the forest sector may interact with other sectors of the economy thereby influencing the net effect of a forest policy. In this thesis, three studies are conducted at three levels of abstraction; local, regional and international. These studies investigate a range of institutional, micro, and macroeconomic interactions, in competitive and non-competitive markets which affect the behaviour of forest product firms, and the forest products industry at large in Canada.

The study addresses the following three questions. The first question is: whether and how institutional and market forces interact to affect the timber supply from public forests. The second question is: what is the socioeconomic impact of a forest policy which reduces harvests of timber in a region where forestry is a dominant element in economic activity? Finally, the third question is: how does a specific Canadian forest product industry respond to changes in domestic and/or in foreign economies?

With the advancement in computer technology, a wide range of analytical techniques are available to undertake a comprehensive analysis of these diverse issues/problems. Non-parametric techniques are used to examine the first two issues while a parametric approach is used to investigate the third issue. It is hoped that the information provided by these analyses will help: 1) individuals interested in modelling the forest sector worldwide; 2) corporate managers of forest product firms from both within the region of the studies and elsewhere in making investment decisions; and 3) government policy makers in making decisions on the efficient use of forest resources.

1.1 Impact of Institutional Regulations on Timber Supply

In many countries the widespread belief that market forces do not allocate forest resources in optimum manner has led to a considerable amount of public involvement in forest management, and Canada is no exception. In Canada, approximately 94 percent of the forest land is owned by either federal or provincial governments. However, harvesting rights and forest management responsibilities are given to the private sector through numerous types of tenure arrangements. These arrangements, through the imposition of regulations and the creation of incentives, influence the behaviour of forest product firms (Haley and Luckert 1990). Consequently, timber supply from public forest lands may be different from that of private lands where behaviour is largely determined by market forces. For example, conventional econometric studies show that higher stumpage prices generally have a positive effect on the quantity of timber supplied.[2] However, this reasoning may not hold if government regulations, overseeing harvests on public forest lands, limit the flexibility of forest products firms to respond to prices. In the presence of government regulations superimposed within a market economy, the supply behaviour of private firms operating on public forest lands becomes an empirical issue.

In the past, studies conducted on the influence of market forces on timber supply from public forests have generated contradictory conclusions.[3] The first paper of this thesis provides an empirical examination of timber supply behaviour from public forest lands for quota holders in Alberta. First, the short-run supply behaviour of quota holders in the face of constraints on the length of harvest contracts and forced vertical integration[4] is predicted. Second, the shadow prices of those constraints are estimated. Both the objectives are pursued through the use of an optimal control approach.

1.2 Socioeconomic Impact of a Forest Policy

British Columbia (B.C.), like other jurisdictions in North America, is facing an increasing demand for non-timber values. These changing public values are causing policy makers to contemplate reductions in timber harvest levels (Alavalapati et al. 1994).[5] Forest

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[2]For Example, Binkley (1987) has noted that higher stumpage prices mean that more of the timber inventory is economically accessible for harvest.

[3]See Buongiorno et al. (1985), Heaps (1988), Brazee and Mendelsohn (1988), and Adams et al. (1991) for details on timber supply from public lands.

[4]Generally, tenure holders in Canada are required to set up timber processing plants in order to gain access to timber from public lands causing log markets to be thin.

[5]For example, in the U.S. vast areas of old growth forests of the Pacific North West are protected to provide habitat for the spotted owl. See Sample and Le Master (1992) for more information on the economic effects of northern spotted owl protection.

lands in B.C., many of which are considered environmentally sensitive, are slowly being removed from areas used in calculating the annual allowable cut volumes (Binkley et al. 1993). One means of reducing harvests could be to increase fees paid by tenure holders as they harvest timber (i.e stumpage price). Along these lines, in response to the growing concerns for the environment, on April 14, 1994 the government of B.C. released its Forest Renewal Plan. Under this plan, the forest industry will pay $2 billion over 5 years to replant B.C. forests and clean up past abuses (Vancouver Sun, April 15 1994). Although forest industry officials supported the plan with a view that it provides long-term planning, stabilizes annual allowable cut levels, and ensures a more certain future, they expect reduced profits for the industry in the short-run since stumpage prices are expected to increase by approximately 80.0 percent.

Given that the forest industry remains an economic mainstay of the province[6], it is believed that reduced harvest levels could have significant implications for the economy of the province. The second paper of the thesis investigates the short-run effect of this policy on forest and other product sectors, and on the income distribution between two income classes and two regions in B.C. The study also explores the effect of market power in shifting the burden of a domestic policy to consumers in the importing countries. The computable general equilibrium (CGE) approach used in this analysis accounts for inter-industry linkages, permits prices of inputs to vary with respect to changes in output prices,

[6]The forest sector in B.C. contributes approximately 11 percent of provincial gross domestic product and accounts for about 6 percent of total provincial employment. Also, forest sector shipments account for 46 percent of total manufacturing shipments for the province (B.C. Ministry of Finance and Corporate Relations 1993).

and accommodates the indirect effects of a policy on the overall economy.

1.3 Impacts of Macroeconomic Interactions on the Forest Sector

Producers of forest products in Canada depend heavily on international markets to sell their products. The exported value of forest product shipments accounts for approximately 50 percent of the value of total forest product shipments produced. In particular, forest products exports to the United States (U.S.) account for more than 65 percent of total forest product exports of Canada (Forestry Canada 1992b). Therefore, it is reasonable to expect that changes in the U.S. macroeconomy, or in policies with regard to the use of forest products in the U.S. may have significant impacts on Canadian forest products exports and thus on the Canadian forest industry at large.[7]

Changes in either a policy or the macroeconomy may have both direct and indirect effects on the Canadian forest sector. For example, a change in the U.S.-Canada exchange rate, causing the Canadian dollar to depreciate, may be expected to have a positive effect on forest products exports. However, if devaluation of the Canadian dollar results in higher interest rates, this may work counter to the exchange rate effect. In the past, not many studies have accounted for these dynamic interactions affecting the Canadian forest industry.[8] In the third paper of this thesis, dynamic interactions between selected U.S. macroeconomic variables and Canadian pulp industry are investigated. A vector error

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[7]For example, Harris (1992) argued that the US-Canada exchange rate is a key determinant of export performance and international competitiveness of the Canadian economy.

[8]Jennings et al. (1991) and Sarker (1993) considered the dynamic interactions affecting the Canadian lumber sector.

correction approach is used to determine the effect of shocks in domestic and foreign macroeconomic variables on Canadian pulp price. This approach allows for direct estimation of the long-run steady-state equilibrium condition, implied by theory, along with short-run dynamic adjustments based on nonstationary data series (Kesevan et al. 1992).

1.4 Plan of Study

The study is organized into five chapters followed by appendices. Following the introduction, chapter two is devoted to investigating the effect of institutional constraints on the short-run timber supply behaviour of quota holders in Alberta. The third chapter examines the socioeconomic effects of a recent stumpage price increase policy on the economy of B.C. Both welfare and distributive effects of the policy are examined. Chapter four explores the dynamic impacts of a set of macroeconomic variables on the Canadian pulp industry. The fifth chapter provides a general discussion and conclusions of the research.

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CHAPTER 2 Effect of Institutional Constraints on Short-run Timber Supply of Quota Holders in Alberta

2.1 Introduction

There exists an issue in the forestry economics literature on the price responsiveness of timber supply from public forests in the face of allowable cut constraints which are dictated by sustained yield policies. Some have argued that timber supply from public lands may not be responsive to the price (Buongiorno et al. 1985). On the other hand, some studies have shown that timber supply from public forests may be responsive to price (Heaps 1988; Adams et al. 1991). In the Canadian context, the price responsiveness of timber supply may depend on the flexibilities that tenure holders have within tenure regulations.[9] For example, tenure holders are typically required to follow some designated allowable annual cut, but are allowed some flexibility in cuttings levels over time. Also, firms in Canada are generally required to operate timber processing plants as a condition of gaining access to public timber. Accordingly volumes of public timber are tied directly to processing capacities of plants causing log markets to be thin and limiting the flexibility of firms to respond to price.

Suggestions have been made with regards to potential policies which could make timber supply on public lands more responsive to price. For example, Brazee and Mendelsohn (1988) have suggested that extending the length of time on harvest contracts may provide opportunities to practice flexible harvest strategies in response to price. Uhler (1991) noted that the log markets could help producers sell timber species and grades

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[9]Haley and Luckert (1990) describe and compare forest tenures across Canada emphasizing impacts of tenure characteristics on the behaviour of forest tenure holders.

which are not matched with the technology of their timber processing plants. This flexibility would allow tenure holders to be more price responsive since processing capacities will no longer constrain their timber supply decisions.

Whether and how existing institutional constraints and market forces interact to affect the timber supply behaviour of firms is an empirical question. In this study two issues are investigated. First, the supply behaviour of timber quota holders in Alberta is modelled in the presence of annual allowable cut constraints and forced vertical integration. Second, shadow prices of these institutional constraints are estimated. The paper is organized as follows. A brief review of the quota system in Alberta is provided in the next section. The timber supply model is then described along with the underlying assumptions of the approach. Next, the results of the timber supply model are presented and used to estimate shadow prices of institutional constraints for the period 1986 to 1991. The paper concludes with a summary of findings and implications for further research.

2.2 An Overview of Quota System in Alberta

The quota system in Alberta, which was introduced in 1965-66 and currently accounts for approximately 50% of the lumber production in the province, granted established forest products firms the right to cut specified volumes of timber in particular management units. The quota system was thought to provide greater security to the operator than the previous renewable licence system, with volumes being granted for a twenty-year term.[10] This twenty-year quota period was further divided into four five-year

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[10]See Bankes (1986) for an extensive discussion on quota system in Alberta.

quadrants. Within each quadrant, quota holders are allowed to harvest with complete flexibility but are penalized if they deviate more than ± 10% by the end of the quadrant.

The Forest Act, Timber Management Regulation (1991:4-5)[11] specifies that:

"The total volume produced pursuant to any quota during each consecutive quota quadrant may not deviate from the authorized quadrant volume by more than 10%

If production exceeds that authorized for a quota quadrant, the Minister shall reduce the authorized volume for the following quadrant by an amount equal to the over cut volume

When production in any quota quadrant exceeds 110% of the volume or area authorized for that quota quadrant, the quota holder shall pay to the Minister a penalty of $4.65 per cubic meter for a coniferous quota or $24.70 per hectare for a deciduous timber allocation on the entire overcut volume or area

When production in any quota quadrant is less than 90% of the authorized quadrant volume or amount of forest land, the quota holder shall pay an under utilization charge of 25 cents per cubic meter for a coniferous timber quota or $2.50 per hectare for a deciduous timber allocation to the Minister in respect of the unproduced volume or area exceeding 10% of the authorized quadrant volume or amount of forest land.......

Where actual quota production in a quadrant equals or exceeds 90% of the authorized quadrant volume, the Minister may at his discretion authorize the quota holder to produce the undercut volume in the period of time covered by the next quadrant subject to the stipulation that the production so authorized will not be charged to any quota quadrant"

Historical evidence suggests that very few firms deviate significantly from the production regulations and amounts paid by quota holders towards penalties for any significant deviations appear to be negligible.

Another regulation is that "each quota holder is required to set up a timber

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[11]Section 100 in Forest Act, Timber Management Regulation 1991 contains additional conditions on timber harvesting (Province of Alberta, 1991).

processing mill "located within 35 kilometres of the Town of X, Alberta" (Bankes 1985). This implies that producers of timber from public forests are constrained from selling logs in the open market because timber is awarded based on processing plant requirements. As timber is harvested, mostly during the winter season,[12] tenure holders face provincially determined stumpage prices, which do not vary with product price.[13] This consideration taken together with the vertical integration of quota holders suggests that analyzing the price responsiveness of timber supply to stumpage prices would not be meaningful. Instead, investigating lumber supply behaviour in response to lumber price and then translating lumber supply into timber supply is more appropriate.

Figure 2.1 illustrates how timber is converted into lumber so that revenue may be derived from timber production. From each cubic meter (cmt) of timber approximately 0.37 cmt lumber is produced with 0.36 cmt of wood chips as a commercial by product. The rest of the timber volume is waste. Since wood chips are a by-product in the lumber production process, the share of revenue from wood chips in total timber revenue is small[14]. Lumber and wood chips are sold in units of thousand board feet (MBF) and bone dry units (BDU) respectively, both of which contribute to the revenue of the firm.

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[12]Firms harvest timber mostly in the winter season because frozen ground facilitates log skidding and transportation.

[13]According to the new regulations (since January 12, 1994) a base stumpage rate of a $1.40 per cubic metre for coniferous timber is charged and companies will pay an additional amount depending on their volume of output and lumber prices quoted in American markets.

[14]Simulations conducted in this study indicate that between 1986-91 the share of revenue from wood chips in total timber revenue averaged approximately 8%.

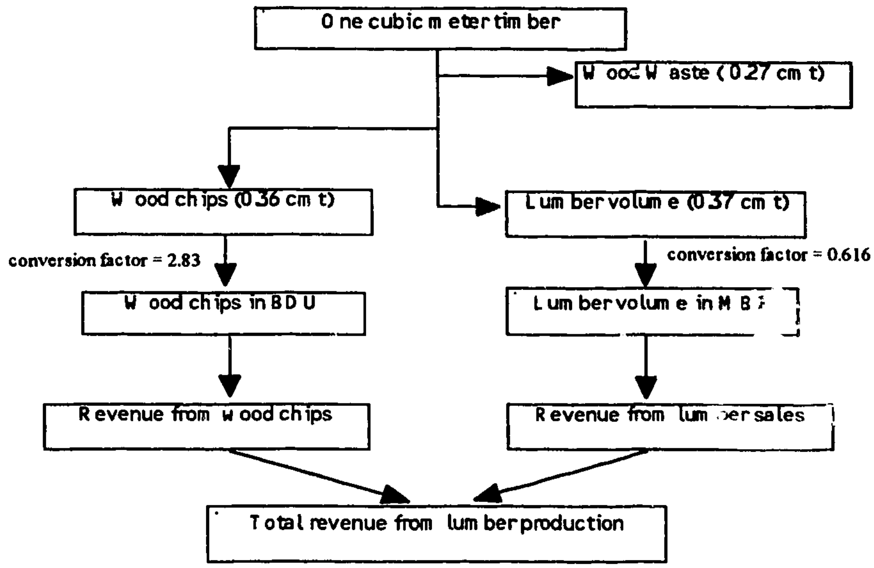

Figure 2.1 Schematic representation of revenue from timber production.

2.3 Model Specification

The optimal harvest of renewable resources, or the extraction of exhaustible resources, may be caste as a dynamic allocation problem (Conrad and Clark 1987). It is assumed that a quota holder is concerned with seeking that harvest rate through time, subject to the constraints he/she faces, which maximizes profits. An optimal control approach is used to determine the production path of lumber and investigate the effect of institutional constraints on the supply behaviour of quota holders.[15] Since timber harvesting is discrete in time, discrete optimal control theory provides an attractive

[15] Optimal control theory has been applied extensively to study optimal timber harvesting and forest management practices. Lyon and Sedjo (1983) and Sedjo and Lyon (1990) examine long-term timber supply issues including questions about change in timber stocks over time. We focus on short-run supply decisions dealing the rate at which an existing stock is harvested in response to market forces and institutional constraints.

framework (Lyon and Sedjo 1983). Following the principle of optimality, optimal control decomposes a time period into a series of smaller single-time period problems and maximizes the objective function subject to constraints. Furthermore, optimal control, unlike dynamic programming, does not require specification of the number of states (ie. harvest volumes) for a variable at each decision stage. Thus it accommodates an infinite number of states at each stage.

2.3.1 Data

Monthly data on timber quantities harvested per quota holder (n=56) and wood chip prices from 1986 to 1992 were obtained from the Alberta Land & Forest Services. Data on lumber prices and interest rates were collected, respectively, from Alberta Forest Industry Report series and CANSIM D 14006. Since firms rarely deviate from production regulations in each quadrant, it may be assumed that production decisions in each quadrant are independent. Accordingly, data for the quadrant 1986:4 -1991:3 were used for further analysis.[16] Monthly data were aggregated into semi-annual data in order to reduce the potential for inventories to distort supply behaviour while retaining the difference in winter and summer harvesting conditions.[17] As a result, the 1986:4 to 1991:3 quota quadrant is divided into 10 planning periods. Accordingly, data on lumber price, wood chip price, and interest rates were aggregated.

2.3.2 Assumptions Underlying the Model

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[16]Since the timber year runs from April 1 to March 31, the period from 1986:4 to 1991:3 is considered as one quadrant.

[17]Data on inventories were not available for analysis.

Several considerations were built into the model based on the quota system in Alberta. First, it is assumed that wood chip revenues do not affect the timber production behaviour of quota holders because wood chips are a by product in lumber production. Second, the price of lumber is assumed exogenous to quota holder's production because firms are small relative to the size of the market in which they sell.

The third assumption deals with the production technology of quota holders. Data over a 5 year period revealed that timber production among quota holders ranges from less than 0.1 million cubic meters to greater than 5.0 million cubic meters. We assume that, given this range of production, quota holders use different technologies in production. Therefore, despite constant technology in the short-run, the unit cost of production may well vary across firms. However, processing mills within certain ranges of production capacities are assumed to use the same production technology and thus have similar cost structures. The classification used to categorize the quota holders is shown in Table 2.1.

Table 2.1. Quota holders category by their timber production capacity.

Quota holders category	Timber production capacity in a quadrant
Big	>1,000,000 cubic meters
Medium	>100,000 and < 1,000,000 cubic meters
Small	<100,000 cubic meters

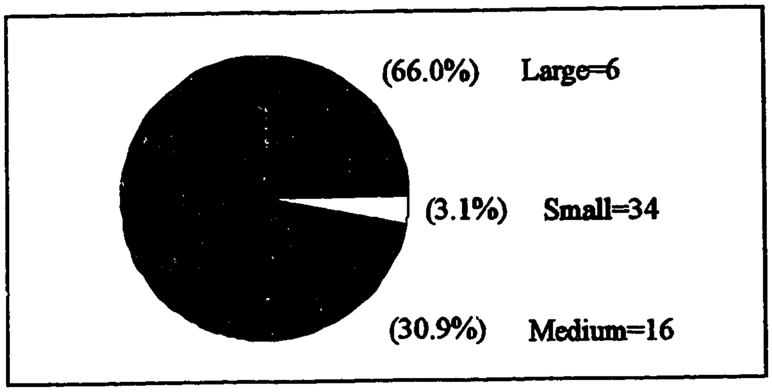

Figure 2.2 Quota holders timber production by size and category

Figure 2.2 shows the number of quota holders by size and the share of timber production by category. Approximately two thirds of total quota holders' production is shown to be produced by six big quota holders. On the other hand, there are 34 small quota holders which account for approximately 3% of total production. Medium quota holders account for approximately one third of total production. In the analysis that follows models are set up for each category to model timber supply and estimate shadow prices of institutional constraints.

Fourth, it is assumed that lumber prices, wood chip prices, and interest rates change over time according a Markovian process[18]. In a Markovian model, the probability that a variable changes from a current state S_i to some future state S_j, depends only on S_i. The state transition probabilities, P_{ij}, give the probability that a variable changes from state S_i to S_j in one time period and must be determined for every ordered pair of states S_i, S_j.

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[18] "A Markovian price expectation structure refers to any stochastic model in which price is conditional on previous prices; hence, the assumption embraces random walk, rational expectations, autoregressive, and many other conditional models which are often used to model price movements in agricultural markets. The case of random (white noise) price is considered as a limiting case of Markovian model" (Taylor, 1984:351).

Calculation of Expected Values

Quarterly data from 1985:1 to 1993:1 on lumber price, wood chip price, and interest rate were used to estimate the following models:

$$P_{t+1}^{L} = \alpha^{L} + \beta^{L} P_{t}^{L} + \epsilon_{t}^{L} \quad (1)$$

$$P_{t+1}^{C} = \alpha^{C} + \beta^{C} P_{t}^{C} + \epsilon_{t}^{C} \quad (2)$$

$$R_{t+1} = \alpha^{R} + \beta^{R} R_{t} + \epsilon_{t}^{R} \quad (3)$$

where P^L is price of lumber, P^C is price of wood chips, R is interest rate, the superscripts L,C, and R denote respectively lumber, wood chips and interest rates, α and β are parameters, and ϵ is an error term. The statistics of the three first order autoregression models are reported in Table 2.2.

Table 2.2 Results of the autoregression models for prices and interest rates.

Model	α value	β value	R^2 value	St. error
lumber price	-13.597 (-0.24)	1.1068 (4.13)	0.36	41.11
wood chip price	5.499 (1.94)	0.881 (13.49)	0.86	2.84
interest rate	0.413 (0.46)	0.939 (10.55)	0.78	1.04

Note: Values in parenthesis are t-statistics

The β values are all significant at the 0.01 level suggesting a Markovian structure for all the three variables. Estimated values were used to calculate state transition probability matrices following Taylor's hyperbolic tangent approximation method:[19]

$$F(e_t) = 0.5+0.5\tanh(0.7971\, e_t+0.03731\, e_t^3+0.00003923\, e_t^5) \quad (4)$$

where $e_t = \epsilon_t /$ standard error. The state transition probabilities for lumber prices, wood chip prices, and interest rates are presented in appendix 2.1. The state transition probability matrices are used in determining the probability that a variable will be in a certain state after n periods given the state of a variable in period 0. For example, let $\pi(i)$ be the state probability of the price of lumber, and P is the price transition matrix. Following Howard (1960), the probability that the lumber price will occupy state j after n periods can be written as follows:[20]

$\pi(0) = [\,0\;0\;0\;1\;0\;0\;0\;0\,]$ (initial state probability)
$\pi(1) = \pi(0)P$
$\pi(2) = \pi(0)P^2$
$\pi(3) = \pi(0)P^3$
•
•
$\pi(n) = \pi(0)P^n$

Using these probabilities and the number of states specified in the model, we can calculate the expected values for lumber price for all periods of the model.

For a quota holder, timber is a nonrenewable resource[21] and his/her sole objective is to determine the optimal path of harvest. We model this problem as maximizing profits

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[19]Taylor (1984) presents a flexible method of fitting a conditional probability density function. See Teeter and Caulfied (1991) for an application in forestry.

[20]In this study, we considered 8 states of lumber price ranging from $170 to $240 with an interval of $10. A value of 1 in the fourth column of initial state probability implies that the initial lumber price is $200.

[21]Trees allotted to quota holders for harvest are already matured and are therefore not the subject of silvicultural activities.

from the lumber production process which yields the corresponding Hamiltonian:[22]

$$\tilde{H}(.) = [P(t)Y(t) - \frac{\theta Y(t)^{\beta}}{X(t)}] - \delta(t)\lambda(t+1)Y(t) + F(X_T) \qquad (5)$$

$$X(t+1) - X(t) = -Y(t) \qquad (2.6)$$

$$X(1) = \textit{total lumber quantity} \qquad (2.7)$$

$$Y(t)_{max} \leq \textit{maximum capacity} \qquad (8)$$

$$\sum_{t=1}^{10} Y(t) \leq X(1) \qquad (9)$$

where: Ĥ = is a current value Hamiltonian;

t = planning period t = 1,..........10 with period 11 being the terminal period (T);

Y(t) = lumber production in period t;

X(t) = lumber stock in period t;

δ(t) = 1/(1+r(t)) is a discount factor in period t;

r(t) = the interest rate in period t;

β and θ = parameters in the cost structure;

P(t) = the price of lumber in period t;

λ(t) = the user cost or intertemporal cost in period t;

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[22]The Hamiltonian is essentially a multiperiod Lagrangian which optimizes the objective function over time solving for the optimal time path. See Conrad and Clark (1987) for more details.

and F(.) = terminal value of lumber.

Equation (2.5) is the objective function that maximizes the net present value of lumber production over time. The first term on the right hand side of equation (2.5) is revenue from a unit sale of lumber, the second term is the unit cost of lumber production, the third term is the opportunity cost of a unit of lumber production, and the last term is the terminal value of the lumber stock remaining at the end of each planning period. Equation (2.6) is the equation of motion, describing the change in lumber stocks between periods. Equation (2.7) is the initial condition showing the total quantity of lumber that can be produced in the planning period. Equation (2.8) specifies that the quantity of lumber production in any period cannot exceed the maximum capacity of production. Finally, equation (2.9) specifies that the total quantity produced during the planning period must be smaller, or equal to the initial quantity. The necessary first order conditions require

$$\frac{\partial \tilde{H}(.)}{\partial Y(t)} = [P(t) - \frac{\beta \theta Y(t)^{\beta-1}}{X(t)}] - \delta(t)\lambda(t+1) = 0 \qquad t = 1,2.....,10 \tag{10}$$

$$\frac{-\partial \tilde{H}(.)}{\partial X(t)} = [\delta(t)\lambda(t+1) - \lambda(t)] = -\frac{\theta Y^{\beta}}{X(t)^2} \qquad t = 1,2......10 \tag{11}$$

$$\frac{\partial \tilde{H}(.)}{\partial \lambda_{t+1}} = X(t+1) - X(t) = -Y(t) \qquad t = 1,2........10 \tag{12}$$

$$\frac{\partial \tilde{H}(.)}{\partial X(T)} = \lambda(11) - F'(.) = 0 \tag{13}$$

Defining Y(t)/X(t) = Z(t), and β=2, we can write equation (10) as follows:

$$Z(t) = \frac{[P(t)-\delta(t)\lambda(t+1)]}{2\theta} \qquad t = 1,2,....10 \qquad \textbf{(14)}$$

Given equation (2.13) (i.e. the fact that the user cost of lumber production after the planning period equals zero), equation (2.14) can be used to calculate a Z(10) value. Substituting a Z(10) value into the right hand side of equation (2.11), a $\lambda(10)$ value can be computed. Again using $\lambda(10)$ and the expected value of P(9) in equation (2.14), Z(9) can be calculated. Knowing Z(9) we can return to equation (2.11) to solve $\lambda(9)$, and so forth. Using Z(t) values and equations (2.7) and (2.12), Y(t) and X(t) values can be calculated.

2.3.3 Model Calibration

Since actual cost structures of quota holders are not known, models for big, medium, and small quota holders were calibrated by changing the parameter, θ, in the cost structure. Furthermore, in order to account for seasonal conditions in timber harvest two θ values, one for the winter period and another for the summer period, are used. More timber being harvested in winter periods suggests that the unit cost of harvest is lower in that season than that of the summer period. Accordingly, a smaller θ value is required to reflect winter versus summer harvest costs. Since an infinite combination of θ values exist, a grid search was conducted to select θ values, where the objective was to find that pair of θ values which minimize the sum of squared errors (SSE) between actual and model predicted lumber volumes over the entire planning period.[23] By defining θ_w for winter and θ_s for summer a grid search is made as follows:

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[23]It should be noted here that these θ values do not change between years since technology is assumed constant in the short-run.

$\theta_w = \Psi + \Phi$

and $\theta_s = \Psi + (\Phi)^\zeta$ where Ψ is a base value[24]; $\Phi = 1,2, \ldots\ldots..1000$; and $\zeta = 1.5$.

The θ values which minimized the SSE are reported in Table 2.3.[25] The stock left at the end of the planning period by using these θ values is reported in column 5. Since regulations allow quota holders to deviate ±10% of total production at the end of quota quadrant, the percentage of stocks shown in column 5 are acceptable.

Table 2.3 Parameter values in the cost structures for different quota holders

Quota holder category	Φ value	θ_w	θ_s	stock left (%)
Big	68	108	600.74	0.06
Medium	85	125	823.66	2.18
Small	6	41	49.7	2.01

Once models were calibrated they were used to represent the base case in estimating the shadow prices of institutional constraints. The revenue from lumber production can be obtained by multiplying the lumber quantities by the expected values of lumber price for each time period. The cost of production is subtracted at each stage in order to derive the net revenue from lumber production. Wood chip quantities are calculated from lumber quantities as shown in figure 2.1. Quantities of wood chips are

[24]The models for big and medium quota holders could not run with a base value smaller than 40. On the other hand the model for small quota holders could not run with a base value smaller than 35. Therefore, a base value 40 is fixed for big and medium quota holders, and a value of 35 is fixed for small quota holders.

[25]For the Ψ and ζ values used in the grid search, the θ values reported in Table 3 are unique. However, other Ψ and ζ values may result a different set of θ values.

multiplied by the expected values of wood chip prices to derive the expected revenue from wood chips. The net revenues from lumber and wood chips are added at each stage and discounted using the expected values of interest rates to determine the total net present value (NPV) of lumber production for the entire quadrant.

Three types of situations are analyzed. First, in order to estimate the shadow price of forced vertical integration we simulate a situation where log markets would exist. The presence of log markets is simulated by removing the restriction that lumber production at any time period should not exceed the maximum capacity (equation 2.8). As described earlier, in the presence of log markets, timber processing capacities would not restrict profits as excess logs could be sold. Second, in order to calculate the shadow price of the quadrant length, a situtation where the quota period is divided into two 10 quadrants is simulated. Finally, a situation where log markets would exist and the length of quota quadrant is 10 years is simulated. In all three cases, first, lumber supply is estimated and then the corresponding timber supply is presented.

2.4 Results and Discussion

2.4.1 Timber Production

The net present value (NPV) of timber production and the percentage of prediction error of timber production[26] estimated for each quota holder category is reported in Table 2.4 The values of prediction error suggest that the model does reasonably well in predicting the behaviour of quota holders.

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[26]Prediction error is calculated as ($\sqrt{SSE}$ / initial timber stock of each quota holder category) * 100.

Table 2.4 Net present values and prediction errors of timber production by quota holder category

Quota holder Category	Actual NPV ($millions)	Model NPV ($millions)	prediction error (%)
Big	360.425	458.220	12.0
Medium	158.066	202.948	10.0
Small	23.049	26.350	16.0

Figure 2.3a-2.3c show actual production and calibrated model timber production respectively, for big, medium, and small quota holders. It is shown that the actual timber production for big and medium quota holders fluctuates heavily between seasons. In each year, harvest in the second season (i.e. fall and winter) is higher than that of the first season (i.e. spring and summer). However, the harvests in the first two winter seasons are smaller than those of final years. On the other hand, the production pattern of small quota holders is shown to be different from both big and medium quota holders. Production in later stages of the quadrant is estimated to be zero for small quota holders with a surge at the end of the quadrant. Production regulations discussed in section 2.2 may be responsible for this surge.[27] Also, seasonal conditions do not seem to have a significant effect on their supply behaviour.

[27]The dynamic cost of deviating from the production regulation may be so high that quota holders may loose the quota and the right to get access to public timber.

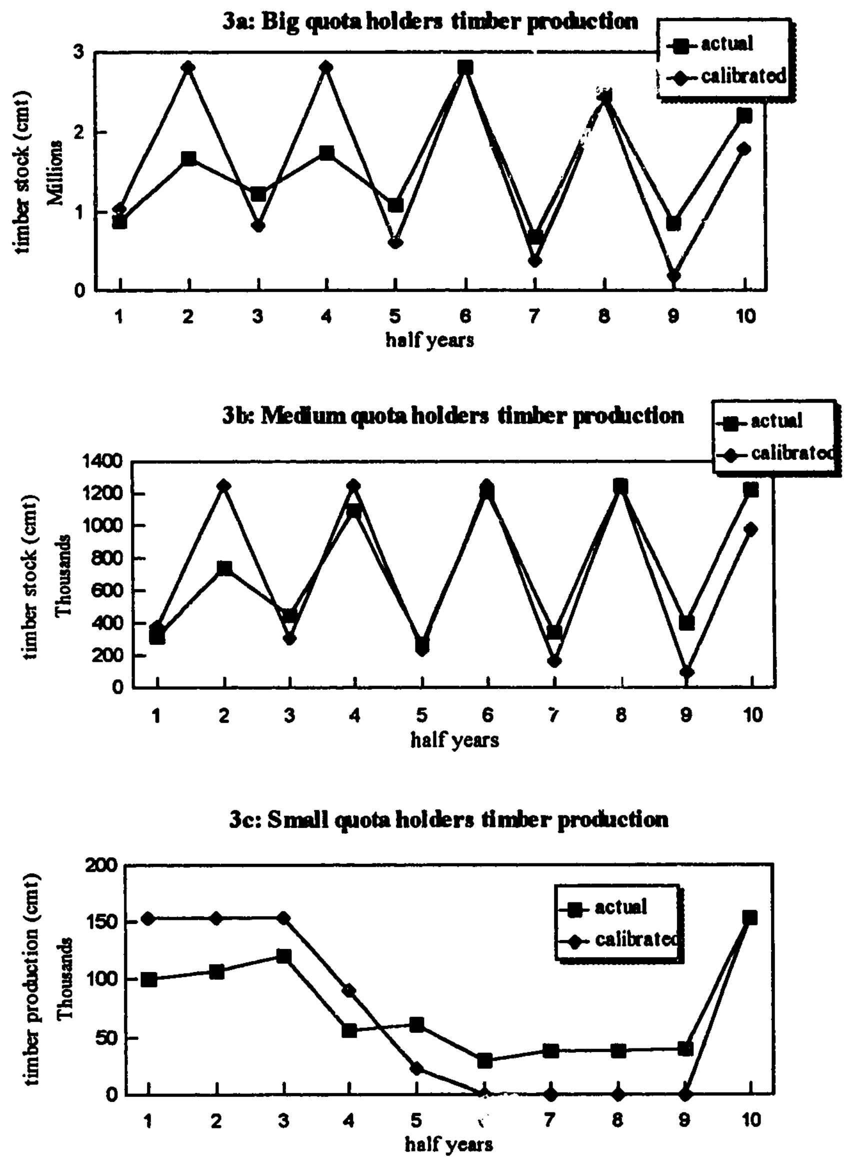

Figure 2.3 Actual and model calibrated timber production for quota holders.

2.4.2 Timber Production With Log Markets

The predicted timber production patterns with and without capacity constraints are presented in figures 2.4a-2.4c, respectively, for big, medium, and small quota holders. In the figure, it is shown that the constraint was binding in the early stages of quota quadrant for all quota holders where production increases substantially. If there are no capacity constraints, the net present values of timber production is estimated to increase by 5.13%, 6.08%, and 8.3%, re vely, for large, medium, and small quota holders, and 5.53% for all quota holders. Sinc of capacity constraints in lumber production is treated as a proxy for a firm wh bility to either sell or process logs, these values can be taken as the shadow prices of absence of log market for quota holders.

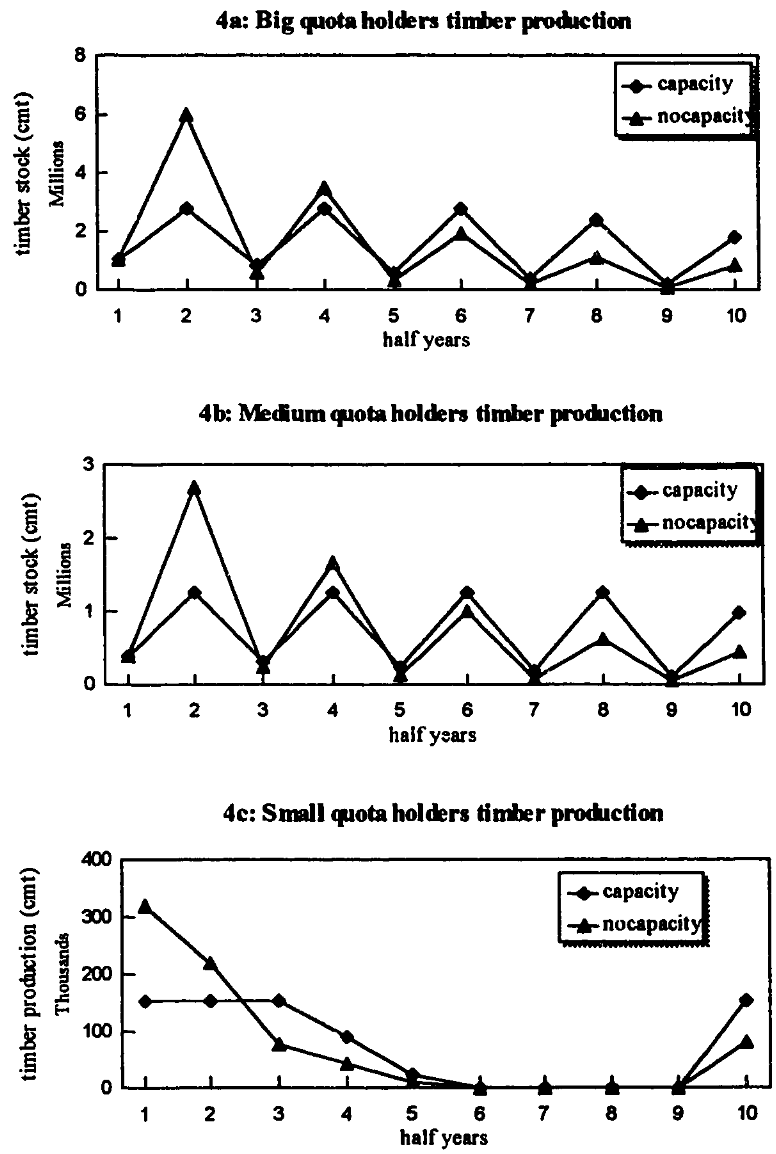

Figure 2.4 Timber production for quota holders with and without capacity constraints.

2.4.3 Timber Production When Quota Quadrant Length is 10 years

In th analysis, the net present value of timber production is estimated based on a 10 year quadrant. Assuming that quota volume is distributed equally across quadrants, the stock available for a 10 year quadrant is taken as being twice the quantity available in a 5 year quadrant.[28] Then net present values of 10 year quadrant and two 5 year quadrants are compared to estimate the shadow price. The net present value of two 5 year quadrants is calculated by: 1) assuming that the net present value of the second 5 year quadrant equals the first 5 year quadrant; 2) discounting the net present value of the second 5 year quadrant for 5 years; and 3) adding the present values of the two 5 year quadrants.

The timber production paths when the quota quadrant length is 10 years are shown in figures 2.5a-2.5c, respectively, for big, medium, and small quota holders. Production paths are shown to deviate significantly from the five year ones, especially the production path of small quota holders. For all quota holders, the capacity constraints are still binding in the early periods despite the increase in the length of quadrant. For big quota holders, an extension of 5 years in quadrant length causes the net present value of lumber production to rise by approximately 7.0% while for medium quota holders the net present value increases by 6.0%. In the case of small quota holders, the net present value of production increases by 12.7% with an increase in the quota quadrant period from 5 to 10 years.

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[28]This assumption is made because data is not available for two 5 year quadrants.

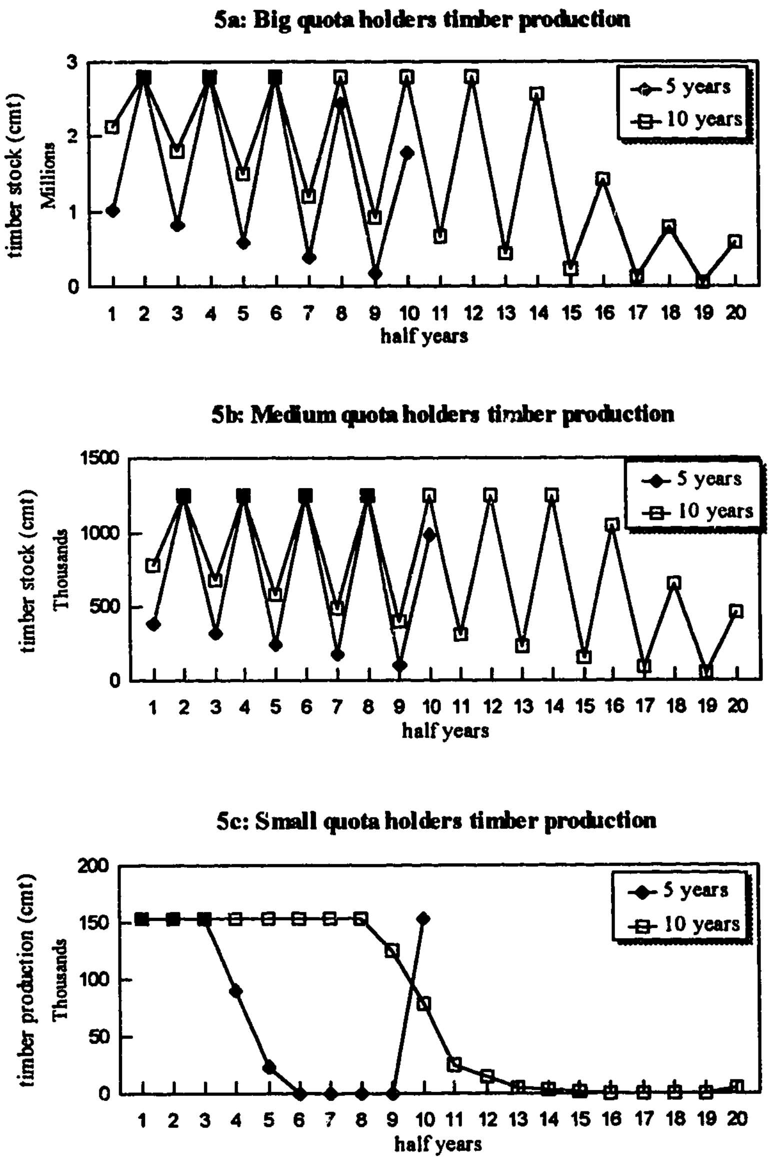

Figure 2.5 Timber production for quota holders when the length of the quadrant is 10 years.

2.4.4 Timber Production When Log Markets Exist and Quota Quadrant Length is Extended

Timber production behaviour in a situation where log markets exist and the quota quadrant period is 10 years is shown in figures 2.6a-2.6c, respectively, for big, medium, and small quota holders. When quota holders face no processing capacity constraints, their production increases dramatically in the early stages of the quota quadrant as a full ten years worth of volume may be re-allocated for early harvests. Accordingly, the quantities harvested during the first few periods of this scenario are approximately twice as large as harvests in the beginning periods of the scenario with a 5 year quadrant and no capacity constraints (see figure 2.4a-2.4c). Because of the huge increase in harvest in the initial periods, the net present values are much larger than those of two 5 year quadrants with no capacity constraints. In this scenario, the net present value of lumber production, for big quota holders, rises by 27.8%. For medium quota holders the increase in net present value is by 29.6% while for small quota holders the increase is 35.9%.

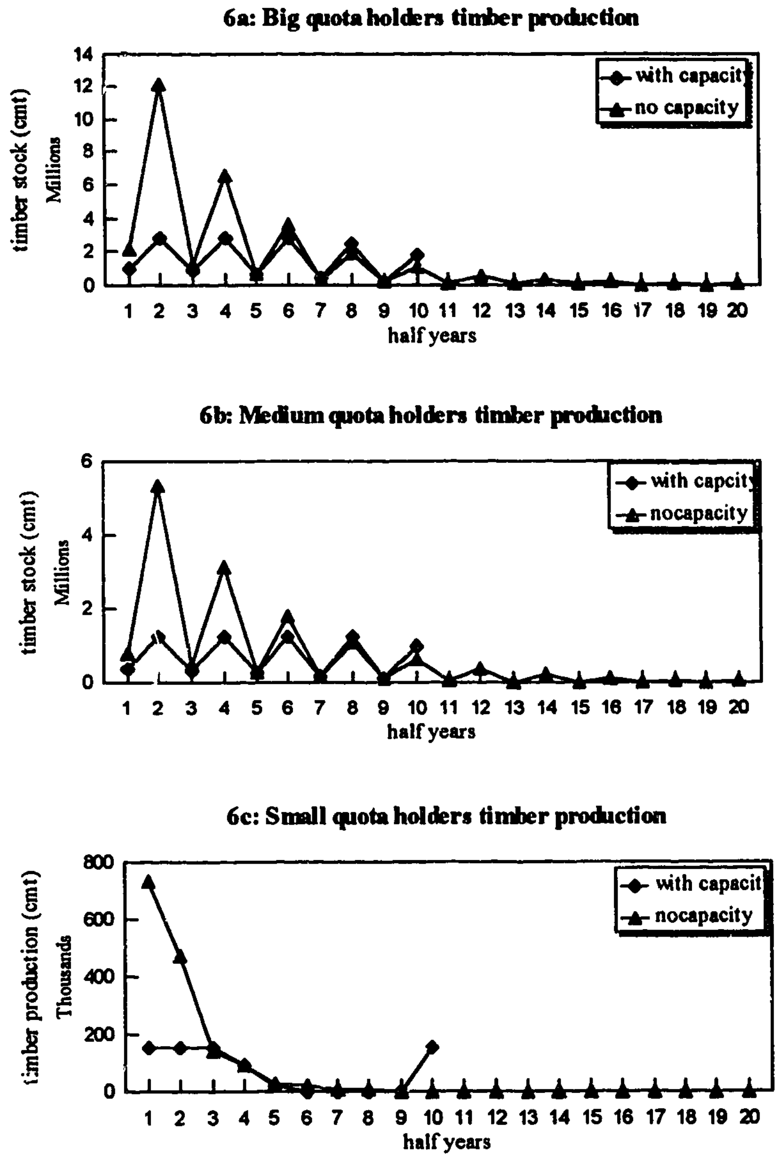

Figure 2.6 Timber production for quota holders when log markets exist and the length of the quadrant is10 years.

Table 2.5. Net present values of lumber production and shadow prices of institutional constraints by quota holder category and by scenario (values are in million dollars)

#	Scenario	Big QHs	Medium QHs	Small QHs	Total QHs
1	Actual NPV (5 years)	360.42	158.06	23.05	541.54
2	Calibrated NPV (5 years)	458.22	202.94	26.35	687.51
3	NCC NPV (5 years)	481.74	215.28	28.53	725.55
4	CC NPV (5+5 years)	770.07	341.07	44.28	1155.43
5	NCC NPV (5+5 years)	809.60	361.79	47.95	1219.36
6	CC NPV (10 years)	826.38	362.89	50.36	1239.64
7	NCC NPV (10 years)	984.26	442.01	60.18	1486.45
	SP of CC (5 years)[a]	23.52	12.33	2.18	38.03
	SP of 10Y vs 5+5Y[b]	56.30	21.82	6.08	84.21
	SP of CC + 10Y[c]	214.18	100.94	15.89	331.02

Note: NPV= net present value; NCC = no capacity constraints; SP = shadow price; CC= capacity constraints; Y= year; [a]#3 minus #2; [b]#6 minus #4; and [c]#7 minus #4.

Table 2.5 presents the summary of net present values under different scenarios by quota holders category and for all quota holders. The shadow prices of capacity constraints and limitations on the length of quota quadrants are added across big, medium, and small quota holders. The shadow price of capacity constraints when the quadrant length is 5 years is shown to be approximately 38 million dollars for all quota holders in Alberta. The quota holders are expected to make about 84 million dollars (7%) more if the length of quota quadrant is extended from 5 years to 10 years. Finally, if log markets exist and the length of quota quadrant is extended to 10 years, quota holders make approximately 331 million dollars (28.6) more.

2.5 Summary and Conclusions

Short-run timber supply behaviour is investigated under institutional constraints.

An optimal control approach is used to predict timber supply and estimate shadow prices of institutional constraints. Expected values of prices and interest rates are used in the model which are derived from Taylor's hyperbolic tangent transformation approach. Quota holders are divided into three categories based on their timber production capacities, because it is thought that these quota holders use different technologies in the short-run. The cost structure of large, medium, and small tenure holders are calibrated so that the modeled behaviour mimics the actual lumber production. Because of institutionally vertical integration, timber supply is modeled in response to prices of processed timber products. Calibrated models are used to determine the shadow prices of processing capacity constraints and annual allowable cut restrictions. Results indicate that quota holders incur substantial costs due to institutional constraints. Both capacity constraints and limitations on the length of quota quadrant are shown to be binding for all categories of quota holders.

The strength of the model specified in this study lies in its capacity to integrate both government and market forces to predict timber supply on public lands. Conventional econometric models used by earlier researchers to predict the timber supply have not accounted for institutional constraints.[29] On the other hand, traditional mathematical models, which used either dynamic programming or linear programming techniques, have been aimed at determining the shadow prices of institutional constraints and optimizing forest management.[30] The optimal control technique used in this study facilitates the

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[29]See Buongiorno et al. (1985).

[30]See White (1989) for dynamic programming applications in forestry.

estimation of lumber supply (and thereby timber supply) of quota holders under various constraints.

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CHAPTER 3 Effect of a Stumpage Price Increase Policy on the Economy of British Columbia: A Computable General Equilibrium Analysis

3.1 Introduction

The forest industry of British Columbia (B.C.) makes significant contributions to the provincial economy. The forest sector share of gross domestic product (GDP) and direct employment in 1992 was, respectively, approximately 11 percent and 6 percent of provincial total (Ministry of Finance and Corporate Relations 1993). Forest sector shipments accounted for 46 percent of total manufacturing shipments for the province and accounted for 59 percent of all provincial exports with the top two being softwood lumber at 28.3 percent and market pulp at 14.7 percent. These figures indicate that any changes in policies that affect the forest sector, either directly or indirectly, may have a significant impact on the overall economy of the province. In the recent past, concerns for the environment have prompted public agencies to impose a series of regulations on the use of public forests (Nelson and Hackett 1993).[31] Several provinces are reducing their annual allowable cut (AAC) to reflect the growing demands on Canada's forests for non-timber values (Forestry Canada 1992). Binkley et al. (1993) noted that there could be a reduction of 10-25 percent of AAC in B.C.

3.1.1 Forest Renewal Plan

On April 14, 1994, the B.C. government released its Forest Renewal Plan. Under the plan the increase in stumpage and royalty revenues are estimated to total $600 million

[31]For example, the European Economic Community brought increasing pressure on the government of B.C. to reduce harvest levels (Duchesne 1991).

annually.[32] Since the Forest Renewal Plan is forestry industry financed, the provincial average stumpage rate is forecasted to increase from $15.17 per cubic metre to $27.43 per cubic metre, an increase of 80.8 percent (Financial Post 1994).[33] Furthermore, the increase in stumpage rates is expected to differ between the Coast and Interior regions. The target stumpage rate in the Interior is forecasted to increase from $15.17 per cubic metre to $27.47 per cubic metre (81.8 percent) while the stumpage rate is to rise from $17.20 per cubic metre to $28.03 per cubic metre (63.8 percent) on the Coast (Ministry of Forests 1994).

Currently stumpage fees in B.C. are levied following the Comparative Value Pricing System[34] as a charge per cubic metre of timber harvested from Crown lands. This manner of levying stumpage fees introduces distortions that would be absent were it levied as a lump-sum charge based on the value of stand as determined by the timber cruise (Percy 1986). Under a lump-sum charge system, the value of stumpage payable for the stand is independent of the volume of timber harvested. However, if stumpage is payable as a per unit levy, it affects the volume of timber harvested (See Nautiyal and Love 1971

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[32]Out of this $400 million a year or $2 billion over five years will go into a new fund which will be used to replant B.C. forest and clean up past abuses (Vancouver Sun 1994).

[33]Some believe that this is a strategy which the B.C. government has chosen to reduce harvest levels in response to the growing concerns for the environment. Others argue that the increase is a response to the long standing argument from U.S. lumber producers, that B.C. subsidizes its lumber producers with low stumpage prices.

[34]The Comparative Value Pricing System is a means of assessing the relative value of each stand of timber being sold. In this system the total stumpage revenue collected approximates an overall forest revenue objective set by government (Ministry of Forest 1987).

for details). An increase in the per unit stumpage charge causes an increase in variable cost and thereby a reduction in the volumes of timber harvested. This result suggests that there would be a corresponding reduction in timber harvest levels in response to the increase in stumpage prices which were announced under the Forest Renewal Plan.

The aims of the Forest Renewal Plan may be viewed as being laudable - improve forest sector productivity, ensure a sustainable timber supply while employing best forestry practices, undertake job skills re-training programs, address environmental concerns, assist value added manufacturers, and increase research and development. Yet the means of financing this plan clearly have significant implications for the B.C. economy since the forest industry remains an economic mainstay of the province. Moreover, the significant differences in stumpage price increases between the Coast and Interior regions will lead to different effects on the regional economies.

3.1.2 Objectives of the Paper

The overwhelming economic importance of the forest sector to B.C. means that changes in stumpage prices will have pervasive effects on various facets of income distribution. This paper assesses the impact of the stumpage price increases on three key sets of distributional variables for the province. It does so through use of a computable general equilibrium (CGE) model of the B.C. economy. First, we examine how these stumpage price increases affect aggregate economic variables for the province such as real gross domestic product (GDP) and real income and industrial structure. Second, we assess what happens to the incomes of two income classes in the province, the "poor" consisting of those with incomes of less than $20,000 and "average" British Columbians whose income is above $20,000. Finally, we look at what happens to incomes on a spatial basis - changes of average incomes on the Coast and Interior regions. Not surprisingly, the study shows that stumpage price increases of the magnitude set out in the Forest Renewal Plan have significant distributional consequences in terms of each of the above three measures.

The remainder of paper is organized as follows. Structural characteristics of the B.C. economy are discussed in the next section. A brief literature review is presented highlighting the strengths and problems associated with CGE models in the third section. The fourth section is devoted to model specification. Policy simulation results are discussed in the fifth section.

3.2 Structural Characteristics of the British Columbia Economy

There are distinct differences apparent between the Coast and Interior regions of B.C. Table 3.1 clearly indicates that population, employment and income are heavily concentrated in the Coastal region of B.C. However, there is a large share of forestry activity in the Interior of the province. Table 3.2 provides a more disaggregated view of employment by sector and region. The shares of forest sector and other primary sector activity in the interior are both more than twice their Coastal counterparts in terms of employment. The reverse trend holds for manufacturing on the coast. Both government and services account for a greater share of employment on the Coast than in the Interior.

Table 3.1 Economic indicators of B.C., by category, by region
(values are in shares)

Category	Coast	Interior
Population	0.765	0.235
Land area	0.255	0.745
Employment	0.745	0.255
Income	0.797	0.203
Revenue from forests	0.450	0.550
Employment in logging and sawmilling	0.455	0.544
Value from logging and sawmilling	0.445	0.555

Source: British Columbia Economic and Statistical Review 1992; British Columbia Regional Index 1986; Annual Report of the Ministry of Forests 1992/93; Canadian Forestry Statistics 1991.

Table 3.2. Employment of B.C., by sector, by region
(values are in shares)

Category	Coast	Interior
Forest Sector	0.069	0.144
Other pri. sector	0.028	0.087
Manufacturing	0.092	0.047
Service	0.736	0.670
Government	0.075	0.052

Note: shares of Coast and Interior employment respectively, 0.745 and 0.255
Source: British Columbia Regional Index 1986.

A crude measure of income distribution can be observed based on household taxable income. These data are used in Table 3.3 to provide a breakdown of income distribution by region for two broad income categories. In the Interior, households whose income is below $20,000 account for 54.3 percent of the population while the corresponding figure for the Coast is 49.5 percent. Table 3.4 provides a more detailed breakdown for specific communities within the two regions for "wage and salary income" and "other sources". The latter category contains income derived from both government transfers and capital income of interest and dividends. The evidence suggests a greater share of income in the Interior is derived from wages and salaries than on the Coast.

Table 3.3. Income categories in B. C., by region 1991
(values are in shares)

Category	Coast	Interior
Class A	0.495	0.543
Class B	0.504	0.455

Class A = households with income less than $20,000; Class B = households with income above $20,000. Source: Revenue Canada, Taxation Statistics 1993.

Table 3.4. Sources of households income for selected localities in B.C., 1991
(values are in shares)

Division	Wages and salaries	Other sources
Coast		
Victoria	0.587	0.412
Vancouver	0.600	0.399
Interior		
Prince George	0.785	0.214
East Kooteney	0.735	0.264

Source: Revenue Canada, Taxation Statistics 1993.

In aggregate, these descriptive data show the Interior of the province to be more dependent on the forest sector than the Coast and employment income is relatively more important in the Interior than on the Coast. Hence households in the Interior are more dependent on the income derived from the forest sector employment than on the Coast.

3.3 Literature Review

A number of studies have been conducted to determine the effects of forest policies, including a reduction in harvest levels, on the economy of B.C. Percy (1986) used a CGE framework to examine the consequences of various shocks, such as an increase in duty on softwood lumber exports and an increase in transportation costs of forest products exports, to the forest industry and the economy of B.C. Duchesne (1991) analyzed the effect of a 1% reduction in the forest land base by using an updated version of Percy's (1986) CGE model. Binkley et al. (1993) also used an updated version of Percy's model to examine the impact of decreases in the AAC. Horne et al. (1991) used the B.C. Input-Output model to assess the impacts of a 10% reduction in forest related supplies on employment and GDP. Lax and Parker (1992) used an econometric policy simulation model to evaluate the time path of impacts of reductions in the AAC. Despite the differences in the techniques used, all these studies indicated a significant negative impacts on the overall economy of B.C. of harvest reduction.

Among the models used in the studies described above, CGE models have attractive features.[35] The strength of CGE models lies in their ability to account for inter-

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[35]Constantino and Percy (1988) reviewed various models and highlighted the merits of CGE models.

industry linkages while satisfying the constraints imposed by economic theory (Binkley et al. 1993). The essence of a CGE model is as follows. Consumers maximize their utility and producers maximize their profits. The zero homogeneity of demand functions (i.e. no money illusion) and the linear homogeneity of profits in prices (i.e. a doubling of all prices doubles profits) imply that only relative prices are important and absolute price levels have no impact on the equilibrium (Shoven and Whalley 1992). Equilibrium in the model is achieved by a set of prices and levels of production in each industry such that total supply of commodities equals to the total demand for commodities.

Similar to Input-Output models, CGE models incorporate inter sector linkages and thus limit problems of either overstating or understating the effects a policy variable on sectors. However, unlike Input-Output models, CGE models permit the prices (and thus quantities) of inputs employed to vary with respect to changes in output prices and accommodate the indirect effects of policy variables on the overall economy.[36] Furthermore, in contrast to the econometric policy simulation model where prices are treated exogenous, CGE analysis takes prices as endogenous to the system.

In spite of its attractive features, the CGE approach is not without its problems.[37]

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[36]Parmenter (1982) discussed the importance of the indirect effects by giving the following example. It is often argued that tariff protection is necessary to protect employment in the economy. One can also show that protection might sustain employment in the protected industries. However, the effect of tariff on the employment in industries which engage heavily in international trade will be negative (because of an increase in unit costs of production) if the selling prices are fixed on world markets. This implies that policy analyses may lead to erroneous conclusions if they are done on only one sector of interest.

[37]Shoven and Whalley (1992) have discussed the main problems associated with CGE models. The following discussion is drawn from their ideas. See Hazledine and MacDonald (1992) for a detailed critique on general equilibrium models.

One of the difficulties is parameter specification. Elasticities and other key parameter values play a pivotal role in the model outcomes, but no consensus exists regarding such values. This limits the degree of confidence in the validity of the results obtained from CGE analysis. The second problem concerns several key assumptions underlying the model such as full employment, perfect competition, mobility of capital, and the treatment of time. The results may be quite sensitive to the nature of these assumptions made in building the model. The third difficulty is how the policies themselves are presented in the model. For example, the modelling of non-tariff barriers is an especially difficult task in CGE analysis. Finally, most CGE models are not tested in any statistical sense. Since parameters are calibrated using a base year's data, there is no statistical test of the model specification. Despite all these problems, many researchers feel that the CGE approach is useful for policy analysis.[38]

This study departs from previous CGE studies (Percy 1986); Duchesne (1991); and Binkley et al. (1993) in three areas. First, production functions are specified in constant elasticity of substitution (CES) form. Previous studies used a Cobb-Douglas (C-D) functional form which restricts the elasticity of substitution between inputs to unity.

[38]Jones (1965) recorded long ago that general equilibrium models have served as the workhorse for most of the developments in the theory of international trade. Shoven and Whalley (1992) noted that CGE models provide an ideal framework for appraising the effects of policy changes on resource allocation and assessing the welfare effects. Powell and Snape (1993) highlighted the contribution of CGE analysis to the evolution of trade policy in Australia. Conrad and Schroder (1993) argued that the CGE approach is a useful technique to get an understanding of the welfare effect and the qualitative results of a change in a given environmental policy instrument.

CES functions allow substitution between primary inputs and variation across sectors.[39]

The second issue addressed by this study is the effect of policy changes on real income (Dervis et al. 1982). As a welfare indicator, real income is the amount of money required, at a given price level, to purchase alternative bundles of goods along the indifference curve which indicates an attainable welfare level (See Hicks 1940). This interpretation is better suited to the measurement of real consumption than real income because indifference curves are defined over consumption goods alone. As a measure of productivity, an increase in real income is an outward shift in the production possibility frontier for the economy as a whole. In other words, given a level of prices, real income is the maximum value of any bundle of good on the production possibility frontier (PPF) in a given year.

The distinction between the real income in terms of a PPF and a community indifference curve (CIC) is illustrated in Figure 3.1. For simplicity, only two goods are considered. With an initial production possibility frontier (PPF1) and an initial price line, society's welfare level is at CIC1. The position of CIC1 off of PPF1 implies that forest products will be exported while the composite good is being imported. The policy change, in this case a reduction in timber harvest level, causes a PPF shift inward along the forestry axis. The price of forest product increases and the price of composite good decreases causing a steeper slope for the price line after the policy.

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[39]Constant ratio of elasticities of substitution, homothetic (CRESH) functions allow variations in substitution elasticities across different pairs of primary factors of production and among different pairs of intermediate products. Ideally these types of functions would have been used. However, data limitations did not permit their use in this analysis.

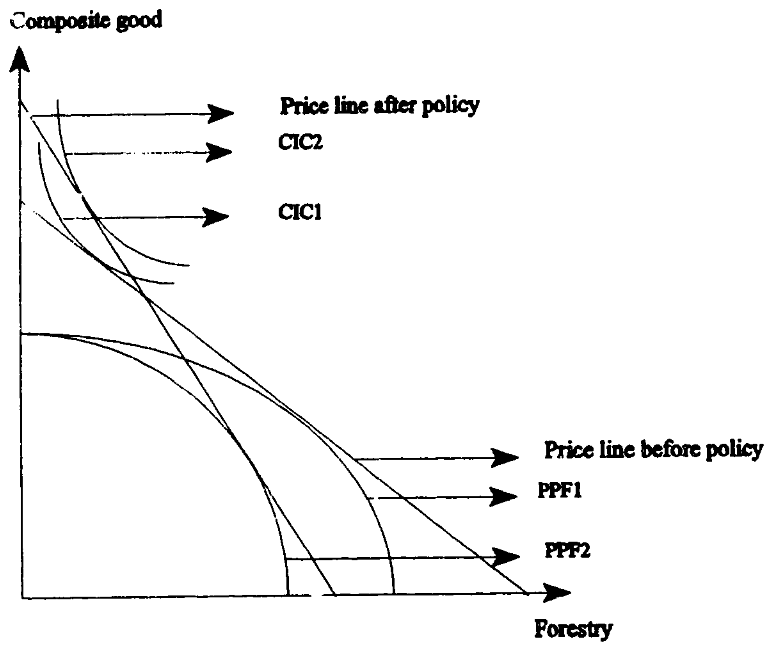

Figure 3.1 Productivity and welfare changes after a policy shock

With the new production possibility frontier (PPF2) and new price line, society's welfare is CIC2. By construction, it is shown in the figure that welfare is increased after the policy change. The logic is that the share of forest products in the consumer basket is small, and the increase in prices of forest products may not affect the consumer price index (CPI) significantly. Conversely, the decrease in price for the composite good (whose share is significant in the consumption bundle) might cause the CPI to decline. Therefore, in the short-run, it is possible that society's welfare may increase when the reduction in forestry output occurs. If the share of forest products is significant in the consumers' bundle, and if the decrease in price for composite good can not offset the increase in price for forest products, a decrease in community welfare is expected. Also, the consumer basket of the average income group may be different from that of the lower income group. In order to examine the welfare effects of reductions in harvest levels on both income groups, separate CPIs for the average and lower income groups are calculated. These indices are used to determine the changes in real income for both income groups.

The third issue investigated in this study is the income distributional effects of a harvest reduction policy on the Coast and the Interior. The structural characteristics of these regions presented above indicate that the impacts of policy may not be identical across the two regions. In the Interior, the impacts of the policy may be higher than in the Coast since the forest sector is relatively more dominant in that region. Regional distribution analysis helps evaluate policies on both efficiency and equity grounds, and may have implications for using Forest Renewal Plan funds.

3.4 Model Specification

The model underlying the analysis is based on the specification of Percy (1986), subsequently updated by Duchesne (1991). Like most models of the ORANI type (Dixon et al. 1982), the input technology is specified in two levels. At the first level, it is assumed that intermediate inputs and primary factor inputs (labour, capital, and land) are demanded in fixed proportions to produce each unit of output. At the second level, substitution is made possible among intermediate inputs, and primary factors using constant elasticity of substitution technology. One exception is that in the Coast and Interior logging sectors, substitution is only allowed between labour and capital.[40] This specification assumes

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[40]In the short-run, labour and capital cannot be substituted for land to maintain the same level of log production.

constant ratio of elasticity substitution, homothetic (CRESH) technology for both logging sectors.[41] Following Armington (1969), domestic and imported goods are treated as imperfect substitutes.

The model divides the B.C. economy into nine sectors: (X1) Coast logging, (X2) Interior logging, (X3) Coast wood products, (X4) Interior wood products, (X5) Pulp and paper products, (X6) other primary products, (X7) Manufacturing, (X8) Services, and (X9) Government. The first two sectors produce logs for the wood products, and pulp and paper industries, and a small proportion of the harvest is exported. B.C. has been disaggregated into Coastal and Interior regions because the resource base, the derived demands for timber, the production technology, and the stumpage values differ significantly between these two regions. The third and fourth sectors produce mainly saw-mill products such as construction grade lumber. It is assumed that the Interior and Coastal wood products industries use only logs from within their regions. The pulp and paper sector produces mainly for the export market and is not regionally differentiated in either output or input. The sixth sector consists of all renewable and non-renewable resource industries other than forests and is heavily export oriented. Sector 7, consists of all manufacturing industries other than wood and paper products. The eighth and ninth sectors are non-traded in the sense that their production is consumed completely within the province. The government sector produces publicly provided private goods and has been modelled separately from services because of differences in factor intensity.

The primary factors of production consist of labour, used in all sectors and

[41]See Hanoch (1971) for details on CRESH functions.

assumed fixed within the province but mobile among sectors; capital, which is specific to each sector; and land, used in sectors X1, X2, X6, and X8. Interprovincial migration and adjustments to the capital stock in response to stumpage price increases are not permitted. These longer run adjustments of population and investment obscure the immediate impact of the policy shock on the economic well-being and income distribution of current residents of B.C. Furthermore, we model the labour market assuming that wages are rigid. This assumption may be appropriate since labour in B.C. is heavily unionized. Also, in the unionized economy, there is a possibility that skilled forest workers are less market responsive than those workers in other sectors (Daniels et al. 1991).[42] It should be noted here that in a Keynesian world depicted by this model, where wages are assumed rigid, there is no mechanism for large scale adjustments of labour across sectors.

Capital is sector specific, so its rental rates, which are endogenous to the model, would adjust to clear the market. A similar assumption is made for land in sector 6 and 8. However, land in sector 1 and 2 is assumed to be responsive to the stumpage prices which are set exogenously. According to this assumption, there would be a reduction in the use of forest land base and a corresponding reduction in timber harvest levels in response to the increase in stumpage prices. However, it is possible that the forest land base allotted to timber production may be fixed due to annual allowable cut constraints, thereby stumpage price changes may not alter the amount of land used. Furthermore, according to tenure regulations firms may be required to produce the same quantity under increased

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[42] Alternatively, full employment can be assumed because unemployed workers may find employment elsewhere in the local economy.

stumpage prices. In such a case the results from this model underestimate the negative effects on the provincial economy. In this study, it is expected that firms, in the short-run, will have some flexibility to adjust the use of forest land base and timber harvest levels in response to the increase in stumpage prices.

In this model, prices in both the logging sectors, the two wood products sectors, the pulp and paper sector, and the two non-traded sectors are endogenous. The prices facing the logging sectors are determined by the derived demands from the regional wood products sectors and pulp and paper. Production of the Coast and Interior wood products sectors and of pulp and paper do influence producer prices. Also, it is assumed that the production of forest products from B.C. is large enough to influence world prices. That is, B.C. faces a downward sloping excess demand curve for its forest products, by the rest of the world purchasers. This suggests that B.C. has the potential to exercise market power, thereby capturing monopoly gains from trade. Because of this market power, simulation results may be sensitive to the magnitudes of the elasticity of excess demand. The sixth sector is assumed to be small in world export markets, and thus is treated as a price-taker. Sector 7, represents import-competing manufacturing and the province will be treated as a small importer relative to world supply.

The model is short-run in nature[43]. In this scenario, the markets for mobile factors

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[43]Following Dixon et al. (1982) the duration of short-run must be long enough for local prices of imports to fully adjust to a tariff increase; for major import users to decide whether or not to switch to domestic suppliers; for domestic suppliers to hire labour and expand output with their existing plants; for new investment plans to be made but not completed; and for price increase to be passed onto wages and wages increase passed back to prices.

respond to policy shocks through price changes while in the long-run the adjustment is mainly through quantity changes. That is, in the short-run, factor price changes create quasi-rents or losses which in the long-run induce interregional factor flows until all incentives for entry and exit are exhausted. The model is not closed in the sense that neither the change in exports equals the change in imports nor the change in savings equals the change in imports. Since the model is short-run in nature and the capital stock is fixed, there is no change in investment. Consequently, we have assumed no savings. The exchange rate is assumed fixed and the balance of payments passively accommodates any change in the trade balance. The modelling exercise also ignores any adjustments of macroeconomic variables such as interest rates in response to changes in the forest sector trade balance. Furthermore, the Forest Renewal Plan envisages that the revenue realized from the increased stumpage price would be invested in silviculture, job skills training, environmental protection, assistance to value added manufacturers, and research and development. In this model, it is not assumed that increased stumpage revenues are used in this way. Instead, the increased revenue is modeled as transfer payments to the households in the region.

Following Johansen (1960), the model is specified in the form of proportional rates of change in which variables are specified in a system of linear equations.[44] This format is used since it requires relatively little data, produces results easily interpreted in terms of elasticity relationships, uses a simple solution algorithm (i.e. matrix manipulation), and suits the economic analysis of a wide range of policy shocks. Although the Johansen

[44]See Appendix 3. [illegible] an example of Johansen method of linearization.

approach allows for flexibility in terms of model size, modification, application, and implementation, it also introduces approximation errors (Prins 1990).[45] Approximation errors result from the inability of the model to cope with large changes in the exogenous variables. For example, the input and output shares used to build the model are treated as exogenous parameters when solving the model, even though the resulting changes in the prices and quantities of forest products change these input and output shares (Prins 1990). Therefore, the results from this model are only valid for small changes in the exogenous variables which do not induce significant changes in the commodity composition of outputs, the industrial composition of factor employments, or the industry composition of input costs (Dixon et al. 1982).

The model simulation is a comparative static exercise which solves for the changes in various variables required to achieve a new equilibrium in response to the shock introduced into the model. Thus the results indicate the particular impact of the policy in question as all other exogenous variables such as productivity growth and rest of the world price changes are assumed unchanged. The model does not consider shocks other than the increase in stumpage prices and does not forecast any variable. Models of this structure have been used extensively, for example, to asses policy scenarios in Australia (Dixon et al. 1982). The model, consisting of 56 linear equations, is presented in Appendix 3.2 . Appendix 3.3 gives tables defining the endogenous variables, exogenous variables, elasticities, and parameters used in the model. Appendix 3.4 provides detailed

[45]See Hertel et al. (1992) for critical comparison between the levels and linearized representations of CGE models.

data and their sources used in the computation of the parameters. The model is set up on a LOTUS 1-2-3 (4.0) spreadsheet and is solved by matrix manipulations.

3.5 Policy Simulation: Results and Discussion

3.5.1 Structural Responsiveness of the Coast and Interior Economy to 1% Increase in Stumpage Price

The results contained in Table 3.5 indicate the structural responsiveness of the provincial economy and each of the regional economies to a 1 percent increase in stumpage rates. They also provide a more analytical flavour to the assertion that the forest sector is more important to the Interior than the Coast. The figures can be interpreted as elasticities of the variables in question with respect to increases in stumpage rates. Structural responses are estimated under different excess demand (ED) elasticity scenarios.[46] Results show that employment, real gross domestic product, and real income of in B.C. fall in response to a one percent increase in stumpage price. Results also indicate that in all scenarios, the B.C. Interior region is more sensitive to the increase in stumpage prices. For example, with the medium ED elasticity (-1.25), the employed labour force in the Interior is expected to fall by 0.031 percent while the fall in Coastal employment is expected to be 0.025 percent. In the same ED elasticity scenario, the real GDP in the Interior is expected to fall by 0.026 percent and the fall on the Coast is expected to be 0.023. This result follows because the share of forest sector in employment and income of the Interior region is higher than in the Coast region. The rental rates on capital in logging and wood products, the use of forest lan base, and exports of wood

[46]Percy and Constantino (1989) provide a range of estimates of ED elasticities.

products in the Interior region fall more than those in the Coast. It should be noted that in both regions, the fall in employment is higher if the excess demand is more elastic. On the other hand, the fall in real GDP is smaller when the excess demand is more inelastic. This is the result of B.C. market power in the international wood products market. The evidence of Table 3.5 demonstrates the Interior is more structurally responsive to changes in stumpage rates, than is the Coast, for a variety of variables .

Table 3.5. Structural responsiveness of Coast and Interior regions to a 1 percent increase in stumpage prices (Values are expressed in percentage changes)

Variable	ED elasticity for B.C. wood products		
	Low (-.75)	Medium (-1.25)	High (-2.00)
Employed labour force Coast	-0.0146	-0.0256	-0.0404
Employed labour force Interior	-0.0181	-0.0310	-0.0481
Wages	-0.0002	-0.0003	-0.0004
Return on capital in Coastal logging	-0.0932	-0.1440	-0.2117
Return on capital in Interior logging	-0.1004	-0.1559	-0.2300
Return on capital in Coastal wood products	-0.0597	-0.0936	-0.1385
Return on capital in Coastal wood products	-0.0691	-0.1087	-0.1617
Logging area in coastal B.C.	-0.0465	-0.0719	-0.1057
Logging area in interior B.C.	-0.0502	-0.0779	-0.1149
Real GDP of Coastal B.C.	-0.0160	-0.0229	-0.0321
Real GDP of Interior B.C.	-0.0184	-0.0264	-0.0372
Real gross domestic product	-0.0166	-0.0238	-0.0334
GDP deflator	0.0041	-0.0003	-0.0062
CPI for average household	-0.0022	-0.0053	-0.0095
CPI for average household	-0.0027	-0.0061	-0.0106
Nominal income for average household	-0.0122	-0.0232	-0.0379
Nominal income for average household	-0.0066	-0.0116	-0.0183
Exports of coastal lumber	-0.0637	-0.1010	-0.1506
Exports of interior lumber	-0.0690	-0.1097	-0.1643
Real income for average household	-0.0101	-0.0179	-0.0284
Real income for poor household	-0.0039	-0.0055	-0.0077

Table 3.5 also contains the effect of a 1 percent increase in stumpage prices on real incomes, as measured by welfare, of average and poor households. The income of poor household falls less than that of average households. This may largely be due to the difference in the shares of wage income and government transfers in the income of average and poor households. The fall in real income is shown to be smaller than the fall in real GDP since the fall in the CPI is higher than the fall in the GDP deflator.

3.5.2 Effect of May 1, 1994 Stumpage Changes

When B.C. stumpage fees were increased on May 1, 1994 they were raised significantly more in the Interior than on the Coast. Recall results in Table 3.5 indicate that for comparable stumpage price increases, impacts will be greater in the Interior than on the Coast. Now, in light of the large increase in stumpage prices for the Interior, we expect the impact on the Interior to be even greater. Table 3.6 provides the results of simulating the actual stumpage increases of 63.8 percent and 81.8 percent, respectively in the Coast and Interior regions. As log producers face a downward sloping demand for the use of crown land, an increase in stumpage price will cause a reduction in the use of the forest base.[47]

[47]A similar assumption is used by Wear and Lee (1993).

Table 3.6. Effect of 63.8 percent and 81.8 percent increase in Stumpage prices respectively, in the Coast and the Interior regions (Values are in percentage changes)

Variables	ED elasticity for B.C. wood products		
	Low (-.75)	Medium (-1.25)	High (-2.00)
Producer price in sector 1	11.111	10.755	10.283
Producer price in sector 2	18.150	17.798	17.326
Producer price in sector 3	5.479	5.196	4.821
Producer price in sector 4	7.658	7.315	6.855
Producer price in sector 5	1.300	1.156	0.963
Producer price in sector 6	-0.002	-0.003	-0.006
Producer price in sector 7	0.031	0.055	0.087
Producer price in sector 8	-0.591	-1.058	-1.683
Producer price in sector 9	-0.291	-0.537	-0.865
Employed labour force Coast	-1.098	-1.922	-3.023
Employed labour force Interior	-1.433	-2.434	-3.773
wages	-0.012	-0.021	-0.032
Return on capital in sector 1	-5.975	-9.189	-13.430
Return on capital in sector 2	-8.188	-12.735	-18.841
Return on capital in sector 3	-3.827	-5.964	-8.784
Return on capital in sector 4	-5.636	-8.885	-13.248
Return on capital in sector 5	-0.941	-0.800	-0.612
Return on capital in sector 6	0.321	0.573	0.909
Return on capital in sector 7	1.752	3.132	4.976
Return on capital in sector 8	-1.606	-2.876	-4.573
Return on capital in sector 9	-1.539	-2.973	-4.889
Logging area in coastal B.C.	-2.984	-4.588	-6.705
Logging area in interior B.C.	-4.091	-6.362	-9.412
Land rent in sector 6	0.321	0.573	0.909
Land rent in sector 8	-1.606	-2.876	-4.573
Output in sector 1	-2.652	-4.078	-5.959
Output in sector 2	-3.769	-5.861	-8.670
Output in sector 3	-2.958	-4.608	-6.784
Output in sector 4	-4.159	-6.555	-9.773
Output in sector 5	-0.509	-0.427	-0.318
Output in sector 6	0.079	0.141	0.224

Variables	ED elasticity for B.C. wood products		
	Low (-.75)	Medium (-1.25)	High (-2.00)
Output in sector 7	0.976	1.744	2.771
Output in sector 8	-0.731	-1.309	-2.081
Output in sector 9	-0.678	-1.311	-2.156
GDP in the Coastal B.C.	-0.936	-1.780	-2.906
GDP in the Interior B.C.	-1.117	-2.083	-3.375
Gross domestic product	-0.969	-1.848	-3.022
Gross domestic product deflator	0.267	-0.066	-0.511
Real gross domestic product	-1.2363	-1.7817	-2.5104
Disposable income	-0.969	-1.848	-3.022
CPI for average household	-0.177	-0.416	-0.735
CPI for poor household	-0.220	-0.476	-0.820
Nominal income average household	-0.958	-1.795	-2.914
Nominal income for poor household	-0.510	-0.890	-1.398
Market price of x1 good	10.778	10.432	9.975
Market price of x2 good	17.605	17.264	16.806
Market price of x3 good	5.391	5.113	4.744
Market price of x4 good	7.535	7.198	6.745
Market price of x5 good	1.271	1.130	0.942
Exports of x6	0.125	0.267	0.456
Imports of x7	-3.100	-5.512	-8.734
Market price of x8 good	-0.563	-1.008	-1.602
Exports of coastal lumber	-4.043	-6.391	-9.487
Exports of interior lumber	-5.651	-8.997	-13.491
Exports of pulp & paper goods	-0.636	-0.565	-0.471
Real income average household	-0.781	-1.379	-2.178
Real income for poor household	-0.291	-0.414	-0.578

Again, the results are provided for a range of values of excess demand (ED) elasticities for B.C. solid wood products. Results indicate that in all scenarios the real GDP both in terms of productivity and consumers purchasing power falls, with greater impacts associated with higher ED elasticities.[48] This suggests that the province bears a greater portion of the incidence of the policy shock in the high ED elasticity scenario. In other words, with high ED elasticities, B.C. has less market power in passing the burden of the policy shock to the consumers in the rest of the world. In all scenarios, both logging and lumber sectors absorb much of the burden. A large fall in the use of the forest base, in rental rates of return for capital (profits), and in output is noticed in these sectors. A corresponding fall in exports is also noticed in both wood products sectors. The fall in these variables is smaller when the ED is relatively inelastic. For example, in the highly elastic scenario, the reduction in land use is more in each logging sector than in the low elasticity case. The results also indicate that the policy change, which affects the forest sectors, causes a greater diversification in the economy of the province. The large contraction of the forest sectors, and the resulting slight fall in nominal wages and large fall in prices for service sectors, promotes the expansion of the domestic manufacturing sector and other primary products sector. This result supports Constantino and Percy (1988) argument that " a contracting sector especially one which forms the economic base of a region, induces expansion of peripheral sectors, particularly those facing highly elastic demand in output markets". In the high elasticity scenario, the model predicts a 8.73 percent decline in imports of manufacturing goods with a 2.77 percent increase in import competing manufacturing output.

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[48] We use the overall price index of the economy as a deflator for the real GDP in terms of productivity while consumer price index is used as the deflator to derive the real GDP in terms of purchasing power. Furthermore, the share of foreign ownership in each sector is netted out in calculating GDP.

One interesting result is that the decline in real income for both average and poor households is smaller than the fall in real GDP. For both income groups, nominal income falls, and falls more if the ED elasticity value is higher. However, the fall in both nominal and real income of poor households is smaller than those of average houholds. This may largely be because: 1) the wage income which declines as a result of the policy shock is small in poor housholds' income; and 2) the CPI for poor households falls more than that of average households because the proportion of forest product prices is small relative to other products and whose prices are increased as a result of the policy. In other words, a large proportion of poor households' consumption is from the service sector which makes up a large component of their CPI. Since their CPI drops significantly, there is a small decrease in their real income.

3.5.3 Regional Effects of the Policy Change

The effects of the May 1, 1994 policy on the regional economy of B.C. reported in Table 3.6 confirms structural responses reported in Table 3.5. For all ED elasticity values, employment in the Interior falls more than in the Coast region. Again, employment in both regions falls more when the value of ED elasticity is larger. For example, employment in the Interior falls by 1.43 percent in the low ED elasticity scenario while the fall is 3.77 percent in the high elasticity scenario. However, the real wage rises as a result of the stumpage price change policy and rises more as the ED elasticity value is higher. In spite of a small fall in nominal wages, a large fall in the CPI results in a significant rise in real wages. It must be noted, however, that the rise in real wages refers to the employed workers only. For all the elasticity values, the real GDP in both regions falls more with higher ED elasticity values. Furthermore, the real GDP of the Interior region falls more than in the Coast. Results also indicate that there is a substantial difference in rental rates of capital of logging and wood products sectors between Coast and Interior regions. For example, in the medium elasticity scenario, the return on capital in Interior wood products falls by 8.88 percent while the fall in return of capital in Coast wood products is only 5.96 percent. Similar differences are shown with respect to the reduction in logging area and wood products exports between the Interior and Coast.

3.6 Summary and Conclusions

In this paper, an attempt is made to study the impact of the May 1, 1994 stumpage price increases on the economy of British Columbia. In particular, the impact of this policy on various sectors, income distribution of two income classes, and two regions of B.C. is assessed. In order to capture the intersectoral linkages and to account for indirect effects of the policy change on all sectors in the economy, a CGE approach is used. Results indicate that the increase in stumpage prices causes a decline both in employment and real GDP. The results also show that for a comparable increase in stumpage rates both employment and real GDP fall more in the Interior than in the Coast. The results demonstrate that the negative impacts of the May 1, 1994 stumpage policy are greater in the Interior of B.C. than on the Coast.

The decline in real income for British Columbians as measured by consumption is smaller than the fall in real GDP. For consumers, when nominal wages are rigid (due to contracts or strong union activity) the change in prices of goods that have major shares in their consumption bundle matter the most. As forest products make up a small share in the consumption bundle, compared to the shares of other sector goods, large increase in prices of forest products do not greatly affect the CPI. In the long-run, however, when the assumption of rigid nominal wages is relaxed, the fall in nominal wages may be equal or even higher than the fall in the CPI.

Finally, some of the limitations of the study should be noted. The results are sensitive to the parameters used in the model, particularly to the ED elasticity values. Since the model is short-run in nature, the feedback effects of increased stumpage revenues on the overall economy are not considered. In the long-run, the returns from the investment of increased stumpage revenues may be higher such that they can completely offset the short-run costs of the policy causing an increase in welfare of the households. Furthermore, the model does not incorporate the non-market benefits associated with the decrease in harvest levels.

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CHAPTER 4 Short-Run Dynamics of the Canadian Wood Pulp Industry: A Cointegration Analysis

4.1 Introduction

Canada is the world's second largest producer of pulp, after the United States (U.S.), and is the world's largest pulp exporter. In 1991, the Canadian pulp industry produced a total of 23.3 million tones of pulp and exported 8.6 million tones valued at $4.8 billion (Canadian Pulp and Paper Association 1992). The U.S. pulp market is the most important to Canadian pulp exporters accounting for over 50% of total Canadian pulp exports. Despite the importance of the pulp sector to the nation's economy, very few studies have been conducted to evaluate the dynamic interactions between macroeconomic and pulp sector variables. Singh and Nautiyai (1984), explored factors influencing Canadian pulp and paper prices. Townsend and Uhler (1986) investigated whether Canadian pulp and paper producers have market power in pricing their products. Some researchers (such as Nautiyal and Singh 1986; and Frank et al. 1988) have studied productivity growth in the Canadian pulp and paper industry. Schembri and Robicheau (1986) have investigated the effects of a change in the Canadian/U.S. dollar exchange rate on the Canadian pulp and paper industry using a translog restricted profit function.

Studies to date have concentrated mostly on how supply-side variables-- factor costs, economies of scale and technological progress-- affect the Canadian pulp industry. However, several types of demand-side dynamic interactions have been neglected. First, the interrelationships between macroeconomic variables (such as exchange rates and U.S. pulp prices) and Canadian pulp sector variables have not been investigated. Second, previous studies have not taken account of indirect effects that each macroeconomic variable may have on the pulp industry by influencing other macroeconomic variables. For example, in response to a depreciation of the value of the Canadian dollar relative to the U.S. dollar, Canadian pulp price would be expected to rise while U.S. pulp price falls. This decrease in U.S. pulp price may have a depressing effect on Canadian pulp price. This indirect effect of U.S. pulp price on Canadian price may offset the potential positive effect of the exchange rate on Canadian pulp price. Analyses that do not account for these indirect effects may be biased.

In this study, we investigate short-run dynamic impacts of macroeconomic variables on Canadian pulp price within the framework of a vector autoregression (VAR).[49] The paper is organized as follows. A graphical model describing possible relationships between macroeconomic variables and Canadian pulp price is presented in the next section. The third section deals with variables used in the model and their data sources. A brief review of the VAR approach and Johansen's procedure of cointegration analysis is presented in the fourth section. Results of the VAR analysis are discussed in the fifth section, and summarized in the final section.

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[49]There is an argument in the literature that VAR models cannot be used for policy analysis since the equations are not structural (See Cooley and Leroy 1985). In the more recent past, however, many researchers have addressed various charges levelled against the use of VAR models to investigate the dynamics of industries. See Bessler and Kling (1986); Bernanke (1986); Sims (1986); Fackler (1988); Sims et al. (1990); and Adamowicz et al. (1991); for extensions on VAR models. In spite of the criticism over the alleged atheoretical nature of VAR models, they are described as convenient tools to investigate the structure of economic relations between macroeconomic impacts and any sector by placing minimal restrictions on the parameters of the equation system (Orden and Fackler 1989) and are frequently used for policy analysis (Hafer and Sheehan 1991).

4.2 A Theoretical Framework

Figure 4.1 presents a simple model which may be used to study macroeconomic effects on Canadian pulp price. It is related to Sarker's (1993) timber trade model. Canada is shown as the exporting nation while the U.S. is the importing region. The supply curves, S_1 and S_2, for pulp are shown to be vertical beyond a certain point because industries have capacity constraints in the short-run. The domestic demand, D1, is shown to be somewhat large. Although Canada is the largest market pulp producer in the world and relies heavily on international markets (Jegr 1985), approximately two thirds of total production is used by domestic paper and paper board manufacturers (Canadian Pulp and Paper Association 1992).[50] Equilibrium values for pulp price and pulp exports are determined by the intersection between the excess supply curve, ES, and excess demand curve, ED.

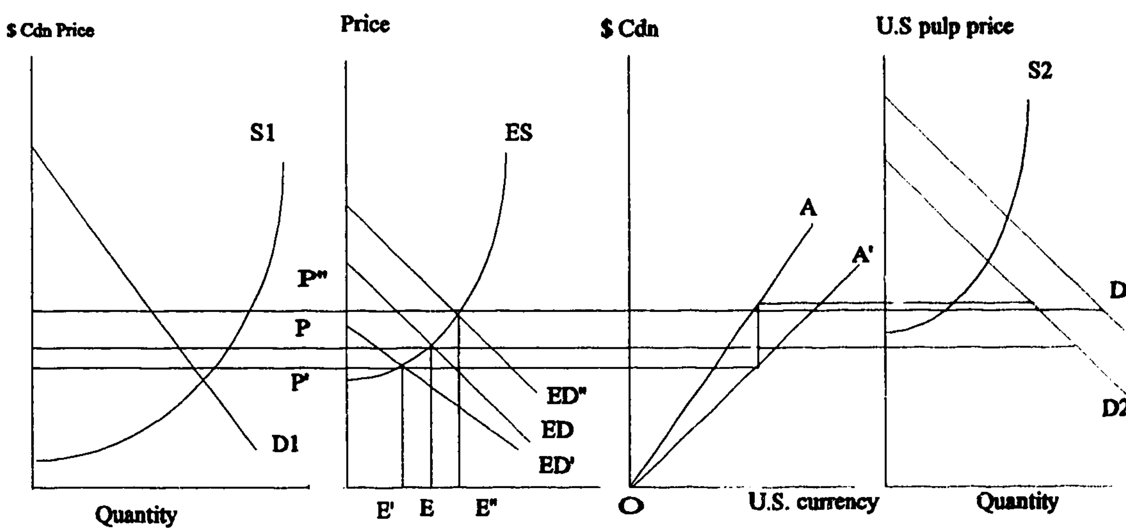

Figure 4. 1 Canada - U.S. pulp trade model.

[50]Reasons for vertical integration within the pulp industry are discussed by Schwindt (1985) and Woodbridge et al. (1988).

Line, OA, shows the exchange rate between Canada and the U.S. to be at par. If the valuc of the Canadian dollar increases, the exchange rate curve shifts from OA to OA' and the excess demand curve shifts from ED to ED'. Exports fall from E to E'and the export price of pulp decreases from P to P'. Alternatively, instead of a change in exchange rates we can examine an exogenous increase in the U.S. demand for pulp to D2'. This increase causes the excess demand curve to shift to ED", other things remaining unchanged, and an increase in the U.S. pulp price to P". Consequently, pulp exports to the U.S. and pulp prices in Canada increase, respectively, to E" and P". The magnitudes of these changes, however, may be quite sensitive to the supply and demand elasticities both in domestic and international markets.[51]

4.3 Variables and Data Sources

Variables which were thought to be of central importance to the Canadian pulp industry were selected for inclusion in the model. Changes in the exchange rate on prices and trade of commodities have been studied extensively (See Dunn 1969; Dornbusch 1987; and Froot and Klemperer 1989). Several studies have also been conducted to analyze the effect of exchange rate variation on the international trade of forest commodities (See Roberts 1988; Jennings et al. 1991; Uusivuori and Buongiorno 1990; Uusivuori and Buongiorno 1991; and Sarker 1993). A depreciation in the value of the domestic currency is generally expected to increase exports of forest commodities. This positive effect, however, occurs only if the devaluation causes a decrease of the price of

[51]If demands are elastic, price fluctuations are minimal. Further, it should be noted that the model in figure 4.1 is static. Therefore, the dynamic paths of adjustment of variables are not shown, but will be explored with the VAR model.

exports in the currency of the trading partner, rather than being fully offset by an increase in the export price in domestic currency (Uusivuori and Buongiorno 1991). The extent to which domestic prices vary may depend on the structure of industry.[52] Dunn (1970) noted that only under perfect competition will a close relationship between changes in the exchange rate and prices be likely. In oligopolistic markets, firms may be expected to bring considerable market power to maintaining stable prices.[53]

The second macroeconomic variable that is considered in this study is the U.S. pulp price. Despite the fact that the U.S. is the largest importer of Canadian wood pulp, it is also the largest wood pulp producer in the world and is, therefore, the biggest competitor for Canada in the international pulp market. These considerations led us to believe that U.S. pulp prices may have significant effects on the Canadian pulp industry. An increase in the price of U.S. pulp, which suggests an increase in the demand for pulp in the U.S., would be expected to have a positive effect on Canadian pulp price.

Third, volumes of domestic use of pulp are thought to influence the price of

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[52]Dornbusch (1987) noted that besides market structure, the extent of product homogeneity and substitutability, and the relative market shares of domestic and foreign firms also influence price adjustment in response to changes in exchange rate.

[53]Opinions vary as to the market power of the Canadian pulp and paper industry. Pearse (1976) noted that the Canadian pulp and paper industry is oligopolistic and expected pulp and paper prices to be inflexible overtime. Singh and Nautiyal (1984) also considered Canadian pulp and paper producers to be oligopolistic. However, they believed that the market for wood pulp to be more competitive than other product groupings in pulp and paper industry. Based on a five-firm concentration ratio of 35 percent for the Canadian pulp market, Schembri and Robicheau (1986) treated the Canadian wood pulp industry as monopolistic. (It should be noted here that Canada accounts for only 15% of the world's pulp production. Therefore, the five Canadian firm concentration ratio in world pulp market would be about 5%) On the other hand, Townsend and Uhler (1986) found that Canadian pulp producers have less market power than newsprint and paperboard producers.

Canadian pulp. Approximately two thirds of total pulp production is being used in domestic paper or paper board manufacturing.[54] A fall in the demand for paper, and thus a decrease in the domestic use of pulp, may result in a surge of pulp into the international market (Woodbridge et al. 1988). This increase in market pulp, when the demand for paper is already low may cause a decrease in the price of pulp.

The fourth variable included in the model is the Canadian pulp price. Singh and Nautiyal (1984) noted that the price of pulp influences domestic paper product production costs and prices of paper board and thus determines the relative competitive position of Canadian paper producers. Also, they argued that the price of market pulp may affect the volume of Canadian pulp exports and thereby the Canadian balance of payments. Furthermore, the price of pulp may influence decisions to invest in processing plants. Therefore, any information which aids in forecasting pulp prices may be important to Canadian pulp producers. The pricing history of wood pulp in Canada is chronically

[54]Several reasons can be proposed to explain the large proportion of domestic use of pulp. First, one could argue that assured continuous flow of specific inputs and economies of scale may have prompted vertical integration in the pulp and paper industry (see Williamson (1981) for details on asset specificity). Second, if a buyer can induce a seller to invest in a specific asset, once the investment is made, then the buyer can start to avoid paying a price that covers the asset holder's fixed costs (See Schwindt (1985) for more details). Canadian pulp producers can limit this problem by using pulp from mills which are affiliated or integrated with their paper mills. Finally, Canada is facing increased competition from new contenders such as Brazil and Chile in international pulp market (Woodbridge et al. 1988). Historically, the market pulp business has been dominated by Canada, the U.S., Sweden, Finland and Norway. However, the share of market pulp of these countries fell from 85% in 1960 to 68% in 1991 causing more pulp to be available for domestic use.

unstable (See Fig.4.2).[55] In this study we attempt to identify the variables that are responsible for these fluctuations.

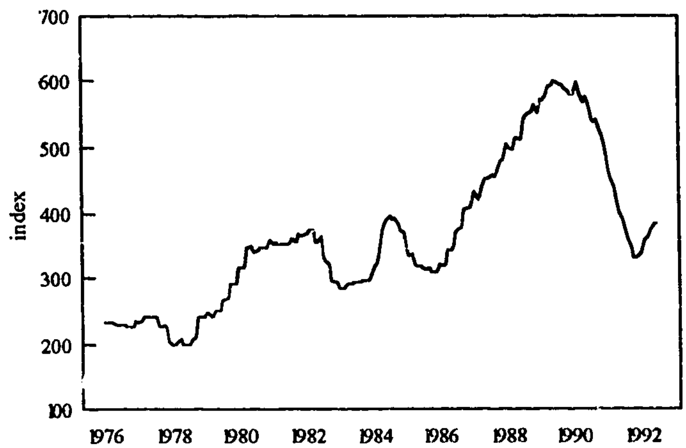

Figure 4.2 Canadian pulp price from 1976:1 to 1976:6.

The variables used in the model, and their data sources, are presented in Table 4.1. The data set contains 198 monthly observations for the period 1976:M1 to 1992:M6. All variables are transformed into natural logarithmic form.

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[55]Alavalapati et al. (1994) found that exports are relatively stable in response to the shocks in macroeconomic variables. Therefore, we did not include pulp exports in this analysis.

Table 4.1 Variables and their sources

Variable	Variable definitions and source
USCXR	the exchange rate between Canadian and U.S. currency expressed in Canadian dollars (CANSIM B 40002)
USPR1	index of the U.S. dollar selling price per tonne of wood pulp in the U.S. Values are expressed in Canadian dollars by multiplying the index of the Canada-U.S. exchange rate (Producer Price Index, U.S. department of Labour, Commodity code 0911, 1967=100)
DOUSE	total Canadian integrated and affiliated use of wood pulp in thousands of tonnes (Derived by subtracting total exports and domestic shipments from total production)
CNPR1	index of the Canadian dollar selling price per tonne of wood pulp sold in Canada (Statistics Canada catalogue 62-001 1971=100)

4.4 The VAR Approach and Specification

4.4.1 Approach

Jennings et al. (1990) were the first to apply a VAR approach to the forestry sector. They used this technique to investigate the causal relationships between the Canadian lumber industry and the macroeconomy. Following Jennings et al. (1990), the VAR approach starts with a set of dynamic regression equations of the form:

$$\sum_{k=0}^{\infty} X_{t-k}\beta(k) = \sum_{k=0}^{\infty} v_{t-k} \qquad (1)$$

where X_t is 1 x n vector of endogenous variables; $\beta(k)$ is a n x n matrix of coefficients for each time period (k) previous to current time (t); and v_{t-k} is a 1x n vector of error terms. It is assumed that v_{t-k} equals zero for all k greater than zero. The vector v_t is assumed to have a mean of zero and a diagonal covariance matrix, Ω. As a consequence, the individual shocks in v_t apply to only one behavioral equation at a time, and the effects of a shock to each behavioral equation on each variable in the system can be determined. The shocks in v_t are assumed to "represent behaviorally distinct sources of variation that drive the economy over time" (Orden and Fackler, 1989). Equation (4.1) can be written in autoregressive form as:

$$\beta(0)X_t = -\sum_{k=1}^{\infty} \beta(k)X_{t-k}+v_t \tag{2}$$

where matrix $\beta(0)$ is a set of contemporaneous parameters on X_t. Multiplying equation (4.2) by $\beta(0)^{-1}$ yields:

$$X_t = \sum_{k=1}^{\infty} D(k)X_{t-k}+u_t \tag{3}$$

where $D(k) = -\beta(0)^{-1}\beta(k)$ and $u_t = \beta(0)^{-1}v_t$. The vector u_t is the "one step ahead" prediction error in X_t and the covariance matrix of u_t is Σ. Equation (4.3) is the autoregressive equation that can be estimated given a specification of the length of lags. As the right hand side regressors are the same for all equations, the ordinary least squares (OLS) method will produce efficient estimates.

By inverting the autoregressive system in equation (4.3), the following moving-average representation can be obtained:

$$X_t = \sum_{k=1}^{\infty} G(k)u_t \tag{4}$$

where G(k) is a matrix of moving-average coefficients derived from equation (4.3). Equation (4.4) expresses the level of a particular variable as a function of the error process. The innovation process, u_t, shows both current and future impacts of a single shock on all variables, assuming that no future shocks occur and all variables evolve naturally. Given the estimate of the covariance of u_t, the parameters of $\beta(0)^{-1}$ can be derived using the Choleski decomposition approach.[56] The parameters of $\beta(0)^{-1}$ give the impacts of v_t on X_t. Given the identification for $\beta(0)^{-1}$, equation (4.4) can be written as

$$X_t = \sum_{k=1}^{\infty} G(k)\beta(0)^{-1}v_t \tag{5}$$

Equation (4.5) is the impulse response function (IRF), which provides the response of all variables in the system to a unit shock in one element of the vector v_t. Equation (4.5) can also be used to decompose the forecast error variance (FEV) of the variables in the system into portions attributable to each element in X_t. The decomposition of FEV indicates the relative strength of interactions between variables (See Judge et al. 1988 for details).

4.4.2 Specification Issues in VAR

Before estimating the model, one of the specification issues to be addressed is the determination of lag length for the model. Hafer and Sheehan (1991) have recently shown that policy recommendations are quite sensitive to changes in lag structure. The lag length for the model was determined by using Sims' (1980) likelihood ratio test. This method compares the models of different lag lengths sequentially to see if there is a significant

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[56]Note that $u_t=\beta(0)^{-1}v_t$. The Choleski decomposition approach assumes that the v_t have unit variance and are orthogonal. Therefore, the matrix $\beta(0)^{-1}$ is derived by solving the equation $\beta(0)^{-1}\beta(0)^{-1\prime}$. The Choleski decomposition removes any portion of a shock to each variable that is explained by contemporaneous shocks to variables previously estimated. This implies that a recursive causality must be imposed on variables included in the model.

difference in results. The likelihood ratio has an asymptotic χ^2 distribution. The sequential pairwise equivalence of models with one through four lags was rejected at the 5% critical level. However, the hypothesis that there was no significant difference between a four and a five-lag model could not be rejected (χ^2=12.05, df=16). Therefore, a lag length of 4 was used for further analysis.

The second specification issue to be addressed, in recursive VAR models, is determining the order of the variables. The variables in the model are ordered, as shown in Table 4.1, based on economic reasoning. In general those variables which are more dependent on other variables should receive a lower place in the list. The macroeconomic variables (exchange rate and U.S. Pulp price) are placed at the top of the list because we expect these variables to have a greater influence on the pulp industry than the pulp industry has on the overall economy.[57] Within the pulp sector variables, domestic use of pulp is listed at the top of the ordering based on the belief that in the short-term, it is fixed because of capacity constraints in the paper producing sector.[58]

4.4.3 Testing Variables for Unit Roots

The first requirement for the use of the VAR model is that the variables must be

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[57]Alavalapati et al. (1994) found that pulp sector activity alone is not big enough to have a significant influence on macroeconomic variables.

[58]The economic reasoning for the ordering of the variables provided in the foregoing discussion is not unique. Alternative explanations can be provided to change the places of variables. For example, Canadian price can be placed above domestic use of pulp assuming that the price of pulp influences the production of paper products and thereby the use of pulp. Therefore, the model was reestimated with several orderings of the variables to see if the results change significantly. The results were fairly robust.

stationary.[59] A variable is stationary if there is no unit root in the data series. The presence of a unit root in X_t, can be tested using an augmented Dickey-Fuller (ADF) test:

$$(1-L)X_t = \alpha + \beta X_{t-1} + \sum_{i=1}^{k} \delta_i (1-L)X_{t-i} + \upsilon_t \tag{6}$$

The null hypothesis of the presence of a unit root in X_t is H_0: $\beta = 0$. Since the estimated β does not have a standard distribution, the critical values provided by Dickey Fuller (1979) are used. Table 4.2 presents the results of ADF tests for a unit root in each of the four variables. Since the absolute values of ADF statistic are not greater than the critical value of ADF at the 95% level of significance, we can not reject the null hypothesis of a unit root for any of the four variables.

Table 4.2 Results of non-stationarity tests for variables used in the model

Variable	# of lags used	ADF statistic*
USCXR	10	-3.01
USPRI	6	-1.62
DOUSE	13	-1.63
CNPRI	6	-1.93

*The critical value of ADF at the 95% level of significance is -3.14.

In a non-stationary VAR model, the individual series move together in the long-

[59]Judge et al. (1988) show that a vector stochastic process is stationary if:
(1) $E(X_t) = \mu$ (all the random vectors have the same mean)
(2) $E[(X_t - \mu)^2] = \sigma_t^2$ (the variances of all random variables are finite), and
(3) $COV(X_t, X_{t+k}) = E[(X_t - \mu)(X_{t+k} - \mu)'] = \Gamma_k$ for all t (the covariance matrices of vectors X_t and X_{t+k} that are k periods apart do not depend on t but only on k).

run only if they are cointegrated.[60] Therefore, the model is tested to determine the number of cointegration relationships among the four variables. The approach used in this study is the maximum likelihood estimation which was developed by Johansen (1988).[61]

4.4.4 Johansen's Cointegration Analysis

In order to conduct Johansen's cointegration analysis we rewrite equation (4.3) as follows:

$$X_t = \alpha + D_1 X_{t-1} + \ldots\ldots + D_k X_{t-k} + \mu_t \qquad (7)$$

where α is a constant term and others are as specified earlier Following Johansen (1988) we reparameterize the model in order to impose the cointegration constraint as follows:

$$\Delta X_t = \alpha + \Gamma_1 \Delta X_{t-1} + \ldots\ldots + \Gamma_{k-1} \Delta X_{t-k+1} - \Gamma X_{t-k} + \mu_t \qquad (8)$$

where $\Gamma_i = -I + D_1 + \ldots\ldots + D_i$, and $-\Gamma = I - D_1 - D_2 - \ldots\ldots - D_k$; $\forall\, i = 1,2,\ldots\ldots k-1$

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[60]The components of the vector X_t are said to be cointegrated of order d, b if: (1) all components of X_t are integrated, I(d) (a variable is said to be integrated of order d if it has a stationary representation after differencing d times); and (2) there exists a non-null vector, α, such that $\alpha' X_t$ is I(d-b) with b>0. The vector α is called cointegrating vector (Harvey 1993).

[61]There are several approaches for estimating cointegration relationships (See Gonzalo (1994) for alternative methods). For example, the two-step procedure developed by Engle and Granger (1987) is good for bivariate models, but does not perform well in multivariate situations. The strength of the Johansen's approach lies in its ability to account for more than one cointegrating relationship. Also, bivariate analysis may be at times misleading. For example, a bivariate relationship between Canadian pulp price and each of the other three variables was tested for cointegration. Results indicate that there is no cointegration relationship between Canadian pulp price and any one of the other three variables. However, in the analysis that follows we found one cointegrating vector among all four variables.

Equation (4.8) is a standard first-difference VAR process except for the term ΓX_{t-k}. This is called a cointegrated VAR or vector error correction (VEC) process. In this model all terms are stationary and the standard asymptotic results apply (Engle and Granger 1987). The impact matrix, Γ, contains the long-run relationships among variables used in the model. The above n-dimensional VAR(k) process is said to be cointegrated of rank r if Γ has a rank r. If r = 0, ΔX_t has a stable VAR(k-1) representation and, for r = n, X_t, is a stable VAR(k) process (Lutkephol 1993). On the other hand if Γ has a rank 0 < r < n, Γ is a product of two matrices, H and C, where H and C are respectively, (k x r) and (r x k) matrices with rank(H) = rank(C) = r. The matrix C is the cointegrating matrix or the matrix of cointegrating vectors and H may be referred to as the loading matrix or the matrix of weights. The estimation of the matrix Γ consists of two sets of regressions; one involves the regression of ΔX_t on the lagged differences giving the residuals R_{ot} and; one which requires the regression of X_{t-k} on the lagged differences giving the residuals R_{kt}. The concentrated likelihood function of the residuals is as follows:

$$L(C) = |\Sigma(C)|^{-T/2} \qquad (9)$$

Maximizing equation (4.9) is equivalent to

$$\min |S_{00} - S_{0k}C(C'S_{kk}C)^{-1}C'S_{k0}| \qquad (10)$$

where S_{00}, S_{0k}, S_{k0}, and S_{kk} are the product moment matrices of the residuals which are defined as:

$$S_{ij} = T^{-1} \sum_{t=1}^{T} R_{it} R_{jt}' \qquad \forall \;\; i,j = 0,k \tag{11}$$

We now let G denote the lower triangular matrix with positive diagonals satisfying $GS_{kk}G' = I_n$; with $\lambda_1, \ldots \geq \lambda_k$ being the eigenvalues of $GS_{k0}S_{00}^{-1}S_{0k}G'$; and $\nu_1, \ldots \nu_k$ being the corresponding orthonormal eigenvectors. Next C and H can be derived as follows:

$$C = [\nu_1, \ldots \nu_r]' G \tag{12}$$

$$H = -S_{0k} C' (C S_{kk} C')^{-1} \tag{13}$$

The estimate of the variance matrix, Σ, can be derived using C:

$$\Sigma = S_{00} - S_{0k} C C' S_{k0} \tag{14}$$

The null hypothesis that there are at most r cointegrating vectors can be tested using the trace test. This is essentially a likelihood ratio test statistic with the form:

$$-2\ln(Q) = -T \sum_{i=r+1}^{n} \ln(1-\lambda_i) \tag{15}$$

Another likelihood ratio test, maximum eigenvalue test, can also be used to test the hypothesis that there are at most r cointegration vectors. It is defined as

$$-2\ln(Q) = -T\ln(1-\lambda_{r+1}) \tag{16}$$

The distribution of these test statistics do not follow the standard chi-squared distribution.

They represent multivariate version of the Dickey-Fuller distribution (Sarker 1993). The critical values generated by Johansen and Juselius (1990) may be used to determine the significance level.

Table 4.3 Results from testing for the number of cointegrating vectors

# of cointegrating vectors	Trace statistic	Trace value (0.95)	λ_{max} statistic	λ_{max} value (0.95)
r = 0	55.03*	48.42	28.16*	27.34
r ≤ 1	26.87	31.26	16.81	21.28
r ≤ 2	10.06	17.84	8.57	14.60
r ≤ 3	1.49	8.08	1.49	8.08

Note: The critical values are taken from Johansen and Jeselius (1990:208).

Table 4.3 reports the test results of cointegrating vectors. The trace and maximum eigenvalue tests indicate that there is only one cointegrating vector. The relevant cointegrating vector can be expressed as:

-4.513 USCXR - 13.157 USPRI - 2.573 DOUSE + 14.26 CNPRI

Assuming the above relation describes a long-run price relationship and normalizing the coefficient of CNPRI, we get[62]

$$CNPRI = 0.3165\,USCXR + 0.9227\,USPRI + 0.1804\,DOUSE + Z_t \qquad (17)$$

The corresponding loading matrix is:

-0.00316 USCXR - 0.00247 USPRI - 0.00024 DOUSE + 0.00732 CNPRI

These values reflect the speed of adjustment of each variable to any shock in the

[62]The coefficients on these variables cannot be interpreted as long-run elasticities because such an interpretation will ignore the dynamics of the system (Lutkepohl 1993).

equilibrium condition (ie. equation 4.17). Using C and H, Γ can be calculated in equation (4.8). Equation (4.8), the VEC model, is reparameterized to express the variables in levels as shown in equation (4.7). The procedure followed was as follows:

$D_1 = I_n + \Gamma_1$

$D_i = \Gamma_i - \Gamma_{i-1}$ $\qquad$ $i = 2,........k-1,$ and

$D_k = -\Gamma - \Gamma_{k-1}.$

Now, the procedure specified to derive equations (4.4) and (4.5) can be followed to obtain impulse response functions.[63] In this case the IRFs reflect the effects of deviations from the long-run equilibrium on the dynamic paths of each variable in response to initial shocks (Sarker 1993).

4.5 Results and Discussion

Forecast error variance decompositions were calculated using the Choleski decomposition. These were calculated from the parameters of the moving-average representation of the VEC model. Table 4.4 presents the variance decompositions for forecast horizons of 6, 12, 18, and 24 months. The decomposition divides the forecast variance into parts explained by each variable in the system. The diagonal values represent FEVs of each variable explained by own innovations. Higher diagonal values of any variable implies that the variable is more exogenous to the system. The exchange rate, U.S. pulp price, and domestic use of pulp appears to be exogenous in the system with over 70% of FEV explained by own innovations after one year. On the other hand, Canadian

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[63]See King et al. (1991) for a detailed discussion about the restrictions required to derive IRFs from a vector error correction model.

pulp price explains less than 50% of FEV by own innovations after one year while the U.S. pulp price explains 60% of the FEV of the Canadian price after 2 years. The exchange rate accounts for only 6% of variation in Canadian pulp price. Domestic use of pulp explains the least amount of variation in Canadian pulp price. This suggests that variables relating to the U.S. economy are more important than domestic variables in forecasting the price of Canadian pulp. Canadian pulp price appears to be the key variable in explaining the error variance in U.S. pulp price in this model.

Table 4.4 Forecast error Variance (FEV) decomposition (%) of M-months ahead

		Shock to			
FEV in	Months	USCXR	USPRI	DOUSE	CNPRI
USCXR	6	95.63	1.02	0.21	3.13
	12	80.35	2.66	0.68	16.29
	18	61.54	5.96	1.45	31.03
	24	48.46	9.28	1.82	40.42
USPRI	6	4.13	76.94	0.03	18.88
	12	6.60	71.22	0.10	22.06
	18	8.91	71.11	0.49	19.47
	24	11.06	71.73	1.18	16.01
DOUSE	6	1.00	1.86	96.39	0.73
	12	1.20	2.40	95.00	1.38
	18	1.36	2.85	94.06	1.71
	24	1.49	3.12	93.54	1.82
CNPRI	6	2.10	44.33	0.54	53.50
	12	2.06	52.52	0.33	45.07
	18	3.81	57.55	1.30	37.32
	24	5.65	6056	2.89	30.88

Although the decomposition of FEV measures the relative strength of relationships among the variables, it does not indicate the time path of a variable's response to a shock in one variable. In order to asses the effects of shocks, impulse response functions (IRFs) were calculated. Specifically, mean responses and variances of IRFs were calculated for twenty four future months using a Monte Carlo integration procedure outlined by Kloek and Van Dijk (1978). IRF confidence intervals were calculated by making 500 draws from parameters of the VEC model (See Doan 1992). Figures 4.3 through 4.5 show the effect of a one-time, 1 standard deviation shock of each variable on Canadian pulp price. Any impulse response for which both mean and confidence interval values lie above or below zero is considered significantly different from zero at the 5% critical level.

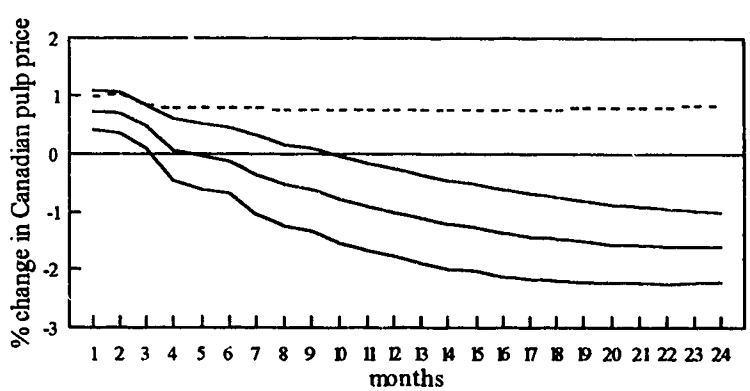

Figure 4.3 Response of Canadian pulp price to a shock in the exchange rate.
Note: The shock is 1 standard deviation increase in exchange rate. The dotted line is the response of the exchange rate to the own innovations.

Figure 4.3 shows the response of Canadian pulp price to a shock in the exchange rate. In response to 1 standard deviation shock in the exchange rate (which implies that the Canadian dollar depreciates), Canadian pulp price increases approximately by 1.0% in the first two months before it starts falling. After one year Canadian pulp price falls by more than 1.0%. These results may be explained by considering the effect of the exchange rate on the U.S. pulp price and the subsequent effect of a change in the U.S. price on the Canadian pulp price. IRFs, which are not reported here, show that (in response to a shock in exchange rate) U.S. pulp price starts to fall after one month, and drops more than 1.0% after one year.[64] The decrease in U.S. pulp price may have a depressing effect on Canadian pulp price. Although the initial increase in Canadian pulp price in response to a shock in the exchange rate indicates some market power for Canadian pulp producers,[65] the significant fall in the later periods raises d [illegible] ith regards to their ability to set prices.

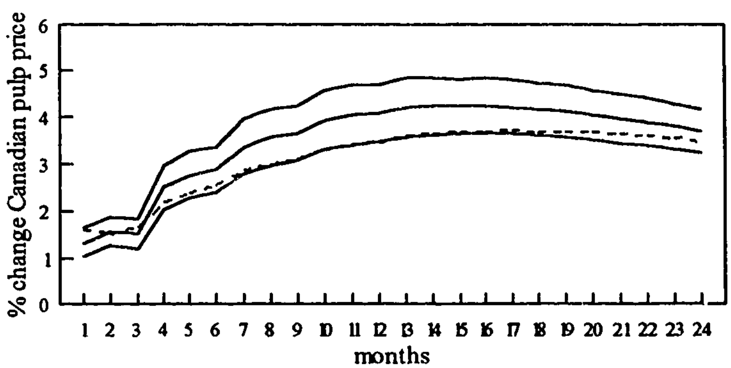

Figure 4.4 Response of Canadian pulp price to a shock in the U.S. pulp price.
Note: The shock is 1 standard deviation increase in the U.S. pulp price. The dotted line is the response of the U.S. pulp price to the own innovations.

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[64]Appreciation of the U.S. dollar causes the unit cost of paper production to increase in the U.S., relative to Canada, and results in a decline in the demand for pulp, causing pulp price to fall. This reasoning may be particularly appropriate in cases where Canadian pulp is a minor proportion of input costs. On the other hand, if the cost of Canadian pulp is significant in the unit cost of paper production, the demand for Canadian pulp rises and the price of Canadian pulp may increase as the U.S. dollar appreciates.

[65]In the long-run a competitive industry also produces such results if the appreciation of the U.S. dollar causes an increase in the demand for Canadian pulp. However, the spontaneous increase in demand for Canadian pulp in response to the appreciation of the U.S. dollar is unlikely under perfect competition.

Figure 4.4 shows the response of Canadian pulp price to the increase in the U.S. pulp price. The results show that the increase in Canadian pulp price in response to the increase in U.S. pulp price is significant at the 5% critical level and is almost one to one. This result suggests that the assumptions of law of one price[66] and homogeneous products may hold between Canadian and U.S. pulp. Furthermore, unlike the effect of exchange rate, the effect of U.S. price on Canadian pulp price persists for a long period. This may largely be due to the increased positive response of U.S. price to its own innovation (see the dotted line in Figure 4.4).

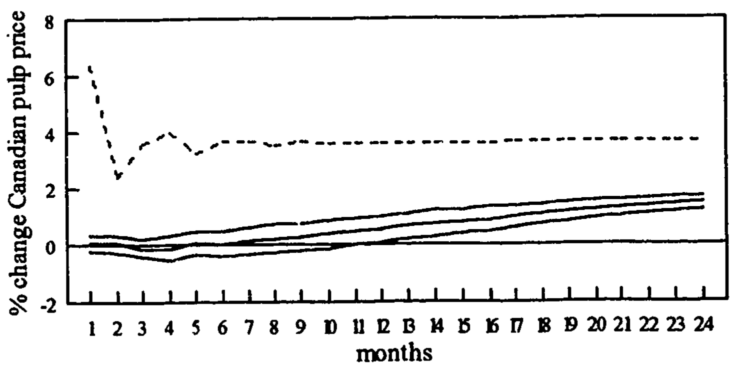

Figure 4.5 Response of Canadian pulp price to a shock in the domestic use of pulp.
Note: The shock is 1 standard deviation increase in the domestic use of pulp. The dotted line is the response of the domestic use of pulp to the own innovations.

Finally, the effect of a shock in the domestic use of pulp on Canadian pulp price is presented in figure 4.5. Although significant, the rise in Canadian pulp price in response to one standard deviation shock (approximately 6%) in domestic use of pulp is only about

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[66]Economic theory states that freer trade ensures that prices in both markets, once adjusted for exchange rates and transportation costs, are equal. See Goodwin (1991) for more details.

2%. Furthermore, the increase in pulp price occurs only after a year, perhaps because an exogenous increase in the domestic use of pulp may have a depressing effect on the volumes of pulp exported to the U.S. The decrease in exports may not be sudden because of contractual supply agreements between firms. IRFs not reported here show that the U.S. pulp price rises in response to the shock in domestic use of pulp after a year.

4.6 Summary and conclusions

This paper explores the short-run dynamic interactions among Canada-U.S. exchange rate, U.S. pulp price, domestic use of pulp, and Canadian pulp price. The VAR approach is proposed to estimate an empirical model. Since the variables used in the model were non-stationary, a cointegration analysis was conducted using Johansen's (1988) maximum likelihood procedure. Results indicated the presence of one cointegrating vector among the four variables. Therefore, a vector error correction model (VEC) was specified to study the short-run dynamic interactions among the variables. Both FEV and IRF analyses suggest that variables relating to the U.S. economy are more important than domestic variables in determining the price of pulp in Canada.[67]

The decomposition of FEV shows that U.S. pulp price and exchange rate explain 66% of error variance in Canadian pulp price, while domestic use of pulp explains only 3% of error variance in Canadian pulp price. IRF results indicate that the effects of

[67]Dynamic interactions estimated from the VEC model differ somewhat from estimates from a non-stationary VAR model. The responses of Canadian pulp price estimated using non-stationary VAR are presented in Figure 4.6 (See appendix 4.1). For example, the results of non-stationary VAR model show that the increase in exchange rate does not cause a significant decrease in Canadian pulp price. Therefore, conclusions drawn from the results of non-stationary VAR models may be biased.

exchange rate, U.S. pulp price, and domestic use of pulp on Canadian pulp price are significant. However, U.S. pulp price is found to be the most important variable in determining Canadian pulp price. The effect of a shock either in the exchange rate or in the domestic use of pulp on Canadian pulp price can be interpreted more meaningfully if we consider the indirect effects of those shocks through U.S. pulp price. This suggests that contrary to methods used in previous analyses it may be important to include indirect effects of macroeconomic variables in policy analysis.

The effect of exchange rates on Canadian pulp price provides inconclusive evidence on the presence of market power for Canadian pulp producers. The immediate significant increase in the Canadian pulp price with a fall in the value of the Canadian dollar indicates that pulp exporters have some market power because a portion of the burden of their dollar depreciation is passed on to U.S. importers. However, the decrease in Canadian pulp price in response to the devaluation of the Canadian dollar in later periods supports the finding of Townsend and Uhler (1986) that Canadian pulp producers are price takers in the international market. This result may be caused by new contenders in the pulp market, such as Brazil, Chile, Portugal, and Spain. Also, since the growth in demand for market pulp is declining due to increased integration of pulp mills with paper or paper board facilities (see Woodbridge et al. 1988), it is not unreasonable to think that Canadian pulp exporters could be foregoing profit, because of lowered prices, in order to maintain market share in the long run.

Finally, some of the limitations of the results should be noted. First, the assumption of recursive identification restricts the contemporaneous interactions among the variables. Although the use of recursive VAR models is common, structural models may produce different results (Adamowicz et al. 1991). Secondly, the model incorporated only a few macroeconomic variables. The results obtained m'.y not be consistent if any theoretically relevant variables have been omitted.[68] Finally, we did not consider effects of policy or structural changes which affect the Canadian/U.S. pulp industry. For example, in the recent past, several U.S. states have enacted legislation on the use of recycled pulp in paper manufacturing. This may have a significant impact on the demand for wood pulp and thus the price of pulp. Intervention analysis can be taken up to address these issues.

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[68]See Braun and Mittnik (1993) the effects of misspecifications caused by omitted variables and incorrect orthogonalization of innovations on impulse responses and vriance decompositions.

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CHAPTER 5 Summary and Conclusions

Economic analysis may provide insights into the behaviour of forest product firms, and the industry at large, and may thereby play a role in directing forest policies to further economic efficiency and/or equity. However, economic analysis of the Canadian forest sector is complicated by issues relating to institutional features, market imperfections, and interactions between relevant variables in the economy. The three studies conducted in this thesis investigate a range of institutional, micro, and macroeconomic interactions, in competitive and non-competitive markets, which affect the behaviour of forest product firms, and the forest products industry at large in Canada.

This thesis examines the economic impacts of several forest policies relating to the Canadian forest sector. First, the effect of a policy relating to the institutional constraints on timber supply behaviour of tenure holders is considered. Second, the effect of a stumpage price increase policy on the overall economy of a region is investigated. Finally, the effect of changes in domestic and/or foreign economies on a specific forest product sector is explored. In this chapter the effects of each policy are summarised and conclusions are drawn with suggestions for future research.

The effect of forced vertical integration and limitations on the length of harvest contracts on the short-run timber supply behaviour of Alberta quota holders is investigated in the second chapter. An optimal control approach is used to predict timber supply and estimate shadow prices of institutional constraints. Expected values of prices and interest rates are used in the model which are derived from Taylor's (1984) hyperbolic tangent transformation approach. Quota holders are divided into three categories based on their timber production capacities, because it is thought that these quota holders use different technologies in the short-run. The cost structure of large, medium, and small tenure holders are calibrated so that the modeled behaviour mimics the actual lumber production. Because of institutionalized vertical integration, timber supply is modeled in response to prices of processed timber products. Calibrated models are used to determine the shadow prices of processing capacity constraints and annual allowable cut restrictions. Results indicate that quota holders incur substantial costs due to institutional constraints. Capacity constraints are found to have higher shadow prices than do the limitations on the length of harvest contract. Both capacity constraints and limitations on the length of quota quadrant are shown to be binding for all categories of quota holders. The shadow price of institutional constraints suggests investigating the possibilities of creating log markets and increasing the length of quota quadrant length.

In the third chapter, the impact of stumpage price increases on the economy of British Columbia is examined. In particular, the impact of this policy on various sectors, income distribution of two income classes, and two regions of B.C. is assessed. In order to capture the intersectoral linkages and to account for indirect effects of the policy change on all sectors in the economy, a computable general equilibrium approach is used. Results indicate that increases in stumpage prices cause a decline both in employment and real GDP. The results also show that for a comparable increase in stumpage rates both employment and real GDP fall more in the Interior than in the Coast. The results demonstrate that the negative impacts of the May 1, 1994 stumpage policy are greater in the Interior B.C. than in the Coast. Furthermore, the decline in real income for British

Columbians as measured by consumption is smaller than the fall in real GDP. For consumers, when nominal wages are rigid (due to contracts or strong union activity) the change in prices of goods that have major shares in their consumption bundle matters the most. As forest products have smaller shares in the consumption bundle, compared to the shares of other sector goods, large increases in prices for forest products do not greatly affect the consumer price index. In the long-run, however, when the assumption of rigid nominal wages is relaxed, the fall in nominal wages may be equal or even higher than the fall in the consumer price index. Although the stumpage price increase policy may cause an increase in forest revenues, the analysis indicates that there are costs associated with it. Also, the costs associated with the policy are higher in the Interior B.C. than those on the Coast. This suggests that the government should consider the differential impacts of the policy in reinvesting the Forest Renewal Plan fund.

The fourth chapter explores the short-run dynamic impacts of Canada-U.S. exchange rate, U.S. pulp price, and domestic use of pulp on Canadian pulp price. A simple theoretical model is presented to explain the impact of exchange rate on Canadian pulp price. The VAR approach is proposed to estimate an empirical model. Since the variables used in the model were non-stationary, a cointegration analysis was conducted using Johansen's (1988) maximum likelihood procedure. Results indicated the presence of only one cointegrating vector among the four variables. Therefore, a vector error correction model (VEC) was specified to study the short-run dynamic interactions among the variables. Both forecast error variance (FEV) and impulse response function (IRF) analyses suggest that variables relating to the U.S. economy are more important than domestic variables in determining the price of pulp in Canada. The results provide weak evidence of the existence of market power for Canadian pulp producers. The results also indicate that the indirect effects of shocks in macroeconomic variables are important in policy analysis. The results suggest that expectations on changes in the U.S. economy are critical to Canadian pulp exporters. Weak evidence of the existence of market power for Canadian pulp producers may be because of: a) increasing competition in the pulp market from new contenders such as Brazil, Chile, Portugal and; b) declining demand for market pulp due to increased integration of pulp mills with paper and paper products facilities.

Finally, some of the limitations of the above studies and suggestions for further research should be noted. First, the shadow prices of institutional constraints and the supply behaviour estimated in Chapter 2 are based only on one quadrant of production data. Similar analysis could be taken up with another quadrant of data for comparison as data become available.[69] Also, the cost structure used in the objective function is derived implicitly from production behaviour. Future research may obtain empirical information on cost structures.

Second, with regards to Chapter 3, the economic impacts of an increased stumpage policy are estimated for the short-run. Future research could investigate the feed back effects of the policy as increased revenues are pumped back into the economy. Also, some of the parameters used in the study are not specifically estimated for B.C. More site specific parameters could be estimated and used. Finally, the CGE model was set up to differentiate between only two regions. Future research could focus on specific forest

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[69]Data for another full quadrant will be available in 1997.

dependent communities in British Columbia to determine the economic impacts of this policy.[70] It should also be noted that the model used is static in nature. Future research could expand the model to accommodate dynamic features (See Pereira 1993 for details on dynamic CGE analysis). The model used in this study is linearized which produces only approximate solutions. Instead, the model could be specified in levels form and results could be compared with those of linearized form.[71]

With regard to Chapter 4, the non-stationary VAR model used in the fourth chapter to investigate the short-run dynamics of the Canadian pulp industry includes only three macroeconomic variables. Also, the restrictions associated with Choleski decomposition of the covariance matrix to generate impulse response functions may limit the inferences drawn. Future research could expand the model to incorporate other relevant variables to see if more than one cointegration relationship exists.[72] Also, different forms of covariance decomposition could be tried to examine the sensitivity of the results.[73]

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[70]See Daniels et al. (1991) for details on the economic impact of a forest policy on forest dependent communities.

[71]See Hertel et al. (1992) for an extensive discussion on linearization and levels models.

[72]See King et al. (1991) and Fisher et al. (1992) for details on using identifying restrictions when more than one cointegration relationship exists.

[73]See Bernanke (1986) for details on different factorization of covariance matrix

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APPENDIX 2.1

Table 2.6 State transition probabilities for lumber price.

From state	To state							
	170.00	180.00	190.00	200.00	210.00	220.00	230.00	240.00
170.00	0.5043	0.0959	0.0902	0.0801	0.0670	0.0529	0.0393	0.0704
180.00	0.3981	0.0958	0.0962	0.0910	0.0813	0.0685	0.0544	0.1147
190.00	0.2990	0.0892	0.0954	0.0964	0.0918	0.0825	0.0699	0.1757
200.00	0.2128	0.0772	0.0882	0.0950	0.0966	0.0926	0.0837	0.2539
210.00	0.1431	0.0622	0.0759	0.0872	0.0945	0.0967	0.0932	0.3472
220.00	0.0906	0.0467	0.0607	0.0745	0.0862	0.0940	0.0967	0.4507
230.00	0.0539	0.0326	0.0452	0.0592	0.0731	0.0851	0.0934	0.5576
240.00	0.0300	0.0211	0.0313	0.0438	0.0577	0.0717	0.0839	0.6606

Table 2.7 State transition probabilities for wood chip price.

From state	To state							
	25.00	30.00	35.00	40.00	45.00	50.00	55.00	60.00
25.00	0.4963	0.4639	0.0397	0.0002	0.0000	0.0000	0.0000	0.0000
30.00	0.0594	0.5195	0.3963	0.0247	0.0001	0.0000	0.0000	0.0000
35.00	0.0008	0.0878	0.5697	0.3270	0.0147	0.0000	0.0000	0.0000
40.00	0.0000	0.0016	0.1256	0.6040	0.2604	0.0083	0.0000	0.0000
45.00	0.0000	0.0000	0.0032	0.1729	0.6193	0.2000	0.0045	0.0000
50.00	0.0000	0.0000	0.0000	0.0062	0.2293	0.6142	0.1481	0.0023
55.00	0.0000	0.0000	0.0000	0.0000	0.0111	0.2931	0.5891	0.1067
60.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0191	0.3616	0.6193

Table 2.8 State transition probabilities for interest rates.

From state	To state							
	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00
6.00	0.6669	0.2508	0.0733	0.0087	0.0004	0.0000	0.0000	0.0000
7.00	0.3207	0.3670	0.2385	0.0661	0.0074	0.0003	0.0000	0.0000
8.00	0.0860	0.2558	0.3662	0.2260	0.0594	0.0063	0.0002	0.0000
9.00	0.0113	0.0843	0.2679	0.3643	0.2136	0.0532	0.0053	0.0002
10.00	0.0006	0.0126	0.0927	0.2796	0.3612	0.2011	0.0475	0.0046
11.00	0.0000	0.0008	0.0147	0.1016	0.2909	0.3571	0.1888	0.0461
12.00	0.0000	0.0000	0.0009	0.0170	0.1110	0.3017	0.3519	0.2174
13.00	0.0000	0.0000	0.0000	0.0012	0.0195	0.1209	0.3120	0.5464

APPENDIX 3.1

An Example of a Johansen Specification

Johansen's approach involves transforming the equations from levels form into percentage changes in the variables. Following Dixon et al. (1980), a typical non-linear equation of a CES functional form is

$$Y = A\,[\sum_{i=1}^{n} \delta_i X_i^{\rho}]^{1/\rho} \qquad (1)$$

where Y is output, the X_is are inputs and A and the δ_is are positive parameters. The input demand functions can be obtained by choosing X_i (i=1,...n,) to minimize $\sum^{n}_{i} P_i X_i$ subject to equation (1). The input demand functions will have the form

$$X_k = Y \frac{1}{A} [\sum_{i=1}^{n} \delta_i (\frac{P_i \delta_k}{P_k \delta_i})^{(\rho/(1+\rho))}]^{1/\rho} \qquad k = 1,\dots n \qquad (2)$$

where P_is are price of inputs. Logarithmic differentiation of the above demand functions result in a set of linear functions of percentage changes of the form

$$x_k = y - \sigma(p_k - \sum_{i=1}^{n} S_i p_i), \quad \sigma = 1/(1+\rho), \quad k = 1,\dots n \qquad (3)$$

where the lower-case x, p and y are percentage changes in the variables denoted by the corresponding upper-case symbols and S_ks are cost shares. Equation (3) indicates that in the absence of changes in relative input prices, the percentage change in the use of input k will equal the percentage change in output. However, if P_k increases relative to a share weighted average of the percentage increases in all input prices, then X_k will increase more slowly than Y.

APPENDIX 3.2

Johansen Specification of the Complete Model[74]

Unit Cost Equations

Equations 1 through 9 express that in competitive equilibrium the change in producer price of a given sector equals the weighted sum of input price changes.

$$-p_1^P+\theta_{81}p_8+\theta_{w1}w+\theta_{r1}r_1 = -(\theta_{m1}+\theta_{71})p_m-\theta_{v1}cst \tag{4}$$

$$-p_2^P+\theta_{82}p_8+\theta_{w2}w+\theta_{r2}r_2 = -(\theta_{m2}+\theta_{72})p_m-\theta_{v2}cst \tag{5}$$

$$-p_3^P+\theta_{13}p_1+\theta_{83}p_8+\theta_{w3}w+\theta_{r3}r_3 = -(\theta_{m3}+\theta_{73})p_m \tag{6}$$

$$-p_4^P+\theta_{24}p_2+\theta_{84}p_8+\theta_{w4}w+\theta_{r4}r_4 = -(\theta_{m4}+\theta_{74})p_m \tag{7}$$

$$-p_5^P+\theta_{13}p_1+\theta_{25}p_2+\theta_{35}p_3+\theta_{45}p_4+\theta_{85}p_8+\theta_{w5}w+\theta_{r5}r_5 = -(\theta_{m5}+\theta_{75})p_m \tag{8}$$

$$-p_6^P+\theta_{86}p_8+\theta_{w6}w+\theta_{r6}r_6+\theta_{v6}v_6 = -(\theta_{m6}+\theta_{76})p_m-(\theta_{66}p_{ind}) \tag{9}$$

$$-p_7^P+\theta_{87}p_8+\theta_{w7}w+\theta_{r7}r_7 = -(\theta_{m7}+\theta_{77})p_m \tag{10}$$

$$-p_8^P+\theta_{88}p_8+\theta_{w8}w+\theta_{r8}r_8+\theta_{v8}v_8 = -(\theta_{m8}+\theta_{78})p_m \tag{11}$$

$$-p_9^P+\theta_{89}p_8+\theta_{w9}w+\theta_{r9}r_9 = -(\theta_{m9}+\theta_{79})p_m \tag{12}$$

Employment of Primary Factor Input

The model treats nominal wages as highly rigid in the short-run and the labour participation rates adjust through changes in employment. Capital is treated as specific to each sector. The supply of sector specific capital to the region is assumed to be a function of after-tax nominal returns. Land is also treated as sector specific like capital. But land is truly specific in the sense that it has no alternate use in the particular industry within the region. The supply of land to Coast and Interior logging is assumed responsive to changes in rental rates of land.

$$-elf_c+\sum_{i=1}^{9}\beta_{ic}x_i-\sum_{i=1}^{9}\beta_{ic}(1-\theta_{wi}^P)\sigma_i w+\sum_{i=1}^{9}\beta_{ic}\theta_{ri}^P\sigma_i r_i+\beta_{6c}\theta_{v6}^P\sigma_6 v_6+\beta_{8c}\theta_{v8}^P\sigma_8 v_8 = -\beta_1\theta_{v1}^P\sigma_1 cst \tag{13}$$

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[74]The system of linear equations are rearranged so that all endogenous variables appear on the left hand side and all exogenous variables on the right hand side.

$$-elf_l + \sum_{l=1}^{9} \beta_{ll} x_l - \sum_{l=1}^{9} \beta_{ll}(1-\theta^P_{wl})\sigma_l w + \sum_{l=1}^{9} \beta_{ll}\theta^P_{rl}\sigma_l r_{ll} + \beta_{6l}\theta^P_{v6}\sigma_6 v_6 + \beta_{8l}\theta^P_{v8}\sigma_8 v_8 = -\beta_2\theta^P_{v2}\sigma_2 ist \quad (14)$$

$$elf_c + elf_I - \lambda w = 0 \quad (15)$$

$$x_1 - (1-\theta^P_{r1})\sigma_1 r_1 + \theta^P_{w1}\sigma_1 w = k_1 - \theta^P_{v1}\sigma_1 cst \quad (16)$$

$$x_2 - (1-\theta^P_{r2})\sigma_2 r_2 + \theta^P_{w2}\sigma_2 w = k_2 - \theta^P_{v2}\sigma_2 ist \quad (17)$$

$$x_3 - (1-\theta^P_{r3})\sigma_3 r_3 + \theta^P_{w3}\sigma_3 w = k_3 \quad (18)$$

$$x_4 - (1-\theta^P_{r4})\sigma_4 r_4 + \theta^P_{w4}\sigma_4 w = k_4 \quad (19)$$

$$x_5 - (1-\theta^P_{r5})\sigma_5 r_5 + \theta^P_{w5}\sigma_5 w = k_5 \quad (20)$$

$$x_6 - (1-\theta^P_{r6})\sigma_6 r_6 + \theta^P_{w6}\sigma_6 w + \theta^P_{v6}\sigma_6 v_6 = k_6 \quad (21)$$

$$x_7 - (1-\theta^P_{r7})\sigma_7 r_7 + \theta^P_{w7}\sigma_7 w = k_7 \quad (22)$$

$$x_8 - (1-\theta^P_{r8})\sigma_8 r_8 + \theta^P_{w8}\sigma_8 w + \theta^P_{v8}\sigma_8 v_8 = k_8 \quad (23)$$

$$x_9 - (1-\theta^P_{r9})\sigma_9 r_9 + \theta^P_{w9}\sigma_9 w = k_9 \quad (24)$$

$$-land_1 + x_1 + \theta^P_{w1}\sigma_1 w + \theta^P_{r1}\sigma_1 r_1 = (1-\theta^P_{v1})\sigma_1 cst - \theta^P_{v1} tech_1 \quad (25)$$

$$-land_2 + x_2 + \theta^P_{w2}\sigma_2 w + \theta^P_{r2}\sigma_2 r_2 = (1-\theta^P_{v2})\sigma_2 ist - \theta^P_{v2} tech_2 \quad (26)$$

$$x_6 + \theta^P_{w6}\sigma_6 w + \theta^P_{r6}\sigma_6 r_6 - (1-\theta^P_{v6})\sigma_6 v_6 = land_6 \quad (27)$$

$$x_8 + \theta^P_{w8}\sigma_8 w + \theta^P_{r8}\sigma_8 r_8 - (1-\theta^P_{v8})\sigma_8 v_8 = land_8 \quad (28)$$

<u>Product Market Equilibrium</u>

The equilibrium condition is that product markets clear. The demand for output of each sector within the region is the sum of final demand by consumers, intermediate uses of firms, and net exports. The demand is derived from a CES utility function.

$$-x_1 + \psi_{13}x_3 + \psi_{15}x_5 + \psi_{18}x_8 + \psi_{1q}(e_1 q + \eta_{11}p_1 + \eta_{12}p_2 + \eta_{13}p_3 + \eta_{14}p_4 + \eta_{15}p_5 + \eta_{18}p_8 + \eta_{19}p_9) = -\psi_{1e} export1 - \psi_{1q}(\eta_{16}p_{tnd} + \eta_{17}p_m) \quad (29)$$

$$-x_2+\psi_{24}x_4+\psi_{25}x_5+\psi_{28}x_8+\psi_{2q}(e_{2}q+\eta_{21}p_1+\eta_{22}p_2+\eta_{23}p_3+\eta_{24}p_4 +\eta_{25}p_5+\eta_{28}p_8+\eta_{29}p_9) = -\psi_{2e}export2 -\psi_{2q}(\eta_{26}p_{ind}+\eta_{27}p_m) \tag{30}$$

$$-x_3+\psi_{35}x_5+\psi_{37}x_7+\psi_{38}x_8+\psi_{3q}(e_{3}q+\eta_{31}p_1+\eta_{32}p_2+\eta_{33}p_3+\eta_{34}p_4+\eta_{35}p_5 +\eta_{38}p_8+\eta_{39}p_9)+\psi_{3e}export_3 = -\psi_{3q}(\eta_{36}p_{ind}+\eta_{37}p_m) \tag{31}$$

$$-x_4+\psi_{45}x_5+\psi_{47}x_7+\psi_{48}x_8+\psi_{4q}(e_{4}q+\eta_{41}p_1+\eta_{42}p_2+\eta_{43}p_3+\eta_{44}p_4 +\eta_{45}p_5+\eta_{48}p_8+\eta_{49}p_9)+\psi_{4e}export_4 = -\psi_{4q}(\eta_{46}p_{ind}+\eta_{47}p_m) \tag{32}$$

$$-x_5+\psi_{57}x_7+\psi_{58}x_8+\psi_{4q}(e_{5}q+\eta_{51}p_1+\eta_{52}p_2+\eta_{53}p_3+\eta_{54}p_4+\eta_{55}p_5 +\eta_{58}p_8+\eta_{59}p_9)+\psi_{5e}export_5 = -\psi_{5q}(\eta_{56}p_{ind}+\eta_{57}p_m) \tag{33}$$

$$-(1-\psi_{66})x_6+\psi_{67}x_7+\psi_{68}x_8+\psi_{69}x_9+\psi_{6q}(e_{6}q+\eta_{61}p_1+\eta_{62}p_2+\eta_{63}p_3+\eta_{64}p_4 +\eta_{65}p_5+\eta_{68}p_8+\eta_{69}p_9)+\psi_{6e}export6 = -\psi_{6q}(\eta_{66}p_{ind}+\eta_{67}p_m) \tag{34}$$

$$-(\Gamma_d-\psi_{77})x_7-(\Gamma_m)import_7+\sum_{i=1}^{9}\psi_{7i}x_i+\psi_{7q}(e_{7}q+\eta_{71}p_1+\eta_{72}p_2+\eta_{73}p_3 +\eta_{74}p_4+\eta_{75}p_5+\eta_{78}p_8+\eta_{79}p_9) = -\psi_{7q}(\eta_{76}p_{ind}+\eta_{77}p_m) \tag{35}$$

$$-(1-\psi_{88})x_8+\psi_{81}x_1+\psi_{82}x_2+\psi_{83}x_3+\psi_{84}x_4+\psi_{85}x_5+\psi_{86}x_6 +\psi_{87}x_7+\psi_{89}x_9+\psi_{8q}(e_{8}q+\eta_{81}p_1+\eta_{82}p_2+\eta_{83}p_3+\eta_{84}p_4 +\eta_{85}p_5+\eta_{88}p_8+\eta_{89}p_9) = -\psi_{8q}(\eta_{86}p_{ind}+\eta_{87}p_m) \tag{36}$$

$$-x_9+\psi_{9q}(e_{9}q+\eta_{91}p_1+\eta_{92}p_2+\eta_{93}p_3+\eta_{94}p_4+\eta_{95}p_5 +\eta_{98}p_8+\eta_{99}p_9) = -\psi_{9q}(\eta_{96}p_{ind}+\eta_{97}p_m) \tag{37}$$

Other Set of Equations

Provincial GDP is specified as the sum of payments to all factors of production. The share of foreign ownership of capital is netted out in calculating the GDP. The GDP deflator is defined as the cost of output weighted by base period sector output. The consumer price index is defined as the cost of a representative basket of consumer goods. The nominal income is defined as the sum of changes in wage, capital rents, and land rents weighted by their shares.

$$-GDP_c+\delta_{wc}elf_c+\delta_{wc}w+\sum_{i=1}\delta_i r_{ic}+\delta_{v6c}v_6+\delta_{v8c}v_8 = -\sum_{i=1}^{9}\delta_{ic}k_i-\delta_{v1c}cst-\delta_{v6c}land_6-\delta_{v8c}land_8 \tag{38}$$

$$-GDP_f+\delta_{wf}elf_f+\delta_{wf}w+\sum_{i=1}^{9}\delta_{if}r_i+\delta_{v6f}v_6+\delta_{v8f}v_8 = -\sum_{i=1}^{9}\delta_{if}k_i-\delta_{v2}ist-\delta_{v6f}land_6-\delta_{v8f}land_8 \tag{39}$$

$$-gdp+\delta_w elf+\delta_w w+\sum_{i}^{9}\delta_i r_i+\delta_{v1}land_1+\delta_{v2}land_2+\delta_{v6}v_6+\delta_{v8}v_8 = -\sum_{i=1}^{9}\delta_i k_i-\delta_{v1} \quad \delta_{v2}ist-\delta_{v6}land_6-\delta_{v8}land_8 \tag{40}$$

$$-gdpd+\delta_1 p_1+\delta_2 p_2+\delta_3 p_3+\delta_4 p_4+\delta_5 p_5+\delta_8 p_8+\delta_9 p_9^p = -\delta_6 p_{ind}-\delta_7 p_m \tag{41}$$

$$-\xi_q q+gdp = \xi_t tax+\xi_p psav \tag{42}$$

$$y_1-\xi_{w1}(w+elf)-\sum_{j=1}^{9}\xi_{rj1}r_j-\xi_{v6}v_6-\xi_{v8}v_8 = \xi_v\xi_1(cst+ist) \tag{43}$$

$$y_2-\xi_{w2}(w+elf)-\sum_{j=1}^{9}\xi_{rj2}r_j = \xi_v\xi_2(cst+ist) \tag{44}$$

$$cpi_1-\pi_{13}p3-\pi_{14}p4-\pi_{15}p5-\pi_{18}p8-\pi_{19}p9 = \pi_{16}p6+(\pi_{17}+\pi_{1m})pm \tag{45}$$

$$cpi_2-\pi_{23}p3-\pi_{24}p4-\pi_{25}p5-\pi_{28}p8-\pi_{29}p9 = \pi_{26}p6+(\pi_{27}+\pi_{2m})pm \tag{46}$$

$$y_{1r}-y_1+cpi_1 = 0 \tag{47}$$

$$y_{2r}-y_2+cpi_2 = 0 \tag{48}$$

Linkage Between Producer Prices and Market prices

Indirect taxes can create a wedge between producer and market prices and will play a major role in tax policy simulations.

$$-p_1+\rho_1 p_1^p = \iota_1 itt_1 \tag{49}$$

$$-p_2+\rho_2 p_2^p = \iota_2 itt_2 \tag{50}$$

$$-p_3+\rho_3 p_3^p = \iota_3 itt_3 \tag{51}$$

$$-p_4+\rho_4 p_4^p = \iota_4 itt_4 \tag{52}$$

$$-p_5+\rho_5 p_5^p = \iota_5 itt_5 \tag{53}$$

$$-export_6 + \phi_6 \zeta_{p6} p_6^p = -\phi_6 \zeta_{t6} tt_6 \quad (54)$$

$$import_7 + \gamma p_7^p = -\gamma p_m \quad (55)$$

$$-p_8 + \rho_8 p_8^p = \iota_8 itt_8 \quad (56)$$

Forest Products Exports

The net export demand for forest products is a function of the sector's producers price and transportation charges in delivering one unit of product to market.

$$-export_3 + \phi_3 \zeta_{p3} p_3^p = -\phi_3 \zeta_{t3} tt_3 \quad (57)$$

$$-export_4 + \phi_4 \zeta_{p4} p_4^p = -\phi_4 \zeta_{t4} tt_4 \quad (58)$$

$$-export_5 + \phi_5 \zeta_{p5} p_5^p = -\phi_5 \zeta_{t5} tt_5 \quad (59)$$

APPENDIX 3.3

Table 3.7 Tables defining variables, elasticities, and parameters

Endogenous variables in the model	
p^p_i i = 1,....9	producer price of sector i
elf_c	employed labour force in the Coast
elf_i	employed labour force in the Interior
w	nominal wage
r_i i = 1,....9	rate of return on capital in sector i
$land_i$ i = 1,2	land used in sector i
v_i i = 6,8	rental rate of land in sector i
x_i i = 1,....9	output in sector i
gdp	gross domestic product
gdpd	GDP deflator
q	disposable income
cpi_i i = 1,2	consumer price index for category i
GDP_c	GDP for the Coast
GDP_i	GDP for the Interior
y_i i = 1,2	nominal income for household category i
y_{ir} i = 1,2	real income for household category i
p_i i = 1,...5&8	market price of sector i
$export_3$	export of lumber from coastal BC
$export_4$	export of lumber from interior BC
$export_5$	export of pulp and paper products
$export_6$	exports of primary industry
$import_7$	imports of manufacturing goods

Exogenous variables in the model	
p_{ind}	price of pri. industries sector
p_m	price of imports or price of sector 7
tt_i i =3,....6	transportation cost in sector i
itt_i i =1,....8	indirect taxes in sector i
k_i i =1,.....9	capital [illegible] sector i
$land_i$ i =6,8	land in sector i
cst	coast stumpage rate
ist	interior stumpage rate
ptf	personal transfers
tax	income tax rate
psav	personal savings
$export_1$	log exports from costal BC
$export_2$	log exports from interior BC

Elasticities in the model	
σ_i i =1,.....9	technical elasticity of substitution in sector i
ϕ_i i =3,4,5,6	export demand elasticity in sector i
γ	import demand elasticity for manufacturing goods (-100)
ϵ_i i =1,.....9	expenditure elasticity in sector i
η_{ij} i,j =1,..9 i≠j	cross price elasticity between sector i and J sectors
η_{ii} i =1,....9	own price elasticity sector i
λ	supply elasticity of labour (100)

Parameters in the model	
α_i i =1,.....9	allocation of capital in sector i
β_{ij} i =1,....9 & j = C & I	allocation of labour in sector i of the Coast and Interior
θ_{wi} i =1,.....9	distributive share of labour in sector i
θ_{ri} i =1,.....9	distributive share of capital in sector i
θ_{vi} i =1,2,6,8	distributive share of land in sector i
θ^p_{wi} i =1,.....9	distributive share of labour in total pri. inputs cost of sector i
θ^p_{ri} i =1,.....9	distributive share of capital in total pri. inputs cost of sector i
θ^p_{vi} i =1,2,6,8	distributive share of land in total pri. inputs cost of sector i
θ_{ji} j,i =1,.....9	distributive share of intermediate input j in sector i
θ_{mi} i =1,.....9	distributive share of imports in sector i
ψ_{ij} i,j =1,.....9	share of output from sector i to j
ψ_{iq} i =1,.....9	share of output from sector i to consumption
ψ_{ie} i =1,.....6	share of output from sector i to export
Γ_d	share of domestic production in x7
Γ_m	share of imports in x7
ζ_{ti} i =3,4,5,6	share of transport cost in sector i
ζ_{pi} i =3,4,5,6	share of producer price in sector i
δ_w	share of wages in income
δ_{ri} i =1,.....9	share of capital rents in income
δ_{vi} i =1,2,6,8	share of land rents in income
δ_i i =1,.....9	share of price i in GDP deflator
ξ_q	share of disposable income in GDP
ξ_{tax}	share of direct taxes in GDP
ξ_{psav}	share of personal savings in GDP

Parameters in the model	
ξ_{wi} i=1,2	share of wages in ith group's income
ξ_{rji} i=1,2; j=1,..9	share of capital rents in ith group's income
ξ_{tfi} i=1,2	share of transfer payments in ith group's income
ξ_i i=1,2	Share of household category i in total income
υ	share of stumpage revenue in households income by transfer
π_{ij} i=1,2; j=3,....9 &m	share of price j in ith group's CPI
ρ_i i=1,....5&8	share of producer price in ith market price
ι_i i=1,....8	share of indirect taxes in ith market price

APPENDIX 3.4
Parameters Values Used in the Model[75]

Allocation of Labour Force

The source used to allocate labour across sectors is Statistics Canada Catalogue (SCC) 72-002 (December 1989). For disaggregation between Coast and Interior B.C. the source used is SCC 25-202 (1987).

$\beta_1 = 0.0163$	$\beta_5 = 0.0203$	$\beta_9 = 0.0689$
$\beta_2 = 0.0103$	$\beta_6 = 0.0435$	
$\beta_3 = 0.0210$	$\beta_7 = 0.0807$	
$\beta_4 = 0.0202$	$\beta_8 = 0.7189$	

The source used to allocate labour between the regions and across sectors within the regions is B.C. Regional Index (1986).

Share of employment for the Coast and Interior in total

$\beta_c = 0.745$	$\beta_I = 0.255$

Shares of employment, by sector, in the Coast

$\beta_{1c} = 0.022$	$\beta_{5c} = 0.019$	$\beta_{9c} = 0.075$
$\beta_{2c} = 0.000$	$\beta_{6c} = 0.028$	
$\beta_{3c} = 0.028$	$\beta_{7c} = 0.092$	
$\beta_{4c} = 0.000$	$\beta_{8c} = 0.736$	

Shares of employment, by sector, in the Interior

$\beta_{1I} = 0.000$	$\beta_{5I} = 0.024$	$\beta_{9I} = 0.052$
$\beta_{2I} = 0.041$	$\beta_{6I} = 0.087$	
$\beta_{3I} = 0.000$	$\beta_{7I} = 0.047$	
$\beta_{4I} = 0.079$	$\beta_{8I} = 0.670$	

Allocation of Capital Stock

The capital stock estimates were based on the distribution of the net capital stock in 1981. The source used is Fixed Capital Flows and Stocks, B.C. 1953-82, Statistics Canada. The capital was allocated between Coast and Interior logging was in proportion to labour force.

$\alpha_1 = 0.0186$	$\alpha_5 = 0.0807$	$\alpha_9 = 0.2204$
$\alpha_2 = 0.0096$	$\alpha_6 = 0.1135$	
$\alpha_3 = 0.0156$	$\alpha_7 = 0.0633$	
$\alpha_4 = 0.0217$	$\alpha_8 = 0.4563$	

[75]The parameters used in this study are from Duchesne (1991) unless specified.

Technical Elasticity of Substitution

The values correspond to Shoven and Whalley (1992). In both logging sectors, substitution is made possible between labour and capital but not between land and, labour and capital. The elasticity of substitution between labour and capital in these two sectors correspond to Dixon et al. (1982).

$\sigma_1 = 0.500$	$\sigma_5 = 0.900$	$\sigma_9 = 0.500$
$\sigma_2 = 0.500$	$\sigma_6 = 0.750$	
$\sigma_3 = 0.850$	$\sigma_7 = 0.815$	
$\sigma_4 = 0.850$	$\sigma_8 = 0.860$	

Expenditure Elasticities

Approximations based on the relative importance of the sectors.

$\epsilon_1 = 1.000$	$\epsilon_5 = 1.000$	$\epsilon_9 = 1.000$
$\epsilon_2 = 1.000$	$\epsilon_6 = 1.000$	
$\epsilon_3 = 1.000$	$\epsilon_7 = 1.000$	
$\epsilon_4 = 1.000$	$\epsilon_8 = 1.000$	

Own Price Elasticities

Own price elasticities for forest wood products are based on Prins (1993). Other sectors own price elasticities are approximations of Shoven and Whalley (1992).

$\eta_{11} = -1.000$	$\eta_{55} = -1.000$	$\eta_{99} = -1.000$
$\eta_{12} = -1.000$	$\eta_{66} = -1.000$	
$\eta_{33} = -1.000$	$\eta_{77} = -1.000$	
$\eta_{44} = -1.000$	$\eta_{88} = -1.000$	

Distributive Shares of Inputs

The distributive shares of labour, capital, land and intermediate input use in each sector are calculated from a B.C. Input-Output table 1984. For the pulp and paper sector, the distribution of output between Coast and Interior regions is obtained in proportion to their relative value added (Source: Statistics Canada Catalogue 25-202. 1987). For both logging sectors, the distributive shares of labour, capital and land are calculated using SCC 25-201. The intermediate input shares in these two sectors are calculated as residuals. For Coast and Interior wood products sectors, distributive shares are calculated using the Province of B.C. Forest and Range Resources Analysis (1984). In each sector, the share of manufacturing inputs is disaggregated between domestic and imported manufacturing using their relative weights.

$\theta_{1w} = 0.4007$	$\theta_{2w} = 0.3100$	$\theta_{3w} = 0.260$	$\theta_{4w} = 0.274$
$\theta_{17} = 0.0450$	$\theta_{27} = 0.0600$	$\theta_{37} = 0.523$	$\theta_{47} = 0.452$
$\theta_{18} = 0.2649$	$\theta_{28} = 0.3153$	$\theta_{38} = 0.050$	$\theta_{48} = 0.061$
$\theta_{1v} = 0.1834$	$\theta_{2v} = 0.2287$	$\theta_{31} = 0.105$	$\theta_{42} = 0.127$
$\theta_{1r} = 0.0730$	$\theta_{2r} = 0.0460$	$\theta_{3r} = 0.025$	$\theta_{4r} = 0.041$
$\theta_{1m} = 0.0330$	$\theta_{2m} = 0.0440$	$\theta_{3m} = 0.038$	$\theta_{5m} = 0.046$

$\theta_{5w} = 0.232$
$\theta_{51} = 0.031$
$\theta_{52} = 0.014$
$\theta_{53} = 0.062$
$\theta_{54} = 0.087$
$\theta_{57} = 0.113$
$\theta_{58} = 0.227$
$\theta_{5r} = 0.149$
$\theta_{5m} = 0.085$

$\theta_{6w} = 0.175$
$\theta_{66} = 0.110$
$\theta_{67} = 0.070$
$\theta_{68} = 0.214$
$\theta_{6r} = 0.264$
$\theta_{6v} = 0.113$
$\theta_{6m} = 0.053$

$\theta_{7w} = 0.218$
$\theta_{77} = 0.233$
$\theta_{78} = 0.284$
$\theta_{7r} = 0.103$
$\theta_{7m} = 0.155$

$\theta_{8w} = 0.313$
$\theta_{86} = 0.018$
$\theta_{87} = 0.076$
$\theta_{88} = 0.262$
$\theta_{8r} = 0.192$
$\theta_{8v} = 0.082$
$\theta_{8m} = 0.057$

$\theta_{9w} = 0.571$
$\theta_{96} = 0.004$
$\theta_{97} = 0.025$
$\theta_{98} = 0.309$
$\theta_{9r} = 0.072$
$\theta_{9m} = 0.019$

<u>Share of Each Primary input in total primary input cost</u>

These shares are calculated from the distributive shares of primary inputs.

$\theta_{1w}^{P} = 0.6098$
$\theta_{1r}^{P} = 0.1111$
$\theta_{1v}^{P} = 0.2791$

$\theta_{2w}^{P} = 0.5302$
$\theta_{2r}^{P} = 0.0787$
$\theta_{2v}^{P} = 0.3911$

$\theta_{3w}^{P} = 0.912$
$\theta_{3r}^{P} = 0.0880$

$\theta_{4w}^{P} = 0.8700$
$\theta_{4r}^{P} = 0.1300$

$\theta_{5w}^{P} = 0.6090$
$\theta_{5r}^{P} = 0.3910$

$\theta_{6w}^{P} = 0.3170$
$\theta_{6r}^{P} = 0.4780$
$\theta_{6v}^{P} = 0.2050$

$\theta_{7w}^{P} = 0.679$
$\theta_{7r}^{P} = 0.3210$

$\theta_{8w}^{P} = 0.5330$
$\theta_{8r}^{P} = 0.3270$
$\theta_{8v}^{P} = 0.1400$

$\theta_{9w}^{P} = 0.8880$
$\theta_{9r}^{P} = 0.1120$

<u>Distribution of Output</u>

The distribution of output to its various uses is done based on the B.C. Input-Output table (use and final demand matrix) 1984. For the manufacturing and service sectors, the distribution of output between Coast and Interior is made in proportion to their relative value added as found in SCC 25-202 (1987).

$\psi_{13} = 0.864$
$\psi_{15} = 0.048$
$\psi_{18} = 0.002$
$\psi_{1q} = 0.006$
$\psi_{1e} = 0.080$

$\psi_{24} = 0.873$
$\psi_{25} = 0.049$
$\psi_{28} = 0.002$
$\psi_{2q} = 0.006$
$\psi_{2e} = 0.082$

$\psi_{35} = 0.199$
$\psi_{37} = 0.005$
$\psi_{38} = 0.097$
$\psi_{3q} = 0.002$
$\psi_{3e} = 0.687$

$\psi_{45} = 0.181$
$\psi_{47} = 0.005$
$\psi_{48} = 0.089$
$\psi_{4q} = 0.002$
$\psi_{4e} = 0.706$

$\psi_{57} = 0.118$	$\psi_{66} = 0.033$	$\psi_{71} = 0.003$	$\psi_{81} = 0.010$
$\psi_{58} = 0.065$	$\psi_{67} = 0.237$	$\psi_{72} = 0.002$	$\psi_{82} = 0.005$
$\psi_{5q} = 0.036$	$\psi_{68} = 0.051$	$\psi_{73} = 0.002$	$\psi_{83} = 0.005$
$\psi_{5e} = 0..781$	$\psi_{69} = 0.003$	$\psi_{74} = 0.002$	$\psi_{84} = 0.008$
	$\psi_{6q} = 0.183$	$\psi_{75} = 0.011$	$\psi_{85} = 0.012$
	$\psi_{6e} = 0.494$	$\psi_{76} = 0.020$	$\psi_{86} = 0.016$
		$\psi_{77} = 0.060$	$\psi_{87} = 0.023$
		$\psi_{78} = 0.404$	$\psi_{88} = 0.314$
		$\psi_{79} = 0.142$	$\psi_{89} = 0.035$
$\psi_{9q} = 1.000$		$\psi_{7q} = 0.354$	$\psi_{8q} = 0..571$

<u>Share of Manufacturing Consumption</u>

The share of manufacturing consumption that is met by domestic production and by imports are derived from the Input-Output table.

$\gamma_d = 0.572$ $\gamma_m = 0.428$

<u>Share of Transportation Costs and Producer Prices of total delivered Price</u>

$\zeta_{t3} = 0.270$	$\zeta_{t4} = 0.325$	$\zeta_{t5} = 0.400$	$\zeta_{t6} = 0.200$
$\zeta_{p3} = 0.730$	$\zeta_{p4} = 0.675$	$\zeta_{p5} = 0.600$	$\zeta_{p6} = 0.800$

<u>Share of Primary Factors in Provincial GDP</u>

The share of each primary factor share is computed as the share of each factor in industry value added times the share of that industry in GDP. The share of each factor in industry value added is derived from the distributive shares above.

$\delta_w = 0.6609$	$\delta_{r5} = 0.0129$	$\delta_{v1} = 0.0015$
$\delta_{r1} = 0.0026$	$\delta_{r6} = 0.0244$	$\delta_{v2} = 0.0015$
$\delta_{r2} = 0.0012$	$\delta_{r7} = 0.0277$	$\delta_{v6} = 0.0105$
$\delta_{r3} = 0.0016$	$\delta_{r8} = 0.1536$	$\delta_{v8} = 0.0834$
$\delta_{r4} = 0.0033$	$\delta_{r9} = 0.0116$	

<u>Share of each primary factor, by industry, in the Coast</u>

$\delta_w = 0.6570$	$\delta_{r5} = 0.0129$	$\delta_{v1} = 0.0030$
$\delta_{r1} = 0.0038$	$\delta_{r6} = 0.0244$	$\delta_{v2} = 0.0000$
$\delta_{r2} = 0.0000$	$\delta_{r7} = 0.0277$	$\delta_{v6} = 0.0105$
$\delta_{r3} = 0.0049$	$\delta_{r8} = 0.1575$	$\delta_{v8} = 0.0834$
$\delta_{r4} = 0.0000$	$\delta_{r9} = 0.0116$	

<u>Share of each primary factor, by industry, in the Interior</u>

$\delta_w = 0.6730$	$\delta_{r5} = 0.0129$	$\delta_{v1} = 0.000$
$\delta_{r1} = 0.0000$	$\delta_{r6} = 0.0244$	$\delta_{v2} = 0.0030$

$\delta_{r2} = 0.0038$	$\delta_{r7} = 0.0277$	$\delta_{v6} = 0.0105$
$\delta_{r3} = 0.0000$	$\delta_{r8} = 0.1415$	$\delta_{v8} = 0.0834$
$\delta_{r4} = 0.0049$	$\delta_{r9} = 0.0116$	

Weights for the GDP Deflator

The share of each sector in the GDP is obtained from the B.C. economic accounts (1987 tables 5 and 6).

$\delta_1 = 0.017$	$\delta_5 = 0.033$	$\delta_9 = 0.161$
$\delta_2 = 0.008$	$\delta_6 = 0.051$	
$\delta_3 = 0.018$	$\delta_7 = 0.088$	
$\delta_4 = 0.025$	$\delta_8 = 0.600$	

Shares of Primary Factors and Transfers in Total Income of Average and Poor Income Group

The Shares are calculated from SCC 13-208 1991 (Table 22). Households with income below $20,000 are considered as poor and the rest as average income group. Sources of income were grouped into three categories: 1) wages and salaries; 2) self employment, investment and other income and; 3) transfer payments. The share of capital and land are calculated from self employment, investment and other income by weighting with shares of capital and land used in different sectors. The share of stumpage in total income is calculated from Ministry of Forests and Lands, B.C. Annual Report (1988).

$\xi_{w1} = 0.7477$	$\xi_{w2} = 0.2853$
$\xi_{r11} = 0.0019$	$\xi_{r12} = 0.0022$
$\xi_{r21} = 0.0010$	$\xi_{r22} = 0.0012$
$\xi_{r31} = 0.0016$	$\xi_{r32} = 0.0019$
$\xi_{r41} = 0.0022$	$\xi_{r42} = 0.0026$
$\xi_{r51} = 0.0081$	$\xi_{r52} = 0.0097$
$\xi_{r61} = 0.0114$	$\xi_{r62} = 0.0136$
$\xi_{r71} = 0.0064$	$\xi_{r72} = 0.0076$
$\xi_{r81} = 0.0459$	$\xi_{r82} = 0.0547$
$\xi_{r91} = 0.0222$	$\xi_{r92} = 0.0264$
$\xi_{v61} = 0.0058$	$\xi_{v62} = 0.000$
$\xi_{v81} = 0.0404$	$\xi_{v82} = 0.000$
$\xi_{tf1} = 0.1030$	$\xi_{tf2} = 0.5923$
$\xi_{st1} = 0.0004$	$\xi_{st2} = 0.0004$

Shares of income sources in the Coast and Interior

ξc 0.800	ξ_I 0.200

Shares of Average and Poor Income Group in Total Income

$\xi_1 = 0.912$	$\xi_1 = 0.088$

Weights for Consumer Price Index

The weights are calculated for both average and poor income groups by using SCC 62-555 (table 3).

weights for average income CPI	weights for poor income CPI
$\pi_{13} = 0.0073$	$\pi_{23} = 0.0055$
$\pi_{14} = 0.0073$	$\pi_{24} = 0.0190$
$\pi_{15} = 0.0162$	$\pi_{25} = 0.0240$
$\pi_{16} = 0.0346$	$\pi_{26} = 0.1853$
$\pi_{17} = 0.2052$	$\pi_{27} = 0.1387$
$\pi_{1m} = 0.13535$	$\pi_{2m} = 0.4920$
$\pi_{18} = 0.4564$	$\pi_{28} = 0.1299$
$\pi_{19} = 0.1195$	$\pi_{29} = 0.$

Share of Producer Price and Indirect Tax in Market Price

The shares are calculated from the B.C. Input-Output table 1984.

share of tax in market price	share of producer price in market price
$\iota_1 = 0.0300$	$\rho_1 = 0.9700$
$\iota_2 = 0.0300$	$\rho_2 = 0.9700$
$\iota_3 = 0.0160$	$\rho_3 = 0.9840$
$\iota_4 = 0.0160$	$\rho_4 = 0.9840$
$\iota_5 = 0.0220$	$\rho_5 = 0.9780$
$\iota_6 = 0.0176$	$\rho_6 = 0.9824$
$\iota_7 = 0.0270$	$\rho_7 = 0.9730$
$\iota_8 = 0.0480$	$\rho_8 = 0.9520$

APPENDIX 4.1

Figure 4.6a Shock to exchange rate

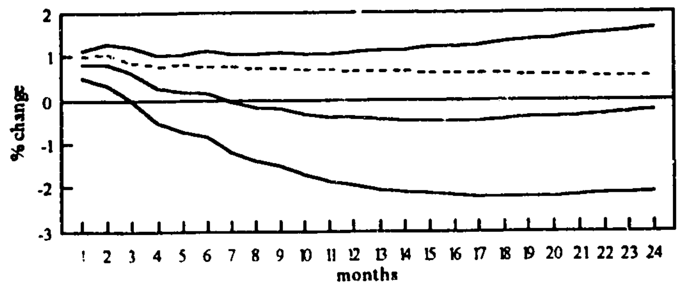

Figure 4.6b Shock to US pulp price

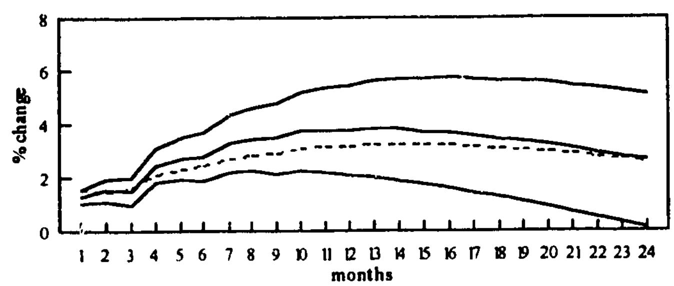

Figure 4.6c Shock to domestic use of pulp

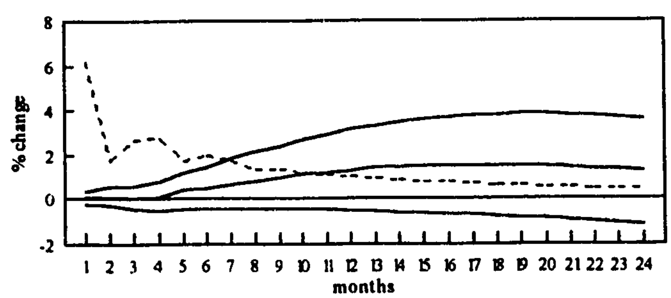

Figure 4.6 Response of Canadian pulp price to shocks in each macroeconomic variable. Note: The shocks are 1 standard deviation increase in each macroeconomic variable. The dotted lines are the responses of the own innovations.