CANADIAN THESES

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THE UNIVERSITY OF ALBERTA

The Economic Impact of Tariff and Quota Restrictions by the United States on Imported Canadian Lumber

by

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF Master of Science

IN

Forest Economics

Department of Rural Economy

EDMONTON, ALBERTA

Fall 1986

ISBN 0-315-32313-2

THE UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR Mohan Lal Sharma

TITLE OF THESIS The Economic Impact of Tariff and Quota Restrictions by the United States on Imported Canadian Lumber

DEGREE FOR WHICH THESIS WAS PRESENTED Master of Science

YEAR THIS DEGREE GRANTED Fall 1986

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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 The Economic Impact of Tariff and Quota Restrictions by the United States on Imported Canadian Lumber submitted by Mohan Lal Sharma in partial fulfilment of the requirements for the degree of Master of Science in Forest Economics.

William E. Phillips
Supervisor

James Beck
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Date. October 15 1986.....

This thesis is dedicated to my parents

Abstract

The purpose of this study is to analyse the impact of a United States tariff or quota on imported lumber from Canada. The study involves an investigation of the market structure of lumber trade between the two countries. This study differs from earlier studies in that it involves estimation of elasticities of lumber demand and supply for the two countries. The assumptions are made that there is no seperate demand for Canadian lumber in the United States and that imported Canadian lumber is a complement to United States domestic lumber supply. The estimation of demand and supply of lumber in the United States lumber market was, therefore, necessary. The residential construction industry accounts for the major share of lumber consumption in the United States. The share of Canadian lumber in total lumber consumption in the United States increased in recent years due to Canadian production cost advantages.

A non homothetic non neutral translog function best approximates the production technology used in the residential construction industries of both countries during 1970-82. Demand price elasticities of lumber in both countries are inelastic. A linear supply model is utilised to estimate supply elasticities of lumber for both countries. Since quarterly data for Canada were not available, annual data for the period 1961-82 were used to estimate a supply model. Lumber supply is elastic in the Canadian sawmill industry and inelastic in the United States

lumber industry. Estimates of supply and demand elasticities for lumber are used to estimate supply and demand schedules in both countries. These schedules are, in turn, used to carry out partial equilibrium analysis.

After protection measures by the United States, [illegible] they be implemented, the demand for lumber in the United States will fall due to a price rise in lumber. Lumber imports from Canada will decline. An advalorem tariff of 20% will adversely affect United States consumers and Canadian producers most among restriction alternatives. The United States government will realize lower revenue from an advalorem tariff on lumber imports than from a fixed tariff. The impact on United States consumers andCanadian producers of a 15% fixed tariff is nearly the same as the impact of a 20% advalorem tariff. However, in the former case, the United States government will realize more revenue.

In the event of a tariff, the lumber industry will need to increase overseas export markets to prevent volume declines. Canadian lumber producers will face stiff competition from other suppliers in overseas markets. Under no circumstances can the overseas markets absorb the potential fall in lumber exports to the United States. The Canadian lumber industry is, therefore, tied to the United States market.

Acknowledgements

I would like to take this opportunity to acknowledge a number of individuals and organizations who contributed to the completion of this thesis.

I am truly grateful to my supervisor, Dr. W.E. Phillips for his encouragement and invaluable suggestions. I also thank the members of my committee, Dr. M. Percy, Dr. L. Chase Wilde and Dr. J. Beck, who during my research and in the preliminary draft, provided invaluable suggestions.

A vote of thanks goes to the Government of India and to the Canadian Commonwealth Scholarship Committee for providing financial support for my graduate program. I am also grateful to the Canadian Forestry Service (Human Resource Development Program) for funding my research.

Mr. T. Williamson, Mr. W. Ondro, Mr. I.E. Bella and Mr. J. Francheschi from the Northern Forest Center, Canadian Forestry Service provided advice and material which contributed to my research.To them all my thanks. Dr. J. Buongiorno, Dr. D. Adams and Dr. R. Haynes provided invaluable advice.

I also would like to thank the members and staff of the Department of Rural Economy, University of Alberta and especially Mr. Reg Norby, Mr. Jim Copeland and Mrs. Wendy Williamson. A special note of thanks goes to my roommates Bob Wills, Sharon McKinnon and Llewellyn Matthews.

Finally, I sincerely thank my wife Manju for her patience, understanding and encouragement.

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I. INTRODUCTION

Free lumber trade between the United States and Canada has benefitted United States consumers and Canadian producers. Higher lumber prices in the United States have favoured lumber imports from Canada which fill the gap between demand and supply of lumber in the United States market. Import demand is determined by domestic demand conditions and is a linear or loglinear function of quantity and price of the imported good relative to the price of the domestic good. If considered an intermediate or finished good, its demand can be derived using production or utility theory i.e., cost minimization or utility maximisation. Lumber is used as an intermediate product in residential construction and in the industrial sector.

Specification and grading of lumber in the producing, milling and consuming sectors are similar for Canada and the United States. The lumber from both countries are quite similar in quality and there is no difference between imported and domestically produced lumber to the consumer in the United States. This indifference is made explicit in this study in determining the demand for Canadian lumber in the United States and in utilizing partial equilibrium analysis to measure the impact of protection. Demand and supply elasticities of lumber in both markets and elasticities of substitution among different components in the residential construction industry are determined. The structure of lumber trade and changes in distribution channels between the two countries followed by an analysis of the impact of tariff and quota in two markets are also included.

A. Background

Canada and the United States are currently first and fourth major exporters of softwood lumber respectively in the world. Canada is a net exporter while the United States is a net importer of lumber, the latter consuming nearly one third of world's lumber imports. Increasing lumber requirements coupled with expected supply problems in traditionally competing supply areas of Scandinavia and U.S.S.R indicate that North American producers can be expected to play an important role in the world's softwood lumber supply (Lindell 1979). The United States and Canada both export a small quantity of logs and lumber to offshore markets. The western part of North America is the major source for such markets. Restrictions by the Canadian government on log exports has helped increase United States offshore exports. The United States has, however, also recently restricted the export of logs from its national forests. Softwood lumber production and consumption in the United States has increased from 32.9 and 41.7 billion boardfeet (fbm) respectively in 1979 to 32.8 and 44.2 Bfbm respectively in 1984 (table I.1 & Widman Management Ltd. 1986). Canadian sawmill operators have a production cost advantage over their counterparts in the United States which

Table I.1: **Production and Consumption of Softwood Lumber in United States and Canada, 1970-82**

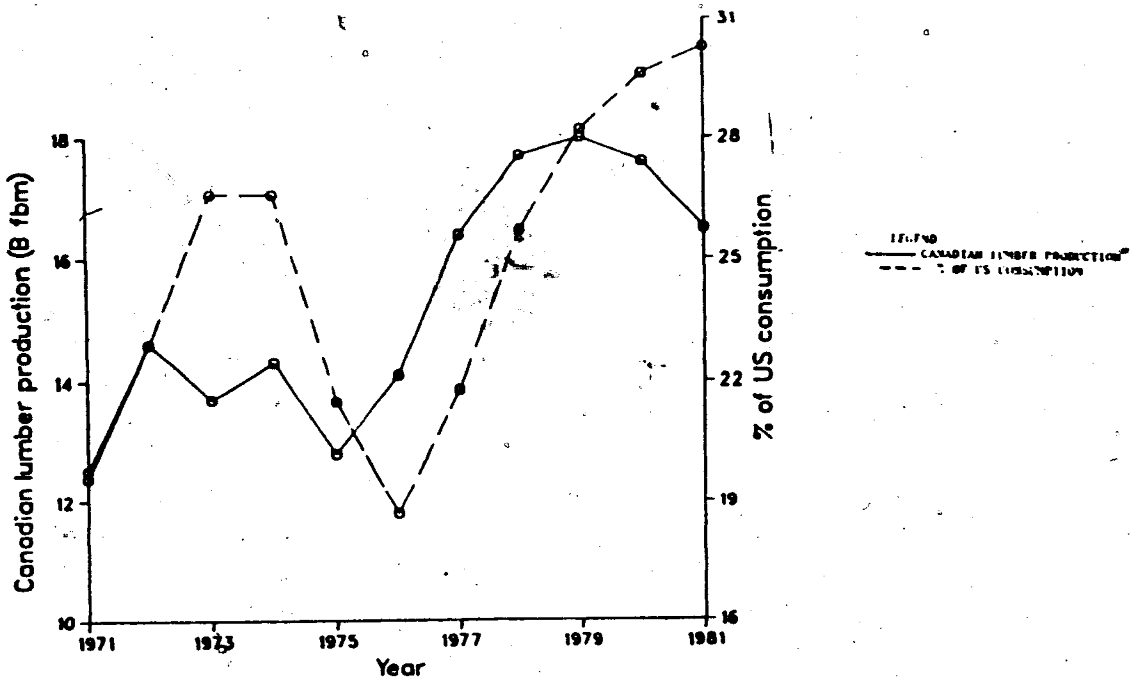
Year	United States				Canada	
	Production	Consumption	Imports	Canadian Share of Consumption	Production	Consumption
	billion fbm			%	billion fbm	
1970	27.5	32.2	5.7	17.7	10.6	3.9
1971	30.0	36.3	7.2	19.8	12.4	4.4
1972	31.0	38.8	8.9	22.9	13.7	4.2
1973	31.6	38.9	8.8	22.6	14.3	4.4
1974	27.7	33.0	6.7	20.3	12.8	4.9
1975	26.7	31.1	5.7	18.3	10.8	4.6
1976	29.9	36.2	7.9	21.8	14.1	4.9
1977	32.9	41.7	10.2	24.5	16.4	5.3
1978	32.3	43.6	11.6	26.6	17.7	5.4
1979	33.5	41.7	10.9	26.1	18.0	5.6
1980	27.3	34.8	9.4	27.0	17.0	6.3
1981	25.8	32.9	9.2	28.0	16.5	5.3
1982	25.2	32.5	9.0	27.7	14.8	4.5

Source: Ulrich (1984) and Widman Management Ltd. (1986).

has resulted in a Canadian lumber consumption share increase in the United states from 24% in 1977 to 30.0% in 1981 (fig. I.1). Lumber quality and favourable foreign exchange rates coupled with lower production costs have provided impetitious to Canadian operators to increase United States market penetration. Lumber producers in the United States are pressing their government to impose tariffs or quotas on Canadian lumber import, claiming that the Canadian federal and provincial governments subsidize lumber producers who in turn are dumping lumber into the United States. Tariff imposition by the United States on lumber imports from Canada will benefit their lumber producers but at a cost to consumers. Lumber producers in Canada will suffer and the net effect will be a worsening of society's welfare as the gainers (United States producers) will not compensate fully the losers (United States consumers). Trade affects each group in both countries. Producers' and consumers' welfare are affected differently by the different trade restriction possibilities. Imports lower prices to the detriment of producers whereas exports raise prices to the detriment of domestic consumers. Government policies respond to the welfare of both groups.

The forest industry is an important part of the Canadian economy in every region of the country and represents a much larger share of its national economy than does the forest industry in the United States. There are nearly 300 communities in Canada that depend exclusively on

Figure I.1: Canadian Lumber Production and Percent Share of Total U.S. Lumber Consumption, 1971-82



SOURCE: BASED ON INFORMATION IN WIDMAN (1986) AND COUNCIL OF FOREST INDUSTRIES (1982)

the forest industry. Direct employment in the industry represent some 260,000 workers (1982) and indirect employment of about one million (Jenson 1983). Canadian export of wood products relative to its total export is five times that of the United States. Softwood lumber accounts for the major proportion of total forest production in Canada. Residential construction accounts for the major share of softwood lumber consumption in both the United States and Canada. Lumber consumption in Canada is highly sensitive to changes in the level of economic activities whereas housing starts is a major variable influencing the demand for lumber in the United States (fig. I.2 & I.3). There is a strong correlation (coefficient of 0.93) between the quantity of lumber demanded and housing starts (USITC 1985). Housing starts account for 23% of lumber consumption in Canada and 33% in the United States (Roberts et al 1985). In part, therefore, the demand for lumber is a derived demand for housing starts. Housing starts in the United States accounted for 50% of total consumption in 1971 and recently this figure has declined to 32% (fig I.4). In Canada during 1971 housing starts accounted for 31.4% of total consumption but declined to 21.7% in 1982 (Widman Management Ltd. 1986). Canadian consumption is much less dependent on the volatile home building industry than consumption in the United States. Non residential and industrial sectors are more stable and account for nearly 50% of total consumption in Canada and 42% in the United

States (Roberts et al 1985). Factors such as population size, mortgage rates and disposable income affect the demand for housing starts and thus lumber demand.

B. Forest Industry in the United States and Canada

The export market is very important to the Canadian lumber industry as it exports nearly 60% of total production of which 70% is shipped to the United States. The domestic Canadian market is particularly valuable during times of recession (Roberts et al 1985). In 1981, the United States imported nearly 9 billion fbm of softwood lumber from Canada which accounted for 30% of United States consumption and 54% of Canadian production (table I.1). The United States exported nearly 1.9 billion fbm of lumber to Canada which accounted for only 8% of total lumber consumption in Canada.

Forest management in Canada is based on sustained yield with a major objective of community stability as opposed to boom and bust conditions. Sustained yield can prevent the abandonment of sawmilling and promote long-run community survival. Intertemporal rationing (sustained yield), which would prevent depletion and thereby assure the continuance of the forest industry community, has been a traditional view of normal forests (Byron 1977).

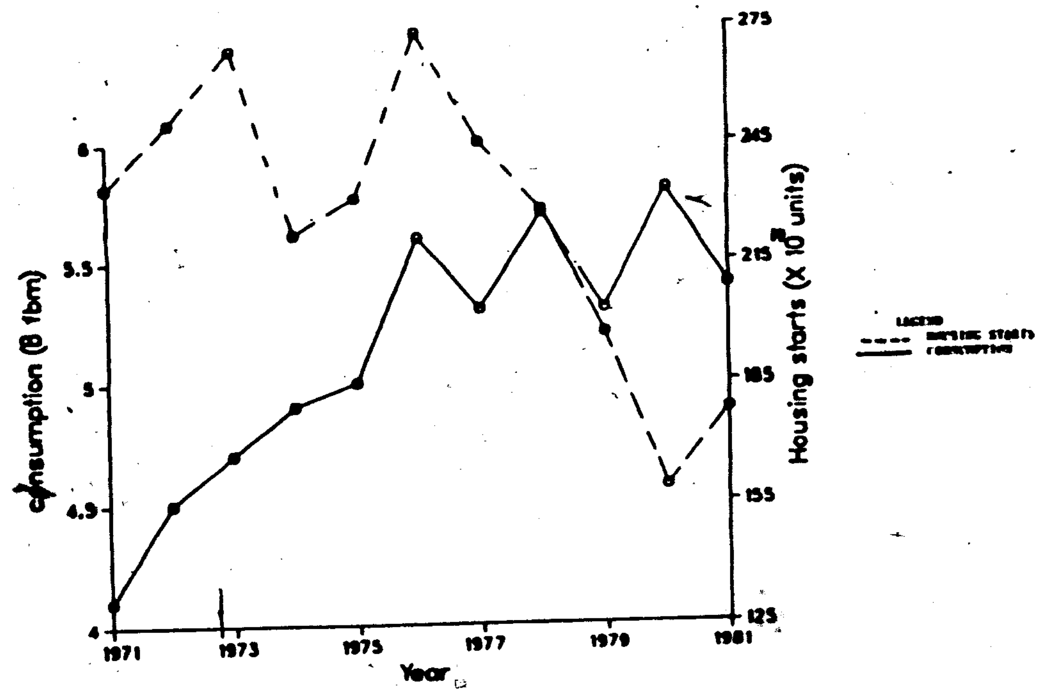
Lumber production in the United States has not kept pace with growing lumber demand. Lumber prices in the United States are sensitive to lumber demand and supply. Lower lumber prices in the Canadian market encourage export to the

United States. Canada exports nearly 60% of its lumber production. Therefore, the lumber market in Canada is indirectly tied to lumber prices in the United States (Jansen 1983). Imports from Canada have filled the gap which has generally moved in the same direction as the level of construction activities in the United States.

Spruce-pine-fir (SPF) constitutes 70% of softwood lumber exports from Canada. During 1960 to 1980 the production of SPF has increased at a faster rate than any other species group. Douglas fir, southern pine and ponderosa pine are leading species produced in the United States. They occupied 67% of total output in United States in 1978 (Buongiorno et al 1979). The main reason for the increased demand for SPF was the high quality and relatively low prices. High prices in the United States encourage imports from surplus areas, mainly from Canada. They provide an incentive for expansion of production capacity in Canada. Rising prices in the United States provide incentive for the development of less accessible forest areas in Canada, but at the same time, provide incentive for intensive management of forests in the United States. Increased demand for lumber in the United States is the reason for the drop in log and lumber exports from the United States. Logs are diverted to domestic use.

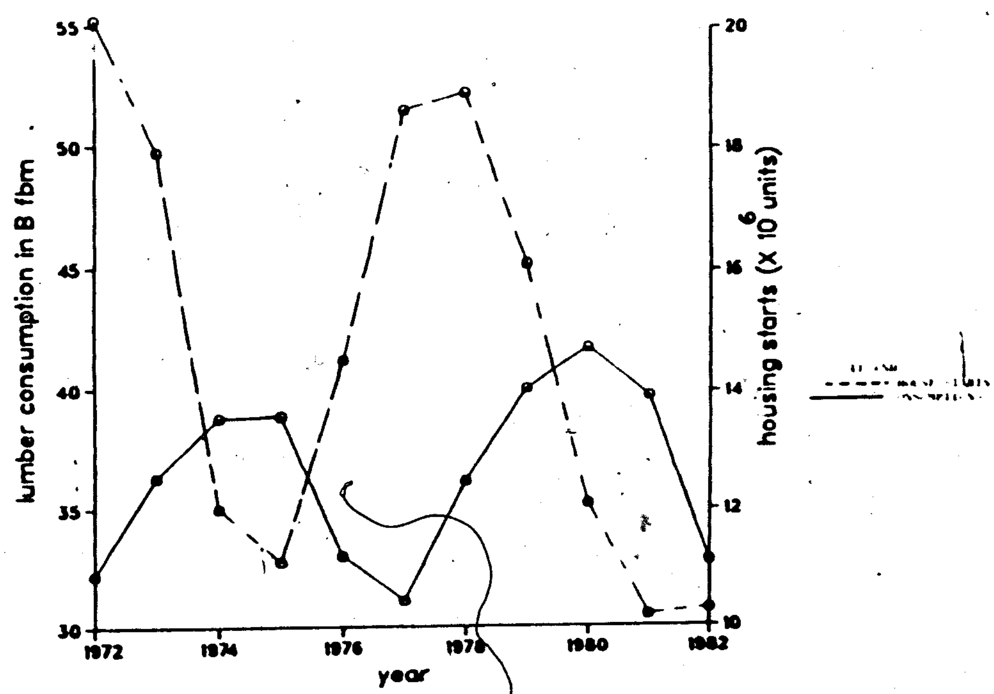
The United States has a productive forest base and efficient sawmills with advanced technology. Still, Canada has maintained the position of a lower cost lumber producer

Figure I.2: Canadian Lumber Consumption and Number of Housing Starts, 1971-81.



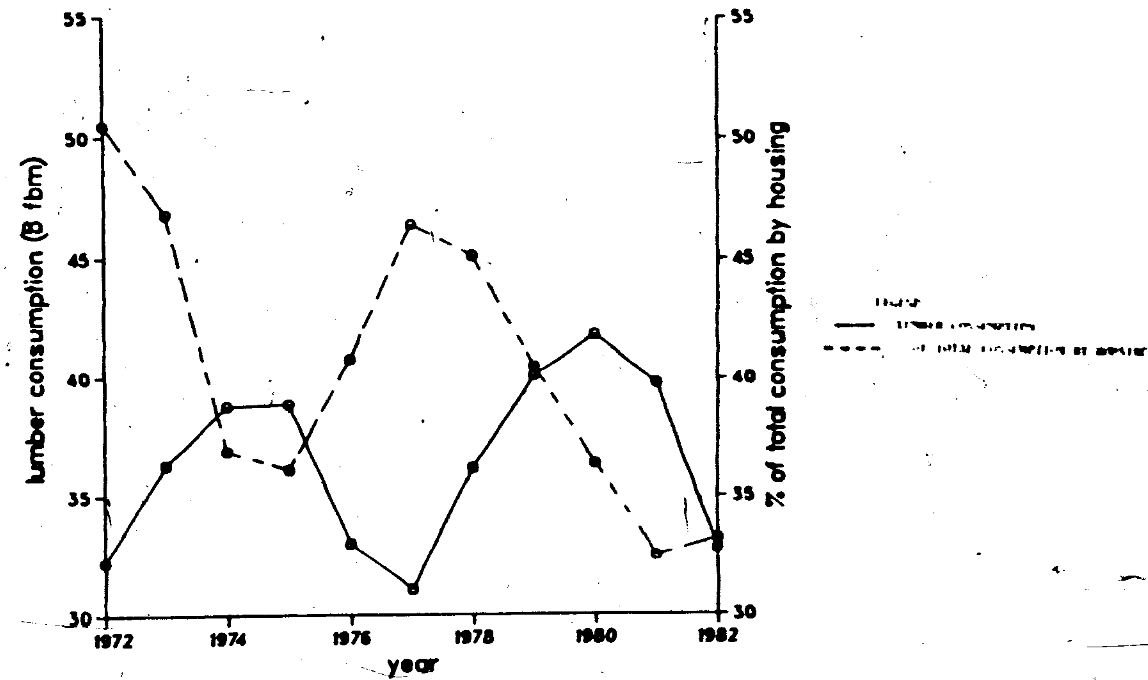
SOURCE: BASED ON INFORMATION IN WIDMAN (1986) AND COUNCIL OF FOREST INDUSTRIES (1982)

Figure I.3: United States Lumber Consumption and Number of Housing Starts, 1972-82.



SOURCE: BASED ON INFORMATION IN COUNCIL OF FOREST INDUSTRIES (1982)

Figure I.4: United States Lumber Consumption and Percent Share Going to Housing, 1972-82.



SOURCE: BASED ON INFORMATION IN WIDMAN (1986) AND COUNCIL OF FOREST INDUSTRIES (1982)

in North America through lower stumpage prices and a devalued Canadian dollar (United States International Trade Commission 1985, Percy 1986, Balter 1985). Significant gains or losses in the share of Canadian lumber in the United States lumber market in the short run is highly dependant on the direction and magnitude of changes in the value of the Canadian dollar in relation to the United States dollar (Balter 1985). British Columbia accounts for the major share of Canadian lumber production and export. Advanced technology and increased productivity has resulted in increased production in eastern Canada in recent years, however. Transportation costs are an important part of delivered price and determine economically accessible markets. Transportation cost and excess supply in eastern Canada have reduced the export from western Canada beyond the north-central region of the United-States in recent years. The western and northern regions are the major and lowest lumber producing areas respectively in the United States. In recent years lumber production has increased in the southern part of the United States due to intensive forest management (Percy 1986). The major consuming and producing regions in North America are given in tables I.2. The United States supply situation is complicated by the variety of timber land ownership arrangements compared to Canada where 90% of land ownership rests with the crown. In the United States, industries own a substantial portion of commercial timber land, whereas in Canada, the lumber

Table I.2: Distribution of Lumber in United States and Canada, 1983

Producing Regions	Consuming Regions: North East	North Central	South East	South	West	Canada
Canada						
- B.C.	18.5	25.6	34.5	14.6	10.3	62.3
- Prairies	0.2	5.3	3.6	1.2	0.4	9.4
- Eastern	43.8	19.9	9.3	1.3	0.2	24.6
United States						
- South	14.9	13.2	43.3	64.6	--	--
- West (Coast)	4.5	4.8	2.1	6.9	42.5	0.7
- West (Inland)	9.2	21.2	6.7	10.0	36.7	2.5
- West (Calif.)	0.4	1.2	0.4	1.3	9.8	--
- North East	8.2	--	--	--	--	0.5
- North Central	--	8.8	--	--	--	--
Other	0.3	--	0.1	0.1	0.1	--
Total	100.0	100.0	100.0	100.0	100.0	100.0

Source: Council of Forest Industries (1985b) pp. 11.

industry uses land on a lease basis. Canadian stumpage prices are fixed by government whereas in the United States they are determined by auction.

C. Lumber Marketing in United States and Canada

United States and Canadian industries follow the same marketing pattern regarding product flow from producers to end users through a series of intermediaries The export of Canadian lumber to the United States is carried out through either wholesalers or broker agents. The agents do not take title to goods but often assume responsibilities for payment of the goods as well as completion of necessary documents. Wholesalers purchase lumber either from brokers or directly from the mills and assume responsibilities for documentation, custom clearance and payment. Mills quote lumber prices generally free on board (f.o.b) mill site. Transportation costs account for nearly 38% of the delivered prices[1] in Chicago and 42% in Atlanta (Council of Forest Industries 1982). Transportation costs are one of the factor responsible for the increase in export of lumber from eastern Canada to the north-east and north-central United States. This factor is also responsible for changes taking place in regional supply and demand patterns in the United States lumber market. In 1984, the north central region accounted for 26.4% of the export from British Columbia against 34% in 1972 (Council of Foresr Industries 1985a).

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[1]Price of 2X4 kiln dry spruce

Except for British Columbia, the majority of lumber produced in North America is consumed in the same or adjacent areas. The lumber industry of British Columbia is located near the raw material and supplies deficient markets in the United States. British Columbia accounts for the major share of lumber export from Canada. In 1984, it accounted for 42% of lumber consumption in the north central United States and 0.1% in the western United States (table I.3).

Extensive road, rail and water transport networks ensure that any mill can service any customer. Trucking is the major mode of lumber shipment by the United States lumber industry, whereas, rail is the major mode used by the Canadian lumber industry. In 1981, 71% of all lumber exported from Canada to the United States went by rail, 16% by water and 13% by road, whereas in 1984, it was 47% by rail, 43% by road and 10% by water carries (Council of Forrst Industries 1985a). The Jones Act prohibits the use of non-United States cargo carriers for intercoast shipments in the United States (Boyd 1983). Freight charges by the United States carriers are generally higher. Canadian shippers on the other hand take advantage of lower freight water carriers for shipment to the United States coast. Waterborne shipment from the United States westcoast to the Atlantic coast are non existant as the United States cargo carriers charge higher rates.

As indicated earlier, Canadian lumber has a quality advantage over United States lumber. SPF (spruce, pine and

Table I.3: Percentage Flow of Softwood Lumber from Canada to United States, 1983

Canadian Producing	United States Markets West	South	South-east	North central	North-east
British Columbia	96.0	82.3	69.8	42.0	28.6
Quebec	0.6	1.8	7.5	3.6	44.3
Maritime	0.1	-	1.0	0.1	5.3
Ontario	1.2	7.6	14.2	41.3	21.2
Prairies	2.1	8.3	7.5	13.0	0.6

Source: Based on Information in Council of Forest Industries, 1985b.

fir) which makes up the major portion of Canadian lumber export is popular with home builders in the United States because of its strength to weight ratio, handling ease and stability (Council of Forest Industries 1982). The competitive position of Canadian lumber is further enhanced by low production costs and lower Canadian dollar to United States dollar. There is a price that will clear current output and surplus inventories. That price must be equal to or less than the market clearing price. The market clearing price is established by forces of competition at a quantity that will meet the demand of all buyers to whom the value of the wood products is equal to or greater than the price. The demand for lumber is complicated by the role of prices and both price and quantity are interdependent on the supply side. In 1984, even though the demand for lumber was rising, prices still declined due to increased supply quantities. The extent of lumber substitutes depends on the trends in relative prices of lumber and other materials. There are technological changes taking place and the demand elasticity for lumber during the 1980's has declined (Manning 1975, Pearce 1980).

D. Lumber Trade between the United States and Canada

The United States forest service has forecasted that demand in the United States is rising faster than the supply and the deficit is greatest in softwood lumber (AO 1981). This deficit has resulted in an increasing share of the United States market for Canadian lumber. The recessionary situation in 1982 sparked United States industry concern. In 1982, the United States softwood lumber producers petitioned the International Trade Commission (ITC) to levy counterveiling duty against softwood lumber imports from Canada claiming that the stumpage pricing policies of the Canadian federal and provincial governments subsidize Canadian lumber and thus undermine the competitive position of United States suppliers. The International Trade Administration (ITA) in 1983 found that the total net subsidies for each Canadian product was less than the required threshhold of 0.5 of the value of production and were considered not to constitute counterveiling subsidy under the law (Jenson 1983).

Presently the United States-Canadian lumber trade is unencumbered by tariff or quota. The future of lumber trade from Canada is under threat from the United States lumber industry as it is again pressing to redefine the alleged subsidies by the Canadian governments. This restriction, if implimented, will affect the present competitive position of Canadian producers. The United States lumber producers will increase production and will profit from an increased equilibrium price in the event of protection measures. Adams et al (1980) have estimated that demand for Canadian lumber will increase to 13.7 Bfbm by the year 2000 but that a 15% ad-valorem tariff will result in a decline to 8.1 Bfbm. This trade barrier will cause prices to rise by 9% in the United States market and to fall by 4% in the Canadian market. Boyd et al (1984) estimated that the tariff of $1/Mfbm will result in a net welfare cost of 8.6-11.0 million dollars annually in the United States alone, depending on the supply elasticity. Even a 5-10% tariff will result in widespread mill closures in Canada. It has been estimated that a tariff would result in a 15% increase in the United States lumber price resulting in a gain of 4,669 jobs in Oregon, Georgia, Albama and Mississippi whereas 46 other states would lose jobs (Blackman 1986a). The National Association of Home Builders in the United States has estimated that, if there is no Canadian retaliation, a tariff will add $2,500 to the price of a single family house (Blackman 1986a).

The export of Canadian lumber to off-shore markets (Japan and the European Economic Community) has increased from 9% and 7% of total export (10.5 Bfbm) respectively in 1976 to 10% and 12% of total export (15.75 Bfbm) respectively in 1984 (Widman Management Ltd. 1986).

E. Purpose and objectives

The purpose of this study is to present a systematic theoretical analysis of demand and supply associated with lumber trade flows and to relate the findings to the observed behaviour of lumber industries in the United States and Canada. The main objectives of this study are:

1. to identify the institutional structure in trade between Canada and the United States;
2. to estimate the demand for softwood lumber in the United States and Canadian residential construction industries;
3. to determine elasticities of substitution between lumber, plywood and other components of residential construction;
4. to estimate the demand for Canadian lumber in the United States residential construction industry;
5. to develop supply models for the United States and Canadian lumber industries; and
6. to estimate the impact of tariff and quota impositions by the United States government on lumber imports from Canada.

Meeting these objectives involves the determination of derived demand and supply relations for lumber which, in turn, will assist in the determination of the ease with which various components of residential construction and sawmilling activities can be substituted for one another. Identification of the institutional structure of trade will assist in filling the deficit of knowledge about producer, consumer and distributor behaviour. The understanding of the institutional market structure discussed in this study will assist in determining technological advance, lumber pricing and future production of producers. The analysis of trade in this study will provide background information useful in framing Canadian government policy should a tariff or quota be imposed by the United States government.

F. Method of analysis

The procedure adopted to achieve the objectives involves examination of the developments in the production and consumption of softwood lumber in the United States Relevant theoretical concepts are studied to determine appropriate models that fit into the concept of intermediate products. In derived demand theory, the demand for an intermediate good is derived from the demand for the final product. The method of analysis adopted in this study is grounded in neoclassical theory of production. Since the difference between demand and supply quantities of lumber in the United States is met from Canadian lumber imports, demand and supply models for lumber in the United States market are required to estimate import demand. The development of duality theory allows the specification of production technology either by a production or a cost function. Flexible forms permit tests of hypotheses that relate to different aspects of the production process and which are not possible with other functional forms. Econometric techniques required to estimate and test the functional form are also discussed. The model also helps in determining own-price and substitution elasticities. The supply of lumber is a function of stumpage price, sawmill productivity, wage rates, fuel energy costs and lumber prices. Loglinear and linear models are developed to estimate supply elasticities. Partial equilibrium analysis involves the use of demand and supply elasticities to estimate supply and demand schedules for the two markets and then to develop excess supply and excess demand relations.

Firms may produce physically identical commodities but complete homogenity pricewise is not likely to occur because of differences in location. This location difference is reflected in a price difference between similar products. Although there are transportation costs involved, only a non-spatial partial equilibrium analysis undertaken. A tariff or quota imposition results in price increases in the United States depending on excess demand and supply elasticities. Shifts in excess supply schedules affect producers' and consumers' welfare. Determination of welfare effects can be useful in making policy recommendations.

G. Study outline

This study continues with chapter 2 which identifies and describes the institutional structure of trade between the United States and Canada. This chapter also describes the different segments of trade i.e., production, consumption and distribution sectors. It includes a discussion of recent trends in these sectors. Chapter 3 contains a review of relevant theoretical concepts and provides analytical foundations for analysis. The transcedental logrithmic cost function and its utility relative to other demand model are discussed. A supply model for the lumber industry in both countries is discussed and compared to other models. Partial equilibrium analysis, both spatial and nonspatial, in a two country case is discussed along with repercussions from foreign exchange rates. The impact of a tariff and quota on trade equilibrium is discussed along with changes in consumers' and producers' surplus. Chapter 4 deals with the econometric issues involved in estimating a translog function and testing for homotheticity and technical change. Econometric issues involved in estimating supply models along with the statistical tests for technical change are discussed. Chapter 4 also deals with data collection and the data set employed in this study. This chapter also concludes with an outline of the procedures for data transformation required for analysis. Chapter 5 contains discussion of the results of empirical estimation of demand and supply parameters for the period of study. This chapter also contains the results of partial equilibrium analysis with and without tariff or quota imposition. Chapter 6 contains a summary and conclusions along with policy implications.

II. Institutional Structure of Lumber Trade

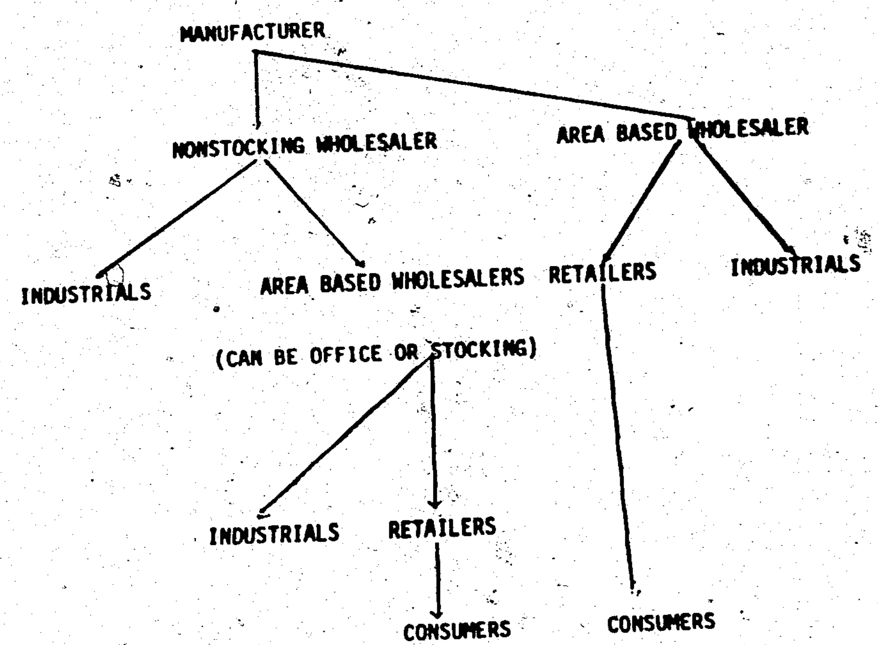
A. Introduction

Knowledge of different channels of lumber trade flow is necessary before attempting to understand the demand for Canadian lumber in the United States. Information about the institutional structure of lumber trade is important for the determination of import demand for Canadian lumber. Any structural change in the distribution pattern will affect demand. Analysis of trade statistics provides insight into production sector factors that affect production decisions, the particular need that products satisfy, the final destination of products, the channels through which they flow from producers to end users, and the competitive edge of imported products over domestic products. The distribution sector provides information about changes taking place in product demand. Firms oriented towards domestic consumption, rather than export, still need information about potential competition from imports and about feasibility of expansion and plant locations.

The lumber industry's performance, like that for the performance of other industries, is a function of its market position, internal efficiency and external conditions. Market structure is the knowledge of market share, concentration and barriers to new entrants. It is not static, but undergoes changes over time. Marketing is a human activity directed at satisfying needs and wants through an exchange process. It guides the producers through production and distribution of goods to the satisfaction of consumers and, if successful, does so at a reasonable profit. The exchange process is the performance of business activity directing the flow of goods and services from producers to consumers. Lumber is marketed in a same manner in the United States and Canada. Consuming, producing and distributing sectors try to maximise profits in an undistorted competitive economy which results in maximum net social benefits. In a perfectly competitive market, the number of firms engaged in the production of a homogeneous product is sufficiently large that no individual firm can, by its own action, alter the price of output. An industry exporting a homogeneous product to the foreign market cannot protect its share of the market through pricing policy, but can match the sales volume of the competitors by increasing or decreasing shipments. There are differences in specie mix between lumber produced in the United States and lumber imported from Canada. The quality differs also. However, the lumber from both countries is used for the same purpose, thus the two product groups can be considered as one analytical variable.

The United States and Canada have similar production and consumption specifications and there is no restriction on lumber movements across the border. Therefore, the long border between the United States and Canada provides a easily accessible market for the lumber industries in both countries. The United States is a fourth largest lumber producer in the world but is also a large consumer thus making it a net importer of lumber as indicated in the previous chapter. Canada's lumber industry produces an excess supply of softwood lumber and has a low cost advantage over its counterpart in the United States. It thus fills the gap between demand and supply in the United States market. Canada has accounted for the major share of increases in consumption in recent years (fig. I.1 & table I.1). Increased demand and techonological changes have resulted in increased production in both countries (table I.1). Demand increased, but in 1984 supply increases affected the equilibrium price in 1984 resulting in a price decline. An analysis of the structure of trade provides information about price, lumber demand and supply. Information on the institutional structure is given in this chapter. The role played by the producers is to provide product while distributors take it to end users for consumption (fig. II.1). The industry first satisfies the domestic demand and then export demand. Since lumber can be shipped freely across the border, the supply gives higher profits than under trade restrictions. In the complex United States-Canada lumber market some 4000 mills, 900 wholesale firms, 6000 traders, 2000 retail outlets and a large number of industrial users are involved in production, marketing and distribution of 3000-4000 rail car loads of lumber every day (Council of Forest Industries 1982).

Figure II.1: Role of Wholesalers in Supply and Demand Among Different Retailers



SOURCE: BASED ON INFORMATION IN COUNCIL OF FOREST INDUSTRIES (1982)

B. Production Sector

Lumber production in Canada and the United States has increased from 7.6 Bfbm and 26.7 Bfbm respectively in 1960 to 18.2 Bfbm and 30.4 Bfbm respectively in 1980. The oil crisis in 1973-74 gave rise to an inflationary effect on lumber prices and, at the same time, depressed residential construction and industrial lumber use. This inflation as well as the recession also affected the cost of production and supply.

Canada has the largest forest acreage in the world but has a lower annual growth than that in the United States. The forest base in Canada consists largely of mature stands and supports an annual economically accessible allowable cut of softwood lumber of 19 Bfbm and a physically allowable cut of 21 Bfbm (Reed 1978). The largest producing region in Canada is interior British Columbia followed by coastal British Columbia and Quebec. In recent years, the share of eastern provinces in Canadian lumber production has increased from 30% in 1975 to 39% in 1983. Spruce, pine and fir accounted for the major increase in production of lumber in Canada and also the major increase in total lumber export (Council of Forest Industries 1982). Lumber production in British Columbia depends on high quality mature stands which , when depleted, will result in lower quality second growth timber. The Canadian lumber industry tends to be a marginal supplier in producing regions of the United States. The Western region of the United States accounts for over 60% of lumber production in the United States. Since 1977, total lumber production in the southern United States has increased. In 1981, the overall United States production level was very low in which the western region accounted for 60% and the southern region accounted for 28% of total lumber production.

The structure of an industry is described by the number and size of firms, competitiveness, product differentiation, barriers to entry and growth rates in market demand. Canadian and United States lumber industries are similar in structure but the Canadian industry is slightly more concentrated and has a larger percentage of larger mills than the United States industry. Nevertheless, the lumber industry in Canada is perfectly competitive and can be classified as unconcentrated (Nautiyal et al 1985a). Production in the Canadian lumber industry has increased in recent years due to improved technology (table I.1) with the major share of the increase coming from eastern Canada. In Canada the Crown holds 90% of forest lands. The lumber industry acquires forest stands from provincial governments on lease and are responsible for regeneration and other silvicultural activities in some provinces. In the United States forest industries held 70 million acres of commercial land and accounted for 4.2 B cubic feet of that nation's timber harvest in 1976.

The lumber price in any region is dependent on its demand and supply in the market. The difference between the price received and cost of production influences producers' decisions and their supply curves. Declining prices could prevent producers from operating profitably within an existing cost structure. Higher prices and demand coupled with more profit due to lower costs of production are responsible for the increase in export from Canada to the United States. In the future, if prices decline and the Canadian industry moves to second growth stands, the cost structure will constrain the availability of lumber. The production process in forestry, as a whole, comprises timber growing, logging operations and industrial wood production. The cost of production depends on input [illegible]or quality, ratio of factors and factor prices. Firms with technical equipment suited to production, suitable raw materials and efficient labor productivity have favourable cost structures. Changes in quality of raw material and factor prices will directly affect cost levels. Factor demands in the Canadian lumber industry are interrelated i.e., disequilibrium in input demand creates compensating adjustment in the demand for other inputs (Singh et al 1986b). Shifts from mature to second growth stands will increase the cost of production and will reduce competitive advantage. Cost of production has two components, fixed and variable costs. The short-run cost is characterised by the presence of fixed factors while in the long run all factors vary. Fixed costs are the amounts spent on errection of the plants and variable costs are composed of wood and nonwood items. Fixed costs are the same in both countries, but wood costs are lower in Canada. The industry has to incur fixed costs even when not in production. Therefore, it will continue production until its revenue can cover all variable costs and at least part of the fixed costs. The supply curve of an industry is an aggregate of individual firms' marginal cost curves. In the long run the firms are able to adjust their scale of operation. The United States lumber industry has a higher total cost because of higher wood costs and higher residual values (United States International Trade Commission 1985).

Wood Costs

Wood costs are a major proportion of the cost of production, 60% in Canada and 75% in the United States (Balter 1985). Delivered log prices or wood costs are a combination of stumpage, harvesting, hauling, road building and other related expenditures. Wood costs have increased at a faster rate in the United States than in Canada due to increases in stumpage. Between 1977 and 1984 wood costs rose from $119 to $156 (U.S) in the United States and $104 to $128 (U.S) in Canada (Balter 1985). Stumpage price is the selling price minus harvesting cost, other related expenditures and allowance for profit and risk. In Canada stumpage prices are determined institutionally and industries get stands on lease. The licensees are responsible for road construction, environment protection and other technical activities and get full allowance in stumpage appraisal in British Columbia and 50% in Quebec (Industrial Forest Service LTD. 1982). In British Columbia, Quebec and Ontario there is a provision for stumpage readjustment based on market conditions. In Alberta, Ontario and Quebec, a base rate and base indices[3] are established for stumpage pricing. The industries in the United States get standing timber land by successfully bidding in open auction. In British Columbia and Quebec stumpage cost is linked to the current market values of end products. Current market values are based on three-months selling prices.

In the United States, standing timber is auctioned to highest bidder (United States International Trade Commission 1985, Industrial Forest Service LTD. 1982). The appraised price in the United States is fixed by the terms of sales, usually 3 years. This technique leads to speculation in a rising market and distress in a depressed market. The stumpage price is highest in the coastal region and lowest in the southern pine producing regions of the United States. Between 1980 and 1984 the stumpage in the coastal region of the United States has declined from $121/Mfbm to $63/Mfbm (U.S.) (Balter 1985).

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[3] Further information on the stumpage price rates is given in Industrial Forest Service LTD. (1982).

Non-wood Costs

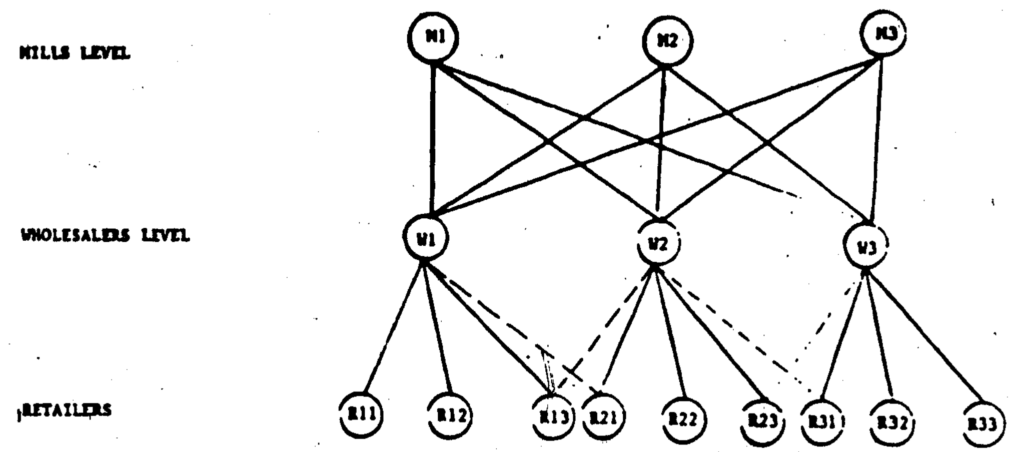
Non-wood costs include costs for labor, fuel energy and other items such as packaging etc. Wages account for nearly 30% and 27% of the total variable cost in the United States and Canada respectively and 3% and 5% for energy (United States International Trade Commission 1985). Since 1978 the output/hour in the forest industries has increased. The increase in the Canadian industry is higher than the increase in United States forest industries (Blackman 1986a). Non-wood costs in the United States rose from $39/Mfbm (U.S.) in 1980 to $49/Mfbm (U.S.) in 1984, whereas during same period, it rose from $29 to $ 36/Mfbm (U.S.) in Canada (United States International Trade Commission 1985). The efficiency of workers in both the United States and Canada has increased. The United States industry worked 300 hours more per year than its Canadian counterpart, yet the production in Canada was 100 bft. per hour higher, partly due to a larger proportion of small sawmills in the United States.

C. Distribution Sector

The distribution sector is an important component of the institutional structure and influences the demand and supply of lumber. This sector provides information to industry about consumers' needs and to producers who then set output targets. The time involved in communicating information to the production sector indicates the efficiency of the distribution sector. The distribution sector is dynamic and reacts to changes in the market. The distribution sector is perfectly competitive as there are a large number of distributors and consumers. Price is set by the market and is readily known to consumers and distributors.

The transfer of lumber from producers to end users works through wholesalers or brokers and commission agents and retailers (fig. II.2). Wholesalers receive lumber from mills and distribute it to retailers. Each constituent plays a role in the efficient flow of lumber to consumers. Each constituent of the distributional channel tries to maximise profits. Wholesaling firms may take possession of the goods from the producers or sell directly to retailers (fig. II.3). They maintain daily telephone contact with mills and retailers or other lumber purchasers. These traders keep up to date records of the stock available with the mills and stock price along with prices which retailers are willing to pay. Wholesalers have their offices located in central places. Merchant wholesalers are independant firms that purchase lumber from mills and take possession of title to the goods, but may, or may not, carry stocks. The brokers may not take possession of title to the goods, but may work on a certain commission of the amount of sale. Independent wholesalers and retailers are strong distributors, but captive (sawmill's own) operators play a significant role at the wholesale level. Their role is growing at the retail

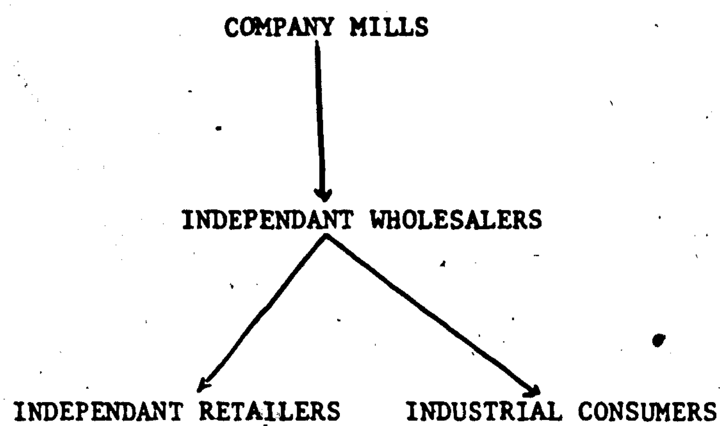
Figure II.2: Distribution Channels for Lumber Trade



SOURCE: BASED ON RICH (1970)

Figure II.3: Structure Changes in Distribution

(a)



(b)

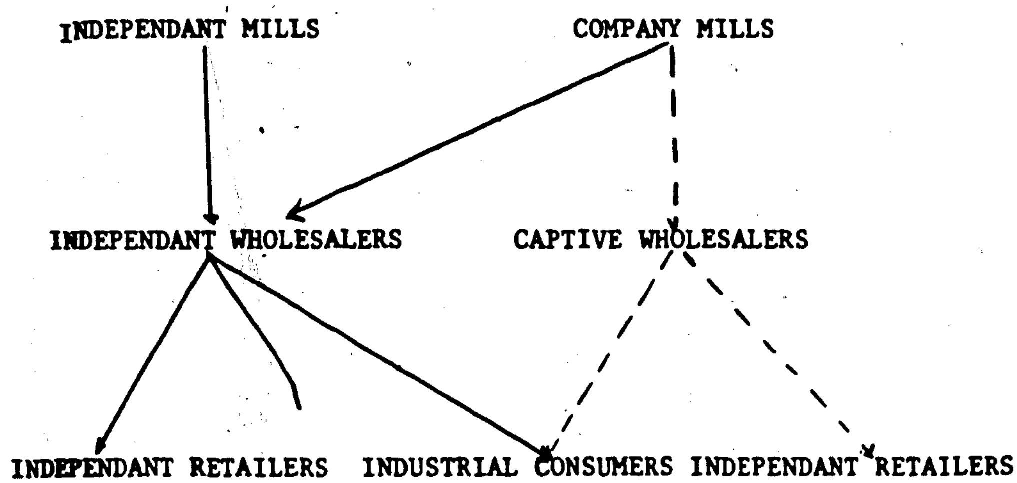
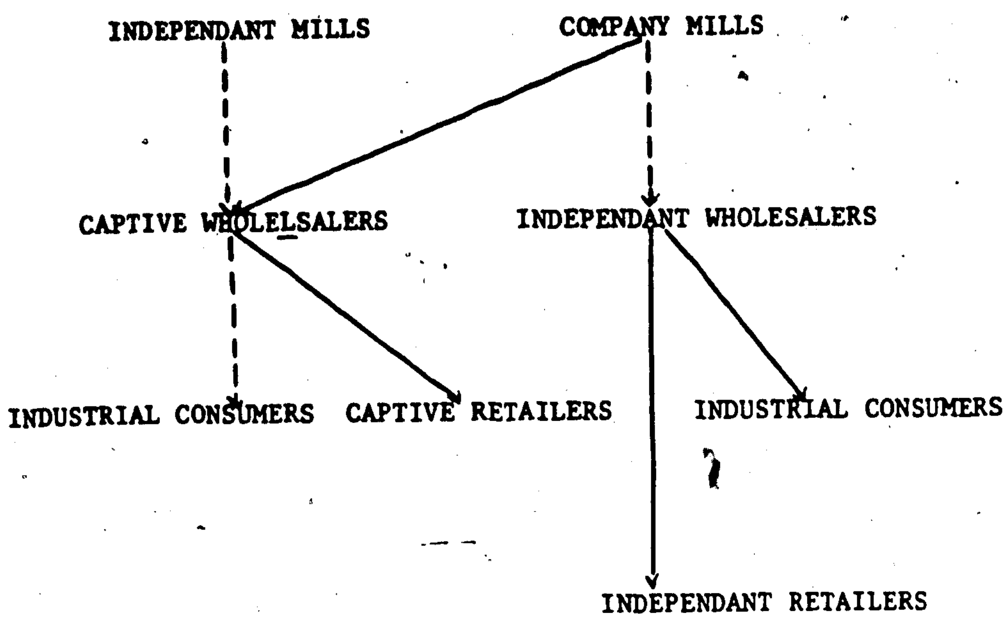


Figure II.3: (Continued)......

(c)



SOURCE: BARNES ET AL (1985)

level.

Vertical integeration, a management tool which leads to strategic financial benefits, often achieves large technical economies and or pecuniary rewards from squeezing non integrated competitors. Vertical integration, forwards or backwards, is practised to increase profits and sales. Lately, forward integration towards end users is gaining importance. It has resulted in certain mills taking up the roles of wholesalers by opening sales and distribution centres located in different central places in the United States markets (fig. II.3).

The mills sell lumber on a car load basis with the price of each railcar negotiated. Mills sometimes circulate their prices to wholesalers and wholesalers to retailers. The retailers are responsible for delivering the goods to the consumers. They maintain inventories and sell at near wholesale price to large volume builders and contractors. Wholesalers bargain with producers for the price of the product while, at the same time, they negotiate with retailers for a competitive price. They also provide necessary information about the needs and wants of consumers to the producers. Brokers and agents find markets for Canadian products landed in the United States. Softwood lumber usually ends up in the north central region where agents locate markets in other regions, mainly the south eastern region. Wholesalers sometimes maintain a hugh stockyard to acquire more bargaining power with producers.

Trends in Structural Change in Distribution

The distribution sector is dynamic and is adjusting to changes in demand and product price. Trends affecting the distribution of lumber are:

1. Increased importance of repositioning of inventory carrying function;
2. Growth of home centres and mass merchandisers;
3. Rising timber costs;
4. Increased transportation costs; and
5. Vertical integration.

Significant changes in the distribution sector are characterized by channel bypassing and vertical integration. This leads to speedy flow of goodsat less cost. Independant wholesalers are the dominant factor, but in recent years in United States market, their share has declined. The share of independant wholesalers declined from 71% in 1963 to 65% in 1980 of total sales (Rich 1981). In United States, during same period, manufacturers' branches of captive distribution have risen from 29% to 35% (Rich 1981). Rich (1984) reported that 15 of the top lumber producers in the United States had captive distribution centre in the United States. Mills can sell their product through captive (mill's own) or independant wholesalers. The captive wholesalers can acquire product from any mill selling at prices lower than that at their own mill (fig. II.3 b). Barnes et al (1985) observed that changes are taking place in distribution channels. They observed that some mills had opened their own retail outlets. Captive wholesalers could sell to their own captive retail outlets or independant retailers.

High-cost working capital has pushed retailers to take up wholesalers' roles. Retailers now prefer to buy in small quantities with less of a time gap between transactions. More and more sawmills have opened distribution centres or formed associations by pooling their resources to reduce overhead costs. Inflation and high costs of working capital have broadened the lines of sales by those who have acquired full fledged distribution yards. Retailers now prefer to buy from stocking yard and at closure of time of sale. Wholesalers without stock and distribution yards have decreased. Smaller mills have decreased as they cannot make use of deregulated rail rates. Large wholesalers continue to profit but smaller wholesalers have become selective. The small office wholesalers have formed an alliance and focus efforts on a defined market. They maintain limited management and pursue particular market opportunities that develop e.g., toy and other industries, but shift to other markets when faced with competition from big wholesalers (Rich 1981).

Pricing

Firms reduce price variability to consumers by setting prices in terms of the currency of the importing country. The industry can absorb the price effects of day to day fluctuations in the exchange rate and can thus adjust the final selling price when such movements reveal a definite and permanent trend. Consumers decide which producers to approach on the basis of delivered price irrespective of origin of the supplier. Price is determined in the market place by meeting the pressure of supply and demand. At equilibrium prices, quantities supplied are equal to the quantities demanded. This price results from negotiations among many sellers and buyers in a competitive market. Lumber mills set up their prices based on either a target or penetration pricing strategy. The prices reflect the costs of production and profit margins. Profit margins are guided by the prices reported in market letters' such as Crow's, Madison's and Random Length[3]. Market prices affect sellers prices and in turn inventory build up. The mills quote either f.o.b mills or destination prices. Buyers prefer prices f.o.b destination as it allows for quick comparisons.

Quoted prices are not fixed but change frequently with market condition. Salespersons maintain telephone contact with retailers. Almost all transactions are negotiated by phone. Quoted prices are affected by the mills' orderfiles and stocklists. The mills may cut their prices to stimulate orders but raise their prices if the order file are getting larger. If one mill lowers its price during a market weakness, other mills follow suit, thus leading to a further lowering of prices and profit margins. Mills often mail

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[3]Crow's publication Inc., Portland, Oregon; Random length publication, Eugene, Oregon; Madison's Canadian Lumber reporter, Vancouver, B.C.

their price lists featuring prices on stock at the mill sites or in rail transit in which rail road car act as warehouses while lumber awaits sale to wholesalers (Rich 1970). Wholesalers also mail out their own price lists to retailers. Geographical supply patterns influence price and mills sometimes lower their prices and sacrifice profits in order to penetrate the United States market and increase sale volumes. Consumers assess delivered prices and select the suppliers. Because of the auction-like nature of the market, it generally follows that the delivered price for a given product in a given location, whether in the United States or Canada, will be approximately the same regardless of source the of supply (Council of Forest Industries 1982).

Transportation Costs

Transportation costs are very critical and determine economically accessible markets. Transportation costs play an important role in the location of an industry, resource development and product distribution. They determine the pattern of trade. Major trade patterns of lumber exports from Canada to the United States in 1983 are shown in table II.1.

Firms either concentrate near the markets or input sites. The lumber industries in British Columbia and the western United States are concentrated near the input sites while the industry in eastern Canada is near major United States markets as well as input sites. Transportation costs of lumber from mills to markets are an important portion of delivered lumber prices. They account for 38% and 42% of the delivered prices of lumber from British Columbia to Chicago and Dallas respectively (Council of Forest Industries 1982). Lumber from British Columbia was competitive with lumber from the southern United States (Fort Worth, Texas) in 1980 but, when transportation costs increased in 1984, even with its lower production cost, British Columbia lumber was slightly costlier (Balter 1985). The share of eastern Canadian lumber mills in the northern United States markets has increased due to their proximity to the United States markets. Networks of roads, rail and water carriers permit efficient shipment from mill sites to market.

Each mode of transportation has different fixed and variable costs. Rail accounts for the major share of lumber shipments from Canada to the United States. During 1977-1984 the share of transportation of lumber from Canada to the United States by road has increased (table II.1). Trucking has the lowest fixed costs but highest variable costs whereas water carriers have the highest fixed costs and lowest variable costs. For shorter distances trucking is the cheapest mode of transportation. Rail is cheaper if the distance is more than 300 miles. Lumber is transported in rail cars to centrally located transfer yards for further distribution by truck. In certain cases lumber is transported to a changeover point by rail and then transported by truck. Loading and reloading are important

Table II.1: Modes of Transport by Percentage of Softwood Lumber Exports from Canada to U.S. Between 1977 and 1984

	Year							
Modes	1977	1978	1979	1980	1981	1982	1983	1984
Road	18.8	22.6	25.1	30.0	41.3	43.1	38.6	43.1
Rail	67.8	65.1	63.6	61.3	49.9	47.6	52.0	46.8
Water	13.5	12.3	11.3	8.6	8.8	8.2	9.5	10.1

Source: Council of Forest Industries, 1985a.

factors in deciding modes of transportation. Mills use piggybacks to avoid reloading costs. Lumber is loaded into trailers and trucked to railheads for further piggyback movement. Firms always try to minimise transportation costs by using a combination of different modes. The lumber industry in British Columbia, for example transports lumber first by rail to a reloading point in Ontario and then by truck to different markets.

Trucking

Trucking is the quickest and cheapest mode of transport up to certain distances. Its rate structure varies with distance with different rates for forward and backhaul. Trucks otherwise returning empty to their home charge cheaper rates and mills sometimes try to make use of this opportunity. The Pacific northwest industry in the United States makes use of this opportunity to compete in the northern United States markets.

Lumber from eastern Canada is exported mainly by road. Since the Pacific north-western lumber industry is near the western United States market, lumber is transported by road. British Columbia lumber is therefore at a disadvantage in western United States markets.

In Canada intra and inter provincial trucking is the responsibilty of individual provinces. In the United States, the Inter-state Commerce Commission regulates interstate trucking while individual states negotiate rates for in-state transport. Neither the United States nor Canadian lumber industries has an advantage in trucking except the advantage of proximity to market.

Rail

Rail transportation accounts for the major share of export shipments from Canada. Canadian railways have lower freight rates than their counterparts in the United States and mills can enter into contracts with the rail companies provided they commit to a certain traffic percentage. The Stagger Rail Act (1980) in the United States has given more freedom to the United States lumber industry such as single line movements and thus lower rates. The act has resulted in increased competition among the carriers, hidden and frequently changing rates and quicker responses to competitors' activities.

Canadian domestic rail rates were deregulated with the passage of the National Transportation Act (1967). Unlike United States law, Canadian law requires rates to be published and prohibits rebates. The United States lumber industry can get rebates from rail companies in the United States. This has affected the competitive position of Canadian suppliers.

Since rail rates are lower in Canada, the western Canadian lumber industry transports lumber using Canadian rail to certain points in eastern Canada and then by truck to the United States markets. Rail-truck combinations have given an advantage to British Columbia producers over western United States producersin northern United States markets.

Water carriers

Waterborne shipments are important for United States destinations at long distances for both British Columbia and the western United States lumber industries. Waterborne shipments from the west coast of the United States has declined from 849 M fbm in 1960 to 4 M fbm in 1979 (United States International Trade Commission 1985). This decline is partly due to the Merchant Marines Act (Jone's Act) which requires the use of United States carriers only or United States-owned water carriers for inter coastal shipment in the United States. Generally the freight rates by these carriers are higher resulting in an addition of $15-18 per

Mfbm to the cost of shipping (Austin et al 1975).

Canadian shippers are flexibile and industry therefore pays competitive world rates. The shipping charges account for 29% of the delivered price in Baltimore for shipments from Oregon. The proportion by rail is 38% (United States International Trade Commission 1985). The British Columbia lumber industry could penetrate the markets of California and the Atlantic coast because of lower rates. Recently, waterborne shipments of American lumber standards Hemlock dimension have declined from 1.8 B fbm in 1972 to 0.8 B fbm in 1980 (Council of Forest Industry 1982). Canadian mills using lower freight rate vessels can penetrate the southern United States market. Waterborne shipments of lumber from the United States west coast are non existent, except in rare cases when lumber is first shipped into Canada and then to the east coast.

D. Consuming Sector

The United States is the major consuming sector for Canadian lumber accounting for nearly 60% of total Canadian production. The domestic Canadian market is the second largest consuming sector available to Canadian lumber. Residential construction accounted for 58% of lumber consumption in the United States and 48% in Canada in 1983. The rest was accounted for by the industrial sectors (Roberts et al 1985).

A larger share of consumption by the industrial sector implies that Canadian consumption of lumber is sensitive to the changes in the general level of the Canadian economy (Roberts et al 1985). The gap between domestic demand and supply in the United States is met by imports from Canada. The markets in the United States are divided into the northeast, north central, south , southeast and western (table II.2). Table I.2 shows that all of the regions in the United States, except the western region, imported lumber from Canada. The northern region is the most lumber deficient region of the United States and accounts for the major share of Canadian exports. The market demand for lumber depends on the amount of activities in the manufacturing and consuming industries. Studies have indicated a downward trend in per capita lumber consumption in the United States (Phelps et al 1984).

The use of a product changes over time due to new product development or substitution. In the long run, changes in use influence demand as much as economic activities (Roberts et al 1985). The percentage of lumber consumption in United States residential construction has declined from 55% in 1972 to 33% in 1982 (fig. I.4). Housing sector consumption is affected by mortgage rates in the short run and by factors like demographics, changing homestyle, per-capita disposal income and relative lumber and substitute prices in the long run. Studies have indicated a correlation value of 0.93 for residential

Table II.2: United States Lumber Markets

Regions	States		Representative Destination Points
Northeast	Connecticut	New York	Augusta, Maine
	Delaware	North Carolina	Concord, New Hampshire
	Dist. of Columbia	Ohio	Syracuse, New York
	Maine	Pennsylvania	Scranton, Pennsylvania
	Maryland	Rhode Island	Detroit, Michigan
	Massachusetts	Vermont	Louisville, Kentucky
	Michigan	West Virginia	Baltimore, Maryland
	New Hampshire		
	New Jersey		
Southeast	Alabama	Mississippi	Birmingham, Alabama
	Florida	South Carolina	Tampa, Florida
	Georgia	Tennessee	Columbia, South Carolina
	Kentucky		Nashville, Tennessee
North Central	Illinois	Missouri	Chicago, Illinois
	Indiana	Nebraska	Topeka, Kansas
	Iowa	North Dakota	Omaha, Nebraska
	Kansas	South Dakota	Greenbay, Wisconsin
	Minnesota	Wisconsin	
Southwest	Arkansas		Tulsa, Oklahoma
	Louisiana		Dallas, Texas
	Oklahoma		
	Texas		

Table II.2: (Continued)

Regions	States		Representative Destination Points
Pacific Northwest	Alaska Idaho Montana	Oregon Washington Wyoming	Pocatello, Idaho Casper, Wyoming
West	Arizona California Colorado Hawaii	Nevada Utah New Mexico	Sacramento, California Salt Lake City, Utah

Source: Council of Forest Industries, 1982.

construction and lumber consumption in the United States (United States International Trade Commission 1985).

The demand for imported lumber varies with the prices for domestic lumber. The magnitude of cross price elasticities of demand for imported lumber with respect to competing products depends on the strength of substitution. The home building industry is influenced by economic conditions. The activity of home building suffered in the early 1980's largely because of increased prices of factors such as labor, mortgage rates, lumber and other building materials. This fall in the home building industry affected the demand for lumber. Input prices affect the cost of houses whereas the changes in preference and structure of the population affect input requirements. Panelwood products have affected the percentage of use of lumber in construction. The overall use of lumber has fallen from 11.5 bft./sq.ft. in 1950 to 7 bft./sq.ft. in 1976 (Phelps et al 1984).

In recent years the demand in each region of the United States has experienced changes due to changes in production and distribution. In 1984 imports from Canada were maximum for the north central region and imports from the British Columbia lumber industry were maximum for the southeast, southwest, west and north central regions and imports from Quebec were maximum for the northeast regions of the United States (table I.2 & Council of Forest Industries 1985b). The British columbia lumber industry exported 56% of its lumber to the northeastern and north central regions of the United States in 1972 but only 40% in 1981 due to increased production in eastern Canada (Council of Forest Industries 1982).

Northeastern Region

This region is the most deficient in lumber production and depends on other lumber producing regions to meet its lumber demand. Historically, this region was a large market for the British Columbia. In 1984 it imported 3.2 B fbm or 20.4% of total Canadian lumber exports. The share of eastern Canadian lumber has increased from 32% in 1976 to 55% in 1980 (Council of Forest Industries 1982). This increase in share of export from eastern Canada is mainly due to market proximity. This region received 24.8% of its import by rail in 1984 to 50% in 1972. The lumber from British Columbia is transported by rail to a point in eastern Canada and then trucked to its final destination. It caters to the markets in Maine, Michigan, New York etc. (table II.2).

North Central

This region consumes its entire production which is only 9% of its total consumption. It receives nearly 40% of this lumber consumption from Canada. Lumber is sometime imported to this region and then moved to other destinations in the United States. The region's location allows it to receive lumber from all of the regions of Canada. It received 42% of its imports from British Columbia and 41% from Ontario in 1984 (Council of Forest Industries 1985b).

The lumber from eastern Canada is transported by truck and the lumber from British Columbia is transported first by rail and then by truck. It caters to the markets in Chicago, Kansas, Nebraska etc. (table II.2). The mobile home building industry is quite large and accounts for 20% of total United States mobile home production which prefers SPF.

Southeast

This region meets the demand for the markets of Florida, Columbia, South Carolina, Tennessee etc. It received nearly 19% of Canadian export in 1984. The major share of it, 69%, was from British Columbia followed by 15% from Ontario. The major shipment volume was by rail from British Columbia but some lumber was shipped by waterborne carriers to Florida. SPF is sold as a premium product and commands a premium of $20-30/Mfbm(U.S) (Council of Forest Industries 1982). Southern yellow pine produced in this region is mainly used in truss rafter production etc.

Southwest

This region includes the markets of Dallas, Tulsa and Oklahama city and received only 11% of its lumber consumption from Canada. In 1984, southern and Pacific northwestern regions accounted for the major share of lumber consumption. It received nearly 82% of the Canadian lumber import from British Columbia in 1984 and 84% was shipped by rail. In 1983, it received 65% of total consumption from southern yellow pine regions of the United States. SPF from Canada is used in mobile home construction and has a premium price.

West

This region is the major lumber producing region of the United States and supplies other regions of the United States. It meets nearly 89% of its consumption internally. It receives Canadian SPF only for trans-shipment to other areas. It caters to the markets of California, Utah, Idaho, Wyoming etc. It faces stiff competition from the low-cost producing industry of British Columbia. In 1984 it received only 11% of Canadian export and 96% of it was from British Columbia.

III. Theoretical and Analytical Specification of Models

A. Introduction

Accurate knowledge of the factors influencing the demand for and supply of softwood lumber in Canada and the United States is essential for analysing the impact of United States trade legislation on Canadian softwood lumber imports. Estimates of demand and supply elasticities in both countries are particularly very important. Unfortunately, earlier studies provide a broad range of different values for these elasticities (table III.1). This variation is in these elasticity estimates arises in these studies primarily from different sample periods, different model specification and finally differences in estimation procedures and data used.

Some authors, McKillop (1967) McKillop et al (1980), Adams & Blackwell (1973), Robinson (1974), Mills et al (1974) have utilised consumer demand theory and have utilised relationships in their model without considering the fact that forest products are generally intermediate in production technology. Buongiorno et al (1979), for example, estimated the demand for imported lumber as a function of ratio of prices of imported and domestic lumber and output (housing starts). This approach is similar to the usual expression of quantity demanded as a function of the price of the good, the price of other consumable products and level of income used in consumer theory.

Table III.1: Estimates of Lumber Price Elasticities (Demand and Supply) for United States Over Different Time Periods

Period	Source	Elasticity: Demand	Elasticity: Supply	Remarks
1929-60	Mckillop (1967)	-3.2	1.7	
1947-67	Robinson (1974)	-0.87	1.21	Douglas fir
1947-70	Mills & Manthi (1974)	.0271±.2169	1.6124±.4621	Douglas fir
		.5072±.4679	1.4639±.5465	Southern pine
1947-74	Mckillop & Others (1980)	-0.17	0.806	Softwood
1960-79	Luppold (1984)	-.297	0.497	Hardwood
1968-77	Rockel et al (1982)	-0.91	-	Softwood lumber for housing only

Recent studies in this area have found the 'final demand' approach unsuitable on theoretical grounds and this in turn highlights econometric problems with the earlier specifications. Modelling the demand for forest products as a final demand does not incorporate techonological, institutional and other economic constraints that have a major impact on demand (Eleazor 1986). Consumer demand theory does not generate enough structure for statistical tests regarding important aspects of the demand for forest products. Furthermore, demand cannot be considered in isolation. Demand is affected by the price of the product and price, in turn, is affected by supply. In order to determine the demand for Canadian lumber in the United States it is necessary to know the supply of lumber in both countries.

SPF (spruce, pine and fir) accounts for the most of the volume of lumber exported from Canada. Douglas fir and southern pine are the species that account for major share of lumber produced and consumed in United States. Although there are slight differences in quality, the common approach is to estimate aggregate demand curve for lumber and not treat as a seperate for imported and domestic lumber. Canadian lumber fills the gap between demand and supply in the United States. Hence, demand for Canadian lumber is an excess demand. The derivation of this excess demand requires detailed knowledge of supply and demand in both countries. Both supply and demand in a market help in determining excess demand or excess supply. Detailed knowledge of the structure of demand and supply in each market permits analysis of impact of a quota or tariff on the flow of trade and on the welfare of individuals involved.

The development of duality theory and the basic nature of forest products as intermediate goods has encouraged researchers like Rockel and others (1982) to utilise derived demand theory in the study for demand of forest products. This approach has not only recognized the basic nature of forest products as intermediate goods, but has also helped in determining elasticities of substitution among factors of production.

This chapter presents the procedures involved in obtaining derived demand for lumber from a cost function using the property of duality and Shephard's theorem. This chapter also presents relevant aspects of production technology that need to be considered in the estimation of a supply model. Use of duality in deriving the supply model is also discussed. Tests for any technological changes and the behaviour of supply to different factors are discussed as well. Partial equilibrium analysis involving spatial and non spatial cases to determine the welfare changes from the imposition of quota or tariff is discussed.

Transportation costs are an important component of delivered price. However, due to difficulties involved in getting data that include transportation costs, the analysis is confined to nonspatial equilibrium.

B. Derived Demand Theory and Demand Function

Derived demand theory is based on the concept that a firm decides which variable inputs along with primary fixed inputs will be needed to produce output. The demand for an input is directly related to the demand of the product derived from it. A firm attempts to determine the optimum mix of inputs such that profits are maximised while costs are minimised. For a given level of output firms with non-optimizing behaviour would not survive.

The demand for a factor of production can be determined either by profit maximisation or cost minimisation behaviour of the firm's manager. A profit function expresses profit of a firm as a function of output price, variable input prices for a given technology and a given endowment of fixed factors of production. McFadden et al (1978) have shown that there exists a correspondence between a set of concave production functions and a set of convex profit functions. In empirical work, the problem is to determine the optimum level of factor use. This problem is solved by using the property of duality. The demand for a factor of production can be determined either by profit maximisation or cost minimisation behaviour of the firm's manager. The advantages of utilising a profit function approach over cost function approach is that it is simpler to estimate and no endogeneous variables, input or output levels, need to be used as explanatory variables in the estimation.

The cost function approach on the other hand provides derived demand estimates of all inputs that are uniquely determined subject to the level of output and inputs forces and technology. The profit function provides Marshallian elasticities but not structural net input substitution (along an isoquant) not output trade offs along the production possibility frontiers (Lopez 1980).

Prior to the 1980's, most of the demand models for forest products were based on production or cost functions of the Cobb Douglas form. The traditional estimation of factor demand functions related the quantity of a product to its price, the price of other inputs and the level of outputs. This approach involved determining demand for each input seperately, but it is appropriate only if the use of one input is independant of others, i.e., globally seperable. The Cobb Douglas function imposes certain restrictions such as unit elasticity of substitution between inputs which is very rigid unless supported by statistical tests.

Another less restrictive functional form is the constant elasticities of substitution (CES) function. A desirable approach is one which allows for testing of different functional forms and does not restrict parameter estimation (Banskota 1984).

Flexible functional forms allow one [illegible]est characterstics of production technology such as homotheticity, returns to scale and technological changes of production technology. Flexible functional forms include a generalised Cobb Douglas form, a generalised Leontief form, a generalised quadratic means of order form and a translog functional form. Unlike the Cobb Douglas form, these other functions permit the estimation of elasticities of substitution and complementarities among inputs and allow tests for specific features of the production structure. The cost function using a translog cost functional form is discussed in this chapter.

C. Cost Function

Cost minimisation and output maximisation for a fixed outlay are alternative ways of characterising production efficiency. Product supply and factor demand equations consistent with a firm's optimum behaviour can be obtained by two different approaches. Duality permits the firm or an industry's production technology to be represented either by a production or a cost function. Another interesting feature of the dual approach is that the production function uses inputs as arguments, whereas the cost function uses output and input prices. It is convenient to use prices rather than quantities as the latter are difficult to determine. Moreover prices are less collinear (Taher 1983).

Cost is a function of input prices and the output level which is represented as:

$$C=C(P_i,Y) \qquad (6)$$

for $i=1,2,3,...,n$

where P_i represents input prices and Y is output. In the short run the cost function of a firm involves fixed as well as variable costs which is represented as:

$$C=C(P_i,Y)+b \qquad (7)$$

where b is the cost of the fixed factor. In the long run there are no fixed costs therefore cost is represented as:

$$C=C(P_i,Y) + F(Y) \qquad (8)$$

where F(y) represent the cost based on plant size which is a function of output.

According to McFadden and others (1978) a cost function corresponds to a well behaved production function if it satisfies the following regularity conditions.

1. Domain: The cost function is a positive real valued function for all positive prices and output, so that

   $$C(P_i,Y)>0 \qquad (9)$$

   for all $P_i,Y>0$ $i=1,2,...,n$.

2. Monotonicity: The cost function is a non decreasing function in input prices and output which implies that a rise in either input prices or output results in a cost increase, and if output tends to increase to infinity, the cost of production tends to infinity. If P_i and P_j represent two sets of input prices such that $P_i>P_j$ and output remains constant, then

   $$C(P_i,Y)>C(P_j,Y). \qquad (10)$$

3. Continuity: The cost function is continuous from below in output and input prices.

4. Differentiability: The cost function is continuously twice differentiable in input prices.

$\partial C/\partial P_i>0$ (11)

$\partial^2 C/\partial P_i p_j<0.$ (12)

The above conditions (11) and (12) help in generating a system of demand functions i.e.,

$\partial C/\partial P_i=Xi$ (Shephard's lemma) (13)

where X_i is the derived demand for input i. Firms maximise profits or minimise costs and simultaneously decide about the optimum mix of inputs rather than independantly deriving demand for each input. The notion of differentiability implies concavity. The above properties, particularly equation 12, are important in estimation as they can be expressed in such a way that a symmetry condition is obtained i.e.,

$\partial X_i/\partial P_j=\partial X_j/\partial P_i$ (14)

for all i and j. A change in the ith factor's demand from a change in the jth factor's price is equal to the change in the jth factor's demand from a change in the ith factor's price where i≠j. The ith and jth inputs are substitutes if $\partial X_i/\partial P_j$ is positive and complements if negative. The symmetry condition helps in reducing the number of parameters and hence increases the degrees of freedom which in turn reduce multicollinearity. Shephard's lemma also helps in symmetry condition by reexpressing it as:

$\partial^2 C/\partial P_i\partial P_j=\partial^2 C/\partial P_j\partial P_i$ (15)

or $\partial X_i/\partial P_j = \partial X_j/\partial P_i$ (16)

where X_i and X_j are two sets of inputs.

5. Homogenity: The cost function is homogeneous of degree one in input prices which implies that a doubling of prices of inputs results in doubling of cost thus staying on the same isoquant i.e.,

$$C(Y,\alpha P_i) = \alpha C(Y,P_i) \quad (17)$$

where α is a positive scalar quantity.

6. Concavity: The cost function is a concave function in input prices which implies that as prices rise, cost also rise but no more than linearily. The cost function is concave in inputs if

$$\partial X_i/\partial P_i = \partial^2 C/\partial P^2_i < 0 \quad (18)$$

for all i. It is essential as the producers minimise costs which implies that following the condition holds for every scalar α where $0 \leq \alpha \leq 1$. If so, then

$$\alpha C(P_i,Y) + (1-\alpha)C(P_i,Y) \leq C\{(\alpha P_i + (1-\alpha)P_i,Y\} \quad (19)$$

By applying Shephard's lemma, the demand for the cost minimising bundle of inputs can be obtained. Besides the above properties, certain restrictions in conformity with the technology or rules of rational behaviour are to be imposed before estimation. These restrictions include linear homogenity in input prices, symmetry, the adding up condition, Cournot's aggregation and Engel's condition which are all discussed by Banskota (1984) and Hassan et al (1976).

Maintained hypotheses are convex technology or cost minimising behaviour, the production possibility set being closed, and intermediate inputs seperable from primary inputs (McFadden 1980). Econometric analysis in production economics takes place against the background of the maintained hypotheses which are not tested but are assumed to be true.[4]

The transcedental logrithmetric functional form developed by Christensen and others (1973) is flexible in nature and helps in the estimation of an unrestricted model which is used to estimate the demand for softwood lumber in residential construction in the United States. Rockel et al (1982), Seriff (1983), Nautiyal et al (1983) and Doran et al (1982) have used this functional form for the estimation of derived demands for forest products. Rockel et al (1982) estimated the derived demand for lumber and other inputs for residential construction in the United States. Buongiorno et al (1979) determined the demand for imported softwood lumber as a function of relative prices of imported and domestic lumber and the number of housing starts, presuming that there exists a seperate demand for Canadian lumber.

This thesis differs from the above studies in that it explicitly treat the demand for Canadian lumber as an excess demand. The other studies employed restrictive assumptions in their analysis of the demand for Canadian lumber so far

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[4] Testing convexity in a constant elasticity of substitution production function by examining the sign of the estimated elasticity of substitution is inappropriate (McFadden 1978).

as they considered it at all. Rockel et al (1982) based their assumption of seperate demand on the claim that species of United States produced lumber differs from those of imported Canadian lumber. Although there is a species difference, quality differences are small and consumers base their decision on lumber prices irrespective of country of origin. In this study, therefore, only one lumber variable is considered for both countries.

D. Translog Cost Function

The translog cost function embraces the usual assumption that it best approximates any arbitrary cost function up to the second order (Eleazor 1986). It permits tests for various feasible alternatives of production technology. The most general form of the translog function, nonhomothetic, approximates up to the second order the cost function (Berndt and Wood 1975 and Binswanger (1974b). This general form yields a particular characterstic of the residential construction industry's technology by imposing certain restrictions. The general form is examined for the relevant production characterstics such as, homotheticity, homogenity, returns to scale, technical change and production possibilities. The nonhomothetic form of the model which permits the above characterstics is written as:

$$\ln C = \alpha_0 + \Sigma_i \alpha_i \ln P_i + (1/2)\Sigma_i \Sigma_j \alpha_{ij} \ln P_i \ln P_j + \alpha_Q \ln Q + (1/2)\alpha_{QQ}(\ln Q)^2 + \Sigma_i \delta_{iQ} \ln P_i \ln Q + (1/2)\alpha_{tt}(T)^2 + \alpha_{Qt} T \ln Q + \Sigma_i \theta_{it} \ln P_i T + \alpha_t T \quad (20)$$

for $i,j=1,2,\ldots,n; i\neq j$ where P_i represents the price of factors $i (i=1,2,..,n)$ and Q is a measure of the level of output. T stands for time and reflects techonology. This model represents the n input one output case and α represents the parameters of the approximating translog function which is estimated. The presence of variables T and Q allows for test of characterstics like homotheticity and technical change.

This general form generates minimum cost input share equations by differentiation of the translog cost function with respect to input prices i.e.,

$$S_i=\alpha_i + \Sigma_j \alpha_{ij} \ln P_j + \delta_{iQ} \ln Q + \theta_{it} T \qquad (21)$$

for $i=1,2,\ldots,n$ where $S_i=P_i X_i/(\Sigma_i P_i X_i)$ and X_i is as given in eqn.(20). S_i and S_j are the shares of ith and jth commodities. A share equation indicates the share of a particular input in the total cost, that is, its importance in the industry's output is judged by its share in total cost. Since the total cost of production is directly related to the price of the product produced, the price of the input will determine the price of the final output. The larger the share of an input, the more dependant the product on it. Similarly, output price depends on input prices. Cost share equations can provide estimates of parameters and allow for hypothesis testing, demand elasticity substitution meassures, technical changes, and scale economies.

Basically, parameters of the nonhomothetic translog cost function can be derived by using cost share equations, the parameters of quadratic output and the time variable are exceptions. Rockel et al (1982) determined these parameters of the nonhomothetic translog function by using a cost function but recent studies have indicated that estimating the cost function jointly with the share equations improves the efficiency of the parameter estimates. It is assumed implicitely that in each observation period the adjustment of the input mix to input price changes is instantaneous and complete (Johnston 1984). This result is also true for the elasticities calculated following the conventional procedures i.e.,

$$n_{ij} = \sigma_{ij} S_i \quad (22)$$

But this assumption is accepted only if the adjustment lags are completed withinthe period under consideration.

The estimation of cost share equations in conjunction with the cost function leads to over identification. Since the share of each input adds up to one, it is possible to drop share equation and permit estimation of parameters. The values of the omitted share equation parameters can be computed using the adding up condition which implies that the following restrictions must hold for the parameters of translog cost function:

1) $\Sigma_i \alpha_i = 1$

2) $\Sigma_i \Sigma_j \alpha_{ij} = 0$

3) $\Sigma_i \alpha_{iQ} = 0$

4) $\Sigma_i \alpha_{it} = 0$

5) $\Sigma_i \alpha_{ij} = \Sigma_j \alpha_{ji} = 0$ (23)

for $i,j=1,2,\ldots,n$; where $i \neq j$. The above conditions are referred as the linear homogenity in input prices assumption.

If the translog function is considered as a quadratic approximation of an arbitrary cost function, an additional constraint, the Slutsky symmetry, is required i.e.,

$$\alpha_{ij}=\alpha_{ji} \tag{24}$$

for all i and j where $i \neq j$, Constraints given by equations 23 and 24 are maintained hypotheses. Since the share equations since add up to 1, it is possible to drop any one share equation. Any one share equation can be dropped as the estimates are invariant with the equation deleted (Berndt and Wood 1975). Suppose the kth share equation is dropped, then equations 20 and 21 are transformed to:

$$\begin{aligned} \ln C = & (\alpha - \ln P_k) + \alpha_Q \ln Q + (1/2)\alpha_{QQ} (\ln Q)^2 + \alpha_t T + \\ & \Sigma_i \alpha_i (\ln P_j - \ln P_k) + (1/2) \Sigma_i \Sigma_j \alpha_{ij} (\ln P_j - \ln P_k) \ln P_i \\ & + \Sigma_i \delta_{iQ} \ln Q (\ln P_i - \ln P_k) + \Sigma_i \theta_{it} (\ln P_i - \ln P_k) T + \\ & 1/2\alpha_{tt} T^2 \end{aligned} \tag{25}$$

and $S_i=P_i X_i/C = \alpha_i + \Sigma_{j=2}^{n} \alpha_{ij} (\ln P_j - \ln P_k) + \delta_{iQ} \ln Q +$
$\theta_{it} T$ (26)

where $i \neq j$.

This approach considers instantaneous stock adjustments. Share equations help in determining the least cost expansion path of inputs. However, input demands in reality are interrelated and time paths of inputs follow dynamic interaction (Mohr 1980). A stock adjustment model can be used to account for short and long-run movements in factor demands. Dynamic adjustments will involve interrelated translog cost-share equations.

E. **Homotheticity, Homogenity and Returns to Scale**

Each of the characterstics, homotheticity, homogenity and returns to scale, describes attributes of the relationship between the level of output and the use of factors of production. Homotheticity means that, for a given factor price ratio, the change in output level will not change the factor input ratio. A change in the ratio with a change in output for a given factor price ratio implies nonhomotheticity. Seperability implies that a firm's decision on the use of one or more inputs is independant of the rest of the inputs. Seperability of inputs is important in production studies as it allows for decomposition of production relationships into additive components. The cost function is multiplicatively seperable in input prices and output if the production function is homothetic. In this case the equation $C=C(P_i,Q)$ can be written as :

$$C=C(P_i).D(Q) \text{ for } i=1,2,\ldots.n \tag{27}$$

This equation implies that any change in the level of output does not in any way affect the ratio of any two derived demand equations. Furthermore, the elasticity of cost with respect to output is independant of input prices.

In a translog cost function, homotheticity requires that the quadratic input price and output interaction terms be equal to zero i.e., all $\gamma_{iQ}=0$. (28)

Homogenity is a special case of homotheticity. A function is homogeneous if the marginal rate of substitution between inputs depends only on the input proportion and is independant of output i.e., elasticity of cost with respect to output is constant. The translog cost function is homogeneous and homothetic if the associated quadratic output term is zero i.e., $\alpha_{QQ}=0$. (29)

Returns to scale are related to homogenity. Any function with one degree of homogenity is said to be function of constant returns to scale. Constant returns to scale function is said to be homogenous of degree x if an increase in inputs by a multiple α increases the output by a multiple α^{x}. The condition of constant returns to scale implies that $\alpha_{Q}=0$. (30)

Any rejection of this hypothesis would indicate that the cost function exhibits either increasing or decreasing returns to scale.

F. Technical Change

Technological change affects the production structure of an industry. A firm produces an output by utilizing an input mix which minimises its cost structure for a given technology. Any change in technology is evident in a change in the ratio of factor mix that minimises the cost structure. A technology is neutral over time if the factor mix remains unchanged over time. Technological change implies that for an original level of output the cost can be decreased by replacing the scarce input by a more abundant and less expensive input. The technological changes are a resource saving type. The effect of technological change can be examined by differentiating a cost function with respect to time where time is taken as a proxy for technical change.

Technical change can be either neutral or biased towards any of the inputs. Technical change is Hick's neutral if the marginal rate of technical substitution (MRTS) between inputs does not change over time when there is an increase in output level at given input prices. In other words, if an input price remains the same then the factor proportion changes with the change in output. Technical change will be biased if the MRTS of input i for j reflects change over time. In the case of a translog cost function, the technical change is represented by the coefficient of interaction between time and inputs, i.e., θ_{it}. If its value is zero, then the function is neutral in technical change. Technological change can be measured by utilising the cost share equations. If each equation is differentiated with respect to time, $(\partial S_i/\partial t)$, it will yield the parametric estimate of technical change which is defined as:

$\partial S_i/\partial t=\theta_{it}>0$ (The Hick's factor is i using)

$\partial S_i/\partial t=\theta_{it}<0$ (The Hick's factor is i saving) and

$\partial S_i/\partial t\theta_{it}=0$ (The Hick's factor is i neutral) (31)

where S_i is the share of ith input in cost and factor prices are held constant (Binswanger 1974a).

G. Elasticities of Substitution and Factor Demand

Elasticity of substitution measures the ease with which one factor can be substituted by other when there is a change in relative input prices at a constant level. In the case of factors which are substites any increase in the price of one input will decrease its demand and increase the demand for a cheaper input, cetris paribus. But, if both the inputs are complements, then the demand of both inputs will decline, ceteris paribus. Estimates of the elasticity of substitution can be derived from the parametric estimates in the cost share equations. Elasticity of substitution is represented as:

$$\sigma_{ij}=1+\alpha_{ij}/S_iS_j=(\partial^2C/\partial P_i\partial P_j).(\Sigma P_iX_i/X_iX_j) \quad (32)$$

$$\text{and } \sigma_{ii}=(\alpha_{ii}+S_i{}^2-S_i)/S_i{}^2 \qquad \text{for } i=1,2,3...,n$$

where i is not equal to j and σ_{ij} is the elasticity of substitution between input i and j. S_i and S_j are the shares of ith and jth inputs. The term σ_{ii} is the elasticity of substitution of the ith input. Inputs are considered complements if $\sigma_{ij}<0$, and substitutes if $\sigma_{ij}>0$.

Demand elasticities measure the change in quantity demanded with the change in price when the factor price of other inputs and output remain constant. These elasticities, own and cross price, can be estimated from the translog function by using parametric estimates and determining the elasticity of substitution as follows:

$$n_{ii}=\sigma_{ii}\, S_i \text{ and } n_{ij}=\sigma_{ij}S_j \quad (34)$$

where n_{ij} and n_{ij} are the own- and cross-price elasticities.

These price elasticities, along with supply elasticities, help in deriving industry demand and supply schedules. A given input price is price elastic or price inelastic if $\eta_{ii}>1$ or $\eta_{ii}<1$ respectively. Even though the partial elasticity of substitution between inputs i and j is symmetric i.e., $\sigma_{ij}=\sigma_{ji}$, the cross-price elasticities are not i.e., $\eta_{ij}\neq\eta_{ji}$.

These estimations are based on the assumption that input demands are adjusted instantaneously to a new equilibrium whenever price changes take place. Industry does not react instantaneously due to uncertainty, adjustment costs and institutional constraints. In such cases, appropriate models would be dynamic translog functions. do so due to uncertainty, adjustment cost and institutional constraints. In order to analyse this behaviour of the industry, the model should

H. Supply Function

The study involves determination of supply function for both the Canadian and United States softwood lumber industries. The estimates from earlier studies by McKillop (1967), McKillop et al (1980) Robinson (1974) and Mills et al (1974), however, provide a range of differing supply elasticity magnitudes (table III.1). McKillop et al (1980) used supply as a function of its own price and the price of inputs involved in production. In these studies the underlying assumptions of the specification were not clearly set out, nor was the economic rationale for the models discussed.

In the short run, plant size of a firm is fixed and the manager of a firm has to maximise net revenue by varying the variable inputs (Henderson 1984). The short-run supply function of a firm can be derived by either first order conditions of profit maximisation or by constrained revenue, i.e.,

$$MC_i = \phi_i(q_i) \tag{34}$$

where MC_i is the marginal cost of ith firm and q_i is its output;

$S_i = S_i(P)$ for P>=min average variable cost.

The aggregate supply function of an industry at any price is obtained by horizontal summation of individual firm's supply at that price (Henderson 1984), i.e.,

$S = S_i(P) = S(P)$ where i=1,2,....,n.

The second order condition requires that marginal cost is rising. The firm's supply function, therefore, will be monotonically increasing in prices at or above minimum average variable cost.

The long run supply function of a firm contains no fixed variables. The firm can vary plant size. The supply elasticity for the firm changes with output prices provided other factors remain constant. Some studies have determined the supply elasticity of lumber to be inelastic in the short-run but elastic in the long run.

The supply function can be written as:

$$S=S(w_1,w_2,\ldots w_n,P) \text{ i.e., } S(W_i,P) \quad (35)$$

where $i=1,2,\ldots,n$, W_i is the price of ith factor, and P is the price of output. The supply equation also gives the impact of changes in factor prices on the supply of the product. The duality approach also helps in deriving a supply function based on cost minimising behaviour of the firm. Hotelling's lemma helps in determining product supply from indirect profit functions.

Shephard's lemma is parallel to Hotelling's lemma and allows derivation of product supply from an indirect cost function. The indirect cost function is represented as:

$$(P_i,Y)$$

which contains a vector of factor prices and output. The supply function conforms to economic theory. The indirect cost function needs to conform to properties that include, homogenity, domain, concavity, differentiability, and monotonicity. These properties are similar to those for the cost function discussed previously (for further detail refer to Beatie et al, 1985). Supply functions are homogeneous of degree zero if input and output prices change by the same proportion resulting in no change in supply i.e.,

$$S(w_1,w_2\ldots,w_n,P)=S(aw_1,aw_2,\ldots aw_n,aP) \quad (36)$$

for all $a>0$. A supply function that satisfies the homogenity condition implies that the sum of all elasticities is zero. The supply function that can be derived from optimization behaviour, as well as the model, will be internally consistent (Andersson et al 1985).The cost minimisation problem can be written as:

$$C(P_i, Y) = \min \Sigma_i \; P_i Q_i \qquad (38)$$

subject to a Cobb Douglas production function of the form:

$$q_1^{\alpha_1} \ldots\ldots q_n^{\alpha_n} \qquad (38)$$

where $\alpha_1, \alpha_2, \ldots \alpha_n$ are the distributive shares of the inputs. The solution for the first order condition of equations (37) and (38) yields the cost function:

$$C(P_1, \ldots, P_n, Y) = G \; P_1^{\alpha_1/z} \ldots\ldots P_n^{\alpha_n/z} Y^{1/z} \qquad (40)$$

where $z = \alpha_1 + \ldots + \alpha_n$ and G is the constant term involving α_1 ... α_n.

The derivative of the cost function with respect to output gives the inverse supply or marginal cost curve:

$$\partial C / \partial Y = H \; P_1^{\alpha_1 (1/z)} \ldots P_n^{\alpha_n (1/z)} Y^{(1-z)/z} \qquad (40)$$

where z<1 and H is a constant term. From this equation the supply function is derived as:

$$Y = J \; P_1^{\alpha_1 (-1/1-z)} \ldots\ldots P_n^{\alpha_n (-1/1-z)} \; P^{(z/1-z)} \qquad (41)$$

where J is a constant which is equal to $H^{(-Z/1-Z)}$. Logrithmic form of the equation (42) is:

$$\ln Y = \ln J - \{(\alpha_1/(1-z)\} \ln P_1 - \ldots\ldots - \{(\alpha_n/(1-z)\} \ln P_n + (z/1-z) \ln P \qquad (42)$$

where P_i and Q_i are price and quantity of ith factor for i=1,2,...,n, P is the price of the product produced and Y is the quantity of supply. The coefficient of the last term gives the supply elasticity of the supply curve. The coefficients of the factor price terms are elasticities of supply with respect to changes in input prices. Technical change if any, during any period can be tested using the Chow test (Johnstone 1984). It is also possible to test for technical change in the industry by including time variable.

The remainder of this chapter deals with the impact of tariffs on the excess demand for Canadian softwood lumber using partial equilibrium analysis where possible the assumptions are made concerning the impact of trade barriers on economic welfare in each of the countries and on specific groups (i.e., producers and consumers). Tariffs or quotas and other non-tariff barriers do lead to less efficient use of factors and consequently yield to net welfare losses. But asrguments in favour protection are based on distributional considerations (i.e.,self interest of various groups) and largely derive from efficiency arguments (i.e., infant industry).

I. Partial Equilibrium Analysis

Trade between the two countries takes place if in the absence of trade a price difference between similar commodities in the two countries exists. The higher prices in the United States which would prevail in the absence of trade and the price differential which emerges includes the imports of lumber from Canada. Lumber flows between the two countries until prices, (net transportation costs) and assuming no trade distortions, aree equalised.From the perspective of United States consumers, prices are lower from trade than would prevail with autorky. While from the perspective of Canadian producers they are higher than otherwise would be the case. On the other hand the free trade prices do make United States producers and Canadian consumers worse off than would be the case cetris paribus.

The demand for Canadian lumber in the United States market is the horizontal distance between the United States demand and supply curves. The combination of excess demand and the related price gives the import demand curve. The import demand curve is flatter and more elastic than the domestic demand curve in all cases except when all of the domestic demand is of zero elasticity (vertical). Infinitely elastic demand or supply schedules generate an infinitely elastic import demand (Darr 1984).

Any price higher than the equilibrium price in the Canadian market will result in exports to the United States. Excess supply in Canada is given by the horizontal distance between its domestic supply and demand at any price. The combination of excess supply at any price gives the excess supply curve. The excess supply curve is flatter and more elastic than domestic supply curve if one of the schedules is of zero elasticity (Kreinin 1983). Infinitely elastic demand or supply results in an infinitely elastic supply schedule. In the absence of transportation costs there may exist one price for both the countries. The trade model is obtained by plotting both excess demand and excess supply curves. The elasticity of export supply and import demand (Kost 1976) is given as:

$$n_{id} = (n_d q_d - n_s q_s)/(q_d - q_s)$$

$$n_{es} = (n_s q_s - n_s q_s)/(q_s - q_d) \qquad (43)$$

The vertical distance between two schedules at any quantity gives the price difference or extra profit for Canadian lumber producers that acts as an incentive for them to peneterate the United States market.

The equilibrium price of the trade model is lower than the equilibrium price of the importing country and higher than the equilibrium price of the exporting country relative to no trade scenerio (autorky). Consumers of the importing country and producers of the exporting country will therefore prefer trade. Any increase in price in the United States will lead to an increased share of Canadian lumber in the United States market whereas any policy directed to decrease the price difference will reduce the Canadian share.

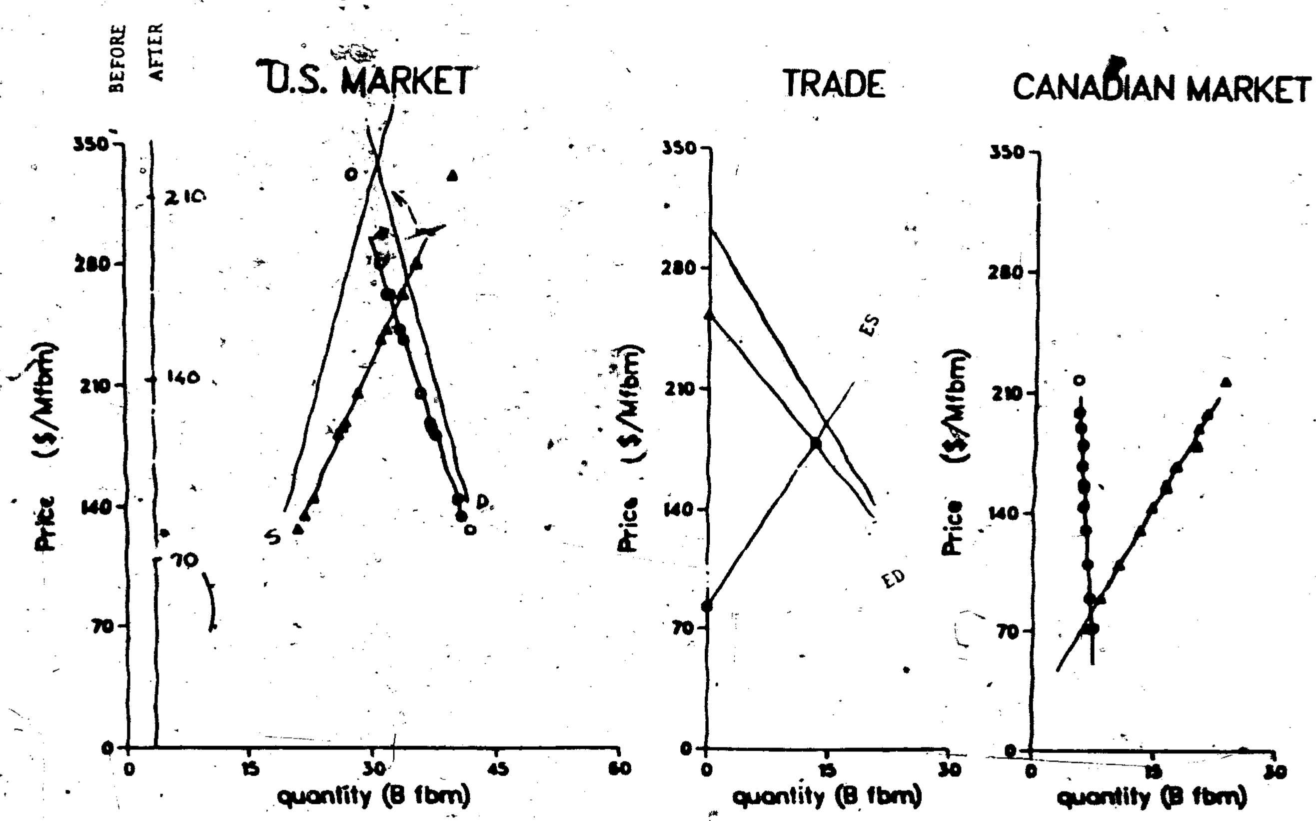
Net welfare of trade is a combination of producers' and consumers' surpluses. The trade situation or net welfare is affected by a shift in excess supply or excess demand. Since excess supply or excess demand curves, i.e., their elasticities are dependant on the demand and supply curves of exporting and importing markets, any change in these market will affect both markets. The Canadian economy is principally export oriented. Any policy change in the United States market will affect their demand and supply schedules and it gets transmitted to their excess demand curve.

Foreign exchange rates affect the price difference in the two markets. Therefore, the Canadian share of United States lumber consumption is influenced by changes in the Canadian dollar relative to United States currency. Exchange rates are based on the relative supply of, and demand for, each country's currency. Demand for a currency reflects the trade balance of each country and speculative elements based on expectations of the future strength of each currency relative to that of other countries.

Floating exchange rates can offset the intended effects from ad valorem and fixed tariffs. If United States currency appreciates relative to Canadian currency, then Canadian lumber becomes cheaper to United States consumers resulting in an increase in the competitive position of the Canadian lumber industry. The change in foreign exchange rates, or devaluation or revaluation of currency by the exporting country will affect trade. Devaluation of currency of the exporting country will shift the demand and supply of lumber in the importing country (fig. III.1). The increase in demand is viewed as higher price to exporters expressed in their currency units. This will stimulate production in exporting country but affects the producers in importing country. The result will be that, at any given price, the importing country will buy more imported goods.

Economic changes generated by trade results in hardships for individuals in the import competing sector. Those affected often argue for protection against free

Figure III.1: Effect of Devaluation by Exporting Country on Equilibrium Trade Pattern for Exports



SOURCE: BASED ON INFORMATION IN KOST (1976) trade. Trade protection occurs when any group of producers or consumers is insulated from the full force of international competition by deliberate economic policies. Industry or political leaders call for government sponsored trade protection for reasons such as protection of a new industry, national security, unfair trade practices, domestic programs and balance of payments. Government regulates trade by tariff or non-tariff barriers. The effects of tariff and non-tariff barriers on economic welfare differ but imports are reduced in either case. Tariffs can be of a fixed or ad-valorem (fixed and proportionate addition to price) form. its lumber producers.

Imports can be restricted by tariff and nontariff barriers. The initial impact of a tariff is to cause the prices for domestic and imported lumber to diverge. If, however, the exporting industry can absorb the impact of a tariff on price difference between domestic and imported lumber in the United States then there will be no effect from the tariff. However, since such tariffs are aimed at reducing the advantage of exporters vis-a-vis local producers, the export declines result in a price rise in the importing country. The consumers thus suffer, whereas producers benefit in the importing country. The consumers either shift to domestic lumber or reduce consumption because of the rising prices. Tariffs cause a protective effect, a revenue effect, a redistribution effect and a dead weight effect. These various effects are illustrated graphically in Ulbricht (1983).

There are repercusion in the exporting country as well. Because of a price decline in the exporting country, production declines but consumption increases.

If a specific tariff is imposed, there will be only an addition to the price irrespective of quantity exported. The excess supply curve will thus shift in a parallel fashion (Kreinin 1983). But if an ad valorem tariff is imposed, the price change will be a function of quantity and the excess supply curve will shift proportionally (Kreinin 1983). The price in the importing country will rise but by an amount less than the tariff amount. Higher prices will result in an increase in production and fall in consumption in importing country. In the exporting country prices will fall resulting in an increase in consumption and a fall in production. The impact of a tariff on price and quantity depends on the elasticities of demand and supply. The net welfare effect of a tariff will be the sum of consumer welfare loss and producer's welfare gain in importing country. There will be changes in the welfares of producers and consumer in the exporting country also.

Quota is a non-tariff barrier which restricts the quantity of imports. It can be fixed either by the volume of import or by the total value. Importers are licensed to import. The economic effects of a quota differs from that of a tariff as the revenue effect in case of quota is disbursed such that it is not certain whoreceives it. Those who get the license get the benefits of increased prices. Quota differs from a tariff, as the producers in the exporting country and consumers in the importing country may be willing to bear the impact of a quota, but still cannot import more than the quota.

There are some administrative problems and increased tendencies toward mismanagement. Importers with enough political clout may get licenses and, in some cases, part of the revenue received may get transferred in exchange for the licenses. The exporting country can still benefit if it has market power and the importing country is unable to replace the imported lumber. Producers in the importing country favour quota and consumers favour a tariff imposition because of the different effects from a price rise. Imposition of a tariff results in a shift in excess supply, and affects producers and consumers in both markets.

J. Review of Relevant Studies

There have been numerous empirical studies undertaken to analyse the wood product market using annual, quarterly and monthly data. A number of studies have been devoted to derived demand estimation but very few have been devoted to supply estimation. Even fewer focus specifically on trade issues between Canada and the United States. The emphasis of this section is to review selected studies related to the objective of this thesis and those involved in estimating the impact of protective measures by the United States government on social welfare.

Adams et al (1980) analysed the impacts of tariffs and quotas on lumber trade. They did not estimate the demand and supply elasticities for Canada.

McKillop (1967), McKillop et al (1980), Robinson (1974), Mills et al (1974), and Rockel et al (1982) determined estimates of demand price elasticities for softwood lumber. The magnitude of demand elasticities in each case differed (table III.1). McKillop (1967) carried out a comprehensive long run econometric study of wood products and estimated both demand and supply elasticities. Models developed by all the above authors except, Rockel et al (1982), suffer from the criticism made earlier that demand is not considered as an intermediate product.

Studies by Robinson (1974) and Mills et al (1974), although covering the same period, also differ in their estimates of demand elasticities but this is due to the selection of different explanatory variables and the models specification. Robinson (1974) included foreign exchange, value of residential construction, price of lumber and freight rate as explanatory variables. Mills et al (1974) considered also construction activities and lumber substitutes. Mills et al (1974), like McKillop (1967), concluded that residential construction was the important demand shifter. The positive value of demand elasticities they attributed to exclusion of lumber species preference index. The positive value of demand price elasticity may be due to the presence of some outlier or sample variance.

Buongiorno et al (1979) specified the demand for imported softwood lumber as a function of residential construction and relative lumber prices. He had based his model on the assumption that since the species imported from Canada are mainly spruce, pine and fir, which are different from United States domestic lumber species, a seperate demand for Canadian lumber exists. This approach is not appropriate, however, since quality differences are slight and consumers base their decision solely on price regardless of country of origin.

McKillop et al (1980) used lagged prices as explanatory variables and utilised housing and industry sector to determine the demand for lumber. He considered substitutes to determine the effect of a rise in the price of substitutes on the demand of lumber. Unlike his earlier estimates of demand price elasticities, the demand for softwood lumber was inelastic this time. He considered varibles such as steel and plywood to determine substitution or complementarity effects. He observed labor to be be a significant substitute for plywood but a complement to softwood lumber. Multicollinearity was present because of complementarity between varibles like industrial production and housing starts. Luppold (1984) also used lagged dependant variables in the estimation of hardwood lumber demand.

Doran et al (1982), Rockel et al (1982) and Sherif (1983) utilised derived demand theory to determine the demand for forest products. Buongiorno used a translog function to specify the derived demand for softwood lumber in residential construction. He utilised plywood, hardboard-particleboard, labor and other materials like steel, cement, brick clay etc. as other variables. He observed the demand elasticity for lumber to be inelastic but with a value of 0.99 (table III.1). They tested the general cost function against different restrictions to determine the appropriate characterstics of production technology in residential construction. Maximum likelihood tests for each model were carried out resulting in acceptance of the generalised Cobb Douglas model. Data constraints did not allow Rockel et al (1982) to estimate using share equations along with a cost function. Share equations along with the cost function gives more information as well as more consistent and stable parameters (Stier 1985).

Eleazor (1986) used a translog function to determine the demand elasticity for imported plywood in residential construction. He used both domestic and imported plywood as variables in a cost function but did not consider other materials. Estimate of demand price elasticities for softwood lumber by Eleazor (1986) were very low.

Very few studies have estimated the supply elasticity for the Canadian softwood lumber industry. McKillop (1967), Robinson (1974), Mills et al (1974) and McKillop et al (1980) determined supply elasticities for softwood lumber in the United States. Robinson (1974) estimated the supply elasticity for Douglas fir. He considered productivity and foreign exchange rate, but not stumpage, as explanatory variables in production. Mills et al (1974) considered a number of supply shifters and observed stumpage as an important variable. They observed wrong coefficient signs for the exchange rate, tariff and transportation rate variables. They considered wood chips as a competitor of lumber in production. Mills et al (1974) observed the lumber supply is elastic in nature whereas McKillop et al (1980) observed it to be inelastic. McKillop et al (1980) used the model with prices of nputs like fuel, sawmill productivity, wages, stumpage and price of lumber as variables. Their approach is based on the derived demand concept. A production function involving these variables based on cost minimisation helps in deriving relationship involvingof supply as a function of prices of inputs and output.

Luppold (1984) expressed supply of hardwood lumber as a function of price of lagged quantity supplied, lumber, wage rate, stumpage, interest rate and time. He assumed that theadjustment to exogenous shocks does not occur fully in one period but is distributed over time. His approach is similar to that of McKillop et al (1980), but the estimates of supply elasticities varyover time. This thesis incorporates some of the variables from Luppold's and

McKillop et al's models to estimate supply functions.

Adams et al (1980) carried out a partial equilibrium analysis to determine the welfare impact of tariffs or quotas. Their study used supply and demand estimates of the Canadian lumber market from other studies. They then analysed the impact of an ad-valorem and a fixed tariff and quota on equilibrium and on the welfare of producers and consumers in the two markets. Boyd et al (1985) derived demand and supply elasticities for the United States market using a transportation model. Then they analysed the impact of a tariff by using different export elasticities of Canadian lumber. This study differs from above studies as it utilised estimated supply and demand elasticities for both Canadian and United States lumber markets and then addresses the impact of protection on resultant demand and supply schedules.

IV. Estimation Procedure and Data Collection

A. Introduction

This chapter presents a theoretical framework for the estimation of demand and supply models and techniques for partial equilibrium analysis. It outlines the techniques used in estimating the models. The latter part of the chapter identifies the data utilised. Since similar models have been used for both the United States and Canadian lumber industries, the discussion of estimation techniques for both countries has been combined, but data collection for both countries have been seperated.

B. Theoretical Framework for Demand

Derived demand theory is appropriate for studying the demand for lumber in the residential construction industry. Factor market theory suggests that the demand for lumber is derived from the production function of the individual builder (Mosak 1938). A resulting function of aggregate market demand describes the manner in which the quantity of lumber purchased varies as price changes within a given time period when all other factors' prices are kept constant. The model should account for all the constituents viz., construction firms, industries and households which influence the use of lumber. The construction industry is the major consumer of lumber, and is influenced by lumber demand. It accounted for nearly 50% of total lumber consumption in United States in 1972, although declined to 33% by 1982 (fig. I.4). The principal consuming sector for the consumption of softwood lumber is new construction. Previous studies (Phelps 1977, Stone & Dickerhoof 1977) have suggested that the growth of softwood lumber imports is chiefly the result of increases in home building activity. Imported and domestic lumber are assumed to be similar in properties and grades. Moreover, there are no significant differences in business procedures, commercial laws, nor custom formalities between the United States and Canada. Indifferentiability implies that there is no seperate demand for imported lumber.

If there exists a seperate demand for imported lumber, then the demand for imported lumber can be written as a function of activity in residential construction, ratio of imported and domestic prices and prices of other goods. Model 1a has been developed on this assumption (table IV.1). Since the prices of imported and domestic lumber are expressed as ratios, it is immaterial whether prices are current or deflated. Model 1a does not reflect substitution or complementarity between domestic and imported lumber. In order to test for substitution or complementarity between domestic and imported lumber, a second model, 1b, was tested but was rejected on the basis of an F test of significance and the present incorrect signs of some of the variable coefficients. The study is not concerned about testing for complementarity or substitution per se. Model 1a was

Table IV.1 Models for Estimating Demand and Supply

	United States	Canada
1.	Single equation static model	not applicable
1a	QMT=f(Hou, PM/PD)	
1b	QMT=f(Hou, PM/W, PD/W)	
2.	Translog models	Translog models
2	Nonhomothetic Ndn Neutral Translog	Nonhomothetic Non Neutral Translog
3	Homothetic Non Neutral Translog	Homothetic Non Neutral Translog
4	Nonhomothetic Neutral Translog	Nonhomothetic NeutralTranslog
3.	Single equation supply models	Single equation supply models
5	QS=f(PS, PF, PSTP, PLA, SWPR)	QS=f(SWPR, PF, PLA, PS, PSTP)
6	QS=f(PLA, PSTP, SWPR, PF, PS, OWS)	not applicable
7	QS=f(PS, PF, PSTP, PLA, SWPR, T)	QS=f(PS, PF, PSTP, PLA, SWPR, T)
8	Not applicable	QS=f(PS, PF, PSTP, PLA, SWPR)
-		Logrithmic Transformation
9	QS=f(PS, PLA, PF, PSTP, SWPR, T)	Same
	Logrithmic Transformation	Same
10	Not Applicable	QS=f(PS, PST, PLAW, SAWPR, PFU)

superior to model 1b but was considered unsuitable for further analysis in the study as it does not recognize the similarity in lumber produced in the United States and Canada which is assumed to be the case in the analysis. Secondly, it gives the elasticities of relative prices which are not suitable for welfare analysis.

The translog model 2, based on classical assumptions of a monoperiodic production function, perfect competition in factor markets, cost minimisation and perfect knowledge of the pertinent economic and technological data, is more appropriate (Eleazor 1986). This model gives derived demand, elasticities of substitution and price elasticities. It also avoids the identification problem due to the presence of demand shifters. Translog cost functions along with share equations have been estimated to obtain demand parameters. Since the assumption has been made that there is no difference between domestic and imported lumber, only one variable for lumber is used. It was specified that lumber (L) along with capital (K), labor (LA) , hardwood and particleboard (HP), plywood (PL), and other materials (M) are the main variables which determine the cost of residential construction (table IV.2). The other materials variable is the aggregate of inputs viz., steel bars, cement, plumbing, heating, aluminium, bricks and clay and is based on the assumption that all of the above inputs can be aggregated. The production function therefore can be written as:

Table IV.2: Definition of Variables used in Demand and Supply Models for United States and Canada

PK	Average quarterly home mortgage rate. Divisia index used as a measure of price of capital.
QK	Average quarterly divisia quantity index of borrowed loan for residence construction.
PLA	Average weekly earning divisia index of special trade construction workers.
QLA	Quarterly divisia quantity index of number of laborers employed in residence construction industry.
PL	Aggregate divisia price index for softwood lumber.
QL	Aggregate divisia quantity index for softwood lumber.
PPl	Divisia price index for softwood plywood.
QPL	Divisia quantity index for softwood plywood.
PHP	Divisia price index for hardboard and particle board.
QHP	Divisia quantity index for hardboard and particle board.
PM	Aggregate divisia price index for other material (plumbing, air conditioning, steel, aluminium, bricks, clay and cement).
QM	Aggregate divisia quantity index for other materials.
Hoi	Index number of new housing units.
PD	Price index for domestic soft-wood lumber.
PM	Price index for imported softwood lumber.
T	Time=1 in the first quarter of 1970.
QMT	Quantity index of imported softwood lumber from Canada.
QS	Quantity index of softwood lumber produced in the country (LQS is the logrithmic form).

Table IV.2: (Continued)

PS	Price index for softwood lumber in the country (LPS is the logrithmic form).
PSTP	Stumpage price index for roundwood logs (LPSTP is the logrithmic form).
PLAW	Divisia price index for the laborers employed in saw mill industry (LPLAW is the log form).
PLA	It is one period lagged PLAW (LPLA is the logrithmic form).
SAWPR	Sawmill productivity is the ratio of quantity of lumber produced and the number of laborers employed (LSAWPR is the logrithmic form).
SWPR	It is one period lagged SAQPR (LSWPR is the logrithmic form).
PFU	Divisia price index for the fuel energy (LPFU is the logrithmic form).
PF	PF is one period lagged PFU (LPF is the logrithmic form).
OWS	It is the product of the divisia price index of laborers and the dummy variable having value 0 during 1970-1975 and 1 during 1976-1982.
PMT	Ratio of price of imported lumber and wholesale price index.
PDT	Ratio of the price of domestic lumber and wholesale price index.
LHO	Logrithmic form of number of house starts in the United States.
EKK	Own price elasticity of capital variable.
ELL	Own price elasticity of softwood lumber.
ELALA	Own price elasticity of labour.
EPLL	Own price elasticity of plywood.
EHPP	Own price elasticity of hard board and particle board.
EMM	Own price elasticity of other material.
W	Wholesale price index.

$$Y=f(L, LA, K, HP, M, PL) \quad (1)$$

where Y is the level of residential construction (number of new housing starts) and L, LA, K, HP, M and PL inputs are as explained earlier. The production function is twice differentiable in inputs, strictly quasi concave, increasing with Y and decreasing with inputs. It is assumed that the amount spent on construction is all borrowed. It is also assumed that building contracts do not extend over a long period. QK represents the money borrowed and PK is the price or mortgage rate.

Decision about residential construction is dependent on the price of the variables considered in this study. It is assumed that theamount spent on construction is borrowed. It is also assumed that building contracts do not extend over a long period. QK represents the money borrowed and PK is the price or mortgage rate. The production cost of residential construction is the sum of expenditures on L, LA, K, PL, HP and M. Total production cost from the property of duality can be written as:

$$C= C(PLA, PL, PPL, PK, PHP, PM, Y) \quad (2)$$

which are respectively the prices of variables labor, lumber, capital, hardboard-particleboard, plywood, other materials and Y is the number new housing starts. The function conforms to the properties explained earlier.

The derived demand for inputs can be obtained from Shephard's lamma as:

$$X_i=\partial C/\partial P_i$$

where X_i is the demand for the ith input. This derivative is very general and does not provide relevant information about production technology. Economic theory provides little information about selecting appropriate functional forms. Therefore, selection of an appropriate function becomes an empirical problem. A nonhomothetic translog cost function (eqn. 20 of chapter 3) provides a framework for testing the possible model that best approximates the production structure. The nonhomothetic translog cost function under perfect competition, once differentiated with respect to input prices, yields an input share demand equation (eqn. 21 of chapter3). Homothetic model 3 and nonhomothetic neutral model 4 nest within the nonhomothetic model 2. Therefore, different hypothesis tests help in getting the appropriate model.

In this study, the derived demand function for lumber ~~has been~~ obtained by using parametric estimates of the translog cost function and share equations. Nonhomothetic model 2 for six inputs and a single output can be written in stochastic form as:

$$\ln C = \alpha_0 + \Sigma_i \alpha_i \ln P_i + (1/2)\Sigma_i \Sigma_j \alpha_{ij} \ln P_i \ln P_j + \alpha_Q \ln Q + (1/2)\alpha_{QQ}(\ln Q)^2 + \Sigma_i \delta_{iQ} \ln P_i \ln Q + (1/2)\alpha_{tt}(T)^2 + \alpha_{Qt} T \ln Q + \Sigma_i \theta_{it} \ln P_i T + \alpha_t T$$

for $i,j=1,2,\ldots,n; i\neq j$ where P_i represents the price of factors $i(i=1,2,.,n)$

$$S_i = \alpha_i + \Sigma_j \alpha_{ij} \ln P_j + \delta_{iQ} \ln Q + \theta_{it} T$$

for $i=1,2,\ldots,n$ where $S_i = P_i X_i / (\Sigma_i P_i X_i)$ and X_i as given in eqn. (20) of chapter 3.

Time variable, T, serves as a proxy for technical change. The disturbance term accounts for errors in optimizing behaviour of the industry. Errors arise from industry's inability to operate at all times along a cost minimising expansion path due to changing relative factor prices and building regulations (Eleazor 1986). The non homothetic translog cost function, on differentiation with respect to input prices, gives respective shares which can be written as above. Since the sum of the shares of each input adds to 1, it is likely that error terms of share equations are correlated and add to 0 resulting in singularity of the variance-covariance matrix of error terms. It is, therefore, necessary to drop one share equation in estimating the model using the cost function and share equations. Such a system in which equations are related through the disturbance terms is called seemingly unrelated regression model. Zellener's two-stage procedure is not invariant with respect to the deletion of any equation (Zellener 1962). Maximum likelihood and iterative Zellener estimations are the techniques giving estimates which are invariant to the deleted equation (Kmenta 1968). The iterating Zellener procedure, leading to convergence, is computationally an efficient method of obtaining maximum likelihood estimates that are invariant to the deleted equation.

The cost function involves more parameters than share equations. Therefore, for sufficient degrees of freedom, it is necessary to have more observations for estimating the cost function alone using ordinary least squares. With fewer observations it is better to use share equations only (Taher 1983). However, the estimates are not explained consistently and incomplete information is provided. Estimation of the cost function and share equations jointly results in sufficient degrees of freedom and gives efficient estimates.

Cofficients of translog models can be estimated directly by using ordinary least square (Klotz et al 1980). Since translog cost functions have a large number of regressors involving second order terms, estimation of cost functions alone will involve a risk of multicollinearity (Singh et al 1986b). This problem can be overcome by estimating share equations alone as a multivariate regression system assuming constant returns to scale, i.e., $\alpha_{QQ}=0$ (Berndt & Savin 1975, Fuss 1977). This, however, imposes restrictions on technology. It therefore becomes more appropriate to estimate a cost function and share equations jointly as a multivariate regression system (Christensen et al 1976). Thus, the above equations comprising model 2 were utilised jointly to determine appropriate characterstics underlying the technology and derive demand for lumber. This approach permits estimation by ordinary least squares (OLS) resulting in efficient estimates. It also lessens the problem of multicollinearity and increases the degrees of freedom without adding unrestricted regression coefficients. It has been assumed that the error terms in the cost function and share equations are homoscedastic and nonautocorrelated. There is non zero correlation between contemporaneous error terms across equations and the variance-covariance matrix of the error terms is non diagonal (Singh et al 1986a). The iterative Zellener procedure was performed on the cost function and remaining share equations. The presence of non linear combinations of elasticities to be estimated in the regression specification and in the imposed restriction necessiates the use of the iterative procedure (Barten 1964). The implied parameters estimates for the omitted share equation can be estimated directly from the estimated parameters of remaining five equations.

A cost minimising industry is assumed to determine simultaneously the optimum combination of inputs rather than treat each input seperately in minimising costs subject to input prices and output levels. The difference results in two different models, nonhomothetic and homothetic. The construction industry is not static and undergoes changes through input substitution. The input substitution leading to a bias for one input due to relative price changes is known as technological change. A nonhomothetic model can be tested statistically using the hypothesis and restrictions explained earlier for selecting the appropriate model. If the construction industry is homothetic or neutral in technological change, then estimates obtained from the nonhomothetic model 2 will be biased. The appropriate model can be obtained by testing the approximate nested model 2 first for homotheticity and then for technical change. The test is carried out from the unresticted to the most restricted model, which is referred to as increasing order of restriction (Rockel et al 1982).

Non homothetic model 2 was tested for appropriateness of model 3, homothetic and homogeneous. The accepted model was then tested for technological change. Testing of the models involve linear restrictions. Homothetic and homogenity tests involve independant restrictions, whereas technological changes can be tested by $\theta_{it}=0$. Since these tests involve linear restrictions, the likelihood ratio test was employed. Given that the restrictions are normally distributed with mean vector zero, the likelihood ratio can be written as:

$$-2\log \lambda = \log(Mlu) - \log(Mlr) \qquad (3)$$

Mlu is the maximum likelihood value of the unrestricted model and Mlr the restricted model. Under the null hypothesis test -2log λ represents an assymptotic chi square distribution in which the number of restrictions represents the degrees of freedom. The null hypothesis is accepted if the calculated chi square is less than the critical value. The accepted model is then used to estimate the derived demand with estimates of own-price elasticites, cross-price elasticities and elasticities of substitution.

C. Theoretical Framework for Supply Models

In a linear relationship the coefficients will represent ceteris paribus effects by independant variables if the relationship contains a complete set of such variables affecting the dependent one. Earlier studies estimated aggregate demand elasticities by a procedure consistent with economic theory. The elasticity of supply of imports was taken to be infinite. In reality it is not so. Therefore, this study involves determinon of supply elasticity estimates for both countries. A supply model for the lumber industries in the United States and Canada have been considered. Supply behaviour in international trade is difficult to capture empirically. Goldstein and Khan (1978) and Dunnlevy (1980) used simultaneous equation estimation techniques to estimate supply behaviour. Haynes et al (1980) indicated that aggregate supply is a supply price and supply quantity formulation. This study, however, is concerned with excess demand to determine the demand for imports from Canada and excess supply in the Canadian market to analyse equilibrium price. It, therefore, does not involve directly the estimation of export supply. The estimates of supply and demand elasticities in both markets are needed to meet the objectives of determining welfare changes in both markets as a result of protective measures by the United States on imports from Canada.

Model specification is very important for unbiased estimation. Exclusion of any variable results in biased coefficients and increased standard errors. Industry produces lumber based on the price of lumber and the price of inputs viz., roundwood, labor, fuel energy. The study involves a model based on the cost minimising property of industry and involves variables lumber price, price of labor, fuel energy, stumpage, and sawmill productivity. Quantity supplied is a function of the price of lumber and the price of all of the variables involved in production. These variables fully explain the production behaviour of producers. The production of lumber involves some lag between initial decisions and actual production. Producers base their decisions on present prices. Therefore, in the study, lagged prices of labor, stumpage, fuel energy, and sawmill productivity are considered. A time variable (T) is included to remove some of the trend that may otherwise be picked up by lagged variables. Inclusion of T variable also helped in testing for technological changes in the industry during the period under consideration.

Serial correlation is commonly encountered in time series data. Serial correlation among residuals of an equation results in unbiased coefficient estimates but leads to underestimates of true variances. The Durbin Watson test is used to detect the presence of autocorrelation. Another potential problem is multicollinearity or high correlation between two or more independant variables giving unbiased coefficient estimates but inflated standard errors. McKillop et al (1980) also considered labor, fuel energy, sawmill productivity, stumpage, and lumber price and used a linear model. He observed that a logrithmic transformation of variables gave inferior results and, therefore, accepted the original model with natural form variables. Luppold (1984) also considered similar variables except that he included one variable to account for a shift in the wage rate elasticity. He interacted the wage rate with a dummy variable having values 0 or 1 for certain periods. This study considered models used by McKillop et al (1980) and Luppold (1984).

If two variables in the model are collinear, then it becomes difficult, if not impossible, to disentangle their seperate influences and obtain reasonably precise estimates of their relative effects. Since this study is not concerned with analysing the wage rate elasticity shift, the model used by McKillop et al (1980) was found more appropriate. Factor analysis was carried out to determine the importance of each variable. Multicollinearity, if present, cannot be removed completely but can be reduced. Multicollinearity can be detected through the examination of the simple correlation coefficient matrix or the variance inflation factor (VIF). The variance inflation factor can be calculated by regressing each variable on other explanatory variables using following formula:

$$VIF(X_i) = (TSS(X_i) \times Var(b_i))/\sigma^2 \qquad (4)$$

where $TSS(X_i)$ is the total sum of squares of residuals obtained by regressng variable X_i on rest of the X variables, $Var(b_i)$ is the variance of coefficient of X_i obtained from the original equation, i.e., by regressing the dependant variable on all explanatory variables (X's) and σ^2 is the variance estimates of the original regression equation. If the variance inflation factor is greater than 10, then the variable is strongly collinear and multicolinearity needs reduction.

Ordinary least squares (OLS), two-stage least squares (2SLS), three-stage least squares (3SLS) and limited information maximum likelihood (LIML) estimation techniques are employed. OLS estimation often serves as an appropriate technique for single equation models. It does not prove appropriate for multivariate systems of equations. OLS gives biased estimates of smallest variance. 2SLS estimation has the second smallest variance, but provides consistent estimates. 2SLS also shows little sensitivity to the problem of multicollinearity. 3SLS estimation out performs these two. The LIML technique gives unstable estimates (Mills et al 1974). McKillop et al (1980) used 2SLS estimation, whereas Luppold (1984) used OLS. Unbiased estimates are neither unequivocally better than biased estimates nor are their consistent estimates necessarily better than inconsistent ones. OLS estimates are biased if variables are omitted from the model unless coefficients associated with omitted variables are zero. Therefore, if the model is carefully constructed and involves all of the variables, then, because of less variance, OLS is a good estimation technique. The study, therefore, utilises OLS for estimation. .

This study considered two models, one with logrithmic transformed variables, and one with natural form variables. The two models are compared with respect to the of sum of square of error and the signs of the variable coefficients. Inclusion of T variable increases the explanatory power and allows testing for technological change by carrying out an F test on the unrestricted model (with T) and the restricted model (without T). The accepted model can also be tested for technological change by carrying out regression of the same model using two periods, 1961-69 and 1970-82. The Chow test is then used to determine the F value (see Johnstone 1984). If the critical value is more than the calculated one, then there is no technical change.

D. Data Collection for the United States

A critical step in the study was the choice of the length of the period covered. The period covered generally must convey important information. This study has considered the period from 1970 to 1982, a period when prices of lumber showed sharp increases followed by a decline. Collection of data for each of the variables identified posed no problem. Quarterly data were considered as they provide greater degrees of freedom and more information than annual data. Monthly data are useful if decision makers are concerned about short-term decisions. However, long-term decisions are of greatest importance in this study. Furthermore, monthly data introduce complications due to seasonal fluctuations (Buongiorno et al 1979). Data for both demand and supply models were collected from published reports by the United States government. Since base years for price indexes of each variable are different, price indexes for all of the variables were converted to the same base year. To avoid large differences among minimum and maximum values, the base year for deriving divisia indexes is taken as 1975.

Demand Model

Quarterly data covering the period 1970-1982 were collected from a number of statistical reports by the U.S. Department of Commerce (*U.S. General Imports for Consumption: Schedule A Commodity by Country, Construction Review* and *Survey of Current Business*) and the U.S. Department of Labor (*Producer Prices and Price Indexes*). Rockel et al (1982) obtained price data for inputs from building material dealers and wages from construction contractors and building trade associations. Since it was not possible to collect such data for both countries given time constraints, the study depended mainly on published data by the United States government.

Collection of data on prices of inputs is not a problem but information on quantities of each variable consumed in residential construction is not available. This was the reason that Rockel et al (1982) did not use share equations along with the cost function to estimate their model coefficients. This study has derived shares for each variable by estimating the quantity of each variable on the basis of some assumptions. Like Eleazor (1986), this study also assumed that the total cost of residential construction is composed of the expenditure of labor, lumber, capital, plywood, hardboard-particleboard and other materials. This study differs from Eleazor (1986) in that he assumed that shipment quantities equalled consumed quantities in residential construction. This assumption is highly unrealistic as is evident from fig I.3 which shows that lumber consumption in 1982 is only about 32% of total consumption.

In this study the total quantities of shipment of each variable are collected from statistical reports. The information on proportion of shipments going to residential construction is collected from published reports to determine the quantities consumed. Pitcher (1977) reported that 43% of output of the brick industry and 23% of output of the clay industry goes to residential construction. The residential construction industry accounts for 40% of ready mixed concrete. Prices of concrete mix represent input costs for cement and reinforcing bars. The residential construction industry accounts for nearly 33% of lumber and 27% each of plywood and hardboard-particleboard (Roberts et al 1985). It was assumed that the residential construction industry accounts for nearly 40% of the shipments of other materials. Other materials include steel, bricks, clay, aluminium, plumbing and heating, cement and reinforcing bars. The quantity of shipments of plumbing, bricks, clay and cement were collected from construction reviews and the shipments of the rest of the constituents was collected from the U.S. Department of Commerce (*Survey of Current Business*).

The information on labor is collected from the U.S. Department of Commerce (*Construction Review*). Special trade laborers include those who are involved in plumbing and heating, painting, brick work and carpentry. The average weekly earnings of special trade laborers is collected from the U.S. Department of Commerce (*Construction Review*). The number of laborers employed in residential construction is collected from the U.S. Department of Commerce (*Survey of Current Business*).

Since the total consumption of lumber in residential construction includes both domestic and imported lumber, the quantity of consumption of main species like southern yellow pine (SYP), spruce, pine and fir (SPF) and Douglas fir were included in the study. The quantity of lumber consumed in residential construction is determined by taking 33% of total lumber consumed). The volume of shipments is collected from the U.S. Department of Commerce (*Construction Review* and *Survey of Current Business*).The price indexes for these species are collected from the U.S. Department of Commerce (*Construction Review*) and the U.S. Department of Labor

(*Producer Prices and Price Indexes*). Since these lumber species are strongly correlated with each other, aggregate quantity and price indexes need to be estimated. Rockel et al (1982) estimated a correlation value of 0.99 for these lumber species and therefore, they estimated an aggregate variable assuming that lumber species can be aggregated.

In this study also similar assumptions are made and aggregate price and quantities for lumber are estimated. The quantity and price indexes for plywood and hardboard-particle board are collected from the U.S. Department of Commerce (*Construction Review*). Since the quantity consumed in residential construction is only 27% of total shipments, the quantity of both variables consumed is determined by multiplying total quantity consumed by 0.27.

The cost of capital borrowed for construction is also included as a variable. Mortgage rates affect residential construction activity. Rockel et al (1982) did not consider this variable but since it is included in construction costs, this study has included it as a varible. The interest paid on loans is taken as the price of the variable. The mortgage rate and the amount of borrowed money is collected from the U.S. Department of Commerce (*Survey of Current Business*).

Rockel et al (1982) used the Boeckh cost index. Since this study involves share equations, the same cost index cannot be used. The cost index is derived from the sum of the expenditures (price X quantity) for each variable. The share of each variable is then determined. It was assumed that the cost of any missing variable will be reflected in the disturbance term. Since this study involves variables with different units of measurement, indexes for price and quantity are constructed using the divisia index procedure (see Diewert 1976, 1978).

The total number of housing starts in each quarter is considered as the output variable. All of these variables were considered in estimating models 2 to 4, but data for model 1a and 1b for the quantity of lumber imported are obtained from the U.S. Department of Commerce (*US General Imports: Schedule A, Commodity by Country*). The price index for imported lumber is obtained from Statistics Canada (catalog. 62007). The domestic price index is obtained from the U.S. Department of Commerce (*Construction Review*). The divisia indexes for price and quantity are derived herein using prices and quantities of imported lumber in a same manner as for domestic lumber. Parameters for the models are estimated using ordinary least squares.

Supply Model

Data for the supply models are collected from different published United States government reports. Quantities of lumber produced and price indexes are obtained from the U.S. Department of Commerce (*Survey of Current Business*). Stumpage price (current dollars) of southern yellow pine, Douglas fir and ponderosa pine is obtained from Ulrich

(1984). Price indexes for fuel energy are obtained from producer price indexes of all the above species. Divisia indexes for stumpage price and roundwood quantities are obtained. The divisia index for lumber price and quantity are obtained in the same manner. Price indexes for fuel energy are obtained from the U.S. Department of Labor (*Producer Prices and Price Indexes*).

Wages paid and number of laborers employed in sawmills are from the U.S. Bureau of Labor Statistics. Sawmill productivity is measured by the ratio of quantity of lumber produced and number of laborers employed in sawmills. Since supply decisions generally involve some time lag, a lagged wage index, a stumpage price index and sawmill productivity are generated. Luppold (1984) has considered a lagged dependant variable as an explanatory variable to account for habit formation and stock collection. Since a lagged sawmill productivity variable is involved, which is the ratio of lagged quantity and the lagged number of laborers, this study does not consider a seperate lagged variable of quantity produced as an explanatory variable.

E. Data Collection for Canada

The same relationships pertaining to data collection for estimation purposes discussed for the United States apply to Canada as well. The quarterly data time series period for the demand models is the same as for the United States. However the supply models for Canada use annual time series data for 1961-82 because of the unavailability of quarterly data. Data are collected from published reports by Statistics Canada. Price indexes for different variables are available quarterly but quantities are given annually. Since the number of housing starts are available annually as well as quarterly, the quantity of each variable consumed for each quarter in the residential industry is estimated from annual data by converting it proportionatly to the quarterly number of housing starts relative to total housing starts in that year i.e.,

> Quantity of a variable in a given year = Quantity of the variable shipped during the same year times the number of housing starts in that same quarter divided by the total number of housing starts in that same year.

Price indexes and quantities for the main lumber species, Douglas fir, spruce, pine and other fir were collected from Statisics Canada (cat. 35204). Since lumber species are strongly correlated with one another, as indicated by the covariances, aggregate price and quantity indexes are estimated. Since nearly 23% of total consumption goes to residential construction in Canada (Roberts et al 1985), the total quantity of each lumber species consumed in residential construction is obtained by multiplying the total shipment by 0.23. Before calculating the divisia indexes, quantities consumed in each quarter are determined. The information on the number of new houses constructed annually and in each quarter is obtained from the Canadian Mortgage and Housing Corporation (*Housing Statistics, 1984*). From the price index of housing starts and the number of housing starts, quantity and price divisia indexes of housing starts is estimated. Since the total expenditure incurred on houses is mainly from borrowed money, the expenditure on residential construction is used as a measure of the quantity of capital input. Mortgage rates are used as the prices of capital and are obtained from the Canadian Mortgage Housing Corporation (*Housing Statistics 1984*).

Nearly 27% of panel products consumed goes to residential construction (Roberts et al 1985). Therefore, the quantity of plywood and hardboard-particleboard consumed in residential construction is obtained by multiplying the total consumption of both products by 0.27. The price indexes for both products were obtained from Statstics Canada (cat. 62007) and their quantities from Statistics Canada (cat. 35206 and 35004). Divisia indexes of price and quantity for both products are determined. The main problem faced is estimation of quantities of constituents of other materials. Price indexes for aluminium, bricks, clay, cement, plumbing and airconditioning and reinforced bars are obtained from Statistics Canada (cat. 62007, 44001, 44218, 44215, 41006 & 41215). Quantities of each variable going to the residential construction industry are not available. For some variables (bars, cement, clay, brick, plumbing and air conditioning), quantities consumed are not available, but total expenditures are. Using expenditure and price, divisia indexes for price and quantity are estimated.

Price indexes and quantities of labor are obtained from Statistics Canada (cat.64201). Moreover, the expenditure on labor accounts for 40% of total expenditures on residential construction (Statistics Canada, cat. 64201). Divisia indexes for price and quantity of labor are estimated using expenditures. As in the case of demand models for the United States, these variables were used to estimate translog models 2 to 4 (Table IV.1).

Supply Model

It was not possible to get quarterly data for explanatory variables like roundwood, sawmill productivity, laborer wage rate and price of fuel energy. Since the test for technological change, and the Chow test require more degrees of freedom than the annual data for the period 1970-1982 can provide, the period covered for supply model is 1961-82. The Chow test required regressions using the of same variables covering the sample periods 1961-69, 1970-1982 and 1961-82. Price indexes and quantities for the same lumber species, as mentioned earlier, are obtained from Statistics Canada (cat. 35204). Price and quantity for fuel energy is obtained from Statistics Canada (cat. 62007 and 35204). Stumpage price and quantity of roundwood are obtained from Statistics Canada (cat. 35204). Number of laborers employed and wages paid in the sawmill industry are also obtained from Statistics Canada (cat. 35204). Divisia indexes of prices and quantities for each variable are derived as explained earlier. Sawmill productivity is the ratio of quantity produced and laborers employed. A time variable is included to test for technological changes. Explanatory variables are then regressed with the dependant variable to estimate parameters of the supply model.

F. Estimation and Data for Trade Analysis

Adams et al (1980) estimated the effect of tariff and quota on imports from Canada. They assumed that Canadian lumber demand is perfectly inelastic, and then, using estimated elasticities of demand and supply, plotted demand and supply curves for the United States and Canadian markets. They then carried out partial equilibrium analysis. This study considered partial equilibrium analysis as an appropriate approach for analysing the United State's and Canadian markets in the presence of protection. Unlike Adams et al (1980), however, this study utilised the estimated elasticities of demand and supply for both markets. Demand and supply in each market is estimated by utilising the relationship:

$$LQ = LA + eLP + U \tag{5}$$

where LP is the logrithmic form of price and LQ is the logrithmic form of quantity supplied or demanded. LA is the constant term, e is the elasticity of demand or supply with the usual signs and U is the error term. The above relation can be written as:

$$LQ = LA + e\ LP \qquad (6)$$

where, LQ is the logrithmic form of mean value and LP is the logrithmic form of mean price. At mean values the above relationship will have an error term equal to zero. LA, determined from this relationship, is put into equation (5) to estimate the quantity demanded at different prices. The estimated values will differ from actual values and the difference will be minimum at the means. The difference is due to the fact that elasticities are estimated along with other variables, whereas in equation (5), only one variable, price is considered. The price of lumber in the Canadian market is obtained from the Canadian Forestry Service (*Forestry Statistics 1985*). The quantity supplied and revenue realised are given in this publication and are used to determine price. Composite lumber prices in the United States are obtained from annual issues of *Random Length*. In this analysis the prices are in United States dollars.

The estimated demand and supply data for both markets are plotted and a best fit is selected. At equilibrium price, demand and supply will balance each other. Equilibrium price in the United States is higher than equilibrium price in the Canadian market. At any price above the equilibrium price in Canada there exists excess supply for export, whereas, at any price below equilibrium price in the United states there exists an excess demand. Excess demand and excess supply for different price levels are estimated. These values are plotted and the best fits representing excess demand and excess supply curves are selected. The equilibrium prices associated with these curves are those at the point where excess supply equals excess demand. These values are between equilibrium prices in the United States and Canadian markets. This trade model was then used to analyse tariff and quota effects.

In spatial partial equilibrium the excess demand and excess supply will be affected by tariff or non tariff barriers. In this non spatial partial equilibrium analysis excess supply will be affected. A fixed tariff will be just an addition to the price of imported lumber. Therefore, the excess supply curve will shift in a parallel fashion (see Kreinin 1983 and Ulbrich 1983). An ad-valorem tariff will make proportionate additions to the price of imported lumber, but the excess supply curve will not now shift in a parallel fashion. The tariff will affect imports and thus consumers' and producers' surpluses. This study analyses the changes in producers' and consumers' surpluses in both markets. It analyses the impact of a 10%, 15% and 20% tariff impositions. The fixed tariff of 10%, 15% and 20% is considered is on equilibrium prices. This study also estimates the revenue which the United States government will realize from the imposition of these restrictions. It contains an analysis of the impact of limiting the imports of lumber from Canada to 10 B fbm. The study then analyses the changes in producers' and consumers' surpluses. The results obtained from this analysis are given in the next chapter.

V. Empirical Results of the Analysis

Empirical procedures for estimating lumber demand and supply models for Canada and United States and non-spatial, partial equilibrium analysis under different protection measures by the United States are discussed in the previous chapters. Estimates of demand and supply price elasticities help in determining excess supply in the Canadian lumber market and excess demand in the United States lumber market. These estimates are vital in assessing alternative trade and related policies. Results obtained from partial equilibrium analysis can help in formulating domestic demand and supply policies in Canada in the event of protection measures by the United States. Since tariff and non-tariff barriers have different welfare effects on producers and consumers of imposing countries, estimates in this study will help in formulating policy for protection measures. Canadian lumber producers and consumers are also affected. Therefore, the Canadian government also will get information to formulate policy about timber supply and, in turn, annual allowable cut. Besides these items, results of this study provide ideas about the relationships among different inputs in residential construction and the sawmill industries in both countries.

Results of demand and supply model estimation for both countries are discussed seperately in succeeding subsections of this chapter. These sections are then followed by a section on the results of different protection measures.

A. Models for the United States

Results of empirical estimation of demand and supply models are discussed seperately. The first subsection focuses on the demand model. It is followed by a subsection on the supply model. A discussion on tests for biased technological change for the selected most appropriate model are examined in Appendix 7. Price and quantity data used in the estimation of demand models are given in Appendices 1 and 2, whereas data used for estimation of supply model are given in Appendix 5.

Demand Models

Models 1a and 1b are the models as defined in table IV.1 and were used to estimate import demand. The results obtained from these models are given below:

Ia	L(PD/PM)	LHO	INT.	SSE	R^2
	-0.5600	0.4100	-0.1840	1.5308	0.5634

Ib	L(PD/W)	LHO	INT.	L(PM/W)	SSE	R^2
	0.6730	-0.1750	0.2050	0.2360	2.3696	0.3508

Model 1a poses no problem as the coefficients for variables housing starts and ratio of imported and domestic lumber prices have the proper signs. Model 1b is estimated to determine complementary or substitution effects between domestic and imported lumber. The problem encountered with model 1b is that variable coefficients for L(PM/W) and LHO do not have proper signs. This may be partly due to multicollinearity between similar variables, domestic and imported lumber. Model 1a with variable coefficients with proper signs is more appropriate for estimating the demand for imported lumber. This study is concerned not only with demand for imported lumber but with the impact of tariff as well. Models 1a and 1b cannot assist in analysing the impacts of protection measures. Therefore, for further analysis these models are not considered.

The translog function was considered more appropriate and does not pose identification problems. Model 2 (nonhomothetic non neutral), Model 3 (homothetic and homogeneous) and model 4 (nonhomothetic neutral) were estimated. Data used to estimate these model's parameters are given in Appendices 1 & 2.

The total cost of construction is given by the sum of the expenditures associated with each variable i.e., ΣPQ. The share of each variable in total expenditure has not remained constant overtime. It has declined since 1972 in the case of lumber (Table V.1). The share of hardboard-particleboard and other materials have increased.

The nonhomothetic model 2 was estimated initially and models 3 and 4 were derived by subjecting the non homothetic model 2 to different restrictive hypotheses. Alternative models 3 & 4, enumerated in chapter 4 and discussed in chapter 3, were, therefore, estimated alongwith model 2.

Parameter estimate results for the different variables are given in table V.2. The t-ratio for each variable obtained is given in table V.3. Likelihood ratio tests are

Table V.1: Average Input Shares in the United States Residential Construction Industry During 1970-1973, 1974-1977, 1978-1982 and 1970-82

Years	SK	LA	SL	SPL	SM	SHP
1970-1973	0.20509	0.18950	0.16197	0.11944	0.16392	0.16108
1974-1977	0.21300	0.18600	0.13967	0.14566	0.15065	0.16594
1978-1982	0.26082	0.18855	0.16300	0.12603	0.10300	0.16431
1970-1982	0.22740	0.18900	0.15475	0.12531	0.14117	0.16165

Note: SK stands for share of capital, SLA stands for share of labor, SL stands for share of lumber, SPL stands for share of plywood, SHP stands for share of hardboard-particleboard and SM is the share of other materials.

Table V.2: Average Cost Function and Parameter Estimates for Residential Construction inthe United States, 1970-1982

Coefficients	Model 2	Model 3	Model 4
α_o	1.3349	1.3064	1.682
α_Q	0.3682	0.3831	0.2536
α_{QQ}	-0.3910	-	-0.4000
α_t	0.0172	0.0181	-0.0015
α_{tt}	0.0001	0.0007	-
α_K	0.3261	0.3900	0.3494
α_{LA}	-0.9896	-1.3200	-1.2178
α_L	0.1730	0.2285	0.1250
α_{PL}	0.4711	0.3324	0.4086
α_{HP}	-0.1718	0.2000	-0.4051
α_M	0.1913	0.1649	0.3088
α_{KK}	0.0947	0.0963	0.0943
α_{LALA}	0.1376	0.1635	0.1974
α_{LL}	0.0776	0.0741	0.8030
α_{PLL}	0.0899	0.1137	0.1048
α_{HPP}	0.1151	0.0990	0.1225
α_{MM}	0.1263	0.1325	0.1356
α_{KLA}	-0.0210	-0.2300	-0.0215
α_{KL}	-0.0197	-0.1300	-0.0195
α_{KPL}	-0.0670	-0.0410	-0.0250
α_{KHP}	-0.0184	-0.2370	-0.0182
α_{KM}	-0.0189	0.0034	-0.0184

Table V.2: (Continued)

α_{LPL}	-0.0060	0.0203	0.0330
α_{LHP}	-0.0234	-0.1340	-0.020
α_{LM}	-0.0254	-0.0340	-0.0142
α_{LAL}	-0.0086	0.0385	-0.0320
α_{LAPL}	-0.0439	-0.0900	-0.1080
α_{LAHP}	-0.0216	-0.0300	-0.3850
α_{LAM}	-0.0420	-0.0640	-0.0670
α_{PLHP}	0.0176	-0.0900	-0.0793
α_{PLM}	-0.0084	-0.0080	-0.0030
α_{HPM}	-0.0313	-0.0310	-0.0250
δ_{KQ}	0.04431	-	0.0141
δ_{LAQ}	-0.0350	-	-0.0240
δ_{LQ}	0.01430	-	-0.0200
δ_{PLQ}	-0.0150	-	-0.0117
δ_{HPQ}	-0.0030	-	-0.0098
δ_{MQ}	-0.0063	-	0.0110
θ_{Kt}	0.0024	0.0021	-
θ_{LAt}	-0.0005	0.0002	-
θ_{Lt}	-0.0008	-0.0011	-
θ_{PLt}	-0.0005	-0.0008	-
θ_{HPt}	0.0002	0.0001	-
θ_{Mt}	-0.0009	-0.0010	-
R^2	0.9955	0.9964	0.9861

Table V.2: (Continued)

DW	1.8734	1.7475	1.7915
LLV	905.6	843.13	875.51

Note: Model 2 is Nonhomothetic function
Model 3 is Homothetic and Homogeneous function
Model 4 is Nonhomothetic with neutral technical change function.
D.W and LLV represent Durbin Watson and log. of likelihood values respectively.

Table V.3: **T-Ratios for Estimated Cost Function Coefficients for United States Residential Construction, 1970-1982**

Coefficients	Model 2	Model 3	Model 4
α_0	24.583	43.2130	45.2900
α_Q	8.1850	8.9151	8.7667
α_{QQ}	-3.7775	-3.998	-4.0190
α_t	5.5582	21.273	19.8300
α_{tt}	0.68900	-	-
α_K	16.7210	23.4800	21.5140
α_{LA}	-8.4006	-10.0500	-11.534
α_L	3.8084	3.1015	3.4691
α_{PL}	3.6919	4.7031	4.1792
α_{HP}	2.7177	3.9976	1.5637
α_M	2.6908	2.7122	2.8503
α_{KK}	34.1380	24.8980	24.793
α_{LALA}	2.8405	7.3492	7.3935
α_{LL}	5.2614	5.1238	5.3234
α_{PLL}	10.3610	1.2959	8.1440
α_{HPP}	23.0360	4.3279	3.8612
α_{MM}	6.8880	5.3785	5.3824
α_{KLA}	-12.2280	-0.0777	-1.8024
α_{KL}	-18.9220	0.0576	-0.3080
α_{KPL}	-18.5260	-0.8615	-0.6310
α_{KHP}	-3.1420	3.6687	3.6702
α_{KM}	-2.6803	0.1151	0.0910

Table V.3: (Continued)

α_{LPL}	2.0751	1.2959	2.5147
α_{LHP}	-3.5045	-2.5310	-6.3596
α_{LM}	-1.1510	-2.8008	-1.7661
α_{LAL}	0.2402	2.1318	2.0041
α_{LAPL}	-0.9950	-4.1683	-4.5588
α_{LAHP}	-1.1886	-1.0103	-1.0090
α_{LAM}	-2.8128	-3.7812	-3.7922
α_{PLM}	0.4640	-0.8179	-0.2710
α_{HPM}	-5.8244	-	-2.1026
δ_{KQ}	4.8493	-	0.9621
δ_{LAQ}	-4.2055	-	-3.6924
δ_{LQ}	1.7474	-	4.2551
δ_{PLQ}	-4.4236	-	-2.0469
δ_{HPQ}	0.5597	-	-1.6985
δ_{MQ}	-0.7679	-	1.1746
θ_{Kt}	6.9482	0.9931	--
θ_{LAt}	-1.9191	-3.6862	--
θ_{Lt}	-4.7376	4.2778	--
θ_{PLt}	-3.1138	-3.0775	--
θ_{HPt}	1.9871	-0.2827	--
θ_{Mt}	-3.4152	1.1297	-

Note: Critical values with 243 degrees of freedom are t(0.05)=1.6450 and t(0.01)=2.3260. These values of t correspond to infinite number of degrees of freedom.

carried out to determine the most appropriate model for approximating residential construction. The chi square test was utilised to test the hypotheses of homotheticity (model 3) and of neutral technical change (model 4) (Johnston 1984). The chi-square test supported model 2 (nonhomothetic and non neutral) (table V.5). Further discussion is confined to the parameter estimates of model 2.

Model 2 estimated parameters are used to estimate own-price and cross-price elasticities and partial elasticities of substitution. Examination of parameter coefficents of model 2 indicated that all of the homothetic parameters (δ_{iQ}) are significant, whereas, the coefficients of all of the biased technical change coefficients (θ_{it}) are not significant (table V.3). Selection of the nonhomothetic and non neutral model supports the fact that output change affects the input demand function. It also indicates that the residential construction industry is not characterized by constant returns to scale and are constrained by factor prices in altering production. Technical change results indicated that the industry is capital and hardboard-particleboard using and otherwise input saving (Appendix 7). Changes in production technique due to changes in relative prices of inputs are the main reasons for factor substitution.

Model 2 has the maximum number of parameters that are significantly different from zero (table V.3). The Durbin Watson test for autocorrelation was indeterminate. Estimated

Table V.4: Test Statistics for Model Selection: United States Residential Construction, 1970-82

Model	No. of Restrictions	χ^2 (1 percent)	χ^2 (5 percent)	χ^2 Calculated
3	7	18.48	14.07	30.09
4	7	18.48	14.07	62.47

Note: Model 3 is characterised by homotheticity and homogenity.
Model 4 is characterised by nonhomotheticity with Hick's neutral technical change.

parameters of model 2 were used to estimate partial elasticities of substitution and cross/own-price elasticitiesies using equation 33, chapter 3. Estimates of own-price elasticities of demand (n_{ii}), cross-price elasticities of demand (n_{ij} & n_{ji}) and partial elasticities of substitution (σ_{ij}) from model 2 are given in tables V.5 and V.6. These values are calculated at sample means.

Calculation of assymptotic standard errors of these estimates assumes that S_i and S_j are nonstochastic (Taher 1983 and Stier 1984). Asymptotic standard errors were calculated, but not given here since the shares are in reality stochastic (Taher 1983).

Partial elasticities of substitution indicate the ease with which different inputs can be substituted or complemented. Table V.5 indicates that hardboard-particleboard are substitutes for lumber, along with plywood. Lumber and other materials are complements. An increase in the price of lumber will result in an increase in the demand for other materials. Any change in relative prices of lumber and plywood or hardboard-particleboard will result in substitution. This change is evident in the change in shares of these variables due to a rise in the price of lumber (table V.2). The decline in the share of lumber resulted from a decline in the share of lumber consumption associated with housing starts relative to total lumber consumption (fig. I.4). Studies by McKillop et al (1980) and Rockel et al (1982) observed that lumber and plywood are

Table V.5: **Partial Elasticities of Substitution in United States Residential Construction, 1970-1982**

	Labour	Capital	Plywood	Lumber	Hardboard	Other Material
Labour	-0.45	0.51	-0.85	0.71	0.29	-0.59
Capital		-1.50	0.41	0.44	0.50	0.41
Plywood			-1.31	0.97	1.87	0.53
Lumber				-2.48	0.07	-0.16
Hardboard					-0.78	-0.37
Other Material						1.26

Note: These substitution elasticities are estimated at the sample means.

Table V.6: Own- and Cross-Price Factor Demand Elasticities' for the Translog Model: United States Residential Construction, 1970-1982

Input Pi	K	LA	L	PL	HP	M
K	-0.34	0.10	0.07	0.08	0.05	0.06
LA	0.07	-0.09	0.11	-0.11	0.05	-0.08
L	0.10	0.13	-.38	0.12	-0.01	0.02
Pl	0.09	-0.16	0.15	-0.16	0.30	0.08
HP	0.11	0.06	0.01	0.23	-0.13	-0.05
M	0.09	0.11	-0.03	0.07	0.06	0.36

'Estimated elasticities are based on the sample means.

Note: K stands for Capital, LA stands for Labor, L stands for Lumber, PL stands for Plywood, HP for Hardboard-Particleboard and M stands for Other Materials.

substitutes, but Eleazor (1986) observed that domestic plywood is a complement. McKillop et al (1980) and Rockel et al (1982) observed very low elasticities of substitution. Results herein are consistent with their findings.

Surprisingly, labor and lumber are substitutes indicating that the demand for labor increases with an increase in the price of lumber. Lumber exhibits a substitute relationship with capital. Labor and capital are complements. Denny and Fuss (1977) found that labor and capital have a complementary relationship in the Canadian manufacturing industry. Eleazor (1986) observed that labor and capital are substitutes.

Cross-price elasticities have similar interpretations as those for partial elasticities of substitution. This similar interpretation is due to the relationship $\bar{n}_{ij}=\sigma_{ij} S_j$. Both cross-price and partial elasticities of substitution indicate complementarity if negative value and substitution if positive. Cross-price elasticities unlike partial elasticities of substitution are not symmetric (table V.6 & V.7). Since cross-price elasticities involve shares of inputs, it makes it possible to evaluate complementary or substitutional relationships between pairs of inputs.

Own- and cross-price elasticities at sample means are presented in table V.6. Each element in the columns measure the percent change in demand for input i (i≠j) from a percent change in the price of input j, i.e, cross-price elasticity. The main diagonal elements represent own-price elasticities at the means.

Own-price elasticities for all of the inputs, except other materials, have the usual negative signs. The unexpected sign for other materials can be attributed to the basic nature of other materials and the aggregation of differ components (Adamowicz 1986). The own-price elasticities of all of the inputs are inelastic. McKillop et al (1980) and Rockel et al (1982) observed that lumber is inelastic but later obtained very high values (table III.1). This study estimated the own-price elasticity of lumber to be -0.38.

Estimating own-price elasticities of all of the inputs during different periods indicates that lumber and labor becomes more inelastic over time (table V.7). The absolute value of the own-price elasticity of capital increased during 1974-77 but then declined during 1978-82. This may be due to the effect of the oil crisis during the 1970's. Eleazor (1986) observed that capital and labor in United States residential construction becomes more inelastic. The own-price elasticity of other materials also shows changes over time. It had an improper positive sign during 1970-73 but a proper sign during 1974-77 and 1978-82 (table V.7).

Cross-price elasticity estimates are indicated by column elements and own-price elasticities by diagonal elements (table V.6). Estimates of cross-price elasticities of lumber and hardboard particleboard show substitute relationships, but the magnitudes are small. Plywood on the

Table V.7: Own-Price Elasticities of Inputs for United States Residential Construction, 1970-73, 1974-77 and 1978-82

	1970-73	1974-77	1978-82
ELL	[illegible]	-0.38	-0.30
EMM	[illegible]	-0.01	-0.03
EKK	[illegible]	-0.42	-0.37
ELA1A	-0.08	-0.07	-0.07
EPLL	-0.14	-0.24	-0.17
EHPP	-0.13	-0.16	-0.09

Note: ELL stands for own-price elasticity of Lumber, EKK stands for own-price elasticity of Capital, ELALA stands for own-price elasticity of Labor, EPLL stands for own-price elasticity of Plywood, EHPP stands for own-price elasticity of Hardboard-Particleboard and EMM stands for own-price elasticity of Other Materials.

other hand shows a complementary relationship with lumber. Eleazor (1986) also observed that lumber and domestic plywood are complements. Rockel et al (1982) observed that plywood and hardboard-particleboard are substitutes. Hardboard-particleboard were expected to be substitutes for plywood but the results indicated that they are complements. This relationship may be due to special uses of both products. This result is in agreement with the fact that plywood has special uses in roofing and sheathing where lumber may not be competing.

Rockel et al (1982) observed that lumber and labor are substitutes but this study, as well as Eleazor (1986) indicates that they are complements. Like Rockel et al (1982), however, a low cross-price elasticity of lumber and other material is observed (table V.6) which is also comparable with the values obtained by McKillop et al (1980).

Eleazor (1986) observed that cross-price elasticities between different variables change due to changes in their shares. It is evident from table V.2 that the share of each variable changes over time. Therefore, the magnitude of cross-price elasticities may be changing over time.

Own-price elasticities also showed changes over time but were not significant (table V.7). The estimated own-price elasticity of demand for lumber is used to recreate its derived demand relation and its demand schedule. The derived demand relationship for lumber can be obtained by the differentiation of the estimated cost function, model 2, with respect to lumber price.

Supply Models

In estimating supply it is unclear a priori whether the response is more appropriately specified with quantity or price as the dependant variable. However, if the supply price is uncertain, one would pursue a pricing strategy based on past market performance. The appropriate specification is a supply price equation (Haynes et al 1983). The static version of the traditional supply quantity equation is:

$$Q_S = \alpha_0 + \alpha_1 PS + \alpha_2 PF + \ldots + e$$

where the variables are as explained in table IV.2. Supply models for the sawmill industry in the United States during 1970-1982 are estimated using data given in Appendix 5. Different linear models (5-10) are estimated and the result are given in table V.8. Since supply decisions are assumed to involve a one period lag, variables stumpage, wage rate, fuel energy and sawmill productivity are lagged by one-period. McKillop et al (1980) using similar variables estimated supply, whereas Luppold (1984) estimated supply model by including and additional explanatory variable of lagged quantity supplied. Model 6 is similar to Luppold's model except that lagged quantity supplied as an explanatory variable is not included for reasons given in Chapter 4. Model 5 is similar to the model used by Mckillop et al

(1980). Model 7 differs from model 5 as it has an extra T variable, whereas model 9 is its logrithmic transformation. The results obtained are given in table V.8.

Both models 5 and 6 have 3 variables significant and DW statistics that lie in the inconclusive region. Generated variable OWS and variable PLA in model 6 have the same magnitude but different signs. Favourable SSE values, R^2 values, numbers of significant variables and variables with proper signs support model 5 over 6. Since variables OWS and PLA serve the same purpose, collinearity may be responsible for the wrong sign of PLA. However, this study is not concerned about wage rate elasticity. Therefore, model 5 is more appropriate than model 6.

Lagged variables are involved. Therefore, model 7 with the T variable is estimated. Inclusion of T variable increased the explanatory power of the model. Again all of the variables, except labor, have the usual signs. Models 5 (without T) and 7 (with T) were compared using an F test. This test supported model 7. The magnitude of the coefficients of the labor variable is still positive, but smaller. Model 7 was then compared with model 9, a logrithmic transformed variable model. The transformation of variables did not increase the explanatory power and labor still has a positive sign. Since model 9 did not improve the results, and because of a low sum of square errors, model 7 is considered as the appropriate supply model.

Table V.8: Estimated Supply Model of the Sawmill Industry in the United States, 1970-82

Coefficients	Model 5	Model 6	Model 7	Model 9
PS	0.3629	0.3156	0.8219	-
	(3.9854)	(3.0988)	(4.6958)	
PF	-0.1598	-0.1557	-0.0690	-
	(-8.2327)	(-7.8468)	(-1.9551)	
PSTP	-0.0532	-0.3286	-0.2392	-
	(-0.8066)	(0.4778)	(-2.7482)	
SWPR	+0.4446	0.4432	0.4514	-
	(5.975)	(5.9577)	(6.5654)	
PLA	0.8968×10^{-6}	0.3336	0.5263×10^{-6}	-
	(0.9269)	(-1.0211)	(0.5997)	
OWS	-	-0.3336	-	-
	-	(-1.0211)	-	
INT.	0.7003	0.7254	0.5124	0.6895
	(10.66)	(9.67)	(5.8672)	(4,5050)
LPS	-	-	-	0.9058
				(6.2032)
LPF	-	-	-	-0.1427
				(-1.6764)
LPSTP	-	-	-	-0.2269
				(-3.5505)
LSWPR	-	-	-	-0.3416
				(2.4998)
LPLA	-	-	-	-0.0046
				(1.0891)
T	-	-	-0.0127	-0.0190
			(-2.9899)	(-5.2493)
R^2	0.7083	0.6895	0.8151	0.7423

Table V.8: **(Continued)**

Coefficients	Model 5	Model 6	Model 7	Model 9
Durbin Watson	1.6961	1.7375	1.6752	1.5869
SSE	0.1950	0.2799	0.1628	0.2093

Note: Critical value with 7 degree of freedoms are t(0.05)=1.895 and t(0.01)=2.978. T ratio values are in brackets. SSE represents sum of square of error.

Model 7 is different from the model used by Luppold (1984) but similar to the model used by McKillop et al (1980). It has lumber, fuel energy, stumpage price, sawmill productivity and time variable coefficients that are significant at the 5% confidence level (table V.8). McKillop et al (1980) observed only stumpage and lumber price to be significant. Since this is a model with natural form variables, the coefficient of lumber does not give the supply elasticity directly. The elasticity of supply is, therefore, estimated at the means. Like McKillop et al (1980), it was observed that, if stumpage increases by 1%, the supply decreases by 0.2%. McKillop et al (1980) observed that a 1% increase in sawmill productivity increases the supply by 0.33%, but this study observed that the increase in supply is 0.43%. This difference between results may be due to the difference in periods involved. The impact of a 1% increase in price of fuel energy is a decrease in supply by 0.22% against 1.0% observed by McKillop et al (1980). Like McKillop et al (1980) the study observed that a 1% increase in price of lumber increases the supply by 0.81%.

Since the F test supported model 7 over model 5, it rejects the hypothesis that technical change is zero. This result was also tested by estimating the model using sample periods 1970-74, 1975-82 and 1970-82. The Chow test also indicated that there is technical change in the sawmill industry during 1970-82. A lumber supply elasticity of 0.8081 is different from the values estimated by other studies (table III.1). Adams et al (1980) estimated the supply elasticity for different United States regions to be from 0.21 to 0.79. The magnitude of elasticities vary with time periods under consideration and models used. The estimated supply elasticity is used to estimate the supply of lumber in the United States. The estimated supply is then used to derive supply schedules which discussed in later sections of this chapter.

B. Models for Canada

Models for Canada have been estimated using techniques similar to those used in model estimation for the United States. In the case of demand models the results supported a nonhomothetic non neutral translog function model. In the case of supply models the period covered is 1961-82 to provide sufficient degree of freedom for the Chow test. The supply model is also similar to the one accepted for United States except that the model is log-linear. The parameters of these models are described in the nexttwo subsection

Demand models

Price and quantity data used in estimating models 2, 3 and 4 are given in Appendices 3 and 4. The total cost is the sum of the product of price and quantity of each variable i.e., expenditure. Share of each variable over time is given in table V.9. The share of hardboard-particleboard has increased over time. The share of lumber declined and then

Table V.9: **Average Share of Inputs in the Canadian Residential Construction Industry, 1970-1973, 1974-1977, 1978-1982 and 1970-82**

Years	SK	SLA	SL	SPL	SM	SHP
1970-1973	0.20434	0.11826	0.17427	0.17633	0.18251	0.14125
1974-1977	0.19783	0.12762	0.15876	0.17361	0.19203	0.14995
1978-1982	0.18513	0.14312	0.14700	0.16007	0.20991	0.14403
1970-1982	0.19900	0.12710	0.14512	0.16295	0.19698	0.14301

Note: SK stands for share of capital, SLA stands for share of labor, SPL stands for share of plywood, SL stands for share of Lumber, SHP stands for share of hardboard-particleboard and SM stands for share of other materials.

Table V.10: Average Cost Function Parameter Estimates for Canadian Residential Construction, 1970-1982

Coefficients	Model 2	Model 3	Model 4
α_0	-0.7380	-0.3630	0.1600
α_Q	-1.6220	-0.9120	1.5900
α_{QQ}	1.1760	-	1.2330
α_t	0.0980	0.0940	0.0540
α_{tt}	-0.5680	-	-
α_K	0.3890	0.3130	0.1760
α_{LA}	-3.5560	-2.6300	4.6400
α_L	1.9784	3.9200	2.8700
α_{HP}	0.3150	0.3350	0.3580
α_M	0.2930	0.3120	0.4100
α_{PL}	1.4550	-1.3110	1.7300
α_{KK}	0.0880	0.0920	0.0980
α_{LALA}	0.0590	0.1430	0.0590
α_{LL}	0.0910	0.0850	0.0270
α_{PLL}	0.1690	0.2610	0.1650
α_{HPP}	0.0960	0.0960	0.0970
α_{MM}	0.1020	0.1090	0.1080
α_{LLA}	-0.0040	-0.0460	0.0700
α_{LPL}	-0.0230	0.0240	-0.0370
α_{LHP}	-0.0140	-0.1460	-0.1510
α_{LK}	-0.0210	-0.0220	0.0100
α_{PLK}	-18.5260	-5.4449	-4.3148

Table V.10: (Continued)

α_{LM}	0.0250	-0.0250	-0.0254
α_{PLLA}	0.0060	-0.0360	0.0160
α_{PLHP}	-0.0240	-0.0210	0.0160
α_{PLK}	-0.0174	-0.0180	-0.0160
α_{PLM}	-0.0170	-0.0270	-0.0270
α_{HPLA}	-0.078	-0.0950	-0.1410
α_{HPK}	-0.0120	-0.1200	-0.1570
α_{HPM}	0.0270	-0.0270	-0.8640
α_{LAK}	-0.0110	-0.0120	-0.0230
α_{LAM}	-0.0230	-0.0230	-0.0230
α_{KM}	-0.0040	-0.0060	-0.0520
δ_{LQ}	-0.0230	-	-0.0510
δ_{PLQ}	0.0033	-	-0.0380
δ_{HPQ}	0.0330	-	0.1340
δ_{LAQ}	-0.0520	-	0.8950
δ_{KQ}	0.1810	-	-0.1330
δ_{MQ}	-0.0710	-	0.1300
θ_{Kt}	-0.0040	-0.0030	-
θ_{LAt}	0.0020	-0.0010	-
θ_{Lt}	-0.0020	-0.0020	-
θ_{PLt}	-0.0010	-0.0010	-
θ_{HPt}	0.0020	0.0020	-
θ_{Mt}	0.0030	0.0030	-
R^2	0.6468	0.6482	0.6568

Table V.10: (Continued)

LLV	651.16	632.13	600.04
DW	2.0157	1.8997	2[illegible]15

Note: Model 2 is Nonhomothetic non neutral.
Model 3 is Homothetic and homogeneous.
Model 4 is Nonhomothetic neutral.
DW and LLV represent Durbin Watson and maximum likelihood function respectively.

Table V.11: T-Ratios of Estimated Cost Function Coefficients for Canadian Residential Construction, 1970-1982

Coefficients	Model 2	Model 3	Model 4
α_0	-2.5363	0.6177	-1.4596
α_K	4.4333	1.6321	3.1781
α_{LA}	-0.7225	-4.2090	-1.8080
α_L	-0.7642	-2.5135	0.6850
α_{PL}	3.8084	0.9180	[illegible]
α_{HP}	2.7177	2.8337	2.8674
α_M	1.4564	7.0000	5.1006
α_t	5.3167	15.4920	4.7203
α_{tt}	-1.0967	-	-1.3000
α_Q	-2.6852	1.7527	-1.4422
α_{QQ}	-0.2022	1.6692	-
α_{LL}	2.7600	0.4652	2.8626
α_{LPL}	2.0751	-0.4928	-0.3582
α_{LHP}	-3.5065	-3.4767	-3.6150
α_{LLA}	-1.2871	1.2157	-1.0694
α_{LK}	-5.9106	-4.3143	-5.8769
α_{LM}	-5.2986	-5.2364	-5.4437
α_{LALA}	1.0692	-1.3168	1.6067
α_{LAK}	-3.8022	-4.2138	-30.8633
α_{LAM}	-5.7175	-5.3644	-5.8139
α_{PLL}	10.361	2.5581	5.6266
α_{PLK}	-18.526	-4.3148	-5.4449

Table V.11: (Continued)

α_{PLM}	0.4639	-6.7075	-6.7395
α_{PLLA}	-0.9950	1.2157	-1.1191
α_{HPK}	-3.1420	-3.8820	-3.1315
α_{HPP}	23.0360	-21.8630	23.191
α_{HPLA}	-1.1886	-2.2488	-1.0910
α_{HPM}	-5.8244	-5.3921	-5.9670
α_{MM}	6.6065	6.6937	6.8420
δ_{KQ}	4.8506	-	-6.8468
δ_{LAQ}	0.2642	-	6.7126
δ_{LQ}	0.7297	-	-4.655[illegible]
δ_{PLQ}	-4.4236	-	[illegible].0469
δ_{HPQ}	0.5597	-	6.3676
δ_{MQ}	-1.9632	-	[illegible].0292
θ_{Lt}	-3.2209	-4.8906	-
θ_{PLt}	-3.1138	1.[illegible]357	-
θ_{Kt}	-8.4491	3.[illegible]162	-
θ_{HPt}	1.9871	3.8033	-
θ_{LAt}	2.4199	3.2760	-
θ_{Mt}	2.1826	1.4734	-

Note: Critical values with 243 degrees of freedom are t(0.05)=1.645 and t(0.01)=2.32[illegible]. These values of t correspond to infinite degrees of freedoms.

increased a little. This increase in the share of hardboard-particleboard is primarily due to a sudden rise in the price of lumber during that period.

As explained in chapter 4, model 2, nonhomothetic and non neutral, is initially accepted. Since models 3 and 4 are nested in model 2 they are derived by imposing certain restriction hypotheses. The estimates of coefficients and their t ratios for models 2, 3 and 4 are given in tables V.10 & V.11. The model that best approximates residential construction production technology in Canada is determined by using the likelihood ratio test. Model 2 is first compared with model 3 and then with model 4. The test values are given in table V.12. The test supports model 2 as the best approximation whereby production isoquants shift down the expansion path altering factor cost-shares. Acceptance of model 2 also supports the fact that output changes affect the input demand function. It indicates that the residential construction industry is not characterised by constant returns to scale but is constrained by factor prices in altering production.

Discussion herein is now confined to model 2 only. The Durbin Watson statistic indicates the absence of autocorrelation. Examination of parameter coefficients indicates that coefficients of all of the technical change parameters, θ_{it}, are not significant (table V.11). The coefficients of all the homothetic parameters, δ_{iQ}, are not significant at the 1 or 5% confidence levels. Changes in

Table V.12: Test Statistics for Model Selection: Canadian Residential Construction, 1970-82

Model	No. of Restrictions	χ^2 (1 percent)	χ^2 (5 percent)	χ^2 Calculated
3	7	18.48	14.07	19.03
4	7	18.48	14.07	51.12

Note: Model 3 is characterised by homotheticity and homogenity.
Model 4 is characterised by nonhomotheticity with Hick's neutral technical change.

production technology due to changes in relative prices of inputs is the main reason for factor substitution. Model 2 has the maximum number of significant parameters.

The estimates of the technological change parameters (θ_{it}) indicate that technology is factor using in labor, other materials and hardboard-particleboard (Appendix 8). Production technology is factor saving in lumber, capital and plywood. This is supported by the decline in their share over time.

Estimated parameters of model 2 are used to estimate partial elasticities of substitution and own/cross-price elasticities. The estimated partial elasticities of substitution are given in table V.13. These values are estimated at sample means. Standard errors are calculated but not reported for the reasons explained earlier. Partial elasticities of substitution indicate the ease with which inputs substitute for one another. Partial elasticities of substitution are symmetric in nature (table V.13). They show that labor and hardboard particleboard are complementary, whereas lumber is a substitute. Plywood is also a substitute of hardboard particleboard. This relation shows that an increase in the relative price of lumber results in substitution by plywood which is the reason for a change in their share (table V.9). The elasticity of substitution between lumber and plywood is only 0.13, whereas the elasticity of substitution for lumber and hardboard-particleboard is 0.42. Thus,

Table V.13: Partial Elasticities of Substitution', Canadian Residential Construction, 1970-1982

	Lumber	Plywood	Hardboard	Other Labor	Capital	Materials
Lumber	-1.59	0.77	0.02	0.42	0.27	0.12
Plywood		1.24	0.13	1.21	0.46	0.17
Hardboard			1.55	-2.63	0.60	0.14
Labor				-3.17	0.60	0.05
Capital					1.80	0.89
Other Material						-1.45

'These partial elasticities of substitutions are calculated at the sample means.

hardboard-particleboard substitutes for lumber more easily than plywood. Other materials also substitute for lumber but with less ease.

Own- and cross-price elasticities are estimated at sample means using the coefficients of model 2. These estimates are reported in table V.14. Cross-price elasticities have interpretations similar to the partial elasticities of substitution but involve shares of inputs. Therefore, it is possible to evaluate whether relations are complementary or substitutable. Own-price elasticity estimates are given in the main diagonal elements and cross-price elasticity estimates by column elements (table V.14).

Own-price elasticities of all of the inputs, except plywood, have expected negative signs. Eleazor (1986) observed a positive sign for domestic plywood and concluded that it may be due to basic nature of it. It is supported by the fact that plywood has special uses in roof and wall sheathing in residential construction, which may be responsible for the lack of substitution by other inputs, even though its price may be rising.

The own-price elasticity of lumber is most inelastic among the inputs. The own-price elasticity of lumber at sample means is -0.23 which is less than the comparable value for United States residential construction. Demand for labor is less inelastic, followed by capital, other materials and hardboard particle board.

Table V.14: Own- and Cross-Price Factor Demand Elasticities[1] for the Translog Model, Canadian Residential Construction, 1970-1982

Input/Pi	L	PL	HP	LA	K	M
L	-0.23	0.003	0.07	0.10	0.06	0.02
PL	0.003	0.2	0.02	0.15	0.1	0.03
HP	0.06	0.02	-0.26	-0.33	0.11	0.04
LA	0.11	0.2	-0.44	-0.4	0.12	0.02
K	0.04	0.08	0.10	0.08	-0.36	-0.18
M	0.02	0.03	0.032	0.01	0.18	-0.29

[1]Estimated elasticities are based on the sample means.

Note: L stands for lumber, K stands for capital, LA stands for labor, HP stands for hardboard-particleboard, M stands for other materials and PL stands for plywood.

The estimates of own-price elasticities indicate that lumber becomes more inelastic over time whereas hardboard-particleboard becomes less inelastic initially but more inelastic during 1978-82 (table V.15). Labor on the other hand shows a more elastic trend over time. Other materials show an increase in elasticity partly due to a rise in prices of all commodities following the oil crisis in the 1970's. Capital has nearly the same value for 1970-73 and 1978-82 and slightly more inelastic during 1974-77. A slightly more inelastic own-price of capital during 1974-77 may be due to a decline in its price index during this period.

The estimates of cross-price elasticities represent complementarity or substitution among inputs. Each element in the columns of table V.13 represents the change in demand of the ith input from the change in price of the jth input ($i \neq j$) when the output level and price of the rest of the inputs remain constant. Cross-price elasticity estimates are more reliable than partial elasticity ones as measures to evaluate substitution or complementary relationships.

The estimated values indicate that lumber is a substitute for plywood, hardboard-particleboard and other materials. This relationship implies that an increase in the price of lumber relative to that of plywood, hardboard-particleboard and other material will lead to its substitution. The magnitude indicates that lumber and hardboard-particleboard are stronger substitutes than lumber

Table V.15: Own-Price Elasticities of Inputs for Canadian Residential Construction, 1970-73, 1974-77, 1978-82 and 1970-82

	1970-73	1974-77	1978-82
ELL	-0.34	-0.27	-0.24
EKK	-0.36	-0.36	-0.34
EPLL	0.14	0.15	0.22
EHPP	-0.14	-0.20	-0.19
EMM	-0.26	-0.28	-0.31
ELALA	-0.37	-0.41	-0.45

Note: ELL stands for own-price elasticity of Lumber, EPLL stands for own-price elasticity of Plywood, EKK stands for own-price elasticity of Capital, EHPP stands for own-price elasticity of Hardboard-Particleboard, ELALA stands for own-price elasticity of Labor and EMM stands for own-price elasticity of Other Materials.

and plywood. Eleazor (1986) observed that the change in shares of the inputs over time affects the magnitude of their cross-price elasticities. Since the share of hardboard particle board has increased over time, the magnitude of the cross-price elasticity must have also increased.

Labor is a substitute for lumber, but a complement to hardboard-particleboard. Labor and capital are substitutes. Eleazor (1986) observed that lumber and plywood are complements in United States residential construction but this study observed them to be substitutes. The result obtained here are similar to the observations made by Rockel et al (1982), but the magnitude differs.

The lower demand price elasticity for softwood lumber in the Canadian residential construction industry indicates that consumers are less responsive to changes in price than their counterparts in the United States. Own-price elasticity is used to estimate demand during the period under consideration as explained in chapter 4. The estimated demand quantities and corresponding prices are used to derive demand schedules.

Supply models for Canada

Supply models are estimated for the period 1961-82. The data used for estimation are given in Appendix 6. The estimation procedure is already explained in chapter 4. Model 6 is not estimated as this study is not concerned about estimating wage rate elasticities. Moreover inclusion of the generated variable OWS does not increase explanatory power but adds to multicollinearity. Model 7 was accepted over model 5 because of a lower sum of square error and supported by an F test. The Durbin Watson statistics for autocorrelation lie in the inconclusive region.

Model 9 contains logrithmic transformations of the variables in model 7. This model was found more suitable than model 7 on the basis of SSE, significance of variables and R^2. Model 9 is then compared with model 8 with unlagged variables. Model 8 with logrithmically transformed unlagged variables was rejected on the basis of less signifcant variables and value of R^2. Model 10 is the restricted form of model 9 having no T variable. An F test for technological change supported the unrestricted model 9 over model 10. Model 9 has more explanatory power than models 5, 7 and 8 (R^2). The coefficients of all of the variables except labor, for model 9 have the usual signs (table V.16). The coefficients represent the demand elasticities as the model is log-linear.

The coefficients of variables lumber price, sawmill productivity, and labor are significant at the 5% confidence level. Examination of the coefficients indicate that an increase of 1% in price of lumber will increase the supply of lumber by 1.43%. Manning (1975) observed the lumber supply in Canada to be inelastic. The difference in estimates of supply elasticities of lumber in this study may be due to selection of a different period and particular

Table V.16: Estimated Supply Models of the Canadian Sawmill Industry, 1961-82

Coefficients	Model 5	Model 7	Model 8	Model 9	Model 10
PS	1.3160	1.3492	-	-	-
	(2.3420)	(2.8580)			
LPF	-0.1986	-0.1954	-	-	-
	(0.1634)	(-0.1564)			
PSTP	-0.2191	-0.2142	-	-	-
	(-0.5742)	(-0.5372)			
SWPR	0.4696	0.4785	-	-	-
	(1.9667)	(1.7518)			
PLA	-0.2475	-0.2422	-	-	-
	(-0.2050)	(-0.2989)			
INT.	1.0056	0.9962	10.90	1.5275	1.4313
	(1.6438)	(1.5506)	(9.1378)	(6.5253)	(4.8269)
LPS			0.0810	1.2463	1.1473
			(0.2746)	(4.9372)	(3.6462)
LPF				-0.5177	-0.5483
				(1.2006)	(1.2354)
LPSTP				-0.0922	-0.0939
				(-1.1651)	(-1.1610)
LSWPR				0.0606	0.0719
				(2.5283)	(2.2433)
LPLA				-0.8162	-0.9299
				(-2.1611)	(-2.1239)
LPLAW	-	-	0.1423	-	-
	-	-	(0.4724)		
LSAWPR	-	-	0.9147	-	-
	-	-	(8.3229)		
LPST	-	-	0.0407	-	-
	-	-	(1.0735)		
LPFU	-	-	-0.1842	-	-
	-	-	(-0.8167)		

Table V.16: ***(Continued)***

Coefficients	Model 5	Model 7	Model 8	Model 9	Model 10
T		0.0055	-	0.1946	-
		(-0.0759)	-	(0.5486)	-
R^2	0.6981	0.6982	0.8317	0.8211	0.8285
Durbin Watson	1.7754	1.7803	1.6996	1.5910	1.5720
SSE(1970-82)	5.2752	5.2696	0.3538	0.3705	0.3720
SSE(1960-69)				0.0055	
SSE(1970-82)				0.3535	

Note: Critical values for 7 degree of freedoms are $t(0.05)=1.895$ and $t(0.01)=2.998$. t ratio values are in parenthesis. Variables are defined in table IV.2.

model used. Adams et al (1980) also observed lumber supply to be inelastic (0.47). As is evident in table III.1, different studies obtained different estimates, therefore it was necessary to estimate supply elasticities in this study instead of using values estimated by others.

Sawmill productivity and labor are significant at the 5% confidence level. A rise of 1% in wages will result in a fall in lumber supply by 0.93%. Further, an increase of 1% in sawmill productivity increases the supply by 0.07%.

Stumpage is not significant at the 5% confidence level. An increase of 1% in stumpage price will reduce the supply of lumber by 0.09%. It was observed that the sawmill industry in Canada underwent technological change during 1961-82. This technological change result was also supported by the Chow test. The accepted model 8 was tested for technological change using the Chow test for the period 1961-69, 1970-82 and 1961-82.

The estimate of the supply elasticity is then used to estimate supply quantities during 1970-82 as explained in Chapter 4. The estimated values and the corresponding prices are used to get a supply schedule for the period 1970-82.

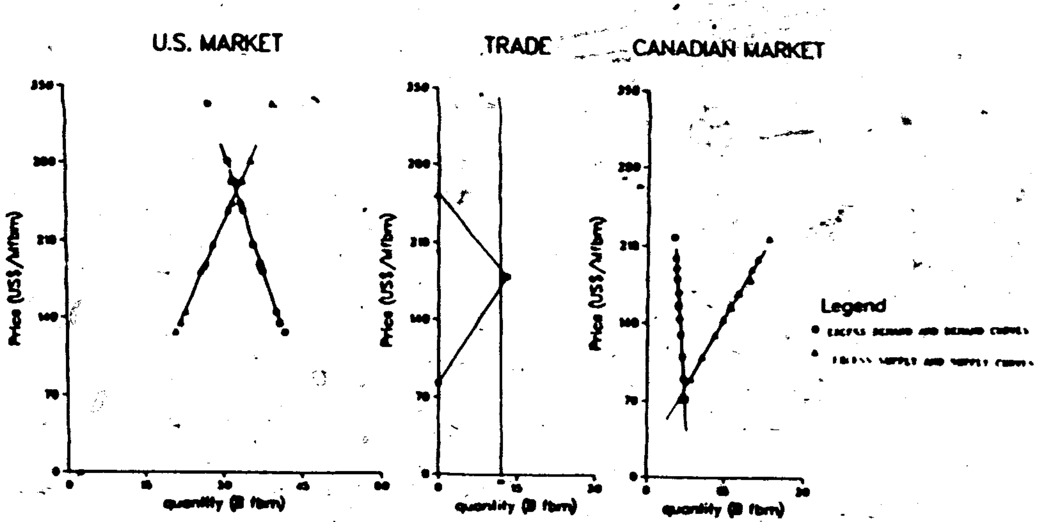
C. Partial equilibrium analysis

Estimated demand and supply elasticities of softwood lumber in United States and Canadian markets are used to estimate demand and supply as explained in chapter 4. The estimated values differ from the actual values because supply and demand elasticites used in their estimation were obtained from models involving variables besides lumber. These difference between estimated and actual values are least at sample means (Appendix 9). Estimated demand and supply with corresponding prices are used to get best fits of demand and supply schedules.

Lumber trade from Canada to the United States is due to the higher equilibrium prices in the United States (Fig V.1). The equilibrium price of lumber in the United States market is $258/Mfbm which is higher than the equilibrium price of $83.3/Mfbm in the Canadian market. This shows that, at prices $258.8 and $83.3/Mfbm respectively, there will be equilbrium in demand and supply in the United States and Canadian markets. There will be excess demand in the United States at any price less than $258.8/Mfbm whereas there will be excess supply in Canadian lumber market at any price higher than $83.3/Mfbm.

The excess demand in United States and excess supply in Canada are estimated at different price levels. The excess demand and excess supply with corresponding prices are used to get excess demand and excess supply schedules. Excess supply and excess demand balance each other at $179.4/Mfbm. Since the price level of $179.4/Mfbm lies between $83.3/Mfbm and $258.8/Mfbm, the trade between United States and Canada benefits the United States consumers and Canadian lumber producers. At this price of $179.4/Mfbm, excess supply of 13.12 billion fbm balances the excess demand of 13.12 Bfbm.

Figure V.1: Impact of a Quota of 10 Bfbm by the United States on Canadian Lumber Imports



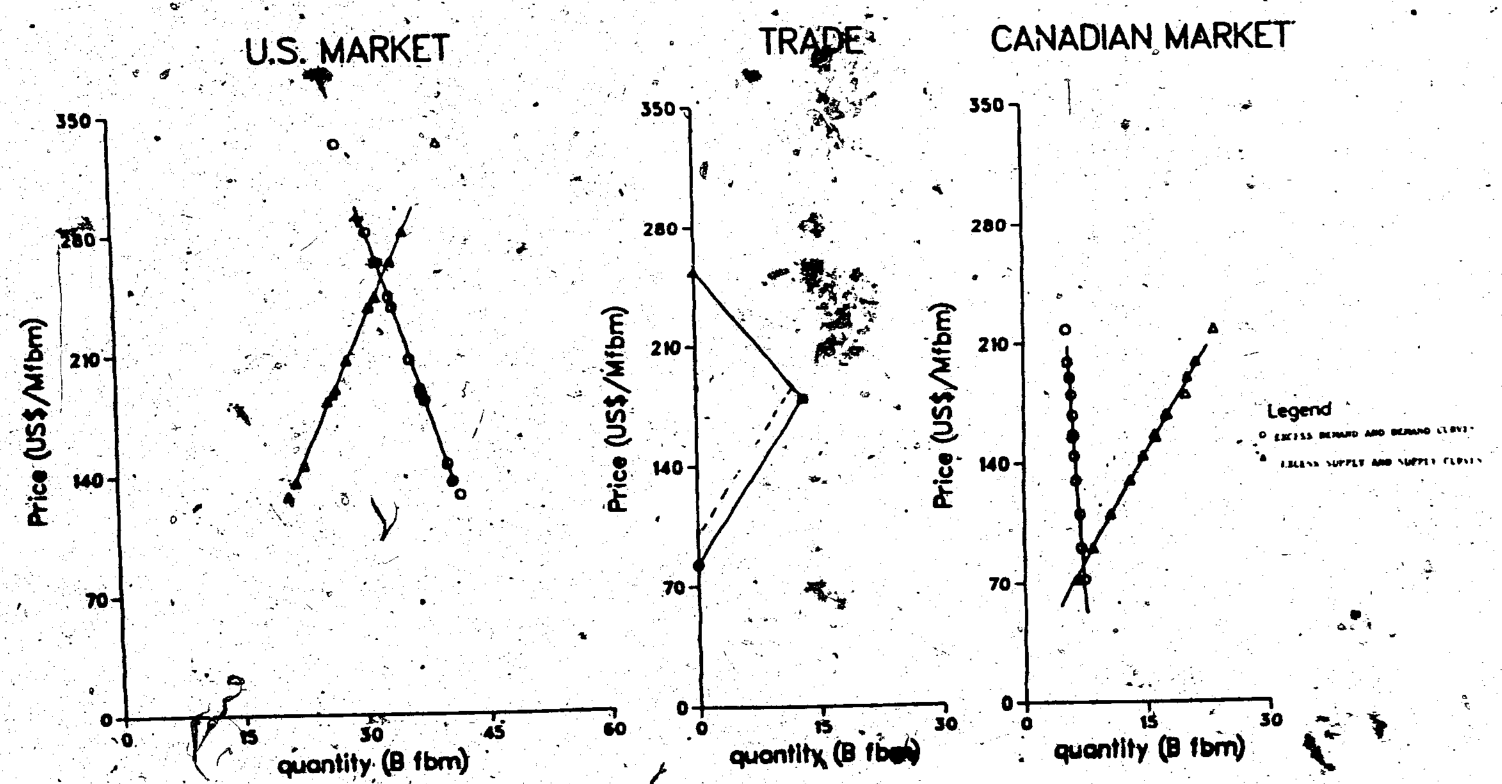
In the event of trade, United States lumber producers suffer due to a lower price received and decreases in available market. The lower cost of production in Canada results in lower priced Canadian lumber. Canadian lumber producers get more profits. United States producers, therefore, try to protect their market through protective measures. Protective measures, tariff and non-tariff, wedge the gap in the prices of imported and domestic lumber. The impact of these measures on the consumers and producers in both the markets has been analysed. In this study, the impact of fixed and advalorem tariff of 10, 15 and 20% are analysed. The effect of a quota of 10 Bfbm is also analysed. Both of these types of measures, tariff and non-tariff, reduce lumber imports of 13.12 Bfbm from Canada.

Quota of 10 Bfbm

A quota of 10 Bfbm would increase the equilibrium price and reduce imports from Canada (fig V.1). By imposing the quota, the importing country does not receive any revenue, but incurs a cost for administration. The benefits from an increased price of lumber to $201.2/Mfbm goes to the importers. The demand for lumber in the United States declines from 39.37 Bfbm to 38.03 Bfbm, whereas, lumber production increases from 26.25 Bfbm to 28.03 Bfbm (table V.17).

Canadian lumber is also affected as the price now available to Canadian lumber producers declines to

Figure V.2: Impact of 10% Fixed Tariff by United States on Canadian Lumber Imports



$161.9/Mfbm. Lumber consumption in Canada increases by 4.3%. Reduced prices to the Canadian producers and the decline of export results in a decline of 14.9% in production in Canada. Consumers in the United States market may be willing to pay more for Canadian lumber, but still, the import from Canada cannot be increased beyond the fixed quota. In the case of a tariff, however, the export can be maintained at its original level if Canadian producers absorb the rise in price after the restriction.

Fixed tariff

The impact of a 10, 15 and 20% tariff on imports from Canada was analysed. The results are given in tables V.19 and V.20. A tariff reduces the imports from Canada and raises the prices in the United States. The United States authority realizes a revenue. Figure V.2 shows the effect of the fixed tariff through the parallel shift in the excess supply schedule. The import of lumber from Canada declines to 12.0 Bfbm at a 15% tariff and the price rises to $174.0/Mfbm (table V.18).

The price rise after the fixed tariff is less than the corresponding rise after the imposition of the quota because of a higher import level. The demand for lumber in the United States declines from 39.37 Bfbm to 39.02 Bfbm (15% tariff). Lumber production in the United States market increases to 27.12 Bfbm. The United States authority also realizes a revenue of $978.9 million. Revenue available to

Table V.17 **The Effect of a Quota of 10 Bfbm on Canadian Lumber Imports by the United States**

	Canada		United States	
	Before Quota	After Quota	Before Quota	After Quota
Consumption (billion fbm)	6.09	6.35 (4.3)	39.37	38.03 (-3.6)
Production (billion fbm)	19.21	16.35 (-14.9)	26.25	28.03 (6.8)
Import/Export (billion fbm)	13.12	10.0 (-23.8)	13.12	10.0 (-23.8)
Price (US$/M fbm)	179.4	157.5 (-12.2)	179.4	201.2 (12.1)
Revenue (US$ million)	-	-	-	-

Note Percentage changes are given in parenthesis. Increases or decreases are indicated by positive and negative signs.

Table V.18: Impact in the United States Market of a 10%, 15% and 20% Tariff by United States on Canadian Lumber Imports

	Before Tariff	After Fixed Tariff			After Advalorem Tariff		
		10%	15%	20%	10%	15%	20%
Consumption (billion fbm)	6.09	6.10 (0.2)	6.18 (1.5)	6.35 (6.3)	6.37 (4.6)	6.47 (6.2)	6.56 (7.7)
Production (billion fbm)	19.21	18.28 (-4.8)	18.18 (-5.4)	18.05 (-5.9)	17.35 (-9.7)	16.88 (-12.1)	16.47 (-14.3)
Import (billion fbm)	13.12	12.18 (-7.2)	12.0 (-8.5)	11.73 (-10.6)	10.98 (-16.3)	10.61 (-20.7)	9.91 (-24.5)
Price (US$/M fbm)	$179.4	$175.0 (-2.5)	$174.0 (-3.0)	$170.6 (-6.9)	$169.8 (-5.4)	$166.7 (-7.1)	$162.3 (-9.5)
Revenue (US$ million)	-	-	-	-	-	-	

Note: Percentage changes are given in parentheses. Increase and decrease are indicated by positive and negative signs.

Table V.19: Impact on Canadian Lumber Markets of a 10%, 15% and 20% Tariff Imposed by the United States on Canadian Lumber Imports

	Before Tariff	After Fixed Tariff			After Advalorem Tariff		
		10%	15%	20%	10%	15%	20%
Consumption (billion fbm)	39.37	39.18 (-0.5)	39.02 (-0.9)	38.91 (-1.2)	3[illegible] ([illegible])	[illegible]7.59 ([illegible]4.5)	37.29 (-5.3)
Production (billion fbm)	26.25	27.0 (2.9)	27.12 (3.3)	27.18 (3.5)	27.00 (2.9)	[illegible].18 ([illegible]2.5)	27.38 (4.3)
Import (billion fbm)	13.12	12.18 (-7.2)	12.0 (-8.5)	1[illegible].73 (-[illegible]6)	10.98 (-16.3)	10.41 (-20.7)	9.91 (-24.5)
Price (US$/Mfbm)	179.4	183.8 (2.5)	184.6 (2.9)	188.1 (4.9)	191.5 (6.7)	192.5 (7[illegible])	196.4 (9.5)
Revenue (Million US$)	-	1013.92	978.95	927.61	914.03	8[illegible]	[illegible]83.68

Note: Percentage Changes are given in parenthesis. Increases and decreases are represented by positive and negative signs.

the United States authority is maximum for a 10% tariff because of the higher import volume. The revenue available varies with the import volume.

The price of lumber in the Canadian market declines to $170.6/Mfbm (at 20%). Consumers in the Canadian market benefit from a tariff as their demand increases from 6.09 Bfbm to 6.18 Bfbm. Lower exports and prices reduce lumber production in Canada. The reduction is maximum with 20% tariff.

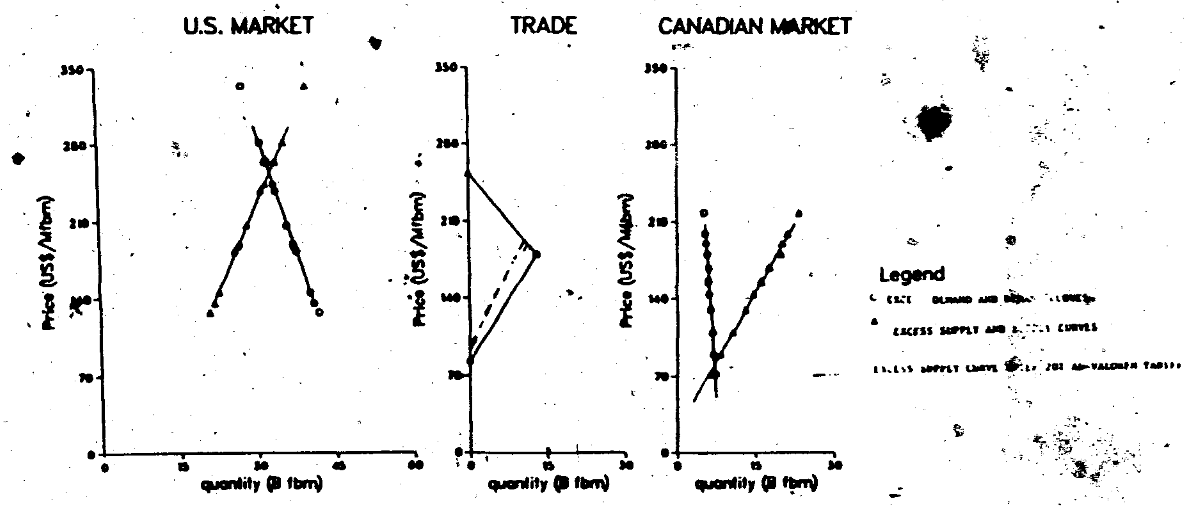
United States consumers would prefer a fixed tariff over a quota. The Canadian lumber producers also would prefer a fixed tariff if restriction is unavoidable as it enables them to either maintain or increase exports provided they can absorb the rise in price after the tariff by lowering their price.

Ad valorem tariff

The impact of a 10, 15 and 20% ad-valorem tariff on lumber imports from Canada was analysed. An ad valorem tariff differs from a fixed tariff as there is a proportionate addition to price (fig. V.3). The result is essentially the same as that from fixed tariff in that there is an increase in lumber price and a decrease in import volume.

United States consumers again suffered as the price rises to $196.4/Mfbm at a 20% tariff (table V.20). The demand for lumber in the United States declines to 37.29

Figure V.3: Impact of 20% Advalorem Tariff by United States on Canadian Lumber Imports



Bfbm (at 20%). The lumber producers in the United States on the other hand benefit through a production increase to 2[illegible].38 Bfbm (at 20%). Lumber import decline is maximum at the 20% tariff (9.9 Bfbm). This import decline is higher than the decline from the 20% fixed tariff.

Consumer demand for lumber in the Canadian market increases to 6.56 Bfbm, an increase of 7.7% after the 20% tariff is in place. The price available to Canadian lumber producers again declines to $162.3/Mfbm with the 20% tariff. Decreases in export's and lower available price to Canadian lumber producers results in a decline in production from [illegible] Bfbm to 16.47 Bfbm with the 20% tariff. The reduction in production is maximum at the 20% tariff (table V.19). The United States authority again realizes a revenue ($783.08 millions) but an amount less than the revenue ($927.6 millon) from the 20% fixed tariff. The decline in imports from the ad-valorem tariff is greater than that from the fixed tariff. Therefore, the revenue available to the United States government is maximum. If increased government revenue is the main aim, then the authorities in United States would prefer a fixed tariff. Canadian producers and United States consumers would prefer a tariff over a quota but a fixed tariff over an advalorem one . United States lumber producers would prefer an advalorem tariff most as it would reduce import greatesr.

The production of lumber in the United States would increase by 4.3% from a 20% advalorem tariff and by 3.5%

from a 20% fixed tariff (table V.19). Consumers in the United States would suffer more from an advalorem tariff. The fixed tariff of 20% reduces the demand by 4.5% against 7.7% by the advalorem one. The impact from the 20% fixed tariff is similar to the impact of a 15% an advalorem tariff, since the production in United States in both cases increases to 27.18 Bfbm. The authority in the United States, however would realize a revenue of $927.01 millions from the 20% fixed tariff and only $844.9 millions from the 15% advalorem tariff. The decline in lumber consumption in the United States would also be less from the 20% fixed tariff. A fixed tariff of 15% will be preferable to an advalorem tariff of 15%, since the decrease in consumption in the United States is less and the authority's revenue is more.

The imposition of a tariff is a political issue. Since the impact from different protection measures differ, the action by the United States will depend on which member of the society get preference. Whatever the decision, the outcome will not be economically efficient as the gainers will not be able to compensate the losers. The welfare of society will not improve. The next chapter discusses possible policy prescriptions in light of results just presented.

VI. Summary, Conclusions and Recommendations

A. Summary

The primary purpose of the study was to analyse the impact of tariff and quota trade restrictions by the United States on imported lumber from Canada. The approach centered around estimating demand and supply elasticities for lumber in both markets. The share of Canadian lumber in the United States market increased over time because of the cost advantage of the Canadian lumber industry over that of the United States and declining Canadian dollar to United States dollar. The market structure was analysed to determine factors that played a role in influencing lumber prices. An outline of distributional channels and trade trend provided background to the analysis of lumber trade between the United States and Canada.

The intermediate product characterstic of lumber led to the use of derived demand theory as most appropriate. The different demand models were then analysed to select the most appropriate ones that explain the production structures of the residential construction and sawmill industries. Statistical tests supported the use of the nonhomothetic and non neutral translog model as most appropriate for the residential construction industry in both countries. The same variables were considered in the for demand and supply models for both countries. Own-price demand elasticities for lumber for both countries are inelastic but the elasticity for Canada is more inelastic. Surprisingly, plywood is observed to be a complement of lumber for the United States residential construction industry, but a substitute for the Canadian industry. The demand for lumber consumption is more attached to new housing starts in the United States than in Canada. The consumption of lumber in new housing in the United States has declined however.

The supply models for both countries were then analysed. The models for both countries are simlar, except, that for the United States, sawmill industry model variables are in their natural form and the Canadian ones are in logrithmic form. The supply model results for both countries indicated technological changes. The supply of the Canadian sawmill industry is elastic whereas the United States supply of lumber is inelastic.

The estimated demand and supply of lumber in both countries is used to carry out partial equilibrium analysis. Higher prices in the United States markets are responsible for the flow of lumber from Canada into the United States. As long as there is a price difference between imported and domestic lumber, trade of lumber between the United States and Canada will continue.

A quota or tariff will reduce the price difference between imported and domestic lumber in the United States which will affect lumber imports from Canada. The impact of tariff and nontariff barriers depends on the elasticities of demand and supply in the United States. Since the demand for lumber in the United States is inelastic, the price rise will affect consumers but the fall in demand will not be large. Lumber supply in Canada is more elastic. Therefore, the fall in price in Canada will affect the quantity supplied more.

Quotas and tariffs affect the countries in different ways. The analysis considered fixed and advalorem tariffs of 10, 15, and 20%. Since the advalorem tariff affects volume of lumber imports from Canada most, the revenue realised by United States government is least among the restriction alternatives. The impact of a 15% fixed tariff and a 20% advalorem tariff are similar. A quota of 10 Bfbm would reduce the import volume of lumber from Canada but the United States authorities in such circumstances do not realize any revenue and United States consumers, even though they may be willing to pay higher prices, can not purchase Canadian lumber beyond the quota. The study supports the view that Canadian lumber producers and United States consumers will prefer a fixed tariff over quota or advalorem tariffs assuming restrictions are inavoidable. In the event of a fixed tariff, and if Canadian lumber producers absorb the price rise by reducing their delivered price, Canada can maintain the same volume of export. However, a reduction in the cost of production is highly unlikely. Therefore, if the same export is to be maintained, the industry will receive less profit.

B. Conclusions

This study is carried out with a view to provide information on the impact of tariff or quota trade restrictions on the lumber markets in the United States and Canada. This information is very important from a Canadian industry's point of view.

The country exports more than 50% of its production to the United States. An advalorem tariff of 20% will reduce Canadian lumber exports by 24.5%. Knowledge of demand elasticities give information about the percentage change in demand from a percentage change in price.

Supply elasticities and cross-price elasticities with other inputs such as stumpage could assist in formulating stumpage pricing policies. Supply in the United States is more responsive to stumpage price than that in Canada. Domestic policy decisions affect domestic supply and demand which, in turn, affects the excess supply and demand. Therefore, knowledge of elasticities of demand and supply can help in policy formulations. Recommendations are made in the event of tariff or quota trade restrictions covering two situations, namely, Canada reduces supply, and second, supply remains unchanged.

Partial analysis in this study involves worst scenerio case. The impact will be maximum in the short run and will be lowerr in the long run.

C. Implications

Unchanged Supply

The United States accounted for nearly 64% of the total Canadian lumber export in 1985. An advalorem tariff of 20% (maximum damage from a Canadian point of view) will reduce the export from Canada by more than 20%. In the event of the restriction, and to maintain the same export volume, the Canadian lumber industry should reduce costs of production, reduce profits, or reduce both. Stumpage prices in Canada are already very low and the labor contracts would not permit a lowering of non wood costs. Therefore, the only possibility of reducing delivered prices is by reducing transportation costs or improving marketing strategies, or both. The industry needs to utilise an optimum combination of transportation modes and to open strategic outlets in the United States according to consumers' needs.

Trends in the distribution structure have been noted. Protection measures by the United States will increase consumption in Canada but since it this consumption is less than 50% of the total lumber production in Canada, it is highly unlikely that the Canadian domestic market will be able to absorb increased available supply. Roberts et al (1985) forecasted that consumption of softwood lumber in Canada will increase to 1.3 million m³ only by the year 2000. Therefore, the only possible alternative is to divert export to overseas markets. If the fall in export volume to the United States is diverted to overseas markets, then it has to face stiff competition from other suppliers. At present the Canadian lumber industry may be able to compete with other suppliers in overseas markets. However, with the depletion of mature stands and movement to less accessible stands, this low cost advantage will disappear. The industry may not be able then to compete in those markets.

Canada has an option to increase the production of chips. Chips are jointly obtained with lumber from roundwood. The decisionto increase the production of chips will depend on the relative price of lumber and the products like panelboard and pulp. The increae in prices of lumber has always been higher than the increase during same period of other wood products. Moreover, there is not a market that can absorb the increased production of these products from diversion of roundwood use from lumber to chips.

Japan accounts for nearly 40% of total Canadian lumber export to overseas markets. However this volume is small in relation the export volume to the United States. Widman Management Ltd. (1986) has reported that due to structural changes in the major consuming sector (housing), Japaneselumber consumption has declined. Concerted efforts to increase exportvolume to overseas market may result in an increase, but it is not a dependable market.

In the event of tariff, if Canada still maintains the same volume of export to the United States by reducing its price, the problem of expected productioncost increases with the depletion of mature stands remains.

The gap between demand and supply in the United States is likely to increase and this gap in all probability will be met from Canadian lumber. Continued lower mortgage rates indicate that the demand for lumber in the United States will increase. This increase and the rise in prices after protection measure will benefit the Canadian lumber industry in the long run when gap between demand and supply widens. Phelps[5] indicated during personal discussion that the United States industry can meet the demand in the event of reduced Canadian lumber imports but it is highly unlikely that supply could ever meet the demand as in the past. The supply of lumber in the United States increased but only slightly. If the demand increases by 44 Bfbm, it is unlikely that all of the increases can be met by domestic supply. Therefore, in all circumstances the United States has to depend on Canadian lumber imports. A Tariff or quota will increase the cost of housing. A Tariff or quota that benefits lumber producers will cost consumers and will not be in the overall interest of the United States. The United States may impose a fixed tariff of 10% which will reduce the import from Canada but the impact on United States consumers will be less.

[5]U.S. Department of Agriculture (Forest Service) Washington, D.C.

Reduced Supply

Canada at present is exploiting 1.6 million m³ which is well below its annual allowable cut (Percy 1986). Canada has the lowest level of forest inventory in the developed world‘. At present levels of exploitation, falldown in economically annual allowable cut is expected. A shift into less accessible stands will increase the cost of production which in turn,will result in Canadian sawmills losing their competitive advantage. Therefore, in the event of protection measures by United States, Canadian authorities can phase out their annual allowable cut to avoid falldown in the future. Higher prices and demand are expected in the future in the United States. Canada can, therefore, find incentive to improve the quality of second growth stands by intensive forest management. Higher quality stands will reduce the cost of lumber production and will improve the industry's competitive position in future which is expected to decline after tariff.

The consumer lobby in the United States is opposing the move to impose restrictions. Free trade maximises social net benefits in both country. Canada and the United States are major trading partners. Any trade restrictions by the United States andsubsequent retaliation by Canada will worsen society's welfare in general. The main objection by the United States lumber producers is that the Canadian lumber industry is subsidized by the Canadian federal and

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‘ Written communication by Dr. B. Stenberg of Royal Institute of Technology, Stockholm to Reed (1978) provincial governments. The International Trade Commission found no justification of this charge during the last counterveil case in 1982. This major hurdle between the United States and Canada needs to be removed through negotiations.

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Appendix 1: Divisia Indexes for Prices of Variables Used in Estimating Demand Models for the United States

Year	Quarter	PK	PLA	PPL	PHP	PM	HOI	PL
1970	1	0.8850	0.7350	0.4026	0.7259	0.4461	0.6939	0.4808
	2	0.8394	0.7350	0.4252	0.7231	0.4648	1.0571	0.4868
	3	0.8542	0.7470	0.4259	0.7200	0.4662	1.0563	0.4854
	4	0.8713	0.7590	0.4139	0.7075	0.4601	1.0563	0.4997
1971	1	0.8890	0.7711	0.4598	0.7064	0.4951	1.0580	0.5289
	2	0.8770	0.7711	0.4476	0.7172	0.4898	1.6433	0.5715
	3	0.9066	0.7706	0.4893	0.7218	0.5187	1.5739	0.6163
	4	0.9727	0.7711	0.4854	0.7249	0.5177	1.3967	0.6130
1972	1	0.8519	0.7711	0.5424	0.7287	0.5623	1.3858	0.6352
	2	0.8417	0.7711	0.5737	0.7413	0.5876	1.8155	0.6627
	3	0.8474	0.7711	0.5929	0.7679	0.6001	1.7494	0.6780
	4	0.8542	0.8072	0.5804	0.7487	0.5950	1.5184	0.6879
1973	1	0.8759	0.8072	0.7279	0.7562	0.7088	1.3788	0.7394
	2	0.8816	0.8193	0.8403	0.7849	0.7931	1.8155	0.8514
	3	0.9100	0.8464	0.5862	0.8200	0.6171	1.7494	0.8906
	4	0.9567	0.8434	0.7065	0.8903	0.7039	1.5184	0.8883
1974	1	0.9784	0.8434	0.7062	0.9167	0.7099	0.8792	0.8619
	2	0.9966	0.8795	0.7842	0.9108	0.7751	1.2523	0.8869
	3	1.0342	0.8916	0.6571	0.8918	0.6871	0.9274	0.8202
	4	1.0558	0.8916	0.6025	0.8244	0.6523	0.6212	0.7496
1975	1	1.0444	0.4036	0.6933	0.8508	0.7290	0.5282	0.7475
	2	1.0182	0.9157	0.6571	0.8579	0.7043	0.8882	0.8341
	3	1.0148	0.9277	0.7397	0.8815	0.7744	095679	0.8203
	4	0.9966	0.9398	0.7400	0.9059	0.7806	0.8147	0.8095
1976	1	0.9886	0.9518	0.8857	0.9244	0.9001	0.7641	0.9236
	2	0.9909	0.9518	0.8723	0.9377	0.8935	1.1951	0.9518
	3	1.0023	0.9759	0.9067	0.9632	0.9250	1.1820	0.8033
	4	1.0080	0.9891	0.9843	0.9670	0.9917	1.0433	1.0332
1977	1	1.0020	0.9990	1.0010	1.0030	1.0090	1.0050	1.0360
	2	0.9966	1.0109	0.9770	1.0400	0.9200	1.5812	1.0685

	3	1.0034	1.0121	1.1590	1.1246	1.1416	1.5282	1.2357
	4	1.0068	1.0241	1.1364	1.1733	1.1427	1.2980	1.2455
1978	1	1.0182	1.0362	1.1932	1.2682	1.2043	0.9853	1.2908
	2	1.0399	1.0482	1.1589	1.3418	1.1848	1.6996	1.3359
	3	1.0740	1.0482	1.2117	1.3269	1.2225	1.5339	1.3519
	4	1.0626	1.0722	1.2389	1.3100	1.2646	1.2792	1.4172
1979	1	1.1344	1.1566	1.2636	1.2692	1.2965	0.8882	1.4098
	2	1.1708	1.1687	1.1659	1.2815	1.2312	1.4759	1.4539
	3	1.2130	1.2048	1.1932	1.2667	1.2590	1.3599	1.5333
	4	1.3759	1.2289	1.1305	1.2977	1.2089	1.0318	1.5271
1980	1	1.3440	1.2410	1.0848	1.3652	1.1831	0.6482	1.4448
	2	1.4465	1.2651	1.0140	1.4782	1.1376	0.8278	1.2962
	3	1.3622	1.2892	1.2293	1.4992	1.2947	0.9837	1.3720
	4	1.4305	1.3253	1.2245	1.5236	1.2973	1.0563	1.3318
1981	1	1.4920	1.3615	1.1877	1.5829	1.2761	0.7192	1.3436
	2	1.5683	1.3615	1.1817	1.6659	1.2804	0.9216	1.3532
	3	1.6492	1.3976	1.1165	1.6662	1.2306	0.7355	1.2867
	4	1.7449	1.4337	1.0379	1.6223	1.1683	0.5739	1.1847
1982	1	1.6720	1.4458	1.0328	1.6625	1.1646	0.4849	1.1611
	2	1.7073	1.4578	1.0417	1.6852	1.1770	0.7501	1.2200
	3	1.6857	1.4699	1.0465	1.6852	1.1909	0.8506	1.2523
	4	1.5456	1.4940	1.0412	1.7000	1.8402	0.8294	1.2138

Notes:

PK = Average quarterly home mortgage rates divisia index, used as a measure of the price of capital.
PL = Aggregate divisia price index of softwood lumber.
PLA = Average weekly earnings divisia index of special trade construction workers used as a measure of price of labor.
PPL = Divisia price index of softwood plywood.
PHP = Divisia price index of hardboard-paricleboard.
PM =Aggregate divisia index of other materials.
HOI = Index of new housing unit started in each quarter.

Appendix 2: Divisia Indexes for Quantities of Variables Used in Estimating Demand Models for the United States

Year	Quarter	QK	QLA	QPL	QM	QL	QHP
1970	1	0.4407	0.9121	0.6834	0.7259	0.8921	0.5988
	2	0.5063	1.0509	0.7564	0.8770	1.0081	0.6920
	3	0.5863	1.1039	0.7676	0.9057	1.0175	0.7138
	4	0.5997	1.0190	0.7595	0.8543	0.9033	0.7225
1971	1	0.6841	0.8392	0.8150	0.8445	0.8856	0.7294
	2	0.9552	0.9980	0.8478	1.0041	1.0581	0.8245
	3	1.0945	1.0819	0.8538	1.0120	1.0823	0.8316
	4	1.0687	1.0270	0.8634	0.9825	0.9889	0.8414
1972	1	0.7952	0.9091	0.9348	1.0127	1.0888	0.8444
	2	0.9656	1.0609	0.9553	1.1057	1.1920	0.9072
	3	1.0971	1.1798	0.9277	1.0832	1.1469	0.9461
	4	1.0924	1.0639	0.9209	1.0368	1.0631	0.9040
1973	1	0.9263	0.9461	0.9840	1.0855	1.0578	0.9017
	2	1.1178	1.2068	0.9892	1.1484	1.0629	1.0323
	3	1.1945	1.3547	0.9117	1.0770	1.0828	1.0028
	4	1.0123	1.2627	0.8986	0.9997	0.9683	0.9852
1974	1	0.9182	1.0290	0.8642	0.9154	0.9386	0.9547
	2	1.1017	1.1878	0.9207	1.0180	1.0578	1.0499
	3	1.1730	1.2772	0.8501	0.9429	0.8776	0.9921
	4	0.9610	1.1668	0.7068	0.7653	0.7586	0.6265
1975	1	0.5759	0.8831	0.7441	0.7250	0.7589	0.6744
	2	0.7086	0.9820	0.8380	0.8922	0.9273	0.8813
	3	0.8802	1.0849	0.8875	0.9581	0.9736	0.9585
	4	0.8737	1.0080	0.8913	0.9328	0.9495	0.9108
1976	1	0.7234	1.8831	0.9551	0.9563	0.9553	0.9701
	2	0.9953	1.0450	0.9657	1.0324	1.0128	1.0188
	3	1.2018	1.1319	0.9723	1.0531	1.0690	0.9241
	4	1.1993	1.0809	0.9794	1.0246	1.0324	0.9895
1977	1	1.0400	1.0090	1.0009	1.0010	1.1225	1.0090
	2	1.4476	1.0749	1.0140	1.1298	1.1091	1.0754

	3	1.7016	1.0729	0.9922	1.0157	1.0906	1.1231
	4	1.6030	1.0769	0.9696	1.0659	1.0386	1.0825
1978	1	1.2188	1.0849	1.0154	1.0428	0.9897	0.9897
	2	1.6917	1.2028	1.0349	1.1648	1.0916	1.0829
	3	1.9789	1.2418	1.9696	1.1237	1.1222	1.0537
	4	1.6720	1.2637	1.0042	1.1310	1.0305	0.8782
1979	1	1.3631	1.2927	1.0128	1.0273	0.9274	0.9508
	2	1.7351	1.3127	1.0387	1.1533	1.0309	1.0216
	3	2.0239	1.3437	0.9856	1.1120	1.0857	1.0695
	4	1.8170	1.3017	0.9488	1.0257	0.9322	0.9459
1980	1	1.3092	1.3297	0.9131	0.9002	0.8613	0.8266
	2	1.2521	1.2408	0.8808	0.7804	0.8029	0.7542
	3	1.4288	1.2178	0.8813	0.9656	0.8731	1.0988
	4	1.5548	1.2567	0.9031	0.9646	0.8237	1.0280
1981	1	1.3165	1.1339	0.8876	0.8853	0.8051	0.9309
	2	1.5186	1.1029	0.9369	0.9655	0.8555	1.0126
	3	1.4922	1.0609	0.8311	0.8590	0.7440	0.9130
	4	1.2060	1.0599	0.7400	0.7390	0.6789	0.6406
1982	1	0.9271	1.0020	0.7267	0.6673	0.5776	0.8743
	2	1.0923	1.0200	0.8163	0.8214	0.7710	0.8745
	3	1.2731	0.9806	0.8882	0.8905	0.7889	0.8747
	4	1.2919	0.9680	0.9300	0.8478	0.7808	0.8751

Notes:

QK = Divisia index of average quarterly new mortgage loans for residencial construction used as capital input.
QLA = Divisia index of the weighted average number of special trade construction workers used as indicator of labor input.
QL = Aggregate divisia quantity index of softwood lumber.
QPL = Divisia quantity index of softwood plywood.
QHP = Divisia quantity index of hardboard-particleboard.
QM =Divisia quantity index for other materials.

Appendix 3: Divisia Indexes for Prices of Variables Used in Estimating Demand Models for Canada

Year	Quarter	PK	PLA	PPL	PHP	PM	HOI	PL
1970	1	0.53014	0.49513	0.54149	0.54894	0.85090	0.81758	0.45752
	2	0.55332	0.50379	0.54749	0.55851	0.85013	0.81696	0.47147
	3	0.56338	0.51461	0.54573	0.55519	0.79410	0.82909	0.48573
	4	0.56003	0.51515	0.56269	0.56516	0.80527	0.83409	0.55136
1971	1	0.57009	0.51387	0.52269	0.56848	0.81006	0.84453	0.55136
	2	0.57344	0.53517	0.58631	0.56117	0.81325	0.84182	0.58909
	3	0.56606	0.54870	0.63840	0.58045	0.81764	0.80855	0.62714
	4	0.58551	0.56277	0.65718	0.58444	0.78532	0.82909	0.66487
1972	1	0.58954	0.57251	0.73280	0.59109	0.80527	0.80230	0.71243
	2	0.59625	0.59199	0.75712	0.60306	0.77925	0.78332	0.75999
	3	0.60831	0.60606	0.80618	0.62434	0.76082	0.80074	0.80750
	4	0.62978	0.62229	0.83404	0.63763	0.77773	0.81972	0.85250
1973	1	0.64319	0.63419	0.86190	0.64429	0.79617	0.81019	0.82815
	2	0.64990	0.65422	0.91823	0.65758	0.78691	0.78965	0.81294
	3	0.66331	0.66883	0.77347	0.69282	0.76696	0.80707	0.79772
	4	0.69886	0.68398	0.81042	0.74468	0.78388	0.86401	0.79233
1974	1	0.75117	0.68885	0.87159	0.87035	0.83914	0.87223	0.79201
	2	0.87793	0.71591	0.92611	0.87832	0.85299	0.87346	0.79264
	3	0.88598	0.73973	0.82435	0.88763	0.84836	0.96845	0.79169
	4	0.89537	0.75595	0.74621	0.89428	0.94062	0.03172	0.77426
1975	1	0.90208	0.77219	0.77720	0.89827	1.00208	0.05546	0.77679
	2	0.90610	0.80303	0.87947	0.92952	1.02514	0.05374	0.77996
	3	0.93763	0.83442	0.97274	0.97872	1.03065	0.95814	0.78313
	4	0.98726	0.87121	0.94532	1.01396	0.92833	0.01188	0.78884
1976	1	1.02280	0.88149	1.02120	0.02327	0.98212	0.04651	0.79708
	2	1.03219	0.91991	1.02180	0.98072	1.01644	0.03204	0.83735
	3	0.98927	0.94859	0.98789	0.96875	1.00239	0.04930	0.87730
	4	0.97720	0.98560	0.98910	0.99136	1.01915	0.02956	0.94895
1977	1	1.00250	1.00100	1.00100	1.00900	1.00150	0.00100	1.04000
	2	1.00870	1.04491	1.04240	1.03723	0.97127	0.90715	1.05105

	3	1.04628	1.07305	1.10662	1.18684	0.88109	0.89975	1.10209
	4	1.19718	1.07846	1.15203	1.32979	0.87390	0.90140	1.15282
1978	1	1.34138	1.08009	1.26893	1.36031	0.87550	0.90058	1.20006
	2	1.37223	1.09557	1.35312	1.43684	0.87470	0.89893	1.25967
	3	1.44936	1.12284	1.41369	1.50931	0.87311	0.90633	1.30691
	4	1.52247	1.12825	1.47668	1.43551	0.88028	0.90797	1.34147
1979	1	1.44802	1.15043	1.54936	1.40625	0.88188	0.97946	1.33830
	2	1.41851	1.18561	1.56087	1.32181	0.95132	0.97699	1.33513
	3	1.33333	1.20563	1.45367	1.12234	0.94892	0.96631	1.33196
	4	1.13213	1.24838	1.35494	1.26130	0.93855	0.99178	1.32816
1980	1	1.27230	1.20996	1.37977	1.41489	0.96329	0.20625	1.36398
	2	1.42723	1.26353	1.41066	1.60838	1.17159	0.20378	1.39918
	3	1.62240	1.31764	1.51121	1.59708	1.16919	0.27773	1.43500
	4	1.61099	1.32359	1.51969	1.60505	1.24102	0.19145	1.45910
1981	1	1.61905	1.32792	1.59540	1.71343	1.15722	0.31964	1.39569
	2	1.72837	1.39719	1.72926	1.92686	1.28273	0.34182	1.33767
	3	1.94366	1.43290	1.73107	1.88032	1.30327	0.53410	1.26187
	4	1.89621	1.43831	1.50999	1.95080	1.49002	0.79129	1.20482
1982	1	1.96781	1.44102	1.49182	1.95013	1.73983	0.64585	1.20165
	2	1.96714	1.49567	1.48637	1.93949	1.59856	0.65982	1.16927
	3	1.95641	1.57143	1.48758	1.84508	1.61213	0.64421	1.20165
	4	1.86117	1.60660	1.45064	1.84109	1.59697	0.67132	1.15726

Notes:

PK = Average quarterly home mortgage rates divisia index, used as a measure of the price of capital.
PL = Aggregate divisia price index of softwood lumber.
PLA = Average weekly earnings divisia index of special trade construction workers used as a measure of price of labor.
PPL = Divisia price index of softwood plywood.
PHP = Divisia price index of hardboard-particleboard.
PM =Aggregate divisiaindex for other materials.
HOI = Index of new housing unit started in each quarter.

Appendix 4: Divisia Indexes for Quantities of Variables Used for Estimating Demand Models for Canada

Year	Quarter	QK	QM	QL	QHP	QPL	QLA
1970	1	0.90127	0.57500	0.42082	0.20026	0.54746	0.21011
	2	0.91395	0.54204	0.74944	0.35660	0.54747	0.19617
	3	0.91938	0.56623	0.79238	0.37704	0.55052	0.34931
	4	0.92301	0.57653	0.78962	0.37576	0.55175	0.36932
1971	1	0.92799	0.57310	0.52875	0.52604	0.56889	0.36807
	2	0.89130	0.58339	0.89494	0.56747	0.56889	0.51529
	3	0.91395	0.58682	0.95977	0.56742	0.59277	0.55586
	4	0.88442	0.57927	0.87441	0.51702	0.64544	0.55581
1972	1	0.86350	0.59918	0.56022	0.36863	0.66442	0.50644
	2	0.88270	0.60329	1.05496	0.69420	0.97409	0.36109
	3	0.90362	0.61016	0.00177	0.71576	0.76546	0.67999
	4	0.89312	0.62251	0.77550	0.64192	0.81506	0.70111
1973	1	0.87047	0.64447	0.56823	0.42382	0.84323	0.62878
	2	0.88967	0.65820	1.07814	0.80330	0.87140	0.41515
	3	0.95245	0.66507	1.16355	0.86670	0.92835	0.78686
	4	0.96812	0.67877	1.05380	0.78516	0.78200	0.84916
1974	1	0.96286	0.71517	0.68084	0.50627	0.81935	0.76909
	2	0.67570	0.76870	1.13136	0.84127	0.88120	0.49591
	3	0.13732	0.89842	0.95765	0.71209	0.93631	0.82405
	4	0.16350	0.90666	0.72523	0.53924	0.83344	0.69752
1975	1	0.16159	0.91627	0.30236	0.29693	0.75444	0.52897
	2	0.05362	0.91313	0.74231	0.72901	0.78628	0.29086
	3	0.11467	0.92725	0.91408	0.89678	0.88916	0.71409
	4	0.15362	0.95951	0.96258	0.94532	1.01030	0.87931
1976	1	0.13768	0.01030	0.61296	0.61532	1.02143	0.92598
	2	0.15670	0.04667	1.34348	1.13871	1.03246	0.60272
	3	0.13496	0.05628	1.08355	1.08770	1.03037	1.11540
	4	0.10236	0.01235	1.01698	1.07089	0.99878	1.06544
1977	1	0.04400	0.01100	1.07200	1.01900	1.00090	1.00900
	2	0.99185	0.02334	1.09909	1.09911	1.01102	0.97955

	3	0.99366	0.03226	1.15409	1.15410	1.05389	1.07662
	4	0.99275	1.07069	1.29227	1.29230	1.11280	1.13048
1978	1	0.99094	1.22512	1.30011	1.45740	1.16473	1.26585
	2	0.99909	1.37268	1.32355	1.48339	1.28292	1.42757
	3	0.00091	1.40425	1.12924	1.44925	1.36803	1.45303
	4	0.07971	1.48318	1.11608	1.44823	1.42927	1.41959
1979	1	0.07699	1.55799	1.45480	1.82939	1.49296	1.41859
	2	0.06522	1.48181	1.42834	1.79627	1.56694	1.79195
	3	0.09330	1.45161	1.21216	1.52415	1.57808	1.75951
	4	0.32971	1.36445	0.29714	1.12821	1.46969	1.49296
1980	1	0.32699	1.15850	1.36087	1.93793	1.36987	1.10512
	2	0.40852	1.30199	1.24767	1.77487	1.39478	1.89827
	3	0.31341	1.46053	1.03765	1.47720	1.46221	1.73854
	4	0.45471	1.66026	1.05861	1.50683	1.52787	1.44704
1981	1	0.47917	1.64859	1.06687	1.65308	1.53644	1.47599
	2	0.69112	1.65683	1.02497	1.50830	1.61298	1.61920
	3	0.97464	1.76870	1.09087	1.67079	1.74832	1.55586
	4	0.81431	1.98902	1.29928	2.01836	1.75015	1.65618
1982	1	0.82971	1.94097	0.96682	1.29382	1.52664	1.97265
	2	0.81250	2.01373	0.97357	1.36771	1.50827	1.26735
	3	0.84239	2.01304	1.05736	1.48546	1.50276	1.33972
	4	0.77636	2.00206	1.03821	1.45862	1.50398	1.45503

Notes:

QK = Divisia index of average quarterly new mortgage loans for home construction used as capital input.

QLA = Divisia index of weighted average number of special trade construction workers used as indicator of labor import.

QL = Aggregate divisia quantity index of softwood lumber.

QPL = Divisia quantity index of softwood plywood.

QHP = Divisia quantity index of hardboard-particleboard.

QM =Divisia quantity index for other materials.

Appendix 5: Divisia Indexes used in Estimating Supply Models for the United States

Year	Quarter	QS	PS	PFU	PAW	QAW	W	PSTP
1970	1	0.88650	0.43270	99.90	0.5440	1.0541	62.92	0.4862
	2	1.00280	0.43070	99.97	0.5741	1.0600	63.08	0.4789
	3	0.99860	0.43210	99.80	0.5875	1.0632	63.61	0.5187
	4	0.89860	0.43610	99.99	0.5827	1.0584	64.67	0.5348
1971	1	0.94000	0.46840	113.10	0.5878	0.9989	65.04	0.5465
	2	1.09470	0.51890	113.90	0.6127	1.0321	65.36	0.6103
	3	1.07620	0.57320	114.80	0.6377	1.0526	66.31	0.6738
	4	1.00600	0.56470	114.80	0.6453	1.0380	67.06	0.7340
1972	1	1.07290	0.59060	116.20	0.6412	1.0257	67.69	0.7998
	2	1.17190	0.61850	117.50	0.6804	1.0600	68.22	0.8630
	3	1.12600	0.64160	119.50	0.6789	1.0739	68.86	0.9243
	4	1.04700	0.65610	121.20	0.6819	1.0487	69.60	0.9900
1973	1	1.04680	0.71150	125.00	0.6776	1.6273	70.03	1.0567
	2	1.08240	0.83380	136.70	0.7338	1.0509	70.72	1.0246
	3	1.06190	0.82740	143.50	0.7384	1.0777	71.78	1.0107
	4	0.96210	0.81740	177.60	0.7395	1.0616	73.95	0.9936
1974	1	0.94720	0.81430	229.30	0.7410	1.0670	76.13	0.9693
	2	1.06330	0.86080	204.20	0.7730	1.0916	78.30	0.8930
	3	0.88380	0.77520	224.20	0.7898	1.9689	80.11	0.8158
	4	0.75290	0.67140	228.30	0.7639	0.8511	83.98	0.7351
1975	1	0.75650	0.68020	232.50	0.7588	0.8511	86.26	0.7627
	2	0.93320	0.76050	239.40	0.8081	0.9057	87.80	0.7109
	3	0.87110	0.75950	251.30	0.8570	0.9647	89.07	0.7495
	4	0.93820	0.75660	257.20	0.8758	0.9620	90.77	0.7962
1976	1	0.95400	0.86460	256.20	0.8998	0.9582	92.20	0.8484
	2	1.01110	0.90042	258.10	0.9425	0.9888	93.21	0.8791
	3	1.06550	0.92820	268.30	0.9842	1.0182	94.69	0.9127
	4	1.01890	0.97280	279.20	0.9970	1.0107	95.92	0.9650
1977	1	1.04000	1.00200	287.00	1.0050	1.0200	97.77	1.0100
	2	1.11080	1.04320	301.60	1.0153	1.0407	99.63	1.0331
	3	1.08600	1.15100	308.60	1.0504	1.0568	100.95	1.0620

	4	1.02440	1.15900	311.00	1.1165	1.0429	103.02	1.1119
1978	1	1.09800	1.22730	313.70	1.1394	1.1034	103.55	1.1557
	2	1.09800	1.20170	318.10	1.1730	1.1489	106.15	1.2152
	3	1.09700	1.27210	325.50	1.2188	1.1296	109.02	1.2969
	4	1.01960	1.33850	331.00	1.2326	1.1173	111.35	1.3619
1979	1	0.93380	1.34810	343.70	1.2224	1.1189	114.27	1.4458
	2	1.02540	1.40310	377.00	1.2779	1.1590	118.09	1.3852
	3	1.06320	1.44690	432.90	1.3420	1.1564	122.81	1.2972
	4	0.92260	1.40840	477.90	1.2906	1.1264	127.16	1.2605
1980	1	0.85640	1.33290	509.60	1.2819	1.0750	133.05	1.2056
	2	0.79210	1.18470	568.20	1.2977	1.9866	139.05	1.1600
	3	0.86820	1.29490	589.30	1.3858	1.0145	141.22	1.1064
	4	0.82300	1.27680	600.60	1.4061	1.9973	144.72	1.0663
1981	1	0.79660	1.24430	662.10	1.4224	0.9663	149.02	1.0303
	2	0.79270	1.26520	706.00	1.4423	1.0257	153.05	1.8860
	3	0.80260	1.21190	703.60	1.4631	1.0123	159.20	0.7263
	4	0.67760	1.12070	699.10	1.4255	0.9475	161.49	0.5933
1982	1	0.58030	1.17100	689.70	1.4438	0.8688	174.27	0.5816
	2	0.77340	1.14750	670.10	1.4723	0.9079	166.37	0.4435
	3	0.78940	1.16160	703.10	1.5542	0.9309	169.60	0.3872
	4	0.78060	1.12890	703.20	1.5094	0.9213	168.86	0.4431

Notes:

PS = Divisia price index of softwood lumber inthe United States.
QS = Divisia quantity index of softwood lumber production.
PFU = Price index of fuel energy: Bureau of Labor Statistics, wholesale price indexes of fuel and power.
PSTP = Divisia price index of stumpage price of round-wood:a weighted average stumpage price for three species, Douglas fir, southern yellow pine and ponderosa pine.
PLAW = Divisia price index of wages in sawmills.
QLAW = Number of laborers employed in sawmills.
W = Wholesale consumer price index.

Appendix 6: Data used in Estimating Supply Models for Canada

Year	QLAW	PLAW	PST	PFU	PS	QS
1961	42540	0.47762	0.20235	0.7940	0.4743	0.6204
1962	38636	0.43274	0.19515	0.7870	0.4502	0.5818
1963	40316	0.48095	0.20174	0.7890	0.4808	0.6106
1964	41475	0.52298	0.20522	0.7850	0.5586	0.6877
1965	43646	0.57038	0.20522	0.7850	0.6868	0.8201
1966	44477	0.61849	0.21495	0.7650	0.7008	0.7979
1967	43242	0.64584	0.23746	0.7730	0.7108	0.7979
1968	42431	0.67794	0.19146	0.8290	0.7443	0.8076
1969	42820	0.74331	0.33310	0.8700	0.9431	1.5630
1970	44425	0.82907	0.40534	0.8910	0.9967	1.4970
1971	42540	0.85971	0.78421	0.9680	0.8700	0.8614
1972	44107	1.09304	1.00170	1.0100	1.1220	1.0309
1973	49387	1.21563	0.72551	1.0260	1.2660	1.1577
1974	53640	1.49345	1.25315	1.0500	1.6210	1.1104
1975	49194	1.60748	0.91764	1.0880	1.4740	1.0375
1976	40788	1.51851	0.38540	1.2270	1.4590	0.8722
1977	47838	2.10727	0.46026	1.3970	1.6380	1.1421
1978	51532	2.54928	0.52309	1.6020	1.9070	1.3274
1979	56101	2.97600	1.05653	1.7770	2.3190	1.4290
1980	57441	3.42083	2.10611	1.9660	2.7470	1.4592
1981	55903	3.71800	1.53722	2.1720	2.4330	1.3724
1982	52916	3.64582	0.94763	2.3310	2.2980	1.3352

Notes: QLAW = Number of laborers employed in sawmills.
PLAW = Divisia price index for laborers employed in saw mills.
PST = Divisia price index of stumpage price of round wood.
PFU = Divisia price index of fuel energy.
PS = Divisia price index of softwood lumber in Canada.
QS = Divisia quantity index of softwood lumber in Canada.

Appendix 7: Note on Technical Change in the U.S. Residential Construction Industry, 1970-1982

Likelihood ratio test supported non homothetic non neutral translog function for residential construction industry. The estimates of the bias technological change with respect to each input is given by

$$\partial S_i/\partial T = \theta_{it}$$

where S_i and θ_{it} are as explained earlier.

Technical change parameters and standard errors in parenthesis for the appropriate model

K	L	PL	LA	HP	M
0.00240	-0.00076	-0.00046	-0.00053	0.00015	-0.00085
(0.00026)	(0.00014)	(0.00013)	(0.00028)	(0.00023)	(0.00027)

Each of the parameter estimates measures the change in factor cost shares in total cost with respect to time. A negative value implies that the technological change is factor saving whereas a positive value indicates a factor using input. Above estimates indicate that lumber, other materials, plywood and labor are factor saving whereas capital and hardboard-particleboard are factor using. Alternatively, rate of technological change declines with the price of capital and hardboard-particleboard and increases with the price of lumber, plywood, labor and other material. All coefficients are significant but not negative therefore we can not reject the hypothesis that the cost structure is a Cobb Douglas function (Sherif 1983). The value of technical change has increased but this increase is almost negligble. This supports the fact that hardboard and particle board is a substitute of lumber and plywood. It also indicates that there exists a technical change but increase in the rateof technical change overtime is nearly zero.

Appendix 8: Note on Technical Change in the Canadian Residential Construction Industry, 1970-1982.

Likelihood ratio test supported nonhomothetic non neutral translog function for residential construction industry. The estimates of the bias technological change (θ_{it}) with respect to price of each input (i=K, L, PL, LA, HP and M) are as follows:

Technical change parameters and standard errors in parenthesis for the appropriate model

K	L	PL	LA	HP	M
-0.0042	-0.0006	-0.0017	0.0014	0.0018	0.0029
(0.0003)	(0.0006)	(0.0007)	(0.0007)	(0.0007)	(0.0022)

Estimate of bias technical change with respect to time given by

$$\partial S_i/\partial T=\theta_{it}.$$

Each of the parameter estimates measures the cost shares in total cost with respect to time. A negative value implies that the technological change is factor saving whereas a positive value indicates a factor using input. Above estimates indicate that lumber, capital, plywood are factor saving whereas other material, labor and hardboard-particleboard are factor using. Alternatively, rate of technological change declines with the price of other material and hardboard-particleboard and increases with the price of lumber, plywood, labor and capital. All coefficients are significant but not negative therefore we can not reject the hypothesis that the cost structure is a Cobb Douglas function (Sherif 1983). The value of technical change has increased but this increase is almost negligble. United States residential construction industry is labor saving whereas Canadian residential construction industry is labor using. This may be due to effect of strong labor contracts. Factor saving indicates that the rate of technical change declines with price of inputs. Saving of lumber and plywood implies thet the industry is replacing them with other material and hardboard-particleboard. Since estimate values are very low therefore there is a technical change but increase in the rate of technical change overtime is nearly zero.

Appendix 9: Estimated Demand and Supply Quantities in the United States and Canada (Bfbm)

Relative Price U.S./Cdn.	United States Demand	United States Supply	Canada Demand	Canada Supply
1.76	41.9	21.0	7.4	6.4
1.42	41.0	22.0	7.0	8.4
1.30	40.4	23.0	6.8	10.6
1.15	37.8	26.0	6.0	16.0
1.43	36.0	28.4	6.2	14.6
1.46	37.2	27.0	6.4	13.0
1.56	33.6	32.0	6.0	16.2
1.41	34.0	31.2	5.8	17.4
1.42	37.4	36.6	5.6	20.2
1.37	27.8	40.0	5.[illegible]	23.2
1.32	32.4	34.0	5.4	21.0
1.52	31.2	35.6	5.8	19.8
1.57	32.2	33.8	6.0	17.6